PULP AND PAPER PROSPECTS IN LATIN AMERICA

UNITED NATIONS
NEW YORK, 1955

FOOD AND AGRICULTURE ORGANIZATION

PULP AND PAPER PROSPECTS IN LATIN AMERICA

First Part

Report of the Latin American Meeting of Experts on the Pulp and Paper Industry

sponsored by

the secretariats of the Economic Commission for Latin America, the Food and Agriculture Organization of the United Nations, and the Technical Assistance Administration

Second Part

Working papers submitted to the Meeting

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E/CN.12/361/Add.1
FAO/ETAP No. 462/Add.1
ST/TAA/SER.C./19/Add.1

October 1955

UNITED NATIONS PUBLICATION
Sales No.: 1955. II.G. 4

Price: $U.S. 4.50; 32/- stg.; Sw. fr. 19.50
(or equivalent in other currencies)

Prefatory Note

The report which follows is divided into two parts. The First Part gives an account of the meeting itself—composition, attendance, organization, proceedings and conclusions; the Second Part reproduces, in full or in condensed versions, the papers submitted to the meeting.

Appendix I gives a list of participants in the meeting and of those who contributed papers but were unable to attend it. Appendix II reproduces the addresses delivered at the opening session.

EXPLANATION OF SYMBOLS

A full stop is used for decimals.

A comma distinguishes thousands and millions.

References to tons, unless otherwise expressly stated, represent metric tons. This applies to both the Secretariat and experts' papers, in the Second Part of this volume.

References to dollars and the $ sign, unless otherwise specified, signify United States dollars.

Use of a hyphen(-) between dates representing years, e.g., 1948-53 normally signifies an annual average for the calendar years involved, including the beginning and end years. "To" between the years indicates the full period, e.g., 1948 to 1952 means 1948 to 1952, inclusive.

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First Part

REPORT OF THE LATIN AMERICAN MEETING OF EXPERTS ON THE PULP AND PAPER INDUSTRY

Introduction

1. The Latin American Meeting of Experts on the Pulp and Paper Industry, held in Buenos Aires in 1954, grew out of the joint action of a number of international agencies which, in the years following the Second World War, had become increasingly concerned with the problems of securing an adequate supply and a fair distribution of pulp and paper.

2. The events which led up to this meeting may be summarized as follows:

(*a*) April 1949—a preparatory conference on world pulp problems was convened in Montreal by FAO;

(*b*) June 1951—a resolution was adopted at the fourth session of ECLA inviting FAO and ECLA to explore the possibilities for development of the pulp and paper industry in Latin America. This resolution led to the preparation of a report by both organizations, presented at the fifth session of ECLA in 1953 and subsequently printed;[1]

(*c*) September 1951—a resolution was adopted by the Economic and Social Council requesting the Director-General of FAO to advise member Governments on the long-term programme required to provide all countries with adequate pulp and paper supplies to meet their increasing needs;[2]

(*d*) December 1952—a consultation of leading specialists from the world's pulp and paper industry was held at FAO headquarters in Rome to determine the technical and economic possibilities for manufacturing pulp and paper from the various kinds of raw material available;[3]

(*e*) The period 1952-53—FAO short-term survey teams visited twenty-four countries to explore, with competent local authorities, to what extent raw materials and other production factors would permit an expansion of pulp and paper production;

(*f*) April 1953—on the grounds of the report mentioned under point (*b*), a resolution was adopted at the fifth session of ECLA recommending that ECLA and FAO together with UNTAA organize a meeting of experts from the pulp and paper industry to examine the over-all question of pulp and paper production and consumption in Latin America.

3. The report which follows is divided into four sections. The first gives the composition of the meeting, describes the way in which the work was organized and sets out the agenda adopted. The second provides a summary of the discussions and lists the general conclusions reached. The third gives the complete version of the different committee reports as approved—in some cases after amendment—in plenary meetings. The fourth brings together in one chapter the various recommendations made by the Meeting in the reports which it adopted and in the course of plenary discussions.

[1] See report *Possibilities for the Development of the Pulp and Paper Industry* in Latin America (E/CN.12/294/Rev.2), United Nations Publication, Sales No.: 1953.II.G.2. New York.

[2] See report *World Pulp and Paper Resources and Prospects* (21943, New York, September 1954).

[3] See report *Raw Materials for more Paper* (FAO Forestry and Forest Products Study No. 6, Rome).

I. Organization of the Meeting

A. Composition, Attendance and Organization of the Work

1. Opening and closing sessions

4. The inaugural session of the Latin American Meeting of Experts on the Pulp and Paper Industry took place in the Aula Magna "Eva Perón" of the Faculty of Law and Social Sciences of the University of Buenos Aires, at Buenos Aires, Argentina, on 19 October 1954. The Minister of Agriculture and Livestock of Argentina, Mr. Carlos A. Hogan, pronounced the opening address in the name of the President of the Republic, General Juan D. Perón. During the course of this session, speeches were made by *Dr. Raúl Prebisch,* Executive Secretary of the Economic Commission for Latin America and representative of the Secretary-General of the United Nations and of the Director-General of the Technical Assistance Administration, and by *Mr. Egon Glesinger,* Deputy Director of the Forestry Division of the Food and Agriculture Organization of the United Nations and representative of the Director-General of FAO and of the Executive Secretary of the Economic Commission for Europe.[4]

5. The Meeting adopted the report of its work at the last plenary session which took place on 2 November 1954. On the same day, at the closing session held in the Aula Magna "Eva Perón", *Mr. Carlos A. Hogan,* Minister of Agriculture and Livestock of the Republic of Argentina, gave the official address in the name of General Juan D. Perón, President of the Republic. Speeches were also made by Messrs. *J. Alfred Hall,* Director of the Forest Products Laboratory of the United States Department of Agriculture and Rapporteur of the Meeting; *Silvio Gagliardi,* Vice-President and Manager of Celulosa Argentina, S.A., in the name of the Latin American experts who attended the Meeting; *E. W. Tinker,* Director of the American Paper and Pulp Association, in the name of the North American experts; *Julius Grant,* Director of the Pulp and Paper Research Company (Great Britain) and representative of the British Paper and Board Makers Association, in the name of the European experts, and *Pierre Terver,* Chief Technical Assistance Officer, Forestry Division of FAO, representing all the international sponsoring organizations.

2. Composition and attendance

6. The Latin American Meeting of Experts on the Pulp and Paper Industry was attended by 154 experts from the following Latin American countries: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, Mexico, Paraguay, Peru, Surinam, Uruguay and Venezuela. Thirty-two experts from Australia, Canada, the Federal Republic of Germany, Finland, France, Italy, Norway, Sweden, the United Kingdom and the United States of America were also present.[5]

3. Organization of the work of the Meeting

(a) *Officers*

7. At its first plenary session, the Meeting elected Mr. Carlos A. Hogan, Minister of Agriculture and Livestock of the Republic of Argentina, as Chairman.

8. The Meeting was serviced by the following secretariat:

Directors:

Carlos Quintana, Director for the Economic Commission for Latin America (ECLA) and the United Nations Technical Assistance Administration (TAA)

Arne Sundelin, Director for the Food and Agriculture Organization of the United Nations (FAO)

Secretary-General of the Meeting:

Tomás Fortunato Desimone, of the Ministry of Foreign Affairs and Worship of the Republic of Argentina

Co-ordinators:

Pierre Terver, for FAO
Alfonso Santa Cruz, for ECLA and TAA

Special Advisers:

Jack Westoby, FAO/ECE
Gerald Welsh, FAO

9. Mr. J. Alfred Hall, Director of the Forest Products Laboratory, Forest Service of the United States Department of Agriculture, was appointed Rapporteur.

(b) *Discussion leaders and drafting committees*

10. For each item of the agenda[6] discussion leaders were appointed to direct the discussions and drafting committees formed, as follows:

Item II: Discussion leader: Carlos Benko (Brazil);
Committee: C. Benko, P. Asenjo, O. A. D'Adamo, J. C. Leone, A. Picasso Oyague, R. Remolina and F. Urencio.

Item III: Discussion leader: W. O. Hisey (United States);
Committee: W. O. Hisey, G. H. Chidester, H. K. Collinge, J. Di Filippo, H. W. Giertz, Stacy May, J. Michon, L. Rys and P. R. Sandwell.

Item IV: Discussion leader: Lucas A. Tortorelli (Argentina);
Committee: Lucas A. Tortorelli, P. Asenjo, L. Golfari, L. Huguet, I. A. de Hulster, R. B. Jefferys, A. G. Ragonese, L. Rys, A. N. Sampaio and E. Valente.

[4] Texts of these three speeches were originally Appendices II, III and IV of this document. They have now been grouped together as Appendix II at the end of this volume.

[5] The complete list of participants and of the representatives of the various international organizations present may be found in Appendix I at the end of this volume. This Appendix, expanded to include contributors who did not attend the meeting, has been removed from the original text of E/CN.12/361.

[6] See subsection B on page 5.

Item V: Discussion leader: Joseph E. Atchison (United States);

Committee: J. E. Atchison, T. M. Cook, D. S. Cusi, J. Di Filippo, J. Guerra, E. C. Lathrop, H. K. Metcalf, L. Morganti, H. Niethammer, W. J. Nolan and G. Pomilio.

Item VI: Discussion leader: Hans W. Giertz (Sweden);

(For this item no drafting committee was formed, since the Meeting contented itself with an examination of the various papers submitted).

Item VII: Discussion leader: Silvio Gagliardi (Argentina);

Committee: S. Gagliardi, P. Asenjo, J. von Bergen, L. Escobar, J. C. Leone, R. Remolina, F. Urencio and F. H. Vogel.

Item VIII: Discussion leader: Stacy May (United States);

Committee: S. May, O. A. D'Adamo, T. M. Cook, D. S. Cusi, J. C. Leone, C. D. McCoy, W. H. Morell, E. W. Tinker and M. Viaud.

Item IX: Discussion leader: Percy R. Sandwell (Canada);

Committee: P. R. Sandwell, P. Asenjo, G. H. Chidester, H. K. Collinge, J. Di Filippo, H. Niethammer and K. Zappert.

11. In addition to the above drafting committees, two working groups were formed to deal with special subjects which the Meeting considered to be of particular interest. One of these dealt with eucalypts, and was composed of:

Discussion leader: R. B. Jefferys (Australia);

Members: R. B. Jefferys, N. Battenberg, G. H. Chidester, J. Di Filippo, J. Grant and J. C. Leone.

This group reported directly to the plenary session, and its report, as finally adopted, is given below after the report on item IV of the agenda relating to other Latin American forest resources.

12. The other group was established to consider the problems of technical assistance, research and training; it was composed of:

Discussion leader: H. K. Collinge (Canada);

Members: H. K. Collinge, J. von Bergen, E. Gagliardi, H. W. Giertz, J. A. Hall, J. C. Leone and H. Thielen.

Its report took the form of recommendations which were submitted directly to the plenary session. These recommendations, as adopted by the Meeting, are given, together with recommendations included in other committee reports, in section IV below.

13. The Meeting unanimously elected Mr. Gardner H. Chidester (United States) to preside over the final plenary sessions in which the texts of the committee and working group reports were discussed and approved.

B. Agenda

14. The Meeting adopted the following agenda for its working sessions:

Item II: *Pulp and paper consumption, production and trade in Latin America*

Item III: *Economic aspects of pulp and paper manufacture from Latin American tropical and sub-tropical hardwoods*

Item IV: *Aspects of pulp and paper manufacture based on other Latin American forest resources*

Item V: *Economics of pulp and paper manufacture from sugar-cane bagasse*

Item VI: *Presentation of papers on selected technical matters*

Item VII: *Review of development prospects for pulp and paper industries in selected Latin American countries*

Item VIII: *Financing of Latin American pulp and paper development*

Item IX: *Newsprint*

II. Resume of the Meeting: its aim, deliberations and conclusions

The aim

15. This Meeting was a continuation of the programme of the United Nations and its agencies aimed at expanding world production of pulp and paper to meet existing shortages and prospective needs. Some years ago it became clear that there would be an eventual limit to production based on temperate zone forests and that the vast forest wealth of the tropics—together with subsidiary and abundant fibrous crops—offered the most probable source from which could be derived the vast quantities of fibre required.

16. At FAO Headquarters in Rome, in 1952, a consultation of specialists in the pulp and paper field explored the problem from two principal points of view: (*a*) the technical suitability of tropical woods and other non-traditional resources as raw materials for pulp and paper; and (*b*) the prospective costs of manufacturing pulp and paper from this kind of raw material.

17. That meeting concluded that processes were available for the technically successful manufacture of pulp and paper products from tropical woods; and that there was reason to believe that such operations might prove economically feasible. It further analysed and set forth the problems that ought to be examined and solved before large-scale development was undertaken.

18. This present Meeting devoted itself to an examination of those and other problems in the region of Latin America and under the special conditions to be found there. Briefly, those problems were to determine the following:

(*a*) Present and probable future demand for pulp and paper in Latin America, in the region as a whole and in individual countries;

(*b*) The processes, and costs for meeting current requirements;

(*c*) The probabilities, taking into consideration all fibre resources available for pulp and paper, of future requirements being satisfied by Latin American resources alone or in combination with necessary and available imports;

(*d*) The capabilities of known technical processes, their costs and their probable results when applied to Latin American woods and fibre crops with a view to producing the necessary kinds and qualities of paper to meet Latin American needs;

(*e*) The areas requiring co-ordinated technical research in forestry and technology to realize a development programme;

(*f*) The economic, political and social obstacles to the expansion of existing industry and the creation of new industry to meet present and future needs;

(*g*) The criteria by which new projects should be evaluated;

(*h*) Available sources of financing for developing pulp and paper industries.

The deliberations

19. The deliberations of the Meeting are summarized below in the order in which the items appeared on the agenda.

Consumption, production and trade

20. It is conservatively estimated that consumption of pulp and paper will approximately double by 1965, reaching nearly 3 million tons as compared to about 1.5 millions per annum in the period 1948-52. If economic developments are generally favourable this figure may be considerably exceeded. These estimates in no way represent the maximum levels of consumption capable of being realized if adequate supplies of pulp and paper should become available, for historical data show clearly the relation between abundant availability of paper and its increasing rate of consumption.

21. These increased requirements are not likely to be met by imports from Europe or North America, nor can they be met by Latin American projects under construction, or in the planning stage. The regional capacity for pulp and paper production must rise steeply over the next few years in order to meet clearly foreseen requirements.

22. Two particular aspects require special attention: (*a*) the production of mechanical pulps or pulps capable of replacing mechanical pulp for newsprint, and (*b*) kraft pulp or combinations of pulps for high-strength wrapping paper.

Tropical and sub-tropical hardwoods

23. The very magnitude of the basic resources in tropical and sub-tropical woods quite rightly offers a major challenge to industry. But the obvious abundance of the resource and the small degree of current exploitation raise three different kinds of problems:

(*a*) Those pertaining to the estimate of the resource, its composition and capacity for continuous replenishment, and its probable future evolution under the impact of exploitation; these are problems of resource management;

(*b*) Since these forests yield wood not hitherto well known to pulp and paper technology, the adaptation of known processes to them in both conventional and unconventional ways requires an appraisal of costs, technical results, and capacity to satisfy the requirements for different kinds and qualities of paper; these are largely problems of pulp and paper technology;

(*c*) The fact that certain possible sites are in undeveloped regions, where industrial, social and transport facilities either do not exist or are but meagrely developed, raises important economic problems.

24. From the silvicultural point of view, the guiding principle is the perpetual maintenance of an adequate and satisfactory supply of material to the contemplated industry. In spite of lack of accurate knowledge as to the

way these forests react to the harvest, an optimistic view of their long-term behaviour is expressed. This view is based upon the known facts of tropical silviculture, the vigour and growth capacity of the forests, and the apparent need for the present of *attainable* management and conservation plans.

25. Such plans must be based upon original inventory, perpetual inventories that take account of the dynamic effects of the harvest, and such modifications in forest practice as will arise from increased experience. This has been the history of the opening up of all new forest types; there is no reason to expect that tropical experience will be different. For example, results in certain areas of Peru indicate that *cecropia* grows well in clearings and in reasonably pure stands. If this holds good in further practice, it will afford an excellent example of stand improvement through harvesting, with the new forest better adapted to the requirements of pulp and paper.

26. In some areas, opening the forest for exploitation will involve considerable expense. Where veneer woods or saw timbers constitute important components of the stands, attention should be given to proper utilization of such timbers, so that potential high values may be realized and extraction costs, road building and other development costs distributed. Further, proper integration of other forms of utilization with pulp and paper may often make feasible an otherwise impossible project.

27. The selection of the process for pulping mixed tropical woods must be based upon versatility in application to a multiplicity of species, and on the need to adapt the resultant pulp to the products desired. In general, the sulphate process, because of its ability to pulp a great variety of broad-leaved species and because of its tolerance to bark and extractives, is agreed to be the most adaptable to tropical woods. Considerable investigation has amply shown the flexibility of the sulphate method when applied to quite heterogeneous mixtures of tropical woods.

28. In some cases, wood sorting will be needed, e.g., to eliminate species of high silica content or otherwise unsuitable for processing.

29. In the production of pulp that can be substituted for groundwood in newsprint or other products, the conventional groundwood process can be applied successfully to certain species, providing those species occur in ample quantity. However, conventional production of mechanical pulp from mixed tropical species does not appear feasible.

30. Certain other processes, notably the neutral sulphite semi-chemical process and the more recently developed cold soda process, seem to offer the possibility of meeting Latin America's needs for a type of pulp suitable for the manufacture of newsprint; appropriately blended these pulps may be used in a wide range of other papers too. The capital investments and plant sizes, especially in the case of the cold soda process, need not be large.

31. With regard to plant location of pulp and paper projects in Latin America, problems will be confronted that do not arise in highly industrialized regions. Capital requirements for developments necessary to the installation in under-developed areas may be high but may, on the other hand, be compensated by the lower cost of certain other items. The *entrepreneur* will seek to balance advantages and disadvantages offered by various sites and will concentrate his attention on that site which offers the optimum combination of suitable locational factors.

32. When projects are contemplated in a region where basic community services are entirely lacking, but where—for economic and social reasons—Governments wish to encourage industrial development, it is possible that methods can be worked out between private capital and government authorities that will provide for government financing of so-called "settlement" facilities. Unless such policies are adopted, the attention of private capital will necessarily be drawn towards projects located in developed areas near urban consumption centres.

33. It is considered unlikely that pulps from tropical broad-leaved woods will make any substantial contribution to the world market for many years to come, but they may be of great significance in the satisfaction of Latin American requirements. Broadly speaking, this applies especially where proper integration can be achieved with those areas capable of producing long-fibred pulps. In the regional market, prospects are good for both bleached and unbleached pulps from tropical broad-leaved woods and especially for papers made therefrom.

34. It is impossible to generalize concerning minimum economic size for mills proposed in Latin America. However, as a rule capital costs will be heavier if sites in undeveloped regions are compared with those in industrial areas; but certain other costs, such as those for pulpwood and wages, will tend to be lower.

35. The Meeting concluded that available data demonstrated the possibility of converting tropical woods into satisfactory paper at competitive prices in national or regional markets, *provided the site were correctly chosen.*

Other forest resources

36. Although the tropical and sub-tropical forests of Latin America loom large as eventual potentialities, the region is by no means devoid of other important forest resources. These comprise considerable broad-leaved and coniferous temperate forests, as well as large existing plantations in both categories.

37. General factors governing forest practices and the utilization of natural temperate broad-leaved forests are akin to those applying to similar forests elsewhere. Once a decision has been reached, on a basis of economic and land classification studies, to devote land to permanent broad-leaved forest, the harvest must be depended upon to bring the forest to good composition and acceptable yield. Existing pulping methods can serve well to effect this process and make possible the profitable utilization of present stands to improve future crops.

38. In both broad-leaved forests and natural coniferous stands, the general problems of protection from fire and over-grazing are of great importance.

39. Natural regeneration of existing forests must sometimes be supplemented by planting, and, in such cases, opportunity may be afforded to improve composition and yield through choice of species or even transformation of a natural broad-leaved stand to more profitable conifers.

40. Extension of the natural coniferous forests in South America and Mexico by plantation methods, based upon adequate research, appears to warrant special attention.

41. As for plantations, they attract pulp and paper manufacturers because of the convenience with which the yield can be adapted to the requirements of processes and products. Also, since plantations can often be developed in proximity to industrial areas, many problems arising in more remote locations are avoided.

42. In general there are two principal instances where plantations are recommended: (*a*) when they constitute the best form of land utilization. Numerous examples are found in north-eastern Argentina and in Brazil with their plantations of Paraná pine and eucalypts; (*b*) when they represent profitable use of currently unprofitable forest sites, whether of unforested land or land covered with woodland of little or no economic value. Examples are the plantations of *Pinus radiata* in Chile and the plantations in the Paraná Delta.

43. There is a large and important field for research in planting in Latin America to ensure reafforestation of a great deal of deforested or poorly forested land, and to create new forests. Careful testing of exotic species and selection of superior strains of native species offer fields for extensive co-operation between the various research institutions. As extension of present arrangements for exchange of seeds and information is needed.

44. Particular attention should be given to the relationships between spacing, growth rate and wood properties in order to achieve optimum yields and utilization opportunities.

45. The Regional Forestry Office of FAO is in an excellent position to function as a collecting and distributing agency for pertinent information. The Meeting suggested the desirability of amplifying that Office's facilities to accomplish these ends.

Eucalypts

46. Extensive plantations of eucalypts, on the basis of many years of careful experimentation, especially in Brazil, offer encouraging prospects as a source of material for a permanent pulp and paper industry.

47. With regard to processes, the sulphate, semichemical, soda and the new cold soda process, all seem to be applicable to numerous species of eucalypts for the production of a wide variety of papers, ranging from fine bonds to newsprint. In the case of groundwood, Australian and Latin American experience indicates that mechanical pulps from plantation eucalypts are likely to be of poor quality and their use for newsprint limited to low percentages in blends.

48. More intensive research on and experiments with the eucalypts should produce results of considerable value to Latin America, especially if advantage is taken of the very extensive work already carried out in Africa and Australia.

Bagasse

49. Latin America produces annually about 26 million tons of wet bagasse, or more than enough for 4 million tons of pulp. However, only 1 to 1½ per cent of this quantity is actually being pulped in nine existing mills. In general, increased supplies of bagasse for pulping are dependent entirely upon changes or improvements in sugar-mill procedures. Chief among these is the replacement of bagasse—used as fuel in the sugar mills—by oil or, in some countries, by coal or natural gas.

50. The capital costs involved in substituting oil for bagasse are not at all high, the major cost element in the substitution being that of the fuel itself. Generally, where the substitution has been made, one ton of oil has replaced about 6 tons of wet bagasse.

51. Existing mills pulping bagasse offer a wealth of experience in the practical baling, storage and handling of bagasse to permit continuous pulping operations in spite of the generally short duration of the sugar campaign.

52. Separation of the pith from the fibre in bagasse has been found generally advantageous in pulping; the pith can be profitably marketed for various uses.

53. As for pulping processes applicable to bagasse, all the standard processes seem to be satisfactory, except the acid sulphite method.

54. Some important grades of paper are being made from furnishes consisting of bagasse pulp alone. However, it is believed that the major contribution of this important raw material will be as a blending pulp. Mixed with other pulps, bagasse pulp can impart improved properties to the blend.

55. While there seems to be no doubt that bagasse will make a significant contribution to an expansion of Latin American pulp and paper production in the long term, its possibilities in the short term are limited by the fact that alternative fuel must be used to release substantial amounts.

Development prospects

56. Most Latin American countries give a prominent place in their plans for industrialization to the development of adequate productive capacity for paper. They clearly recognize the social and economic value to them of a creative industry based on a renewable resource, and the capacity of pulp and paper to generate new and allied industries.

57. Analysis of the plans offered by the different countries serves to emphasize the attention being given to the various types and grades of commercial papers, and the inadequacy of the plans for the production of newsprint. This is not because of any lack of recognition of the importance of newsprint, but because economic considerations, and, in some cases, government policy, have caused plans to be directed toward grades other than newsprint.

58. Raw material supply differences and specific economic circumstances may be expected to give rise to a tendency toward specialization within countries as regards types of pulp and particular grades of paper. In some cases domestic markets will be too small to absorb the output of large and specialized mills; hence it would be desirable to facilitate the development of intra-regional markets in pulp and paper.

59. The need for international co-ordination of developments is clear, and it is hoped that international organizations will find it possible to study this field and

render assistance in those problems that cannot be solved by individual Governments or private enterprise.

Newsprint

60. If proposals for increasing newsprint production in Latin America are considered inadequate, this is not due to lack of interest. All countries, without exception, are intensely interested in expanding or beginning newsprint production for well known and impelling reasons.

61. Latin American newsprint production today is based mainly on traditional fibres using more or less conventional methods. This production will expand, but many Latin American countries lack traditional fibres.

62. Processes available today give promise for the production of newsprint from tropical woods in combination with long-fibred pulps. Technical results indicate the possibility, for example, of substituting semi-chemical pulps from broad-leaved species for groundwood, possibly reducing the furnish of long-fibred coniferous pulp, and thus leading to the production of satisfactory newsprint of unconventional composition. Technically, the newsprint problem may be solved along these lines.

63. Attention is called to the economic implications of promoting newsprint production in Latin America. In only very few cases can newsprint mills operate, even in the domestic market, if exposed to the unhampered competition of foreign newsprint. Governments wishing to ensure domestic supplies of newsprint must take cognizance of the economic disadvantages under which such a new industry may have to operate.

64. Newsprint mills are generally specialized and represent large investments and large production. Thus the need for intra-regional arrangements to facilitate the expansion of this key industry in Latin America for the betterment of the region is again apparent.

Financing

65. The need for expansion of pulp and paper production in Latin America is real and urgent. Raw material from forest and field exists in sufficient quantity and, with good management, in perpetual supply. The will to encourage expansion exists on the part of interested Governments. The technology is sufficiently advanced to warrant optimistic expectations of success. There remains the important problem of mobilizing the necessary capital to finance this development.

66. The amount of new investment estimated to be required per year to achieve a reasonable standard of paper production by 1965 is between $50 million and $90 million. These figures need not be regarded as unattainable. The annual foreign exchange requirements would amount to about half of 1 per cent of the region's annual foreign exchange earnings. Furthermore, the reduction in requirements for foreign currency for imported paper will, in many cases, exceed in a couple of years the amount of foreign exchange needed to establish the industry.

67. However, capital—whether public or private, local or foreign—will only become available for projects which succeed in satisfying strict criteria.

68. Two recent proposals may, if they come to fruition, provide private undertakings in less developed areas with a more direct access to international lending facilities. The utilization of either would meet the recognized need for some institution able to channel international loans to private undertakings.

69. If private foreign capital is to participate in Latin American pulp and paper expansion through direct investment, it must be satisfied concerning the soundness of the project as a business risk; general conditions in the project area must be such that the enterprise can operate successfully for a reasonable period, and that no difficulties will arise in remitting earnings and in eventually repatriating capital.

70. The most important source of financing will be domestic capital, and though joint enterprises uniting domestic and foreign capital may become of increasing importance, it must be recognized that no significant expansion of the Latin American pulp and paper industry can take place unless domestic capital is willing to set the pace.

71. It is desirable that the attention of the Latin American Governments be drawn to the necessity for (*a*) according priority to the pulp and paper industry in establishing development plans; and (*b*) mobilizing domestic capital and facilitating the movement of international capital in order to realize this expansion.

Technical assistance, research and training

72. Throughout the Meeting, repeated emphasis was given to the need for more research in silviculture, planting and forest products technology. Likewise the need for trained men was emphasized, especially to facilitate pulp and paper expansion.

73. There was agreement on the desirability of ensuring regional co-operation in the programming of national and individual research, educational and training activities. For reasons of economy and efficiency, such co-ordination was deemed highly desirable.

74. It was the belief of the Meeting that the proposed establishment of a Latin American Research and Forestry Training Institute represented a satisfactory solution of this problem. Therefore, the Meeting urged Governments of Latin American countries, as well as the international and bilateral organizations concerned, to implement the recommendation of the fourth session of the FAO Latin American Forestry Commission (Buenos Aires, 1952) as soon and as fully as possible.

75. It was felt to be urgent that early and adequate attention be given to the creation of central research and training facilities in the field of pulp and paper, forestry and forest products. In developing such a central institute, it was strongly recommended that the closest co-operation should be maintained with existing facilities for teaching engineering and applied sciences.

76. To co-ordinate these proposals, and to afford a serviceable channel for technical assistance, the Meeting recommended that a group of experts be placed in Latin America in the near future under the Technical Assistance Programme. This group should include one or more specialists on industrial problems, and one or more on technical and economic aspects of the pulp and paper industry.

General conclusions

77. The foregoing all leads to the general conclusions enumerated below: 1. Latin America needs somewhere

between 1.5 and 2 million tons of additional pulp and paper supplies yearly by 1965. 2. Most—in fact nearly all—of this increase must come from new Latin American production. 3. There must be a steep increase in the rate of completion of new production projects in order to meet the requirements. 4. Raw material supplies in wood and other fibres are adequate for all foreseen needs. 5. Established processes and new processes, operating along unconventional but proven lines, can adequately accomplish the technological task. 6. Unconventional fibres, bagasse, straw, grasses, etc., will play an important part in long-range pulp and paper supplies. 7. Excellent opportunities for expanded industry based on planted forests already exist and may be expected to increase. 8. Development of new production enterprises in undeveloped regions should carry governmental co-operation to cover "settlement" costs. 9. The important item of increased newsprint production from Latin American materials poses special problems of large investments and inter-Latin American co-operation. 10. The technical task of newsprint production can be solved by a combination of conventional and unconventional processes and materials. 11. Capital investments required by the whole programme are not so large as to be forbidding. The total is very small in comparison with the current rate of total investment in Latin America. 12. Foreign exchange required will be quickly compensated by reductions in import requirements. 13. Combinations of foreign and domestic capital will be most favourable for development, but the lead must be taken by domestic capital. 14. Project proposals, whether for banking or private capital, must be sound business risks and presented as such. 15. Government policies should take cognizance of the need to encourage new industry. 16. Governmental policies should move in the direction of encouraging inter-Latin American trade in pulp and paper in order to ensure adequate supplies for all countries and the most rational use of the region's resources. 17. Provision should be made for greatly increased research looking towards management of the resources, utilization and training of personnel. 18. International co-operation, with participation of international agencies, is the most economic and satisfactory means of completing and fulfilling existing national and private efforts in this field.

III. Sectional reports

Pulp and paper consumption, production and trade in Latin America[7]

78. Latin America today consumes about 1½ million tons of paper and board, including about 400,000 tons of newsprint.

79. An appraisal of the prospects for developing pulp and paper industries in Latin America calls for an assessment of the future level of demand, an appreciation of the possibilities of procuring pulp and paper supplies from other regions, and an estimate of the extent to which projects currently under construction, or due to be completed in the near future, are capable of satisfying expected future needs.

80. Estimates of future requirements must take as their starting point current consumption, or effective demand. Today, in many Latin American countries, effective demand falls short of real demand. Countries where exchange restrictions limit consumption would of course consume more if restrictions were removed. And the removal of particular deficiencies in local supply, e.g., in mechanical pulp or newsprint, would undoubtedly lead to increased consumption in the countries concerned. Thus, any estimate of future consumption based on current effective demand might prove too low if, in fact, local production expanded sufficiently or if free import became more general.

81. The estimates of future consumption contained in Secretariat paper 2.0 were arrived at by making use of the high correlation which exists between *per capita* income and *per capita* consumption of paper. Three categories of paper were studied separately: newsprint, other printing and writing paper, and all other paper and board. In each case it was established that income elasticity was higher at lower income levels; in other words, while a given increase in *per capita* income was followed by a more than proportionate increase in paper consumption, this increase was greater for lower income countries than for high income countries. The income elasticities were applied to estimated demographic trends, making two separate sets of assumptions concerning the annual rise in *per capita* income that may be expected in Latin American countries during the coming years. The first set of assumptions was based on the expectation that only a minimum rate of economic growth would be realized; the second corresponded to a more favourable (though not the maximum possible) rate of economic growth.

82. Since the starting point was average effective demand in the years 1948-52, the resultant estimates do not represent either forecasts of future consumption or estimates of the full potential demand that could be realized; they simply represent the levels of consumption that would be attained if consumption were to rise in accordance with the income elasticities determined from present data.

83. The Meeting endorsed the procedure followed in arriving at estimates of future demand, and experts from Brazil, Chile, Colombia, Cuba, Mexico, Peru and Venezuela confirmed that the figures contained in the Secretariat paper corresponded fairly well to the results of individual studies carried out in their own countries. The representative of UNESCO stated that further confirmation of the global estimates was found in the independent study which UNESCO had commissioned from the Intelligence Unit of *The Economist*, London.

84. Attention was drawn to the contrast between paper consumption in urban and in rural areas, and to the rise in consumption that would accompany the very rapid increase in urbanization that was taking place in many Latin American countries today. It was suggested that studies of the percentage of income devoted to paper consumption at different income levels be undertaken in each country; it was believed that such studies would serve to confirm the Secretariat's findings.

85. Given only minimum economic growth, the Secretariat estimated that Latin American consumption would rise by 1965 to 2.7 million tons, including nearly 800,000 tons of newsprint; if economic development were favourable, consumption would rise to 3.5 million tons, including just under a million tons of newsprint.

86. While approving the orders of magnitude indicated by these global figures, various experts commented in detail on certain of the figures appertaining to individual countries and recommended that their comments be appended to the published version of the Secretariat paper.

87. It was felt that the trend of demand in Europe made it unlikely that there would be any substantial increase of export availabilities in that region. So high were the levels of production and consumption in North America that uneven development in the former or variations in the latter would make available for export fluctuating amounts which might, from time to time, be substantial.

88. In the past, various factors, including the problem of foreign exchange, had limited Latin America's capacity to import. Though some experts believed that conditions had changed and would possibly improve even more in the future, most considered that these factors would continue to set a limit to imports.

89. The Secretariat paper contained details of existing plans for expanding the region's pulp and paper capacity in the next decade. Even if all should be realized, however, it was evident that they would be insufficient to ensure that the region's future needs were satisfied. It was pointed out, nevertheless, that mills now under construction in Chile provided for an expansion of capacity beyond the requirements of the national market: thus a small exportable surplus might become available there and if further plans materialized this exportable surplus would grow. This would help to offset the rising deficit in other parts of the region.

90. The Meeting agreed on the following conclusions: 1. By 1965 the region's paper needs will have

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approximately doubled as compared with 1948-52. Given favourable economic development, the region's paper needs would be considerably higher. 2. Many projects for expanding the region's capacity are under construction, at the planning stage, or being studied. Even if all were realized, they would not satisfy the expected increase in demand. 3. Unless capacity rises much faster than is at present contemplated, only a steep increase in pulp and paper imports will permit the region's paper needs to be fully met. 4. There is little likelihood that the region will be able to import on the scale required, or that quantities of this order will be available in the traditional producing centres for export to Latin America, especially as needs are rising faster than capacity in other regions of the world which today look to Europe and North America for supplies. 5. Every effort should therefore be made to step up the rate at which new capacity is being developed, both by pressing forward those projects already under study which prove practicable and by exploring further possibilities. 6. Two problems especially call for an urgent solution: first, the development of sources of cheap mechanical pulp, or pulps capable of replacing mechanical pulp, for the manufacture of newsprint; secondly, the development of kraft pulp production, particularly for high strength wrapping papers.

91. The Meeting was of the opinion that the need for a detailed consideration of the measures which could be taken to accelerate the expansion of pulp and paper capacity in Latin America clearly emerged from even a cautious assessment of the region's future needs. It was emphasized that the estimates in no way represented the maximum levels of consumption which were capable of being realized. Historical data showed clearly that consumption levels were largely determined by the extent to which adequate supplies of pulp were available at reasonable cost from either domestic or foreign sources. Levels of consumption even higher than those at present foreseen could be reached if domestic supplies were to become available in sufficient quantities.

92. On the other hand, failure to realize an adequate expansion in the region's pulp and paper capacity would inevitably mean that low standards of paper consumption would act as a drag on the region's educational, cultural and economic progress.

Economic aspects of pulp and paper manufacture from Latin American tropical and sub-tropical hardwoods[8]

Forestry aspects

93. When considering the tropical forest as a source of raw materials for the pulp and paper industry, the forestry expert is faced with two different categories of problems, according to whether the object in view is a short-term supply, based on the existing state of the forest stands, or a long-term supply, taking into account the evolution of these stands following repeated cuttings and various silvicultural interventions.

94. To be able to inform industrial interests on each of these aspects, the forester has to carry out a series of studies. First come what may be termed static studies, giving a clear picture of the present condition of the forest area; these data are provided by different kinds of inventories. Next must be undertaken dynamic studies of the forest stands; these will be carried out on the basis of trials and experiments which should aim at providing, as quickly as possible, a knowledge of how the stands will evolve under different kinds of treatment. From the results of these studies and trials conclusions can be drawn which will permit a definition of the silvicultural methods that should be envisaged in each case, and the establishment of a forest management (and utilization) plan. This plan should be made on the basis of the most adequate forest practices, defining such operations as may be necessary to assure a permanent raw material supply, having regard to conservation and the improvement of the forest capital.

95. A continuing inventory will provide increasingly precise information regarding available forest areas, the volume of standing timber per hectare and the composition of this volume by diameter classes and species, and will be of value both in selecting a satisfactory working site and in defining details in the forest management plan for a short-term working period.

96. In tropical as well as in temperate zones, aerial photography can quickly and economically provide indispensable information upon topography, forest area and the distribution of the different forest types; its efficacy in the tropical and sub-tropical zones is limited by the density and inter-mixture of crown foliage. Essential data upon volume, species and their individual distribution cannot in most cases be directly determined from the photographs.

97. Aerial photography must be followed up and completed by ground surveys of two kinds: rapid surveys, to interpret aerial photographs, and precise studies of the stand based upon careful systematic sampling.

98. It has been established that in general, inventories are more precise the greater the number of sample plots examined within the forest, but since the cost of these operations is proportional to the intensity of the sampling, the forest expert, in agreement with the industrial interests, should fix an economic limit to such studies. The limit fixed will have to take into account the tolerance of the pulping process contemplated to variations in wood mixtures. Great differences within the forest stand may require modification of the pulping process; these variations must therefore be known in advance.

99. Very little information exists at present concerning the long-term evolution of tropical forest stands following intense and repeated cuttings such as those which must be envisaged when supplying a pulp mill.

100. Studies of the consequences of the traditional practice of shifting cultivation can doubtless provide some clues, since this practice has brought about changes in the forests comparable to those which would follow repeated fellings in short-term cycles for pulping.

101. The harm done by shifting cultivation and grazing is much greater than that resulting from repeated cutting for forest products, since destruction of the forests by fire despoils and denudes the forest soil. Nevertheless, it has been shown that this form of agriculture offers no real danger if carried out under proper conditions, and if certain well-known precautions are adopted.

102. Thus exploitation to supply the pulp and paper industry may be regarded in the long term with a certain

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optimism, providing the necessary measures are taken to avoid soil depletion, especially to be feared in tropical forests.

103. As regards silvicultural practices for preserving or improving the make-up and value of a forest, no general rule can be established, since natural, economic and social conditions vary so much from one place to another. In each case, the appropriate methods can be determined only by special studies of local conditions and by experience gained on the spot. These studies and investigations, however, must be based upon certain main principles: 1. It is necessary to be assured that the source of supply is permanent; in the case of tropical areas this means the setting up of management and soil conservation plans. 2. Efforts must be made to transform the heterogeneous forests into a composition of greater economic value from the standpoint of the requirements of the pulp and paper industry, for example, as regards wood size, quality and homogeneity. 3. Because it is important to obtain raw material at the lowest possible cost, the aim will be to obtain the maximum output of best quality material, easy to extract. At the same time the silvicultural practices adopted to achieve this aim must be carried out as economically as possible. It is clear that in most cases the most economical form of intervention will be the exploitation operations themselves.

104. The studies undertaken in the Amazon area of Peru concerning the natural stands of cetico (*Cecropia spp.*) and their possible utilization by the paper industry were considered to be of importance.

105. The excellent technical properties of cetico wood, which can be processed mechanically or chemically to provide pulps suitable for various uses, and the fact that these trees grow in homogeneous stands in clearings of the tropical zone, indicate good possibilities for the pulp and paper industry. Nevertheless, it is difficult, in the light of present knowledge concerning their regeneration and propagation, to reach any definite conclusion for tropical areas in general. Silvicultural studies should therefore be undertaken.

106. The Amazon area of Peru, in view of its special natural conditions, represents an exceptional case which, according to information given during this meeting, allows a regular supply of cetico wood for an industrial unit under contemplation. Consequently the Meeting regards with great interest the contemplated project in this region, and believes that this project will provide valuable information which will contribute to the study of the problem of utilizing cecropia species in other parts of Latin America.

107. There is great need for systematic and continuous research in all fields of tropical and sub-tropical silviculture and forest utilization, and results obtained throughout the world should be made known through the efforts of international organizations interested in forestry and through bilateral arrangements.

108. Consequently, the forestry profession is awaiting with interest the results of the Fourth World Congress on Silviculture, which will meet shortly in Dehra Dun (India) and which is to pay special attention to the problem of tropical forests. It is expected that a great number of Latin American foresters will be helped by the recommendations of this Congress, or by their active participation in it.

Wood extraction

109. It is believed that pulp mills in general should have under their control sufficient forest area to guarantee their own supplies even in those regions where it may be possible to purchase the mill requirements locally. In such a case, the paper industry need not necessarily produce the whole of its supply, but it will be in a position to avert a possible interruption of its operations due to lack of wood or excessive wood prices.

110. The extraction of raw materials in large tonnages from concentrated areas depends primarily upon the planning and establishment of adequate transportation facilities. Although water is still the most economical means of transport, roads will be of greater importance in tropical forests because many tropical species will not float. Barging, however, may prove economical in some cases.

111. It will be necessary, on account of heavy rainfall, to give particular care to the construction of primary roads, that is to say, of permanent roads carrying the whole or the major part of traffic.

112. The climatic conditions which complicate road transport, at least during part of the year, also complicate the harvesting and storage of pulpwood. A possible solution to the problem of assuring an uninterrupted wood supply may be achieved by selecting, in the management plan, an area as near as possible to the mill and on readily accessible terrain, to be reserved for extraction during the most unfavourable season. It has been mentioned that when conditions are particularly difficult, the use of insecticides and fungicides might represent a solution to storage problems.

113. Since in general not all the timber drawn from the forests will be destined for pulp and paper manufacture, the first selection can be made by marking commercially valuable species before felling, in particular for saw logs and veneer logs. Subsequently, it would be possible after felling to segregate wood for the pulp mill into a limited number of categories in accordance with hardness and colour characteristics, in particular sorting out those unsuitable for pulping. The categories segregated will naturally vary according to the pulping process contemplated. It is not believed that this simple segregation after felling will present any serious difficulties.

114. In the case of pulp industries located at a distance from industrially developed centres, special attention should be paid to the kind and quantity of basic equipment, maintenance shops, and stocks of spare parts.

115. Finally, with reference to the over-all forestry or utilization problems, it is hoped that FAO may be able to compile and publish pertinent information available from all reliable sources. The establishment of a Latin American Research Centre would render a valuable contribution towards the development of the pulp and paper industry on this continent. Any effort in this direction would be of great advantage to the Governments concerned as well as to industry.

Pulping processes and paper qualities

116. It has been established that, because of its great tolerance to bark and extractives and a wide variety of wood properties, the most suitable standard method for producing chemical pulp from mixed species is the sulphate or sulphur-soda process. This has the further ad-

vantage of being able to produce stronger and more varied pulps than other commercial processes now known.

117. The pulping conditions for mixed tropical species do not differ essentially from the normal conditions employed for chemical pulping of temperate broad-leaved species, except for a possible adjustment of details for certain single species or groups of species with very high or low density. Two-stage or counter-current alkaline pulping of certain raw materials such as bamboo and eucalypts has shown that technical improvements in pulp quality may be obtained, and this method may be worth considering also for mixed tropical species.

118. Laboratory and pilot scale investigations carried out in France, the United States, Brazil and Mexico, show clearly that it is possible to cook heterogeneous mixtures of tropical woods successfully by the sulphate process. These results are also confirmed by tests carried out on mixed woods from Amapá and Yucatán, the locations of the hypothetical mills studied in the Secretariat papers. Industrial experience in the mill in Abidjan, West Africa, working on mixed tropical woods, amply confirm the laboratory tests.

119. Although pulps produced from mixtures of tropical woods possess good paper-making characteristics, improved qualities may perhaps be obtained by segregating the woods into groups or eliminating certain species prior to cooking and subsequently blending the pulps obtained. The decision for or against segregation in any given case will depend on a variety of technical and economic factors.

120. Among tropical timbers, species may be encountered with high silica content or other peculiarities of chemical composition which may give rise to difficulties in processing. These difficulties may appear in the recovery of the black liquor, bleaching or other phases of the process. Experience in pulping numerous broad-leaved species, however, suggests that such difficulties may be overcome by known techniques.

121. In most cases tropical woods will probably be barked by hand, principally because this method is inexpensive when labour rates are low and makes the use of complicated equipment unnecessary. Mechanized barking should be studied; it may present difficulties with certain groups of species. The debarking of standing trees by chemical treatment is a promising recent development on temperate zone species and may prove suitable for accessible forest areas.

122. Experience in North America suggests that temperate hardwoods may be successfully processed without barking, making use of modern screening equipment and centrifugal pulp cleaners. There is reason to believe that this method would give satisfactory results on some mixtures of tropical woods. The pulping of unbarked wood may involve heavier chemical consumption in digestion.

123. With the possible exception of certain species with unusual properties, it has been found that the bleaching of mixed tropical wood pulps does not present any special problem—the ordinary multi-stage operation commonly used today for sulphate pulps gives satisfactory results, although brightness stability may require special consideration.

124. There is sufficient practical experience to demonstrate that bleached pulps made from many mixtures of tropical woods may be used without admixture of long-fibred pulps for the manufacture of printing, writing and a variety of fine papers in commercial operation. Laboratory and limited industrial experience suggest that from these pulps, without adding long-fibred pulps, an even wider range of papers may be produced, including those wrapping papers for uses in which the highest requirements of strength are not considered essential. Since the fibre properties of the mixed tropical woods have been found to be equal, and in the case of certain groups of species superior, to those of temperate zone hardwoods and eucalypts in common use, it seems clear that pulps from tropical wood mixtures can also be used for the production of even the highest strength grades (e.g., wrapping and sack papers, kraft-liner), providing they are blended with quantities of long-fibred (coniferous) pulps; in some cases these quantities may be relatively modest.

125. When a mill is contemplated in a tropical region it will normally be conceived as a wholly or partly integrated project. Tropical hardwood pulp is not likely to be of great significance in the world market, but may be significant in developing "area integration" of pulp and paper manufacture. Indeed, it is unlikely that unbleached pulp from tropical hardwoods could compete successfully on the world market with unbleached long-fibred pulp, although special grades of purified or bleached pulp may well find a place. In the regional market, however, the prospects are better for both bleached and unbleached pulp, but especially for papers made therefrom.

126. In so far as chemical pulp may be considered to be too expensive for the furnish of some varieties of paper, some processes which are of limited applicability with respect to raw materials or product properties may make it possible to produce cheaper pulp for special purposes. Preliminary investigations show them to be sufficiently promising, at least for some single species and groups of species, to warrant further study.

127. Most of the tropical species, pulped by the processes described below, give pulp of low colour, which may require brightening or partial bleaching before it can be used in printing papers of even the lowest grade.

128. Groundwood pulp is of major importance in newsprint manufacture and of some lesser importance in a wide range of other paper products. The conventional groundwood process can be applied to certain tropical and sub-tropical species, notably some cecropia species and other low-density woods frequently occurring in second-growth forests. However, the production of mechanical pulp from *mixed* tropical species by the conventional grinding process does not appear feasible at present. The applicability of the chemi-groundwood process to mixtures of tropical woods has not been proved, although it may well be of use on selected species or for selected purposes.

129. Some processes offer the possibility of producing groundwood type pulps from mixed, as well as from individual species, e.g., disk-refining processes with pretreatment of the wood by steam or chemicals. For example, a cold caustic treatment followed by disk refining has yielded promising results for the production of newsprint-type groundwood. Because newsprint is one of Latin America's particular needs, it would seem that closer investigation of this and any other process capable

of yielding newsprint-type groundwoods from mixed tropical species is desirable.

130. The neutral sulphite semi-chemical processes have proved to be of particular interest for converting broad-leaved species from temperate zones. These processes are adaptable to most temperate hardwoods and to some tropical species. Mill construction costs are somewhat lower than those of chemical pulp mills and relatively small units are being operated economically in developed countries. Although the rapid expansion of the various semi-chemical processes is based largely on the use of pulp for corrugating medium, unbleached neutral sulphite pulp is now being used for newsprint; bleached neutral sulphite semi-chemical pulp is being employed for glassine and, in blends with other pulps, also for writing and printing papers.

131. Potential uses for semi-chemical pulps from tropical woods, in appropriate blends, may be considerably broader. Further exploration of the economic possibilities for adapting the semi-chemical processes to tropical species for specific products such as liner and corrugating board may well be considered. In fact one such operation is already working satisfactorily in Latin America. Generally, such operations would be limited largely to integrated production units.

Locational factors and site selection

132. The general principles of location for the pulp and paper industry are no different from those for industry generally. No site will ever prove ideal from the standpoint of all the locational factors which have to be taken into account—raw material, power, fuel, chemicals, labour, transport, markets, etc. The *entrepreneur* will seek to balance the advantages and disadvantages offered by various sites under each of these headings, and will concentrate his attention on that site which offers the optimum combination of locational factors.

133. A new pulp and paper project in an undeveloped area will not necessarily require more investment *in the mill proper* than would a similar project in an industrialized region; it may even require less. The higher freight on the machinery and the higher erection costs may be offset by the fact that certain buildings can be of lighter construction or may be dispensed with altogether in tropical sites; careful international purchasing of machinery may also lead to savings.

134. Capital requirements for those elements of the project other than investment in the mill proper may, however, be very high in undeveloped areas, and for two main reasons. First, a mill in a remote area will have to be planned to be self-sufficient in many respects; it will probably have to provide its own power, it may have to develop its own sources of chemicals (e.g., to install an electrolytic plant for the manufacture of chlorine and caustic soda from salt), it may even have to develop its own mines for fuel supply. Secondly, besides ensuring the elementary needs of the production process, it will have to provide certain basic community services (transport, non-industrial power, communications, education, health, etc.) which, as a general rule, will exist already in an industrialized area; this need gives rise to what may be termed "settlement" costs.

135. It would be a mistake to assume that all tropical forests present the same problems. The establishment of a mill in the deep forest calls for very much higher total investment than the establishment of one in an area where certain facilities (and especially transport) already exist. But there are tropical forest areas which have already been partly developed in this sense. Certain "settlement" costs will inevitably be incurred in any tropical mill project, but in a remote site these may be so high as to render any project prohibitive.

136. These considerations serve to underline the paramount importance of exercising every possible care in selecting a site for a new pulp and paper project. Site selection in any country, for any industry, is important; it is important in Latin America for pulp projects based on any one of the region's many resources. The impact of "settlement" costs on most of Latin America's tropical forests makes imperative an especially intensive investigation of the locational factors involved when the establishment of a pulp and paper mill based on tropical woods is under study.

137. If projects are to be contemplated in a region where basic community services are totally lacking, and it is nevertheless believed that such industrial development ought to be undertaken for economic and social reasons, it is desirable that some way be found of financing such facilities other than by charging them as capital costs on the paper operation. Otherwise it is unlikely that private enterprise will undertake the risks involved. One solution to this problem is suggested by the practice adopted in certain countries where provision has been made for public authorities to furnish "settlement" facilities where the development of industrial enterprises has been judged to be in the national interest.

138. The relative influence of various locational factors will change in the course of time, and it is necessary to distinguish the short-term and the long-term view. If a new project in an undeveloped area has to bear the entire burden of "settlement" costs, there will be a tendency for private capital to prefer projects which are located near the urban consumption centres.

139. There are today in Latin America examples of mills located in urban areas which have been forced to close down as local raw material resources became depleted. At the same time, those paper mills originally established near market centres to operate on imported pulp are steadily being forced, as a result of the trend to large-scale production in the standard paper grades, to concentrate either on specialty production or on low-grade products based on waste paper.

140. A long-term view would take into account the fact that in an undeveloped area the burden of "settlement" capital declines after an initial period, while the differences in costs determined by environment will tend to diminish.

141. Today the pulp and paper industry in Latin America has the advantage of being in its preliminary stage; every effort should therefore be made to ensure that any units established are suitably located and of economic size.

142. In particular, it is of the greatest importance that the principle of permanent raw material supply be maintained. Some areas of tropical forest may be found to contain only species which are eminently and economically suitable for pulp and paper manufacture. More usually, in tropical areas, the forest will contain species possessing qualities which may have most value when used as saw logs or veneer logs. In such cases the utiliza-

tion of the forest so as to yield the maximum value should be aimed at from the beginning. In any event area integration of all forest products industries so as to yield the maximum economic value and proper diversity of production should be the ultimate objective.

Costs and economic size

143. In general, capital costs for mills in undeveloped regions will tend to be heavier than for mills of the same size in industrialized areas, as will also chemical costs in most cases, while pulpwood costs, wages, and sometimes also fuel costs, will tend to be lower. The balance will vary according to the site chosen.

144. The problem of the minimum economic size of a mill to be located in an undeveloped area, however, is by no means a simple one. If the product is destined for the national market, it will enjoy certain economic and commercial advantages which flow from its proximity to that market. Such countervailing factors may partly or wholly offset the relatively heavy incidence of capital charges; these tend to diminish more steeply in undeveloped areas as mill size increases. Nevertheless, the danger of establishing units which are too small to be of economic size is a real one, to be guarded against.

145. There is a considerable difference between paper converting costs in a non-integrated paper mill and in an integrated paper mill section, especially for small units. Therefore the establishment of a new pulp mill in an undeveloped area should, if possible, be integrated with a paper section to convert at least part of its production.

146. The experts' conclusions, reached after an exchange of experiences, were facilitated by the Secretariat studies of hypothetical mills in Amapá and Yucatán, undertaken in order to throw light on the problem of erecting mills in tropical areas, and in particular to examine the effect of location on investment and cost. The Meeting considered that the Secretariat documents represented a valuable contribution to the study of the problem of establishing pulp mills in the tropics and commended the use of prepared comparative estimates in meetings of this kind; the procedure adopted therein to arrive at figures of production and investment costs was deemed valid for the purposes of exposition. After discussion, the experts concluded that, on balance, the estimates probably erred on the side of caution (e.g., in the low proportion assumed of species pulpable and in the forest yield) and thus tended to understate probable earnings.

147. As regards the two particular locations studied, the Secretariat papers contained preliminary figures which indicated that the Yucatán project held distinct promise, especially as more favourable sites within the area appear to exist. The Amapá project seemed less attractive, but information brought forward in the discussion of the Secretariat papers indicated that further investigations might reveal production costs lower than the estimates contained therein.

148. While the experts did not have sufficient time and information to arrive at definite conclusions regarding these two Secretariat examples, they concluded that the Secretariat data further demonstrated that the possibility existed, *providing the site was correctly chosen*, of converting tropical woods into satisfactory paper at competitive prices in national or regional markets.

149. While studies similar to those presented on Amapá and Yucatán would always be necessary for arriving at a preliminary judgement in considering new projects, such studies could never dispense with the need for more comprehensive and detailed investigations. Moreover, it was pointed out that there might well be other sites in Latin America, and not necessarily in the areas studied, which might prove to be more favourable.

150. Any mill project in an undeveloped area, especially if it is based on a non-traditional raw material, needs not only careful analysis of all cost factors, but also technical investigations which may involve considerable expense. This capital outlay is imperative especially in the case of new processes or processing techniques. Technical assistance by international agencies might offer some help in connexion with the essential preliminary investigations.

151. Informed and objective advice in the preliminary stages of planning can be decisive in ensuring the viability of the final project; it can ensure that unsound schemes are discarded at an early stage and, as regards those projects which are eventually realized, it can, by indicating the most economic combination of machines to be employed, reduce initial investment cost and hence the consequent burden of capital charges.

152. The Meeting emphasized the note of caution which was expressly sounded in the Secretariat papers.

153. Because a large-scale pulp and paper mill calls for a very heavy investment, the need to safeguard against possible failures makes a cautious—even extremely conservative—view advisable when considering projects in undeveloped areas.

Aspects of pulp and paper manufacture based on other Latin American forest resources[9]

154. Apart from its vast tropical and sub-tropical forests, Latin America possesses further substantial raw material resources in the coniferous and broad-leaved forests which grow in temperate or cold climatic zones.

155. In addition, the region possesses important reserves in the extensive forest plantations of native and exotic species, both coniferous and broad-leaved, which have been established in many countries.

156. The success obtained from these plantations in some areas and with certain species, allows the statement to be made that Latin America has an enormous potential output of raw materials for the pulp and paper industry.

157. The meeting paid particular attention to two aspects of this problem; the first being its technical features (exploitation of natural forests, plantation techniques, transformation processes) and the second, and even more important, the place each resource should occupy within the framework of forestry policy and within that of the general policy for developing pulp and paper production in this region.

Plantations

158. For the manufacturer, there is no doubt that raw materials from plantations have, in the main, advantages over those extracted from natural forests. The technical facilities in the management and exploitation

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of these plantations, the uniformity of the supply and of the mill product, as well as the normally high quality of the output, are all arguments in favour of artificial methods. However, the problem is rather more complicated than it first appears, since other important factors relating to natural and economic conditions must also be taken into consideration before arriving at a conclusion.

159. In Latin America, the exact locations where plantations are to be established in relation to natural forests, should, as noted above, be defined on the basis of the two criteria linked with forestry practice and with the policy for paper production.

160. First of all, in each area being studied, it is necessary to define the place which regulated natural forests and artificial plantations should occupy within the general planning of soil utilization. Such planning must take into account locational conditions (nature and utility of soils, topography, etc.), economic factors (yield according to the different types of soil exploitation and marketing of products) as well as social factors (maximum use of rural and urban man power).

161. Forests, of whatever class, must take advantage of, or have to be created on, soils possessing forestry qualities. This term is used in its widest sense; it is applicable not only to soils that, for climatic or protective reasons, should be wooded, but also in cases where rational exploitation of forests—already existent or artificially created—represents the best and most economic among the various types of soil utilization possible in the area.

162. It is evident that in naturally wooded regions, if climatic and protective reasons are of importance, the maintenance of natural forests is to be recommended. It is also understood that, very frequently, and notwithstanding protective requirements, the exploitation of such forests may be undertaken if the necessary precautions have been taken to ensure perpetual use of these forests and of the protection they afford. Rules for extraction should thus be based upon a carefully prepared plan for regulation.

163. When studying the best type of soil exploitation for natural stands and even more so for a colonized zone, it is advisable, in the first place, to compare, on a long-term basis, the income from the exploitation of the natural stands with that accruing from agricultural or pastoral activities established after clear cutting. Later it will be essential to determine whether the plantation of certain species might—in the case of suitable soils—compete favourably on such soils, not only with regulated natural forests, but also with certain forms of agriculture which are believed to be profitable.

164. Considering this aspect of the problem only, it may be said that plantation can be recommended in two main cases: (*a*) When it constitutes the best form of soil utilization, as is frequently the case in north-eastern Argentina and in the south of Brazil with the plantations of *Araucaria angustifolia* and eucalypt; (*b*) when it represents the only remunerative activity, whether in non-wooded areas or in those covered by woods with no economic value at all. This is true of *Pinus radiata* plantations in Chile and in particular of the Paraná Delta for the plantation of salicaceous and some pine species.

165. A further aspect to be studied is the importance which should be given to plantations and their nature when it is necessary to meet certain special requirements of the transforming industry. In this case it is no longer a question of producing large quantities of raw materials without definite specifications; it is necessary to extract a type of wood with certain characteristics and capable of producing pulp to meet specific needs which pulps from other available resources cannot meet.

166. No general solution can be provided to this aspect of the problem, since it deals with species and requirements which vary from one area to another, according to the natural possibilities of each and the markets to be supplied.

167. The Meeting gave particular attention to this technical aspect of the problem and has recommended action for the international organizations concerned.

Natural forests

168. Once the place which natural stands should occupy in the economy of an area has been determined, it remains to establish how such forests should be managed to ensure their conservation and enable them to provide the raw materials required by pulp mills. In the case of natural stands it is not always possible to limit the research to sustained yield, since at the start the quality is often rather poor. As occurs in the case of tropical and sub-tropical forests, progressive improvement in the nature of the stands will have to be attempted to ensure long-term production which will better both quality and quantity.

169. This is a matter of forestry management and often of treatment. As regards the aim of producing pulpwood, the chief objective of the forester should be to discover or to continue regeneration which is as regular as possible in time and space.

170. If the forester adopts natural regeneration, which is often uncertain and irregular, he must help and protect the process (such is the case of the coniferous forests in Mexico especially). Fire is generally a scourge, but in certain cases, however, prudently directed and limited, it can be of use. In Latin America, grazing in the forests must almost always be severely regulated. The rotation of extraction must be carefully studied, taking into account not only the main factor of the yield, but also the technical and legal protective needs, as well as the most suitable size of the pulpwood for the paper industry.

171. Allowing for either the destructive factors which at once eliminate natural regeneration or the composition of the stands which hinder or prevent such regeneration, the forester must often adopt more active measures and sometimes introduce artificial regeneration. This type of regeneration may be effected with the same species found in the primitive stand or—according to individual cases and requirements—with other species. It leads to the progressive transformation of a natural forest with no economic value into a rich artificial forest. Interesting results of such methods, used in the Paraná Delta, have been submitted to the Meeting.

Considerations relating to pulping

172. It was recognized that well-established techniques already existed for the manufacture of pulp and paper from coniferous and salicaceous species and that the subject of pulping broad-leaved species generally,

was similar to that dealt with in another section of the report. However, a rather special problem arose in the case of producing pulp and paper from eucalypts and a second section on current experience in this field is given. (See paragraphs 177 to 195.)

Conclusions

173. To encourage the development of forest plantations on a rational basis and in the interests of Latin America's pulp and paper industry—without overlooking the large plantations now being made—the Meeting recommended the organizations concerned to take the following steps: 1. To study on a systematic basis, at the various experimental forestry stations in Latin America, the possibilities of introducing those exotic species which grow rapidly and are of interest to the pulp and paper industry. 2. To carry out systematic and comparative research at the same experimental stations into the different conditions for establishing and treating forest plantations based on native or exotic species which have already been, or could be, introduced. 3. To study at qualified laboratories the products of the plantations. Such studies would deal with the suitability of the wood for conversion into pulp and, above all, the quality of the pulps thus obtained. Not only wood specimens should be studied, but also each species individually according to its conditions of growth and the plantation methods for treatment. It would be particularly desirable to gather data on the relations between the rate of growth and the value in paper of the end-product for each of the existing species.

174. The combined results of these studies, as well as similar research undertaken elsewhere in the world into the same characteristics, should be collected by the Regional Forestry Office of FAO, analysed and distributed to the Governments and organizations concerned.

175. The Meeting suggested that the Regional Forestry Office, which has already undertaken work of this nature, should be given greater facilities to allow it to arrange either the exchange or free distribution of seed samples of forest species for the purpose of experiment and trial plantings.

176. Finally, the Meeting also recommended that FAO should urge Governments to grant all possible facilities for public services and private enterprise to obtain—by purchase or exchange—seeds for the wider extension of this work. As regards the temperate natural forests of Latin America, the Meeting in general felt that their use was economically feasible as a means of meeting the requirements of the paper industry, although in some cases delicate problems existed, which should receive the attention of specialists and Governments.

Pulp and paper manufacture from eucalypts[10]

General

177. The adaptability and rapid growth of many species of eucalypts in Latin America indicate that the many plantations established, especially in Brazil, should provide a plentiful and cheap supply of raw material for the manufacture of pulp and paper. Sufficient knowledge has been accumulated to dispel any doubts as to the wisdom of setting up an industry based wholly or mainly on the supply of pulpwood from the plantations.

Processes and species used

(a) *For mechanical pulp*

178. In Australia mechanical pulp is made only from *E. regnans, gigantea* and *obliqua,* all of which need to be over 200 years old. Australian and Latin American experience indicates that mechanical pulps from plantation eucalypts are likely to be of poor quality and their use for newsprint should be limited to low percentages, the exact amount depending upon the quality of the pulp with which it is to be blended.

(b) *For semi-chemical pulps*

179. Semi-chemical pulps have been made from eucalypts in Australia on a laboratory and very limited semi-commercial scale. Results indicated that these pulps could be used as the greater part of the furnish in the manufacture of corrugating paper and perhaps also for liner board. Bleached semi-chemical pulps from eucalypts resemble pulps of this kind made from other sub-tropical or temperate broad-leaved woods and should find similar usages.

180. In Australia a low-grade pulp has been produced semi-commercially by cooking the chips with lime at a pressure of 90 lb. per square inch, followed by treatment in a disk refiner. This pulp, however, can only be used as part of the furnish in the manufacture of low-grade boards. Nevertheless it offers possibilities when such products are manufactured at a distance from sources of waste paper, when capital costs have to be kept low and when land is available over which the effluent may be spread with advantage.

181. Experimental work at the United States Forest Products Laboratory, Madison, has shown that the cold soda process has distinct possibilities for producing pulp from Latin American eucalypts that might be considered for the manufacture of newsprint. Further work needs to be undertaken, however, before any definite statement can be made regarding the use of this process for such a purpose.

(c) *For chemical pulps*

182. For the production of chemical pulps for paper and board the sulphate process appears to be the most suitable. Besides possessing other advantages, pulps made by this process can be used for a wider variety of papers than is feasible with pulps produced by the soda or sulphite methods.

183. The species used in Australia in the manufacture of chemical pulps are *E. regnans, gigantea, obliqua, sieberiana, eugenioides, capitellata, radiata, viminalis, goniocalyx* and small quantities of eight or more other species. In Latin America the species available for chemical pulping appear to be mainly *E. saligna, E. grandis* and *E. globulus,* and these have proved satisfactory in this region. *E. saligna* and *E. grandis* are also used successfully in South Africa.

184. In Australia a bleaching process has been developed which enables dark-coloured sulphate pulps made from old eucalypt timber to be bleached to 85 brightness with little loss in strength. Experience in Latin America indicates that similar results may be obtained when bleaching sulphate pulps from very young eucalypt timber by using conventional bleaching methods.

[10] Report of the special working group appointed to study this subject within item IV.

185. This is no reason why a modified process should not be employed. Latin American experience indicates that about 10 per cent of sulphur, based on the amount of caustic soda used, is required in order to obtain pulps comparable to those produced with the sulphate process. Although the modified soda method—compared with the sulphate process—offers a certain degree of flexibility, the availability and cost of the raw materials, i.e., sulphur on the one hand and sodium sulphate on the other, would probably determine individual choice.

186. In both Australia and Latin America two-stage cooking has produced lighter-coloured and more easily bleached pulps than single-stage cooking.

187. Difficulties experienced in Australia in recovering the chemicals from spent liquors produced in the manufacture of pulp from certain old and slowly-grown eucalypts have not been encountered in pulping operations with Latin American eucalypts.

(d) *For dissolving grade*

188. In the manufacture of dissolving pulps the sulphite process has some advantages when young clean eucalypts of even quality are available. The process is being used successfully in several countries.

189. In Australia where young clean wood is not available, experimental work has been concerned with the sulphate process. Pulps prepared on a semi-commercial scale have given satisfactory results when tested overseas. These pulps were made from *E. regnans*, but as this timber is not available in sufficient quantities other species are being tried. Semi-commercial tests indicate that satisfactory pulps can be made from these species provided the timber is of even quality. This even quality stipulation is a prerequisite for any process involving the manufacture of dissolving grade pulps. The method employed in Australia consists of pre-hydrolysis followed by a normal sulphate cook.

190. The possibility of producing at the same mill a wide range of pulps including ordinary grades for papers and boards, semi-chemical pulps and also dissolving pulps should focus attention on the sulphate process as the logical method to adopt. However, the possibility of producing sodium bisulphite pulp and also sulphate pulp in the same mill, with a combined chemical recovery process, should not be overlooked.

Uses of eucalypt pulps

191. Experience in Australia has proved that bleached soda pulps from eucalypts can be used to provide up to 100 per cent of the furnish in the manufacture of high-grade writing and printing papers. Experience in Latin America has shown that bleached sulphate pulps from eucalypts can be similarly used. In Australia and Latin America up to 60 per cent of unbleached eucalypt sulphate pulps are used in the manufacture of wrapping and certain types of bag paper, and up to 30 per cent in the manufacture of multi-wall bag paper. Up to 80 per cent of eucalypt sulphate pulp has been used in the furnish for kraft liner boards and up to 50 per cent in the liner furnish for lined board. The following table is provided in order to set down the above data in summary form:

Product	*Type of Pulp*	*Percentage*
Fine writings and printings	Bleached	90–100
Wrapping and bag papers, excluding multi-wall bag kraft	Unbleached	60
Multi-wall bag kraft	Unbleached	30
Kraft liner boards	Unbleached	Up to 80
Liner of boards	Bleached and Unbleached	50
Newsprint	(See text)	

192. Apart from their present use in the above grades of papers and boards, eucalypt pulps have been employed in the manufacture of body paper for parchmentizing, light-weight fruit wrap and as a major part of the furnish in high-grade toilet tissue.

Conclusions

193. In Australia approximately 100,000 tons per annum of eucalypt pulp is being successfully used in the manufacture of fine writings and printings, wrapping and bag papers, liner boards, etc. Experience in Australia, Latin America and South Africa indicates that the young plantation eucalypts of Latin America should be at least equal, and perhaps even superior to the mature eucalypts used in Australia.

194. Thus the plantation eucalypts of Latin America appear to be a valuable source of raw material for chemical pulp manufacture.

195. The outlook for the production of mechanical pulp is not so encouraging. In Australia over 50,000 tons of eucalypt groundwood pulp are being employed in the manufacture of newsprint, but timber of the type and age used for this purpose in Australia is not available in Latin America. The production, therefore, of newsprint from eucalypts currently found in Latin America would appear to depend upon the development of some other low-cost process such as the cold soda process.

Economics of pulp and paper manufacture from sugar cane bagasse[11]

General availability of bagasse

196. Every ton of raw sugar produced in sugarcane[12] milling operations gives rise to the production of approximately one ton of bone dry bagasse. In Latin America the average yearly production of fresh bagasse (containing 50 per cent moisture) amounts to approximately 26 million tons. This quantity would be sufficient to produce a minimum of 4 million tons of pulp annually or enough to meet the region's current paper requirements three times over if it were all available for papermaking. Bagasse is, however, at present the main source of fuel in the sugar mills themselves, as it is available on the spot in a quantity sufficient to meet requirements. Consequently, without fuel substitutions, only a small part of the huge quantity of bagasse in the region can be regarded as potentially available for the manufacture of pulp and paper. While most of the paper mills are too small to supply enough bagasse to feed a pulp mill of economic size, it may pay to procure bagasse from several sugar mills in the same region. Currently, only between 300,000 and 400,000 tons of fresh bagasse per annum, i.e., 1 to 1½ per cent of the total quantity pro-

[11] Item V on the agenda.

[12] From one ton of sugar cane there may be produced approximately: sugar, 110 kg; alcohol, 10-12 litres; bagasse (bone dry), 110 kg; paper pulp, 37-55 kg; pith, 27-33 kg.

duced, are converted into pulp by the nine existing mills using bagasse in this region.

197. The general question of availability and cost of bagasse as a raw material for paper-making is intimately bound up with sugar-cane milling operations. Individual sugar mill installations differ from country to country, within the same country and even within the same district, as to the kinds of end-products they make and the quantity of steam they require. A survey of six Latin American countries[13] showed that local conditions, with respect to bagasse availability and to all the other factors involved in establishing a bagasse pulp mill project, vary so widely that on-the-spot studies and surveys are quite indispensable.

Releasing bagasse for pulp

198. There are two principal methods by which additional quantities of bagasse may be released for pulp production. These are (1) by improved thermal efficiency in the sugar mill and (2) by using an alternative fuel.

199. With regard to improving thermal efficiency in sugar-cane milling operations, the various methods—in order of importance—by which this may be achieved are as follows:

(*a*) Improvements in steam generation and combustion efficiency;

(*b*) Reduction in heat losses;

(*c*) Improvements in process steam utilization;

(*d*) More efficient mechanical utilization of steam.

200. It should be emphasized that it is primarily in the first three methods mentioned that effective economies must be made if more bagasse is to be released. By these methods a considerable measure of success can be achieved at comparatively low cost. In contrast, the capital requirements for improving efficiency in the mechanical utilization of steam are rather high and this method can make but a negligible contribution toward fuel saving, i.e., saving bagasse.

201. The amount of bagasse which may be released by means of better thermal efficiency will differ according to the type of operations being carried out in the sugar mill. Thus:

(1) In cases where raw sugar mills are integrated with either a refinery or an alcohol distillery, or both, the possibilities of releasing bagasse are extremely small.

(2) Relatively modern sugar mills producing only brown or raw sugar may, by taking care in the production and utilization of steam, release up to 20 or 30 per cent of the bagasse produced.

(3) Sugar mills that produce only direct alcohol by fermentation may, without large investments in improving their regular equipment, liberate up to 40 or 50 per cent of the total bagasse produced.

202. In the case of releasing bagasse by utilizing a substitute fuel, the only practicable fuel alternative in Latin America will usually be oil. However, in some countries the use of natural gas, coal, or wood may be taken into consideration.

203. The use of an alternative fuel will free all the bagasse produced. Contrary to popular belief, in most cases the investment costs involved in converting to operation on a substitute fuel are not high. In any event, amortization of these conversion costs does not represent an important element in the total cost of the fresh bagasse at the sugar mill. The major element is the cost of the substitute fuel itself.

204. In sugar mills where fuel oil has been substituted for bagasse, the general experience has been that one ton of fuel oil will replace approximately six tons of fresh run-of-the-mill bagasse containing 50 per cent moisture. Conversion to fuel oil opens up the possibility of greatly improving the output of the boiler plant as a whole, considerably reduces fuel handling costs, simplifies control, and increases capacity.

Baling and storage

205. In the different sugar-producing countries of Latin America, the cane grinding season ranges from seventy-five to 225 days or more per annum. Since a pulp and paper mill must operate on a year-round basis, it follows that a stock of bagasse must be made to enable production to be maintained at the level required. Unless the grinding season extends throughout the year, and there are few, if any, areas where it does, this means that a considerable portion of the material has to be baled. It is this factor, along with considerations of ease of handling, storage and transport, which largely accounts for the fact that common practice in bagasse pulping is to bale all the material as it comes from the sugar mill and store it against demand.

206. There is a considerable amount of experience as to the proper procedures which should be followed and the most suitable types of equipment which can be used for baling. Average experience is that fibre losses incurred under proper storage conditions amount to about 10 per cent, owing to deterioration. If the bagasse is not stored properly the deterioration loss may amount to as much as 30 per cent or even more. In the main, but depending upon local conditions, a large size of bale and a high baling rate are important in order to make the best use of the capital invested in baling station equipment.

Pith separation

207. Bagasse contains a large amount—which may be as much as 30 per cent—of parenchymatous substance or pith. Its physical structure is quite different from that of bagasse fiber, and it is attacked in quite a different manner by the chemicals used in pulping. Most authorities maintain that optimum results in machine operation, product quality and low chemical cost per ton of pulp produced, will only be achieved by using bagasse fibre from which the maximum amount of pith has been removed. Several methods of partial or complete pith separation have been developed.

208. Pith is a product which has many uses. It may, of course, be used as fuel in the mill boiler installation, its calorific value being only slightly less than that of whole bagasse. However, it has more profitable applications in the preparation of feed materials and as an absorbent for nitro-glycerin in the manufacture of dynamite. It may also serve as a raw material for the manufacture of furfurol, as a filter medium, etc.

Bagasse pulping processes

209. The characteristics of bagasse fibre are such that it may easily be pulped by any one of the commercially

[13] Argentina, Brazil, Cuba, Mexico, Peru and Venezuela.

known pulping methods; the acid sulphite processes are not recommended. The selection of any particular process for a given mill location depends on a great number of interrelated factors which require careful, on-the-spot investigation.

210. Important progress has been made in the past few years in bagasse pulping and, since there has been successful commercial operation of pulp mills using this raw material, it can safely be stated that there are no technical difficulties which stand in the way of full utilization of bagasse fibre as a source of pulp.

Properties and uses of bagasse pulps

211. The quality and character of pulps from bagasse and their conversion into paper are well understood. Many industrial examples prove that bagasse pulps may be used to advantage in a great variety of paper products ranging from wallboard to the finest grades of tissue. Fine pulps from bagasse will improve sheet formation and have a relatively high tensile and bursting strength. Folding resistance is good. In general, tearing resistance is less than that of coniferous pulp. Owing to their special character, bagasse pulps can be refined with very low power consumption, and if handled properly they may be regarded as rather free-draining pulps. They blend easily not only with all grades of groundwood and chemical pulps made from wood but also with inert fillers.

212. In the case of fine bleached papers, the addition of bagasse pulp often improves the quality and gives the paper certain characteristics which cannot be obtained with wood pulp alone. It has been shown that when unbleached bagasse pulp is added in proper proportions to pulps of the kraft type, papers of extremely high strength can be made. Shipping containers manufactured from bagasse have exceptional properties. Corrugating medium from bagasse excels in crush resistance. For liner boards, bagasse pulps can be mixed in substantial proportions with unbleached sulphate pulps from wood.

213. It has been established that a newsprint-type paper can be produced from bagasse pulp. However, it is still an open question whether it can be manufactured commercially to compete both in price and in quality with the standard article which is universally accepted by the trade at the present time.

General conclusions

214. The Meeting reached the following conclusions: 1. Successful industrial experience shows that bagasse may be used to great advantage as a source of raw material in meeting future requirements of pulp and paper in Latin America. 2. At present, there are well known processes in commercial operation which produce satisfactory pulps without technical difficulties. The choice of process depends upon many factors, including those of a local nature, and careful study is to be recommended in each case. 3. Although some grades of paper can be made from a furnish consisting of bagasse pulp alone, it is believed that a major contribution which this raw material will make as a source of pulp in Latin America will be as a blending pulp in admixture with pulps from other fibrous raw materials. 4. For pulp mills with a daily capacity of 20 tons, the quantity of whole fresh bagasse (50 per cent moist) which needs to be made available annually may be reckoned at approximately 36,000 tons in the case of bleached grades and about 24,000 tons for coarse board-type pulps. Respective requirements for 50-ton daily capacity pulp mills would be of the order of 90,000 tons and 60,000 tons per annum. These are conservative estimates. 5. Since bagasse is today used as fuel in the sugar mills, the freeing of additional quantities of this raw material for pulping will require either the introduction of measures for economizing fuel in the sugar mills or the substitution of an alternative fuel for bagasse. 6. The first course can liberate substantial quantities of bagasse, but the actual amount freed will depend on the type of operation undertaken at the sugar mill, and on the degree of thermal efficiency already achieved. Even in the most promising cases the savings are not likely to exceed 20 to 30 per cent of the bagasse produced. On the other hand, the measures that need to be adopted are not unduly expensive and are capable of being applied singly or in concert. 7. The most profitable operation will result when full utilization is made both of the fibre and pith for purposes for which each fraction is particularly suited. 8. From the standpoint of bagasse availability, it is clear that the limitations imposed by the need to replace bagasse as fuel in sugar-milling operations—either by the creation of surpluses (through improved utilization of steam) or by substitution of another fuel—lead to the conclusion that the contribution which this raw material can make to the region's pulp and paper industry will, on a short-term basis, be limited as to volume. 9. On a long-term basis, there is no doubt that bagasse, because of a variety of favourable economic factors, will have an important part to play in the increased expansion which will be required. Its role has an obvious significance in those cane-producing countries where supplies of other fibrous raw materials are lacking. 10. In relation to other non-forest sources of raw material for pulp and paper available in Latin America, sugar-cane bagasse, being a by-product of an established industry, appears to offer good possibilities for immediate increases in production.

Presentation of papers on selected technical matters[14]

215. At the sessions devoted to this item, the various papers presented to the Meeting as background documents were discussed. (See Part I of this report.)

Review of the development prospects for pulp and paper industries in selected Latin American countries[15]

216. In the sessions for this item on the agenda, studies which had been presented on prospects for the development of the paper industry in Argentina, Brazil, Chile, Colombia, Mexico, Uruguay and Venezuela were

[14] Item VI on the agenda.

[15] Item VII on the agenda. The complete text of the report adopted by the Meeting when discussing this item is not reproduced here. The central part of that text (original paragraphs 217-274) summarized the prospects in each country according to the contents of the papers presented at the Meeting. As more complete versions of these documents are reproduced latter on in this volume, the above-mentioned paragraphs have been omitted, retaining only the introduction thereto, and the conclusions of this section. For the complete text see E/CN.12/361, FAO/ETAP No. 462 ST/TAA/SER.C./19. The numeration of the paragraphs is maintained in this version to avoid confusion, the missing paragraphs being indicated between brackets.

discussed. During the debates, through statements made by certain participants, data also became available on Bolivia, Paraguay and Peru. Thus the information discussed during the sessions related to almost 90 per cent of the region's paper consumption.

[217-274] (See footnote 15).

Conclusions

275. From the statements made by experts from various countries, the general conclusion can be drawn that all the nations of Latin America are showing great interest in the development of their paper industries and are making substantial efforts to achieve that end. There is a general tendency to create or expand productive capacity to meet the growing needs for pulp and paper.

276. In the past, emphasis was primarily placed upon the construction of paper mills; the current tendency is to balance the industry by developing pulp mills.

277. Most Latin American countries give the development of productive capacity for paper a prominent place in their list of priorities for industrial development. In doing so, they are not only concerned with creating permanent sources of paper supply, but take into consideration other basic advantages. Among the latter are the benefits to be drawn from utilizing abundant natural resources, diversifying their economies, and securing the parallel development of other important industries, such as the manufacture of the chemicals required for pulp production.

278. No less important is the fact that pulp industries, owing to the substantial investment required and to the need for a regular supply of raw materials, in themselves constitute a guarantee that the forests will be protected and rationally exploited as well as an incentive for the creation of new resources by means of plantations.

279. As regards the transformation of these raw materials into pulp and paper, the general conclusion of the meeting was that, although no technological problems exist for the manufacture of chemical pulp, the economic production of mechanical pulp based on tropical or sub-tropical resources still requires more research. The outstanding exception is the case of the cetico in Peru which has proved to be an excellent raw material for the production of mechanical pulp by conventional processes.

280. It is apparent, from the prospects offered by individual countries, that existing plans to meet the demand for newsprint are inadequate, although in every case the importance which should be given to this type of development is fully appreciated. Apart from technological difficulties, problems of another order—principally of economics and of government policy—have caused current projects to be directed more towards other grades than towards newsprint. The suggestions of participants nevertheless indicate that it is urgent to reconcile the need for developing newsprint output in order to economize in foreign exchange and to supplement industrialization with the need for a permanent source of newsprint at sufficiently low prices to encourage cultural progress in these countries. It is of great importance that Governments should make every effort to accomplish this aim by encouraging the establishment of newsprint mills.

281. The difficulties of financing are a serious obstacle to the development of the paper industry. The general conclusions regarding this matter are given elsewhere in this report.

282. Since the characteristics of the raw material vary from one country to another, it is logical to expect that the development of the paper industry in each country will tend towards specialization as regards the types of pulp and even the specific grades of paper. On the other hand, the domestic market for paper products in the majority of countries is too small to absorb the output of large-scale mills specializing in specific types of pulp and in a limited number of paper grades. Taken together, these two conditions lead to the conclusion that it is both necessary and desirable to encourage a complementation of markets on a regional basis.

283. The Meeting was in agreement that an effort should be made to ensure that in the development of Latin America's paper industry the region should be considered as a whole. It was thought that the present meeting was the first important step towards achieving this object, and expression was given to the hope of increased international co-operation in the future to obtain balanced industrial development.

284. In the discussion it was also stressed that all development projects should be submitted to a careful examination in order to evaluate as accurately as possible their economic and technical characteristics, as well as their real contribution to the general economic development of the country concerned.

285. When the experts discussed the problems encountered in carrying out present pulp and paper projects, emphasis was placed on the necessity for obtaining technical assistance from international organizations in order to study certain problems which could not be tackled by private enterprise or by individual Governments alone and also to co-ordinate national efforts to solve these problems. It was further pointed out that a need existed for technical advice on specific problems arising from development projects, and it was thought that this should be provided by both forestry and industrial experts who had studied the industrial development of Latin America as a whole and who had also had experience in other countries outside the region.

286. This aspect of the discussions was referred to the special committee charged with drafting concrete proposals on technical assistance, research and training. (See Part IV.)

Newsprint[16]

287. An assessment of the prospective balance ten years hence between Latin American requirements and regional production makes it clear that newsprint presents a special problem. Latin American countries, without exception, are intensely interested in expanding, or initiating, domestic production of what is judged to be an essential raw material. Having experienced shortages in the past for various reasons, each country is anxious to achieve some measure of security of supply. Secondly, in many Latin American countries today newsprint consumption falls below the levels which may be considered appropriate to the stage of political, economic and cultural development which has been reached, simply because the countries concerned are unable to devote to the

[16] Item IX on the agenda.

purchase of newsprint the amounts of foreign exchange they would like; for the region as a whole, the capacity to import is likely to be limited in the future also.

288. If Latin American countries had unlimited foreign exchange available with which to purchase imported newsprint, the problem would present itself in a different light. Under those conditions, the traditional producing centres, Canada and, to a lesser extent, Scandinavia, would have the incentive, as they undoubtedly have the resources, to expand productive capacity to a point where any conceivable rise in Latin American demand, during the next decade or so, could be met.

289. Newsprint production is one of the most specialized paper-making processes, governed by strict product specifications and low margins of profit. The economics of the process favour the installation of relatively large mills.

290. It is evident that, at the present time, newsprint, production in Latin America is unlikely to be realized from most of the region's fibrous resources at costs which will permit prices to compare favourably on the world market with those of, e.g., Canadian newsprint—at all events in normal times.

291. Thus, it may be recognized that, if Latin American countries are resolved to expand newsprint production—and plainly there are many valid reasons why they should—the problems that confront many of them are more economic than technical.

292. Newsprint is today being made from groundwood pulp and up to 20 per cent of coniferous wood chemical pulp, either unbleached sulphite or semi-bleached sulphate.

293. The Meeting heard statements summarizing experience in Latin America to date relating to the production of mechanical pulp for newsprint: it is made from salicaceous species in Argentina, from *Araucaria angustifolia* in Brazil, from *Pinus radiata* in Chile. These resources are of considerable magnitude and they are the basis for the current expansion of Latin American newsprint production. The region's potentialities, however, are by no means limited to the resources at present exploited.

294. Development work devoted to the problem of finding raw materials to take the place of conventional spruce groundwood, thereby broadening the raw material basis of newsprint manufacture, has proceeded along four separate lines.

295. The technical problem of producing newsprint from pines, especially those with a high resin content, may be considered solved. This makes technically possible the use of natural stands of conifers in Mexico and Central America, and of existing coniferous plantations in Argentina.

296. The Meeting stressed the desirability of exchanging experience and conducting research on plantation conifers to ascertain which species and varieties, suitable for newsprint production, could be successfully grown under the varied conditions met with in the region.

297. The production of groundwood from temperate broad-leaved species by the conventional grinding process has increased rapidly in Europe and the United States. In Latin America the main broad-leaved species suitable for conventional grinding are the plantation willow and poplars of the Paraná Delta, the *Cecropia* species, and, to a lesser degree, the eucalypt plantations.

298. The willows and poplars present few difficulties. In spite of the fact that in Australia *Eucalyptus regnans* from 200 to 300 years old is used to produce a satisfactory newsprint, it is doubtful whether the short-fibred eucalypts of Latin America can ever serve as the basis for large-scale production of newsprint by conventional means. The *Cecropia* species are found locally in homogeneous stands in the region, and these, as well as certain other low density species, arise frequently as second growth in the tropical rain forests. Not all these species are likely to prove suitable for newsprint, but promising tests have been carried out on Peruvian cetico and further investigation may bring to light similar species, possibly even more suitable for newsprint production.

299. Various processes have been developed for producing groundwood-type pulps from higher density broad-leaved species, the general principle being to carry out a steam or chemical pre-treatment to soften the wood before conventional grinding, thus minimizing fibre destruction in the grinding process. The application of such processes, e.g., the chemi-groundwood process, to mixtures of tropical wood species, is likely to give rise to technical difficulties, though it is conceivable that pulps could be produced capable of reducing the amount of chemical pulp required for the manufacture of newsprint.

300. Recently, several processes have been developed for producing groundwood-type pulps by making use of non-conventional equipment, e.g., by fiberizing in disk mills or refiners after softening the chips by a steam or chemical pre-treatment. One of these, the cold caustic soda process, is simple to operate, should not require heavy capital investment, and gives high yields with good strength properties; for some species the pulp will be dark in colour and require bleaching. This process might offer possibilities for the future production of newsprint from mixed tropical woods.

301. The production of the chemical pulp of the newsprint furnish does not present the same problem as the production of the groundwood. It can be manufactured as semi-bleached sulphate from different pine species or by the sulphite process from, for example, *Araucaria*, as is the case in Brazil and Argentina. It was stated during the Meeting that part of the chemical pulp can also be provided by broad-leaved chemical pulp or by bagasse pulp.

302. The production of newsprint from bagasse has long been technically possible, but so far no one has succeeded in making, at a competitive price, an acceptable newsprint capable of being run on high-speed machines. A recent development (the use of a pre-hydrolysis process followed by a neutral sulphite semi-chemical cook) may provide the possibility of successful economic operations in certain countries.

303. The technical progress of recent years has multiplied the processes which can be considered for newsprint manufacture and has potentially widened the range of raw material from which newsprint can be made.

304. The diversity of the raw materials which can now be used for newsprint manufacture calls for a new

approach to the problem; no longer is it possible to think rigidly in terms of fixed proportions of conventional pulps. Those countries which lack the traditional materials, and yet feel impelled to develop an indigenous newsprint industry, will undoubtedly solve the problem by examining the various possible blends of the different pulps which can be produced from their native resources; some Latin American countries have already found a solution along these lines. At the same time, it should be recognized that the region's existing resources, and the possibilities of adding to them, have by no means been fully explored, particularly if the complementary resources of neighbouring countries are taken into account.

305. The Meeting concurred with the suggestion that Latin American countries should, by encouraging experiment, facilitating seed exchange, and pooling experience—particularly in regard to the planting of tropical and sub-tropical conifers—assist one another to discover those species which acclimatize best in their particular countries.

306. The economic implications of developing newsprint production must not, however, be overlooked. Few newsprint mills in Latin America, existing or potential, can operate with commercial success, even in the domestic market, if exposed to the unhampered competition of foreign newsprint in the markets they serve. Hence economic policies in Latin American countries in relation to newsprint differ widely. Some countries, regarding newsprint as an essential raw material, facilitate newsprint imports by low tariffs and preferential exchange rates. And among those countries which do produce newsprint themselves, some take steps to afford the domestic industry a measure of protection (by tariffs on newsprint or facilities for pulp imports), while others take the view that the domestic product should be capable of holding its own with the imported product.

307. The Meeting recognized that the initiation or expansion of newsprint production in Latin America was desirable, for reasons both cultural and economic. In certain countries the resources are such that newsprint can be produced profitably. In others it will be difficult to produce newsprint to sell competitively without substantial protection.

308. It emphasized that a price has to be paid if a country decides to embark on high-cost production. Whether that price is worth paying is a matter for decision by each individual country concerned. The wider economic implications of such a course should be carefully examined before a decision is taken.

Financing Latin American pulp and paper development[17]

309. A rapid rise in Latin America's paper needs is envisaged during the coming decade. If these needs are to be satisfied, considerable investment will be required. Since, however, the pulp and paper industry is not the only industry, or branch of economic activity, in urgent need of development in the region, it is pertinent to ask what degree of priority should be accorded to investment in this field.

310. The Meeting considered that the pulp and paper industry had several claims for special consideration. First, adequate levels of paper consumption form an essential part of reasonable living standards; economic advancement, improved social services, educational and cultural progress, all call for more paper. Secondly, a new pulp and paper mill may, in two years or in certain cases even less, furnish a quantity of paper for which the foreign currency requirements, were that paper to be imported, might exceed even the amount of foreign exchange generally needed to establish the mill; in other words, pulp and paper investment based on local raw materials has a high import-saving value. Thirdly, an expansion in the domestic paper supply permits the development of new, valuable, employment-generating, paper converting industries. Fourthly, by investing in pulp and paper the region will be able to mobilize a variety of important indigenous resources, including non-wood fibres such as bagasse and straw. Fifthly, investment in this field will make possible the development of a range of industries utilizing the co-products and by-products of the paper industry, notably the chemical industry. Finally, pulp and paper investment can facilitate the establishment of other forest industries; in fact, only an industrial development of this kind can assure the economic utilization of the great potential resource of Latin American forests.

311. There is therefore a compelling case for encouraging the development of the pulp and paper industry in Latin America. Ample fibrous resources are available in the region as a whole to sustain this development, even if traditional paper-making fibres only are taken into account, and proven techniques are available today which makes possible also the conversion of the region's vast reserves of non-traditional fibres. Thus the over-all supply of usable raw materials presents no problem.

312. More difficult, however, is the problem of securing the necessary capital to finance this development. It is estimated that even if only minimum economic growth is realized, an annual investment of about $50 million will be required to assure, without incurring an increased burden of imports, a reasonable standard of paper consumption by 1965. If a more favourable economic development takes place, then about $90 million will need to be invested annually. Since the foreign exchange expenditure generally represents about half the cost of pulp and paper projects in Latin America, such exchange requirements may be reckoned at between $25 and $45 million a year.

313. Large as these figures are, they need not be regarded as unattainable. A $90 million a year investment corresponds to only 1½ per cent of average total Latin American annual investment during the post-war period. Annual foreign exchange requirements of $45 million correspond to little more than half of 1 per cent of the region's annual foreign exchange earnings. Because the Latin American economy is dynamic, showing one of the highest economic growth rates in the world, the targets indicated cannot be regarded as unrealistic.

314. It is not enough, however, to urge upon the industrialized nations their obligations to provide the capital for this kind of expansion in less developed countries. Nor is it enough to list the steps which the less developed countries should take to create a climate favourable for investment. Both these considerations are of genuine importance, but they have been outlined with such particularity on so many occasions, and are now

[17] Item VIII on the agenda.

so well-documented, that the Meeting did not consider that an elaboration of these themes would form the most fruitful basis of discussion.

315. A more practical starting point is to consider what sources of capital are available and what kind of questions will have to be answered before capital, be it public or private, local or foreign, is directed into the pulp and paper field.

316. As to the sources of capital, domestic capital may be either private or public, the latter including financing by development banks and various quasi-public institutions as well as by Governments and central banks. There will often be enterprises financed from both sources, and the relative frequency of public, private and semi-private enterprises will depend very much on the economic and political background and conditions in the country concerned.

317. If momentum is gained by the present movement in a number of Latin American countries towards establishing facilities through which securities in industrial enterprises can be sold widely to the public, the task of mobilizing domestic private funds will be greatly facilitated.

318. Foreign assistance to all the types of companies mentioned may be forthcoming from a variety of sources. It may take the form of loans or be limited to an exchange financing service. Apart from the International Bank, which generally concerns itself with development loans, almost all the equipment-producing countries have agencies that provide credit facilities to cover their national enterprises' sales abroad.

319. Foreign investment capital—risk capital in the form of direct investments—may participate in several ways. The enterprise may be totally owned by foreign capital, or foreign and domestic capital may be united in a joint enterprise. In the past, foreign direct investors have favoured joint enterprises where the domestic capital has been raised privately.

320. One of the first questions arising is whether or not there is a sufficient market to warrant the establishment of a new pulp and paper project. Two of the Latin American republics have a population of less than a million, while ten others have populations of under three and a half millions. Investors, before deciding upon an operation in the small countries of Latin America, would no doubt wish to be satisfied that market possibilities, including export prospects, were sufficiently promising to warrant any new development.

321. An illustration of the kind of points on which investors will need assurance is afforded by the criteria which the International Bank adopted in arriving at its decision to grant a $20 million loan to Chile for the only Latin American pulp and paper project that has so far received financial assistance from an international lending agency. These were:

(*a*) A first class presentation and justification of the project, with clear and detailed specifications set forth in cost terms; this presentation, naturally, was to be prepared by thoroughly competent persons or agencies specialized in this work, and having experience in the pulp and paper field;

(*b*) Evidence of the project's value to the country's economy, in utilizing domestic natural resources and leading to an improvement in the foreign exchange situation, both through import savings and ultimate export earnings;

(*c*) Convincing proof that the management available was competent and experienced;

(*d*) Evidence of ample raw material resources, and of a plan for managing them on a sustained yield basis;

(*e*) Studies of the local market, and its prospective growth, demonstrating that it was capable of absorbing a sizable proportion of the mill's output;

(*f*) A cost analysis indicating that production would be at competitive prices in the markets contemplated;

(*g*) A large enough margin in the estimates presented to demonstrate that, even were domestic demand and foreign market sales to fall short, by a considerable percentage, of the levels estimated, the enterprise would be able to repay its loans and at the same time show a good profit;

(*h*) Evidence of specific offers of sufficient domestic equity capital;

(*i*) The consideration that the repayment guarantee offered by the Corporación de Fomento was forthcoming without requiring an active vote in the directorship of the company concerned.

322. These are not necessarily the criteria which the Bank would adopt in similar cases; nor can it be assumed that satisfaction on all these points would assure a favourable reception of a request for a loan in any future case. But it is certain that any form of capital contemplating pulp and paper investment would need assurances on most of these points, and perhaps on several others. These criteria can thus serve as a general guide to sponsors of other development projects who seek capital. There will obviously be less reason for emphasis on the ability to compete in international markets in the case of a project whose entire output could be absorbed by the national market. The assurance needed in such a case would be that the product could compete successfully with those of other projects that might be established within the country concerned, or, under reasonable protection, with imported products at the price at which they could be sold within the area.

323. The limited part which the International Bank has played in Latin American pulp and paper development springs from the constitution and mode of operation of the Bank itself. The Bank, for the expansion of its loanable funds, is dependent upon its ability to market its own securities. Because its constitutional requirements call for a governmental guarantee, it has considered itself precluded from financing projects of the type generally conducted by private enterprise in those cases where the nature of the governmental guarantee has tended to compromise the initiative of private management.

324. Two recent proposals for the establishment of international investment agencies, however, might go a long way towards filling the gap which undoubtedly exists. The first is the proposed creation of an International Finance Corporation, to be sponsored by the International Bank, which will be empowered to make equity investments and/or loans without government guarantees to private undertakings, both in industry and agriculture, in the less developed areas. The second is the proposal to be submitted to the Río Conference by the group of Latin American economists convened

recently on the invitation of ECLA. The idea underlying this latter proposal was that an Inter-American Development Fund would make loans to public or private financial agencies, which in turn would lend to private enterprises, in accordance with conditions previously established between the banks in each country and the Fund. There is a plain need for some institution able to provide private undertakings with a more direct access to international lending facilities than is at present available.

325. Since for pulp and paper plants the investment in machinery normally amounts to about one half of the total investment required, the establishment of a plant requires a quite large foreign exchange investment. In so far as any items of such equipment can be procured locally—and in a number of Latin American countries some facilities for producing certain parts of it seem to exist—the possibilities of local acquisition should receive careful consideration in order to reduce the amount of foreign exchange required. Up to the present time the most important foreign source of financing Latin American pulp and paper development has consisted of medium-term credits offered by machinery-supplying countries; this source of credit may be expected to continue and grow in importance. In recent years exporters have competed for markets partly on the basis of the credit facilities they have been able to offer; the present tendency is for differences in the credit facilities offered by the various exporting countries to diminish. This will permit purchasing countries, upon the basis of the price and suitability of the equipment itself, to exercise a wider range of choice in effecting their purchases. Of course, unless or until general convertibility of currencies is established, the availability of a particular foreign exchange will remain a major determinant of choice.

326. The Meeting next turned to a consideration of the possibilities of private foreign capital participating through direct investment in Latin American pulp and paper expansion. It was emphasized that this capital, if it is to be attracted, must be satisfied that the project it is considering is completely sound as a business risk; it must also be satisfied that the general conditions obtaining in the area in which the project is to be located are such that the enterprise can be expected to operate successfully, and that difficulties will not arise in remitting earnings and in eventually repatriating capital. Foreign capital will generally be attracted to an area that offers better prospects than it is able to obtain elsewhere.

327. Since direct foreign investment will normally imply an active voice in the management and control of a company it will bring with it a fund of experience in administration and technology. Another major advantage of this form of financing over loans is that, as an equity investment, it shares the risks of the enterprise; it can make no claim for return in either local currency or foreign exchange unless the venture is successful.

328. While it is conceivable that there may be projects which are entirely foreign-financed, there is an increasing and desirable trend toward establishing joint enterprises. Indeed unless local capital makes a substantial contribution, foreign capital may be disinclined to participate in the venture. No significant expansion of the Latin American pulp and paper industry is likely to take place unless domestic capital is willing to set the pace.

329. A thorough examination and prospectus of the project will be a requirement of all investors, domestic or foreign. Every aspect of future operations and commercial prospects must be covered by complete technical and economic studies. The completion of these investigations generally takes at least a year, and the time required may run into several years if intensive studies are needed to establish the adequacy of the raw materials supply. The group intending to operate the project must be prepared to finance the heavy expenses involved in these essential preliminary investigations. It is the responsibility of the owners or prospective owners and operators of the project to bring the results of such technical and economic reports to the attention of the financing agencies in the form they usually require for the consideration of financing. If the investigations have been sufficiently comprehensive and lead to satisfactory conclusions, and if the foreign investors are also satisfied on the more general grounds mentioned above, it should be possible to procure the necessary capital.

330. The Meeting heard with interest and appreciation a statement on behalf of the American Paper and Pulp Association offering the services of that Association and its members to any groups in the Latin American industry wishing to avail themselves of such help in carrying forward their development programmes. It is anticipated that similar co-operation will be forthcoming from the pulp and paper industries of other countries.

331. For various reasons the main flow of investment capital for all purposes into Latin America since the war has been from the United States; this flow has averaged, net, about $250,000 million annually during the last eight years. Statements by European experts indicated that the limitations which post-war circumstances has imposed on the flow of investment funds abroad were steadily being removed. It can be assumed that European capital will be ready, available ana willing to help in Latin American expansion. It must be emphasized, however, that the interest expressed in the region will lead to direct investment in the pulp and paper industry in Latin America only to the extent that new projects succeed in satisfying the rigorous criteria earlier outlined.

332. The Meeting did not believe that an expansion of pulp and paper capacity in Latin America threatened the interests of the traditional exporting countries. It believed rather that the region's great consumption potential would require continued imports alongside a rapid development of indigenous production. It expressed satisfaction with the efforts of United Nations organizations, in particular of those bodies which had sponsored this conference, to encourage, by undertaking studies and carrying out surveys under the expanded technical assistance programme, the development of the pulp and paper industry in Latin America.

333. The Meeting agreed on the following conclusions: 1. An expansion of the pulp and paper industry in Latin America is vitally necessary. There is every indication that well-placed investment in this field will prove profitable. For a variety of reasons, this industry is one in which joint investment of domestic and foreign capital offers advantages over what can be achieved by either operating alone. 2. To ensure this needed industrial development it is necessary to stimulate the flow of domestic capital in a measure which will at least cover

locally-incurred investment costs, working capital requirements and the requisite down-payment on foreign equipment. There is a similar need to encourage a flow of foreign capital to finance the purchase of equipment and the contracting for those technical services that must come from abroad. 3. Various forms of financing this development exist, including long-term loans by international financing agencies, medium-term credits for machinery purchases and direct investment by both local and foreign capital. Projects must be carefully drawn up to establish that they are sound business risks and that the climate for investment in the intended area is favourable. 4. It was considered that the attention of Latin American Governments should be drawn to the special part which pulp and paper industries can play in general economic and cultural development and the consequent desirability of: (*a*) according priority to these industries in establishing development plans; (*b*) ensuring that these plans are carefully drawn and documented to set forth the order of feasibility of potential projects in terms of their respective prospects for fulfilling, in the most effective and economic manner, the needs of Latin America as a whole and its several Republics; (*c*) mobilizing domestic capital and facilitating the movement of international capital in order to realize this expansion. 5. Because an adequate and sustained raw material supply is vital to the industrial development contemplated, the Meeting considered that Latin American Governments should take steps to establish or improve credit terms for afforestation as well as for industrialization. 6. Certain developments would involve "settlement" costs so high as to inhibit private investment if charged as capital costs on the paper operations. The Meeting considered that in those cases where developments of this kind are deemed to be in the national interest public authorities should provide basic community services. 7. The Meeting expressed the hope that the conclusions of this meeting would be made known to those banks and financial institutions likely to be interested, so that the attention of those concerned in countries outside Latin America would be drawn to the desirability of taking all the necessary measures to: (*a*) facilitate the financing of equipment sales; (*b*) facilitate the export of private capital.

IV. Summary of recommendations

334. The Meeting, through its various committees and its plenary meetings, approved the recommendations which are brought together below and classified according to the agenda item under which they were made. These recommendations, which were implicit in the texts of Part III of this report, are transcribed literally in the following paragraphs, with the additional recommendation on technical assistance, research and training which was put forward by the special working group nominated by the Meeting for that purpose.

Tropical forests

335. There is great need for systematic and continuous research in all fields of tropical and sub-tropical silviculture and forest utilization, and results obtained throughout the world should be made known through the efforts of international organizations interested in forestry and through bilateral arrangements. With reference to the over-all forestry or utilization problems, it is hoped that FAO may be able to compile and publish pertinent information available from all reliable sources. The establishment of a Latin American research centre would render a valuable contribution towards the development of the pulp and paper industry on this continent. Any effort in this direction would be of great advantage to the Governments concerned as well as to industry.

336. Any mill project in an undeveloped area, especially if it is based on a non-traditional raw material, needs not only careful analysis of all cost factors, but also technical investigations which may involve considerable expense. This capital outlay is imperative especially in the case of new processes or processing techniques. Technical assistance by international agencies might offer some help in connexion with the essential preliminary investigations.

Other forest resources

337. To encourage the development of forest plantations on a rational basis and in the interests of Latin America's pulp and paper industry—without overlooking the large plantations now being made—the Meeting recommended the organizations concerned to take the following steps: 1. To study on a systematic basis at the various experimental forestry stations in Latin America the possibilities of introducing those exotic species which grow rapidly and are of interest to the pulp and paper industry. 2. To carry out systematic and comparative research at the same experimental stations into the different conditions for establishing and treating forest plantations based on native or exotic species which have already been, or could be, introduced. 3. To study at qualified laboratories the products of the plantations. Such studies would deal with the suitability of the wood for conversion into pulp and, above all, the quality of the pulps thus obtained. Not only wood specimens should be studied, but also each species individually according to its conditions of growth and the plantation methods for treatment. It would be particularly desirable to gather data on the relations between the rate of growth and the value in paper of the end-product for each of the existing species.

338. The combined results of these studies, as well as similar research undertaken elsewhere in the world into the same characteristics, should be collected by the Regional Forestry Office of FAO, analysed and distributed to the Governments and organizations concerned.

339. The Meeting suggested that the Regional Forestry Office, which has already undertaken work of this nature, should be given greater facilities to allow it to arrange either the exchange or the free distribution of seed samples of forest species for the purpose of experiment and trial plantings.

340. Finally, the Meeting also recommended that FAO should urge Governments to grant all possible facilities for public services and private enterprise to obtain seeds—by purchase or exchange—for the wider extension of this work. As regards the temperate natural forests of Latin America, the Meeting in general felt their use to be economically feasible as a means of meeting the requirements of the paper industry, although in some cases delicate problems exist, which should receive the attention of specialists and Governments.

Development prospects

341. It is apparent, from the prospects offered by individual countries, that existing plans to meet the demand for newsprint are inadequate, although in every case the importance which should be given to this type of development is fully appreciated. Apart from technological difficulties, problems of another order—principally of economics and of government policy—have caused current projects to be directed more towards other grades than towards newsprint. The suggestions of participants nevertheless indicate that it is urgent to reconcile the need for developing newsprint output to economize in foreign exchange and to supplement industrialization with the need for a permanent source of newsprint at sufficiently low prices to encourage cultural progress in the Latin American countries. It is of great importance that Governments should make every effort to accomplish this aim by encouraging the establishment of newsprint mills.

342. Since the characteristics of the raw material vary from one country to another, it is logical to expect that the development of the paper industry in each country will tend towards specialization as regards the types of pulp and even the specific grades of paper. On the other hand, the domestic market for paper products in the majority of countries is too small to absorb the output of large-scale mills specializing in specific types of pulp and in a limited number of paper grades. Taken together, these two conditions lead to the conclusion that it is both necessary and desirable to encourage a complementation of markets on a regional basis.

343. In the discussion it was also stressed that all development projects should be submitted to a careful

examination in order to evaluate as accurately as possible their economic and technical characteristics as well as their real contribution to the general economic development of the country concerned.

FINANCING

344. It was considered that the attention of Latin American Governments should be drawn to the special part which pulp and paper industries can play in general economic and cultural development and therefore the desirability of: (*a*) according priority to these industries in establishing development plans; (*b*) assuring that these plans are carefully drawn and documented to set forth the order of feasibility of potential projects in terms of their respective prospects for fulfilling, in the most effective and economic manner, the needs of Latin America as a whole and its several Republics; (*c*) mobilizing domestic capital and facilitating the movement of international capital in order to realize this expansion.

345. Because an adequate and sustained raw material supply is vital to the industrial development contemplated, the Meeting considered that Latin American Governments should take steps to establish or improve *credit terms* for afforestation as well as for industrialization.

346. Certain developments would involve "settlement" costs so high as to inhibit private investment if charged as capital costs on the paper operation. The Meeting considered that in those cases where developments of this kind are deemed to be in the national interest, public authorities should provide basic community services.

347. The Meeting expressed the hope that the conclusions of this meeting would be made known to those banks and financial institutions likely to be interested, so that the attention of those concerned in countries outside Latin America would be drawn to the desirability of taking all the necessary measures to: (*a*) facilitate the financing of equipment sales; (*b*) facilitate the export of private capital.

Technical assistance, research and training[18]

1.

348. The creation and development of new pulp and paper production along sound technical and economic lines requires a volume of advice and direct technical assistance in Latin American countries that cannot yet be adequately obtained from existing agencies or local sources. In fact this is broadly true in all the fields of forest management and forest products technology.

349. The deliberations of the Meeting clearly demonstrated that advice was actively desired by many individuals contemplating the development of pulp and paper facilities in Latin America and by representatives of the Governments of the Latin American Republics. It was also evident that a serious shortage of technically trained personnel for supervisory and managerial positions had hampered the progress of existing industries and undoubtedly would hamper the establishment of new industries. It was considered that steps should be taken to overcome this shortage and to ensure that it should not continue far into the future.

350. Discussions in the Meeting brought out the economic desirability of ensuring regional co-operation and programming of individual and national research and training activities. Co-ordination of this kind was thought to be not only necessary but feasible and technically desirable. It was strongly felt that, at the regional level, concentrated co-ordinated effort must be ensured, especially in connexion with research and personnel training.

2.

351. During the numerous discussions, it became apparent that knowledge concerning the rational production of the various Latin American raw materials, their possibilities and technical conditions for transformation, was in many cases inadequate. It was concluded that silvicultural and technological research should be continued and intensified. The value to each country of preparing and implementing a national research programme was noted. Nevertheless, some of this research could easily be carried out on a regional basis by one agency working for the mutual interest. This possibility became a real need when it was a matter of long and costly research, requiring the use of specialized equipment and the services of highly qualified experts.

352. Most important of all, in order to avoid duplication and even useless efforts, national and regional research should be co-ordinated and each of the countries or organizations concerned should be kept informed of the results of such research and of the work carried out elsewhere in the same field.

353. Having been informed of the proposed establishment of a Latin American Research and Forest Training Institute and of the activities and studies undertaken by FAO to implement this project, the Meeting urged the Governments of Latin American countries concerned, as well as the international organizations, bilateral aid programmes and public or private agencies likely to take part in such a project, to implement the recommendation formally adopted at the Fourth Session of the FAO Latin American Forestry Commission (Buenos Aires, 1952), as soon and as fully as possible.

354. The Meeting strongly endorsed the findings of the Buenos Aires conference of 1952 and in particular urged that early and adequate attention be given to the creation of research facilities for investigation in the field of pulp and paper production, as well as in related fields of practical forestry and of forest production.

355. The Meeting strongly recommended that, as part of and in association with the Latin American Research and Forest Training Institute, adequate facilities be provided for the training of supervisory and technological personnel not only in the fields of pulp and paper technology, but also in all important allied fields of forest products technology. The Meeting urged that, in developing a central institution of this kind, the closest co-operation be maintained with existing facilities in Latin America for the teaching of engineering and applied sciences.

356. It was also recommended that such an institution should endeavour to establish co-operative arrange-

[18] Recommendation prepared by a special working group composed of the following experts: H. K. Collinge (Canada), Discussion leader; E. Gagliardi; H. W. Giertz; J. A. Hall; J. C. Leone; H. Thielen; J. von Bergen.

ments with similar institutions throughout the world. It was further emphasized that this institution should attempt to supplement and not to replace those methods of training based on fellowships, scholarships and direct technical experience in other parts of the world. It should be prepared to assist in the extension of advanced training of this kind.

3.

357. The Meeting drew the attention of those responsible for the various technical assistance programmes to the importance which should be given, within the general framework of the region's economic development, to the problems outlined above. The Meeting advised Governments to call as much as possible upon such assistance, especially during the initial stages of preparing specific development plans. It also recommended most strongly that Governments, in formulating their requests, should take into consideration the special needs of existing enterprises and groups considering new projects.

4.

358. The Meeting considered that, in order to co-ordinate all these proposals, it would be necessary, within the near future and for an adequate period, to place a group of experts at the disposal of the Latin American countries.

359. In the initial stage this group should include one or more experts on industrial problems and one or more specialists on the economic aspects of the pulp and paper industry.

360. The Meeting believed that such facilities should be provided through the expanded technical assistance programme of the United Nations, which, within the framework of a joint regional plan, embracing ECLA, FAO and TAA, for stimulating the development of pulp and paper production in Latin America, would appoint the experts and would provide them with the required working facilities.

361. The Meeting consequently recommended that Governments should take all possible steps towards this aim in conjunction with the international organizations concerned.

362. It proposed in particular that Governments should make every effort, in the meetings and councils of the United Nations and its specialized agencies, especially the Economic and Social Council, to secure the adoption of the recommendations required to establish such a regional project. Such recommendations should enable Governments in due course to draw up joint requests to ECLA, FAO and TAA.

363. Finally, the Meeting recommended that the various bodies responsible for the preparation of technical assistance programmes should give this project the priority it merited, having due regard for the need and importance of the development of pulp and paper production in this region.

364. The experts recommended at the final plenary session, that the attention of the international agencies concerned be drawn to the desirability of convening at some future date a second Latin American meeting of pulp and paper experts to report on the progress made and to consider special problems.

Second Part

WORKING PAPERS SUBMITTED TO THE MEETING

Table of Contents

* The original symbol under which the individual documents were issued is retained in this table of contents to facilitate reference.

* Condensation of a statement made in the course of the meeting.

I. Introduction

This Second Part of the report consists of the papers submitted to the Meeting. In all, seventy-three papers were received and circulated, ten compiled by the Secretariat, sixty-three contributed by the experts. Excluding the numerous charts, tables and illustrations, they aggregated some 1,600 pages.

It had been hoped to publish all these papers in full, but this has proved impossible owing to the cost involved. Moreover, some inevitable duplications would have occurred, since the several instances the same subject was studied in two or more papers. At the same time, certain of the more technical information was of very specialized interest.

In tackling the delicate problem of reducing the large volume of material to the compass required for publication, certain general principles have been followed. The texts of the basic Secretariat papers have been included almost in full. This has been done because they were written on the basis of the many expert papers received; moreover, they attempted to summarize the new information and data placed at the disposal of the Meeting and were fundamental to the discussions which took place.

Certain of the expert papers, deemed either of general interest or incapable of condensation, have also been published in full. All the other papers have, however, been compressed—in varying degrees. Some have undergone but slight editing, others have been drastically condensed, while for others it has been possible to include only a short summary which can do no more than give a key to the contents of the original paper. The aim has been to limit the size of the report and to maintain the general interest, while yet indicating clearly the ground covered.

This thankless task had to be carried out very quickly if early publication was to be ensured, and the editors had inevitably to take many arbitrary decisions. It cannot be claimed that these decisions were sound in all cases, but it is hoped that the unavoidable editing has not done violence to the views contained in any of the contributions.

It is recognized that many readers will, after perusing this report, wish to see the original full-length version of certain of the papers reproduced here in an abbreviated form. A limited number of the original papers is available, and may be supplied upon application to the Forestry Division, Food and Agriculture Organization of the United Nations (Viale delle Terme di Caracalla, Rome, Italy), or to the Economic Commission for Latin America (Casilla 179-D, Santiago, Chile). The request should specify which papers are required, and whether in English or Spanish.

II. Pulp and paper consumption, production and trade in Latin America

PULP AND PAPER CONSUMPTION, PRODUCTION AND TRADE IN LATIN AMERICA[1]

SECRETARIAT

1. THE WORLD PATTERN OF CONSUMPTION AND SUPPLY

In the course of the last four decades world consumption of paper and board has roughly quadrupled, while consumption per head has nearly trebled.

Table 1

WORLD CONSUMPTION OF PAPER, 1913 TO 1950–52

Year	Total consumption (million tons) Newsprint	Other paper and board	Total	Consumption per head (kg per head) Newsprint	Other paper and board	Total
1913.....	3.1	8.7	11.8	1.8	5.0	6.8
1935–38..	7.3	20.6	27.9	3.5	9.5	13.0
1950–52..	9.4	37.5	46.9	3.9	15.4	19.3

It will be observed that the consumption of other categories of paper and board (notably, of packaging grades) has increased much more rapidly in recent years than has the consumption of newsprint.

Consumption has not increased evenly throughout the world. As the following figures show, the contrast between consumption in the economically highly developed countries and that in the less developed regions has tended to increase rather than diminish since pre-war days.

Table 2

CONSUMPTION PER HEAD OF PAPER AND BOARD, 1935–38 TO 1950–52

	1935–38 (kg per head)	1950–52 (kg per head)	Percentage increase
Europe, North America and Oceania.....................	45	71	57
Latin America, Africa, Near, Middle and Far East.........	1.7	2.4	38

Europe, North America and Oceania, with just under 24 per cent of the world's population, consume nearly 88 per cent of the world's paper and board, including 85 per cent of the world's newsprint.

The disparities between consumption levels in the various regions are brought out in the following table, which also includes the most recent estimates available of percentage literacy in each region.

Even the regional differences shown in this table are far from telling the whole story. Consumption per head in the Far East would be very much lower than 1.6 kg if Japan were excluded; and in Africa the Union of South Africa, with but 6 per cent of the continent's population, consumes over half the continent's paper and board. Within the Latin American region, as will be seen later, there are considerable disparities in consumption levels.

Table 3

PAPER AND BOARD CONSUMPTION BY REGIONS, 1950–2

Region	Estimated * literacy (per cent)	Paper and board consumption (Average 1950–52) Total (thousand tons)	Per head (kg)	Of which: newsprint per head (kg)
Europe.............	90–95	11,820	29.8	5.3
USSR...............	95–100	(1,920)	(9.4)	(2.0)
North America.......	95–100	28,570	169.9	34.0
Latin America........	45–55	1,450	8.8	2.5
Near and Middle East.	15–25	100	1.3	0.3
Far East............	25–35	1,920	1.6	0.4
Oceania.............	85–90	670	51.9	16.6
Africa..............	15–25	450	2.2	0.4
World..............	45–55	46,900	19.3	3.9

Source: United Nations Educational, Scientific and Cultural Organization.
* Age group 10 and over.

All the regions of the world where consumption is low today are dependent, to a greater or lesser extent, on imports from the more developed regions.

Table 4

PAPER AND BOARD PRODUCTION AND CONSUMPTION, 1950–52, BY REGIONS

(*million tons*)

Region	Production	Consumption	Percentage of production exported	Percentage of consumption imported
Europe.............	13.11	11.82	10	—
USSR...............	(1.92)	(1.92)	..	..
North America.......	29.04	28.57	1.6	—
Latin America........	0.81	1.45	—	44
Near and Middle East.	0.03	0.10	—	72
Far East............	1.50	1.92	—	22
Africa..............	0.09	0.45	—	80
Oceania.............	0.29	0.67	—	57

Their degree of dependence varies from over one-fifth in the case of the Far East to four-fifths in Africa; for Latin America it is 44 per cent. Dependence on imports, it should be remembered, does not necessarily connote low consumption. Australia and the Union of South Africa, for example, both depend largely on imports and yet enjoy a relatively high level of consumption. Income levels, as well as the existence of local supplies, determine consumption standards.

[1] Originally issued as ST/ECLA/CONF.3/L.2.0.

The figures cited in table 4 do not fully state the dependence of the less developed regions, for their ability to satisfy even that part of their domestic demand for paper and board indicated in the table is to a varying extent dependent on supplies of imported wood-pulp. If pulp products consumption in these regions is expressed in terms of pulp equivalent and these figures are compared with domestic pulp production, total dependence on imports is found to be much higher than was indicated in the preceding table.

Table 5

ESTIMATED PULP DEFICITS IN 1950-52

Region	*Pulp equivalent of pulp products consumed*	*Pulp production*	*Total dependence on imports (expressed in pulp equivalent terms)*
	(million tons—average 1950–52)		
Latin America	1.27	0.35	72
Near and Middle East	0.10	0.02	80
Far East	1.53	1.12	27
Oceania	0.63	0.23	64
Africa	0.38	0.07	82
TOTAL—FIVE REGIONS	3.91	1.79	54

For the five regions taken together, import dependence is 41 per cent in terms of paper, 54 per cent in terms of pulp. For Latin America the respective figures are 44 and 72. The regional pulp deficit in Latin America is close on a million tons. That is to say, self-sufficiency, were it feasible and desirable, would have required in 1950-52 additional indigenous production not only of 640,000 tons of paper, but also of 920,000 tons of pulp.

The import requirements of the less developed regions are met today by imports from Europe and North America, the only two regions having a surplus. High consumption standards in these two regions mean that exports represent but a small fraction of total paper production there—10 per cent for Europe and 1.6 per cent for North America, as table 4 shows. These exports, though marginal in terms of total production, are, however, neither unimportant nor precarious. In the case of Europe certainly they represent a substantial trade important to the economies of several countries, and not merely to the wood-surplus countries of Northern Europe. Since it is to these two regions that Latin America, as well as the other deficit regions, must look for any increase in imports, it is of some importance to assess the probable future course of availabilities for export there.

There must be reservations as to the part which North America can play in meeting increasing deficits in the less developed regions in the long term. Such reservations do not, however, spring from any fear that production in that continent is not capable of a considerable further expansion. In recent years United States pulping capacity has adjusted itself rapidly to the phenomenal rise in demand—some, in fact, regard it as temporarily over-expanded at the present time. As for Canadian newsprint output, which has stepped up sharply since the war, there is no doubt that, given any measure of restoration of multilateral trading a substantial production could be developed in Canada for overseas export.

The reservations flow in part from the marginal, and hence uncertain, nature of the North American surplus (because of the exceptionally high level of production and consumption in that region) and, more particularly, from the problems of payment involved. Dollar scarcity today inhibits deficit countries from placing overmuch reliance on imports from North America, especially where other commodities present competing claims in dollar import programmes. Conversely, overseas markets which are subject to interruption through dollar scarcity, afford no strong attraction for North American producers in normal times. For this reason, if for no other, it would be unrealistic to look for an expansion in North American output capable of permanently satisfying the ever-increasing import needs of other regions.

Thus, while an exportable surplus of paper may remain and amounts of pulp be available for export from time to time, there is not likely to be a steady and growing excess of production in North America over the continent's needs in the long term.

Some of these considerations are equally applicable to any appraisal of prospects of increased supplies from Europe. It has to be borne in mind, however, that the supply/consumption pattern in Europe is very different. It is true that Europe is a surplus region, but in fact virtually all Europe's pulp surplus, and most of its paper surplus, arises in the three northern countries—Finland, Norway and Sweden. In the rest of Europe, only Austria has a significant pulp export, though several Western European countries have an important export trade in paper. Moreover, the pulp and paper industries of Northern Europe, which are primarily export industries, send three-quarters of their pulp surplus, and half their paper surplus to other European countries.

Table 6

EUROPEAN NET EXPORTS, 1950-52

(million tons)

	Wood-pulp		*Paper and board*	
Net exports from:				
Europe	0.62		1.28	
Northern Europe only	3.50		1.84	
of which:				
To Europe		2.69		0.93
To North America		0.43		0.18
To other regions		0.38		0.73

War's end found the European pulp and paper industry facing many problems: capacity (especially of newsprint) destroyed or damaged; capacity—and forest resources—reduced as a result of territorial adjustments which followed the war; the inability of the Soviet Union, pressed by reconstruction needs, to resume her considerable shipments of pulpwood to Western Europe.

By 1950-52 a rapid recovery had been made. Though pulp output was still 800,000 tons below pre-war, a similar fall in pulp exports to North America left pulp consumption at about the same level as in 1937-38. With the same amount of pulp, 1.5 million tons more paper and board were produced, though newsprint output was still well below pre-war. On balance, half a million tons more paper was exported, and consumption rose by a million tons—a very modest rise (on a *per capita* basis, 7 per cent) compared with that which has taken place in all other regions of the world. In the United Kingdom and Germany, in fact, consumption levels were still a long way below pre-war standards.

Recent studies indicate that European consumption will rise by about 40 per cent in the decade 1950-52 to 1960-62, and that European resources, and capacity expansion plans, will just about enable this rise in demand to be met without seriously encroaching on the region's overseas exports of pulp and paper, which are now running at between 1.5 and 2 million tons, expressed in terms of pulp. This, however, will require energetic measures to make the best use of existing resources—the greater use of pine and temperate hardwood to conserve scarce spruce supplies, continued high wastepaper recovery and use of non-wood fibres, and better employment of existing capacity. Should output fail to rise by the desired amount, the likelihood is that domestic consumption levels, rather than overseas exports, would suffer, provided the markets are available.

The general conclusion, however, must be that while European exports of pulp and paper to the less developed regions will continue, and are likely to exceed the high post-war level reached in 1950, it would be unrealistic to count on a substantial expansion in the coming decade. Moreover, it has to be remembered that should the supply/demand relationship in North America give rise once again to a strong demand for European pulp, some supplies that would normally have found their way to other regions would be attracted to the North American market. This redirection, however, is not likely to be as strongly felt in the future as it has been in the past, since many Northern European pulp exporters, conscious of the marginal and fluctuating nature of North American demand for their pulp, are directing themselves increasingly to markets which offer more stability if less acceptable currencies.

Though the import needs of the deficit areas of the world have hitherto been met entirely by imports from Europe and North America, it is perhaps necessary to mention the possibility of future export surpluses arising in the USSR, since this region possesses the world's most extensive coniferous reserves. From the point of view of resources, the possibilities are almost limitless. Hitherto, however, the pulp and paper industry has not received any marked priority in successive five-year plans, which have aimed rather at securing the heavy industry basis essential to further development and at rehabilitating and expanding those industries needed for repairing the ravages wrought by the Second World War. This phase is coming to an end, and the timber industry, for example, is beginning to resume its traditional sawn wood exports to Western Europe now that the most urgent domestic reconstruction needs have been met. Paper consumption in the Soviet Union is still low by Western standards (9.5 kg per head in 1950-52, as compared with 30 in Europe), but the recent shift in the direction of increasing the flow of consumer goods and in increasing consumer satisfactions (involving, for example, higher standards of packaging) might imply a rapid rise in paper consumption. The pulp and paper expansion envisaged in the current (1951-55) Five-Year Plan, however, would seem no greater than will enable rising domestic needs to be satisfied. Indeed, the signs are that in the immediate future rising consumption standards will prompt her to call increasingly on the European surplus.

Thus, great as are the USSR's potentialities, it must be concluded, on the basis of the evidence at present available, that there is little likelihood of her becoming an important exporter of pulp and paper to the deficit regions of the world in the coming decade.

2. Pulp and paper consumption in Latin America

Paper consumption in Latin America rose from just over 600,000 tons in 1935 to around 1,500,000 tons in 1953. This rapid increase, around 150 per cent in less than two decades, was made possible mainly by a considerable expansion in domestic production, which rose from 230,000 to 830,000 tons over the same period. This rise in domestic output did not, however, connote any diminution in imports; it accounted, in fact, for only two-thirds of the total increase which took place in consumption, and in 1953 paper imports were nearly twice as high as in 1935. This increase in consumption, it should be noted, took place in spite of the fact that during this period the price of paper, in relation to prices of other commodities, on the whole increased.

Table 7 shows how average consumption in the years 1948-52 was distributed among the Latin American countries. It will be observed that only four countries—Argentina, Brazil, Cuba and Mexico—consumed over 100,000 tons annually, and that these four countries accounted for 78 per cent of the region's total consumption.

Table 7

Apparent consumption of paper and board in Latin America

(thousand tons, average 1948–52)

Country	*Paper and board consumption*		*Of which: Newsprint consumption*	
	Thousand tons	*Per cent of total*	*Thousand tons*	*Per cent of total*
Argentina	402	30	111	28
Brazil	324	24.5	104	26.5
Mexico	204	15.5	55	14
Cuba	105	8	29	7.5
Chile	65	5	24	6
Uruguay	55	4	17	4.5
Colombia	48	3.5	16	4
Venezuela	48	3.5	10	2.5
Peru	32	2.5	9	2.5
All others (none over 10)	49	3.5	18	4.5
Total	1,332	100	393	100

This concentration of consumption is by no means due solely to differences in population. Consumption standards vary considerably from country to country within the continent, ranging from around 1.5 kg per head in Paraguay and Haiti to 23 in Argentina and Uruguay. Table 8 gives paper consumption per head in each of the Latin American countries, together with some representative figures for countries in other regions. Only one or two countries have a level of consumption approaching that in Western Europe, and consumption per head for Latin America as a whole is but 8.6 kg, little more than a quarter of the European average.

All countries in the region depend on imports to satisfy a substantial part of their paper needs, some entirely

Table 8

PAPER CONSUMPTION PER HEAD IN LATIN AMERICA AND IN CERTAIN OTHER COUNTRIES

(kg per head, average 1948–52)

Consumption group	*Latin America*		*Other countries*	
50 kg...			156.4 USA 106.0 Canada 70.0 Sweden 59.2 Australia	53.8 United Kingdom 53.6 Norway 52.0 Switzerland
20 kg...			48.5 Denmark 48.2 New Zealand 43.7 Finland	43.5 Netherlands 29.4 France
	23.4 Argentina	23.0 Uruguay		
10 kg...	19.5 Cuba	11.2 Chile	10.1 Japan	
5 kg...	9.6 Venezuela 9.0 Panama	7.9 Mexico 6.2 Brazil		
0 kg...	4.7 Costa Rica 4.3 Colombia 3.7 Peru 2.7 El Salvador 2.6 Nicaragua 2.5 Ecuador	2.5 Honduras 2.4 Dominican Republic 2.1 Guatemala 1.8 Bolivia 1.6 Haiti 1.5 Paraguay	2.2 Turkey	0.6 India

so, as the following table, which is based on the last three years for which adequate data are available, shows:

Table 9

IMPORT DEPENDENCE (IMPORTS/TOTAL CONSUMPTION), 1950–52

(per cent)

	All paper and board		*Newsprint only*
Chile	25	Chile	55
Brazil	26	Brazil	67
Mexico	26	Mexico	91
Uruguay	44	Argentina	96
Peru	45		
Argentina	47		
Cuba	67		
Bolivia	84		
Venezuela	85		
All others	100	All others	100
WHOLE REGION	44	WHOLE REGION	85

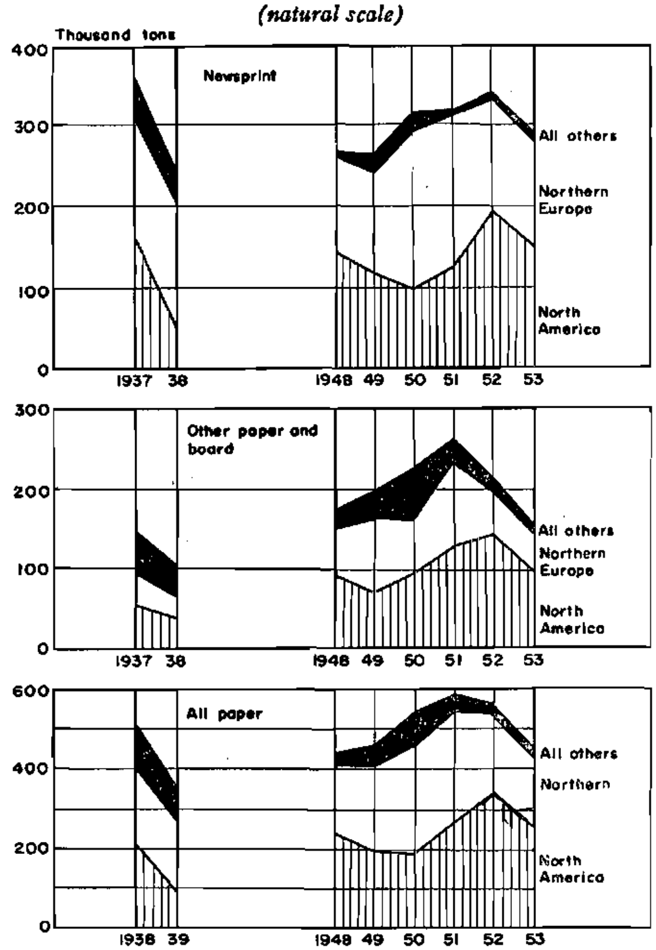
These figures are not, of course, completely up to date, since several new mills have come into operation since 1952. But the general picture they reveal would not be seriously modified were contemporary figures available.

Before the war, the three countries of Northern Europe comprised Latin America's most important supplying area. The data presented in graph 1 include only exports from the world's leading exporters to a dozen Latin American countries. Nevertheless they may be taken as representative, and they show that whereas newsprint imports have in the post-war years fluctuated somewhere around the pre-war level, imports of other paper and board have on the whole been a good deal higher. In spite of the fact that Northern Europe's exports to Latin America have increased slightly as compared with pre-war, exports from North America have risen even more rapidly and now account for more than half the total, nearly all the North American newsprint coming from Canada and most of the other paper and board from the United States. Suppliers other than North America and Northern Europe have never been particularly important, and if anything their importance has declined in recent years.

Graph 1

SOURCE OF LATIN AMERICAN PAPER IMPORTS, 1937-38 AND 1948-53

(natural scale)



3. LATIN AMERICA'S FUTURE PAPER NEEDS

Any attempt to assess the possibility of developing Latin America's own resources to satisfy some of her rising pulp and paper needs requires an appraisal of the future course of paper consumption in that continent.

The first serious attempt to estimate the future trend of paper consumption in Latin America was made in a joint ECLA/FAO study published in February 1954.[2] In this present paper those earlier estimates have been considerably revised. Since, however, the same general procedure has been followed, it will be convenient to describe the method adopted in the earlier study and to indicate the principal revisions which have now been incorporated, and the reasons therefore.

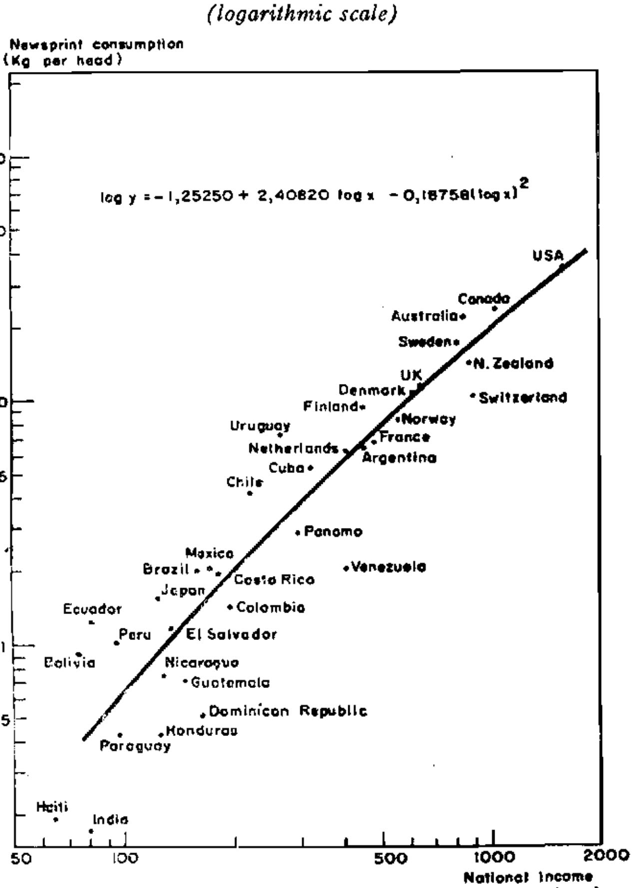
The earlier ECLA/FAO study established the fact that there was a very close correlation between paper consumption per head and national income per head. Consumption per head of (*a*) newsprint and (*b*) other paper and board in the year 1949 was therefore correlated with national income per head in that year for some thirty countries (twenty Latin American, eleven others). The derived income elasticities were applied to base-year consumption in 1950 on the assumption that income per head would rise by 3 per cent yearly. This was the middle of a series of provisional assumptions ranging from 1 to 5 per cent. To minimize accidental errors, for base-year consumption was taken, not actual consumption in that year, but a computed figure derived from a projection of past trends.[3]

For the purposes of this paper, the foregoing estimates have now been revised in several respects. First, a closer examination of the relationship between consumption and income levels made it clear that a second degree curve gave a considerably better fit than a straight line;[4] the implication, that income elasticity is higher at lower income levels, is one which accords with experience. Different income elasticities have therefore been applied in estimating future demand for different countries, according to their respective income levels in 1950, income data for this year now having become available.

Graph 2

RELATIONSHIP BETWEEN APPARENT CONSUMPTION OF NEWSPRINT (IN KILOGRAMMES PER HEAD, AVERAGE 1948-52) AND NATIONAL INCOME (NET GEOGRAPHICAL PRODUCT 1950, IN DOLLARS PER HEAD) IN LATIN AMERICA AND IN 15 SELECTED COUNTRIES OUTSIDE THE REGION

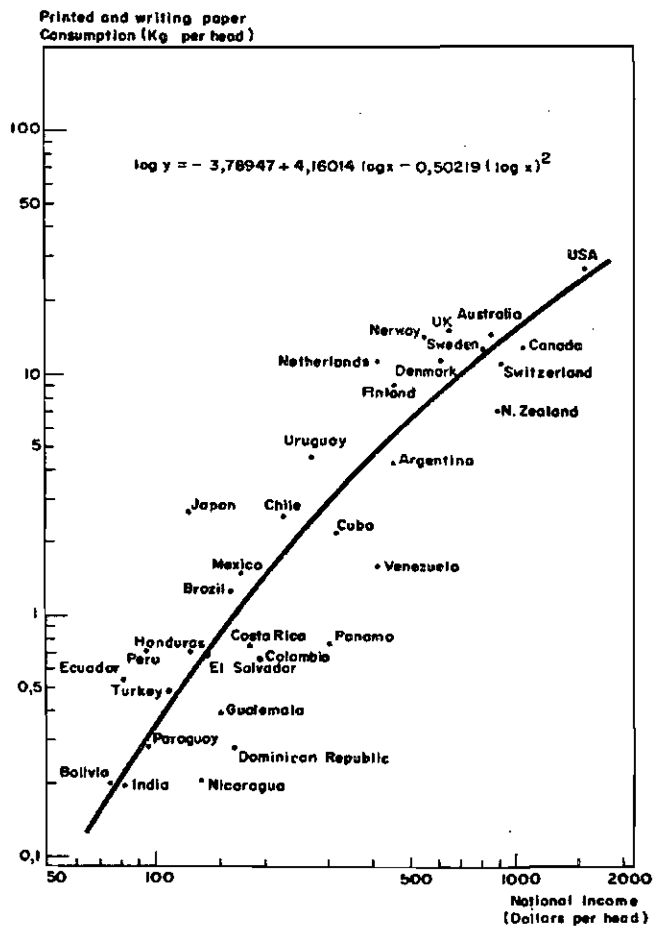
(logarithmic scale)



Graph 3

RELATIONSHIP BETWEEN APPARENT CONSUMPTION OF PRINTING AND WRITING PAPER (IN KILOGRAMMES PER HEAD, AVERAGE 1948-52) AND NATIONAL INCOME (NET GEOGRAPHICAL PRODUCT 1950, IN DOLLARS PER HEAD) IN LATIN AMERICA AND IN 15 SELECTED COUNTRIES OUTSIDE THE REGION

(logarithmic scale)



[2] *Possibilities for the Development of the Pulp and Paper Industry in Latin America* (United Nations Publication, Sales No. 1953.II.G.2.)

[3] The resultant estimates were as follows:

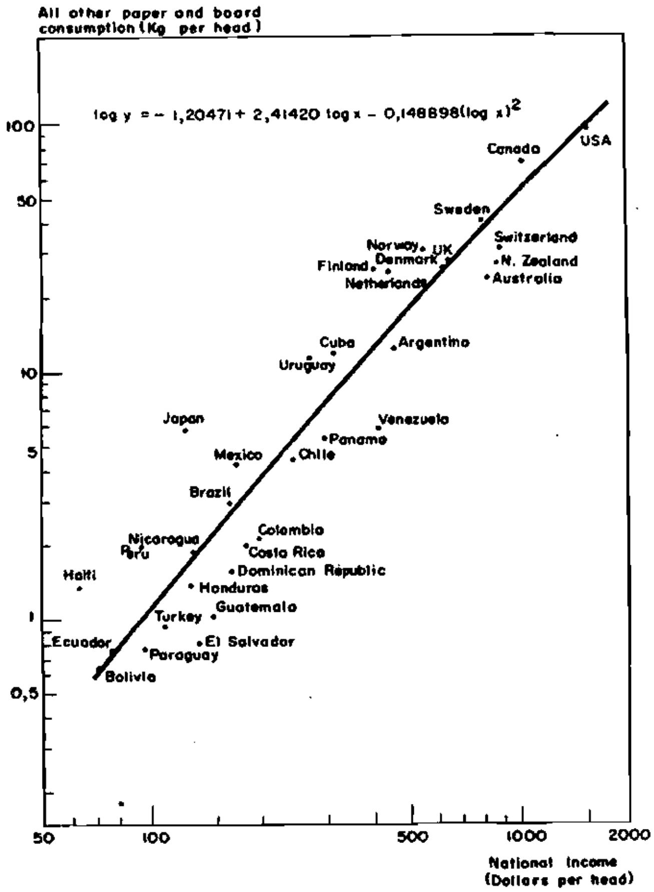
	Newsprint	*Other paper and board*	*Tota*
	(thousand tons)		
Consumption in 1950: actual data....	375	973	1,348
Consumption in 1950: computed data	474	913	1,387
Estimated consumption in 1960.....	886	1,743	2,629
Estimated consumption in 1965.....	1,212	2,425	3,637

[4] Some additional countries were included.

Graph 4

RELATIONSHIP BETWEEN APPARENT CONSUMPTION OF ALL OTHER PAPER AND BOARD (IN KILOGRAMMES PER HEAD, AVERAGE 1948-52) AND NATIONAL INCOME (NET GEOGRAPHICAL PRODUCT 1950, IN DOLLARS PER HEAD) IN LATIN AMERICA AND IN 15 SELECTED COUNTRIES OUTSIDE THE REGION

(logarithmic scale)



Income/consumption relationships were determined for three, instead of two, paper and board categories, namely: (*a*) newsprint, (*b*) other printing and writing paper, and (*c*) all other paper and board. (See graphs 2, 3 and 4.) The statistical data available relating to (*a*) and (*b*) seemed to be reasonably "clean", but inconsistencies in classification made it impossible to accord a more detailed treatment to (*c*).

Base-year consumption figures have not been derived from a projection of past consumption trends, since trends so calculated failed to take into account the marked rise in relative paper prices between the pre- and post-war years;[5] instead, an average of actual consumption in the years 1948-52 has been taken as base.

Additional data which have become available since the earlier study was published have made it possible to check and revise the estimates of population growth; in no case, however, was any significant amendment involved.

Finally, it was clearly unrealistic to assume the same rate of income growth in all Latin American countries. Moreover, much new material has become available in recent months relating to national income growth in many of the countries concerned. After carefully reviewing the available evidence it was decided to proceed on the basis of two different sets of assumptions:

A: taking, for each country in turn, a very conservative assessment of the rate of growth of *per capita* income that may be expected during the coming ten to fifteen years. In all cases the rates of growth assumed were far lower than the historical rates calculated from data for eight recent years.

B: taking, for each country in turn, rates which presuppose a favourable development in the years to come. These rates were based largely on the historical 1945-52 rates, with downward adjustments in the case of all the Central American coffee-growing republics, since it was considered that past rates reflected a coffee-based prosperity which would not necessarily be reproduced in the future. In most cases, indeed, the rates of growth assumed were lower than those indicated by the 1945=1952/53 trend.

Assumption A therefore reflects a deliberately pessimistic view of future developments. This conscious choice was prompted by the fact that any actual planning for the establishment of new industries ought to proceed on a very cautious basis. The planner must be aware of the situation which he may be called upon to face at the worst. The future levels of consumption implied are therefore the minimum levels which are likely to be attained, assuming that the means of satisfying them are available.

Assumption B reflects a more optimistic view of future developments. But it by no means represents the maximum development which could take place. These rates could be exceeded in the Central American republics, for reasons already indicated. Moreover in the case for Brazil, for example, the 3 per cent growth assumed falls below the actual rate which has obtained on an average throughout the period 1935-51. Thus the future levels of consumption which assumption B implies do not represent the maximum rates which might conceivably be attained, but the levels which would correspond to a generally favourable rate of growth—again always provided, of course, that supplies of paper are available, from domestic or foreign sources, to enable demand at those levels to be satisfied.

These explanations will make it possible to set the estimates which follow in perspective. It is necessary to bear in mind also some of the implications of the procedure followed in regard to income elasticities. For each country, and for all three commodity categories, the elasticity assumed has been that corresponding to the country's 1950 *per capita* income (the gradient of the curve at the given income value). This assumption of constant (base point), instead of declining, elasticity over the period of forecast seems to impart an element of over-estimation. But it should be borne in mind that over the short period of forecast (ten to fifteen years) the curve diverges only very slightly from a straight line. Furthermore the countries falling below the income/consumption curve are countries with small or zero domestic supplies of paper—"under-consumers", so to speak. Should domestic supplies increase as a consequence of the establishment of new mills, it may be expected that consumption levels would move nearer the income/consumption curve, i.e., that elasticities would

[5] It is this fact which invalidates country projections based on the income/consumption relationship through time in particular countries. It should be noted that a tacit assumption of the procedure actually followed is that the relative price of paper will not undergo any marked change.

be higher than has been assumed. Nor would this necessarily be balanced by a contrary movement on the part of countries above the curve, implying a tendency for consumption levels to converge on to the curve from both sides. For all the countries at the lower end of the curve, whether they lie above or below, are countries with a low income level, a high degree of import dependence and a low domestic production of paper. The effect of expanding domestic production in these countries will be to lead in the course of time to a new curve expressing the income/consumption relationship, a curve at once higher and less convex. Hence it is not likely that the income elasticities used have led to any over-estimation in future demand.

The foregoing paragraphs have discussed the possibilities of over-estimation inherent in the method followed, which is based on the assumption that consumption will rise in step with income and that relative paper prices will not markedly change. The method implies that low consumption countries will tread the historic income/consumption path already marked out by higher income countries—that countries will move in procession up the income/consumption curve. But this will not necessarily happen, as perhaps two examples will suffice to make clear. Mr. Stevenson's paper[6] shows how much of the recent rise in paper consumption in the United States has been due to paper's success in displacing other materials; for example, the glass milk bottle has been largely replaced by the waxed container. Can it be assumed that paper's substitutive power will only come into play in Latin America when income levels begin to approach contemporary levels in the United States or in Europe? No, because the technological progress in paper-making and converting which makes paper competitive has already been achieved outside Latin America. Paper's ability to replace other materials will be felt much earlier, because of recent technical advances, and paper consumption will rise to levels far above those achieved in more advanced countries when they were still at the real income levels which obtain in the less developed countries today.

[6] 2.2, *Consumption trends in wrapping, packing and industrial papers and paperboard*, by Louis T. Stevenson.

A further example: Latin American exports have to compete in the world's markets with exports from other regions and with domestically produced articles. Many of these are marketed with a much higher packaging standard than is achieved in the domestic Latin American market today—or is likely to be achieved for some time to come. However slowly packaging standards rise within Latin America, its exporters will be driven to improve their standards of packaging, whether they like it or not, if their products are to compete successfully on the world's markets. In this way, too, progress outside the region imposes a higher standard of consumption in the region than would be indicated by the historical income/consumption relationship.

These examples (and others could be quoted) demonstrate the effects of living in "one world". They suggest that the estimates arrived at in this paper are more likely to be on the low side than on the high side.

The assumptions regarding rates of growth in income per head, rates of population growth, and income elasticities for each Latin American country are set out in table 10, and the estimates of future consumption derived from these data appear in table 11. A summary for Latin America as a whole is given in table 12.

4. Latin American production and prospective capacity, in relation to future needs

The estimates of future requirements arrived at in the preceding section may now be compared with current production capacity and with the plans which at present exist for raising that capacity. The demand projections were based on average consumption in the years 1948-52; it is therefore convenient to take 1950 as a base year for discussing present and future developments and, since this paper is concerned with medium-term prospects and their longer-term implications rather than with the short-term supply position, to compare prospective capacity in 1965 with requirements in that year.

Table 10

Data used in preparing estimates of future demand

	Consumption in 1948–52 (kilogrammes per head)			Population (millions)		Net geographical product in 1950 (NGP) ($ per head)	Assumed annual rate of growth in NGP/head (per cent)		Income elasticities		
	Newsprint	Other printing and writing paper	All other paper and board	1950	Estimated 1965		Assumption A	Assumption B	Newsprint	Other printing and writing paper	All other paper and board
Argentina	6.43	4.13	12.79	17.20	23.02	446	1.5	3	1.41	1.50	1.62
Bolivia	0.93	0.20	0.63	3.02	3.69	75	1	2	1.70	2.28	1.86
Brazil	2.00	1.22	2.99	52.12	73.61	162	2	3	1.58	1.94	1.76
Chile	4.10	2.57	4.53	5.81	7.36	224	1	2	1.53	1.80	1.71
Colombia	1.44	0.67	2.17	11.26	15.56	193	2	3	1.55	1.87	1.73
Costa Rica	2.00	0.75	2.00	0.80	1.25	181	1.5	2	1.56	1.89	1.74
Cuba	5.41	2.18	11.90	5.36	7.23	317	0.5	1.5	1.47	1.65	1.67
Dominican Republic	0.52	2.88	1.56	2.12	3.07	165	1	2	1.58	1.93	1.75
Ecuador	1.25	0.53	0.75	3.20	4.48	81	1	2	1.69	2.24	1.85
El Salvador	1.18	0.70	0.81	1.86	2.72	137	1.5	2	1.61	2.02	1.78
Guatemala	0.71	0.39	1.03	2.80	4.00	149	1.5	2	1.59	1.98	1.77
Haiti	0.19	0.03	1.35	3.11	3.82	64	0.5	1.5	1.73	2.34	1.88
Honduras	0.42	0.70	1.40	1.43	2.03	127	1.5	2	1.62	2.05	1.79
Mexico	2.12	1.49	4.33	25.71	37.81	172	1.5	2.5	1.57	1.92	1.75
Nicaragua	0.76	0.20	1.69	1.06	1.63	129	1.5	2	1.62	2.04	1.79
Panama	2.89	0.75	5.40	0.80	1.18	298	1	2	1.48	1.68	1.68
Paraguay	0.43	0.29	0.78	1.41	1.91	95	0.5	1.5	1.67	2.17	1.83
Peru	1.02	0.70	1.98	8.52	11.46	94	1.5	2.5	1.67	2.18	1.83
Uruguay	7.28	4.50	11.23	2.38	2.93	271	1	2	1.50	1.72	1.69
Venezuela	2.09	1.57	5.95	4.97	7.84	408	1.5	2	1.43	1.54	1.64

Table 11

ESTIMATED FUTURE PAPER DEMAND IN LATIN AMERICA, BY COUNTRY
(*thousand tons*)

Country	Assumption	1960 Newsprint	1960 Printing and writing paper	1960 All other paper and board	1960 Total	1965 Newsprint	1965 Printing and writing paper	1965 All other paper and board	1965 Total
Argentina	A	166.6	108.5	341.9	617.0	203.0	133.0	423.2	759.2
	B	205.1	135.2	433.9	774.2	277.1	185.0	605.1	1,067.2
Bolivia	A	3.8	0.9	2.6	7.3	4.4	1.0	3.1	8.5
	B	4.4	1.1	3.1	8.6	5.7	1.4	4.0	11.1
Brazil	A	178.9	117.9	278.0	574.8	234.7	160.3	371.2	766.2
	B	208.7	142.5	329.9	681.1	295.8	213.0	479.9	988.7
Chile	A	32.3	20.8	36.3	89.4	37.9	24.7	43.1	105.7
	B	37.5	24.8	43.0	105.3	47.5	32.2	55.5	135.2
Colombia	A	27.4	13.5	42.8	83.7	35.5	18.0	56.4	109.9
	B	31.9	16.2	50.7	98.8	44.6	23.7	72.7	141.0
Costa Rica	A	2.8	1.1	2.8	6.7	3.6	1.4	3.7	8.7
	B	3.0	1.2	3.1	7.3	4.0	1.6	4.2	9.8
Cuba	A	38.8	15.8	86.1	140.7	43.7	17.9	97.5	159.1
	B	44.8	18.6	101.6	165.0	54.3	22.8	125.0	202.1
Dominican Republic	A	1.7	0.9	5.1	7.7	2.0	1.2	6.2	9.4
	B	2.0	1.1	6.1	9.2	2.6	1.5	8.1	12.2
Ecuador	A	5.9	2.7	3.6	12.2	7.2	3.3	4.4	14.9
	B	7.0	3.3	4.3	14.6	9.2	4.6	5.8	19.6
El Salvador	A	3.6	2.3	2.5	8.4	4.6	3.0	3.3	10.9
	B	3.9	2.5	2.8	9.2	5.2	3.5	3.7	12.4
Guatemala	A	3.2	1.9	4.8	9.9	4.1	2.4	6.2	12.7
	B	3.5	2.1	5.2	10.8	4.6	2.8	7.0	14.4
Haiti	A	0.8	0.1	5.3	6.2	0.8	0.2	5.9	6.9
	B	0.9	0.2	6.4	7.5	1.1	0.2	7.8	9.1
Honduras	A	1.0	1.7	3.3	6.0	1.2	2.3	4.2	7.7
	B	1.1	1.9	3.6	6.6	1.4	2.6	4.8	8.8
Mexico	A	89.1	66.1	186.9	342.1	113.8	86.7	241.9	442.4
	B	104.0	79.8	228.9	405.7	143.4	114.8	312.8	571.0
Nicaragua	A	1.4	0.4	3.1	4.9	1.8	0.5	4.1	6.4
	B	1.5	0.4	3.4	5.3	2.0	0.6	4.7	7.3
Panama	A	3.5	1.0	6.7	11.2	4.3	1.1	8.2	13.6
	B	4.0	1.1	7.9	13.0	5.3	1.5	10.5	17.3
Paraguay	A	0.8	0.6	1.5	2.9	0.9	0.6	1.7	3.2
	B	0.9	0.7	1.8	3.4	1.2	0.9	2.2	4.3
Peru	A	13.6	10.1	27.0	50.7	17.0	13.1	34.2	64.3
	B	16.0	12.5	32.3	60.8	21.7	18.1	44.7	84.5
Uruguay	A	23.1	14.6	36.4	74.1	26.6	17.0	42.3	85.9
	B	26.8	17.3	43.0	87.1	33.2	22.0	54.3	109.5
Venezuela	A	17.4	13.3	51.1	81.8	22.5	17.3	67.2	107.1
	B	18.7	14.3	55.4	88.4	25.1	19.4	75.8	120.3
Latin America	A	615.5	393.9	1,127.9	2,137.3	769.6	505.1	1,428.0	2,702.7
	B	725.6	467.7	1,359.4	2,561.7	984.8	672.2	1,888.8	3,545.8

In 1950 local production amounted to about 725,000 tons, of which 53,000 tons were newsprint. But the *rated* production capacity of the paper industry in 1950 was considerably higher, about 950,000 tons. Assuming that production capacity could be utilized at 100 per cent in the case of newsprint and 90 per cent for other paper and board, then actual production capacity in 1950 may be reckoned at 864,000 tons (including 54,000 tons of newsprint). This estimate is probably on the high side, as most of the mills produce a wide range of products, which results in frequent change-overs and loss in capacity. In addition, some of the integrated mills located far from the forest resources—especially in Mexico—are often affected by temporary shortages of pulpwood which, in turn, prevent the full use of capacity.

A number of projects for expanding the capacity of existing mills as well as for establishing new industries are at present under way in Latin America. These projects (including those completed since 1950) are listed in table 13.[7]

[7] Based on table 24 in chapter 5 of *World Pulp and Paper Resources and Prospects* (UN/FAO, 1954), but revised in the light of more recent information.

This list, which is believed to be fairly comprehensive, includes:

New mills and extensions completed since 1950.

New mills and extensions where construction has already begun.

Projects which have reached the advanced planning stage.

Projects which have not yet passed beyond the stage of preliminary study.

General goals which have not yet been translated into specific projects.

It follows that not all the projects listed will necessarily be realized. Further studies may prove a number of them to be impracticable, on one or several of many different grounds. Moreover, there is plenty of time between now and 1965 for many other projects to be conceived and brought to fruition, since the time-lag between preliminary study and full operation of the completed mill need not, under favourable conditions, exceed three to five years. The intensive reconnaissance work of the last three years in Latin America suggests, however, that any projects which arise over and above those listed are

Table 12

ESTIMATED LATIN AMERICAN DEMAND FOR PAPER, 1960 AND 1965

	Newsprint	*Other paper and board (thousand tons)*	*Total*
Average consumption, 1948–52	393	939	1,332
Estimated consumption in 1960:			
Assumption A	615	1,522	2,137
Assumption B	726	1,836	2,562
Estimated consumption in 1965:			
Assumption A	770	1,933	2,703
Assumption B	985	2,561	3,546
Percentage increase over 1948–52:			
By 1960:			
Assumption A	56	62	60
Assumption B	85	96	92
By 1965:			
Assumption A	96	106	103
Assumption B	151	173	166

UNESCO recently commissioned from the Intelligence Unit of *The Economist*, London, a study of future demand for newsprint and printing and writing paper. These forecasts are compared below with those contained in the present paper:

	Newsprint			*Printing and writing paper (thousand tons)*		
	FAO/ECLA		*UNESCO*	*FAO/ECLA*		*UNESCO*
	Minimum economic growth	*Favourable economic development*		*Minimum economic growth*	*Favourable economic development*	
1960	615	726	714	394	505	344 unadjusted 396 adjusted
1965	770	985	895	477	672	436 unadjusted 502 adjusted

For newsprint, the UNESCO estimate lies close to the upper FAO/ECLA estimate for 1960, and about halfway between the upper and lower estimates for 1965. For printing and writing paper the unadjusted UNESCO estimates lie below, and the adjusted estimates close to, the lower FAO/ECLA estimates. The adjustment seeks to allow for the fact that these papers are not always clearly distinguished in production and trade statistics. Classification difficulties make it impossible to say whether the FAO/ECLA base figures and forecasts are too high or whether the UNESCO adjusted base figures and forecasts are still too low. Any over-estimation in the FAO/ECLA figures is, of course, compensated in the parallel base figures and forecasts for other categories of paper and board.

Table 13

LIST OF PULP AND PAPER MILLS COMPLETED, UNDER CONSTRUCTION OR LIKELY TO BE CONSTRUCTED IN LATIN AMERICA DURING THE PERIOD 1950–65

Country	*Site*	*Capacity (thousand tons annual capacity)* Newsprint	Other papers and boards	Mechanical pulp	Chemical pulp	*Process* *	*Raw material*	*Remarks*
Argentina	Záratae	60	..	50	..	1	Salicaceous species	20,000 tons constructed
Argentina	Puerto Piray	..	..	..	30	2	*Araucaria*	Under construction
	Others	..	120	..	60	..		Argentine 5-yr. plan
Brazil[a]	São Paulo I and IA	..	18	..	34	3	Eucalypt	Completion 1955, 1957
Brazil	São Paulo II, III and IV	..	10	..	44	4	Eucalypt	Completion 1957, 1958 and unspecified
Brazil	São Paulo V	..	7	..	7	5	Bagasse	Completion 1954
Brazil	Paraná VI, VIA and VII	..	71	..	70	4	*Araucaria*	Dates unspecified
Brazil	Sta. Catarina VIII and IX	..	52	..	62	4	*Araucaria*	Completion 1955 and dates unspecified
Brazil	Est. do Rio X, XI	..	..	..	34	3	Bagasse	No dates set
Brazil	Alagoas and Pernambuco XII and XIII	..	..	..	18	?	Bagasse	No dates set
Chile	Valdivia	..	5	..	..	..	*Pinus radiata*	Completed
Chile	Concepción	44	11	40	50	1 and 4	*Pinus radiata*	Under construction
Colombia	Cali	..	24	..	10	..	Imported pulp and bagasse	Completed
Colombia	Cali	..	12	..	..	..	Imported pulp and bagasse	Extension, under construction
Colombia	Puerto Boyacá	20	..	20	..	..	Mixed tropical woods	
Costa Rica	Pacuare River	..	3	..	3	3	Abaca	Completed
Cuba	?	..	20	..	15	..	Bagasse	
Dominican Republic	Río Haina	..	10	..	7	5	Bagasse	
Ecuador	Latacunga	..	3	..	3	..	Agricultural residues	Completed
Mexico	Chihuahua	..	..	..	26	2	Conifers	Completed
Mexico	Chihuahua	..	..	10	..	1	Conifers	
Mexico	Durango	..	..	60	..	1	Conifers	
Mexico	Michoacán	..	..	..	30	4	Conifers	
Mexico	Ayotla	..	..	..	9	5	Bagasse	Completed
Mexico	Mexico City (San Cristóbal)	..	6	..	9	6	Bagasse	Completed
Mexico	Monterrey	..	12	..	..	?	Bagasse	
Mexico	Mexico City	..	..	..	12	4	Conifers (?)	Extension project completed
Mexico	Mexico City	..	22	..	..	..	Waste paper and wood pulp	Three projects, already in operation
Mexico	Mexico City	..	15	..	..	..	Bagasse, etc.	
Mexico	Yucatán	..	30	..	30	4	Mixed tropical woods	
Peru	Pucallpa	15	3	10	5	1 and 4	*Cecropia*	
Venezuela	Lake Valencia	..	12	..	10	5	Bagasse	
	TOTAL LATIN AMERICA	139	466	190	578			

* 1. Mechanical 2. Sulphite 3. Soda 4. Sulphate 5. Caustic soda-chlorine 6. Combined mechanical & chemical.

[a] See paper 7.2.

likely to be, not completely new schemes, but variants of schemes already under study. Thus the capacity totals at the foot of table 13, while they may perhaps understate ultimate achievements by 1965, most certainly overstate probable achievements on the basis of present plans only.

To measure the possibilities of further development of the pulp and paper industry in Latin America, it is important to see how the additional capacity at present contemplated compares with future needs.

Assuming that all the projects listed are carried out, the production capacity in the region will rise to about 1,460,000 tons in 1965, including 185,000 tons of newsprint. This estimated future capacity is compared in table 15 with future requirements, as estimated earlier, on the two alternative assumptions.

This means that by 1965, assuming that all the projects listed in table 13 are completed and in full operation, Latin America's paper production will fall short of probable requirements by 1.25 million tons even if the most pessimistic view is taken of the rate of economic growth in the coming years; nearly half the deficiency would be in newsprint. Given a more favourable economic evolution, the deficit would exceed 2 million tons, including 800,000 tons of newsprint. If a really high rate of growth were achieved, comparable to that which took place in the immediate post-war years, the deficit would be even greater.

Table 14

LATIN AMERICA'S PAPER CAPACITY DEFICIT IN 1965

(thousand tons)

Category	Capacity in 1950	Additions to capacity 1950–65	Estimated capacity 1965	Paper requirements in 1965: At the minimum A	Paper requirements in 1965: Given favourable developments B	Capacity deficit in 1965: If no paper imports A	If no paper imports B	If paper imports at 1950–52 level A	If paper imports at 1950–52 level B
Newsprint	55	140	195	770	985	575	790	220	435
Other paper and board	810	465	1,275	1,935	2,560	660	1,285	375	1,000
TOTAL	865	605	1,470	2,705	3,545	1,235	2,075	595	1,435

In any event, the deficit would be greater than could be met by imports at the recent (1950-52) level. Taking the most cautious view of the future, the region would have to import 600,000 tons more paper than it does today if its paper needs are to be met. A more favourable evolution would give rise to the need for importing nearly 1.5 million tons more than today. The cost of paper imports (expressed in the equivalent of US dollars, at the prices recently ruling) would rise from about $115 million to $230 million on the lower assumption and nearly $400 million on the higher assumption.

These figures relate only to paper: it is necessary also to assess the future pulp situation. For the purposes of illustration, let it be assumed that paper imports in 1965 will be maintained at the recent (average 1950-52) level. To produce in Latin America the quantities of paper required to satisfy needs at the two alternative levels (A and B) it is estimated that the following amounts of pulp would be required:[8]

Table 15

1965 PULP NEEDS (ASSUMING PAPER IMPORTS MAINTAINED)

(thousand tons)

	Mechanical pulp	Chemical pulp
Assumption A	590	1,080
Assumption B	860	1,490

In addition to these quantities of pulp, about 400,000 tons of other fibrous material (waste paper, rags, etc.) would be required in case A, and 600,000 tons in case B.

In 1950 the pulp mills in the region (integrated and non-integrated) had a total *rated* annual production capacity of 238,000 tons of chemical and 218,000 tons of mechanical pulp; actual production was 185,000 and 118,000 tons respectively. The large discrepancy between rated capacity and actual production in mechanical pulp is due to a local over-capacity of about 100,000 tons, mainly in Brazil and Mexico. Many of the Brazilian mills are small and uneconomic, and experience great difficulty in marketing their product in times of normal price level, while the difficulty of obtaining a continuous supply of pulpwood leads to frequent interruptions at many of the Mexican mills. In chemical pulp there is a smaller discrepancy, mainly concentrated in Mexico, where apparently the same conditions exist as for mechanical pulp mills. For these reasons, it is assumed that *actual* production capacity in the region in 1950 was 120,000 tons for mechanical and 200,000 tons for chemical pulp.

Referring now to the projects listed in table 13, it will be seen that present plans would, if realized, add to the region's capacity, between 1950 and 1965, 190,000 tons of mechanical and 580,000 tons of chemical pulp. Total prospective capacity in 1965 may now be compared with estimated pulp requirements corresponding to each of the assumptions regarding rate of economic growth. The resultant figures are presented in two ways: first, assuming that no pulp will be imported in 1965; secondly, assuming that pulp will be imported in the same amounts as in 1950-52. It should be emphasized that all the figures presuppose that paper imports will be maintained at the 1950-52 level.

By combining tables 14 and 16, the 1965 prospect for

[8] Using the following conversion factors, computed from the actual consumption figures for the three-year period 1950-52:

Mechanical pulp:	newsprint x 0.92 other paper and board x 0.125
Chemical pulp:	newsprint x 0.13 other paper and board x 0.62
Other fibres (rags and waste paper)	other paper and board x 0.26

Table 16

LATIN AMERICAN PULP CAPACITY DEFICIT IN 1965

(thousand tons)

Category	*Capacity in 1950*	*Additions to capacity 1950–65*	*Estimated capacity 1965*	*Pulp requirements in 1965* At the minimum A	*Pulp requirements in 1965* Given favourable developments B	*Capacity deficit in 1965* If no pulp imports A	*Capacity deficit in 1965* If no pulp imports B	*Capacity deficit in 1965* If pulp imports at 1950–52 level A	*Capacity deficit in 1965* If pulp imports at 1950–52 level B
Mechanical...	120	190	310	590	860	280	550	255	525
Chemical.....	200	580	780	1,080	1,490	300	710	35	445
TOTAL	320	770	1,090	1,670	2,350	580	1,260	290	970

Table 17

ADDITIONAL PULP AND PAPER CAPACITY REQUIRED AND PLANNED, 1950–65

(thousand tons)

(Assuming that pulp and paper imports are maintained at the 1950–52 rate)

Product	*Additional capacity required* A (minimum economic growth)	*Additional capacity required* B (favourable economic developments)	*Additional capacity planned*	*Further needs by 1965 (extra capacity, beyond present plans, or additional imports* A (minimum economic growth)	*Further needs by 1965* B (favourable economic developments)
Newsprint.................	360	575	140	220	435
Other paper and board.....	840	1,465	465	375	1,000
Mechanical pulp..........	445	715	190	255	525
Chemical pulp............	615	1,025	580	35	445

pulp and paper together, may be summed up, as follows:[9]

Present plans are expressed as a percentage of probable needs in the table below.

Table 18

PLANNED CAPACITY AS PERCENTAGE OF REQUIRED CAPACITY

(assuming no decline in pulp and paper imports)

Assumption	*Per cent* Newsprint	Other paper and board	Mechanical pulp	Chemical pulp
A: minimum economic growth.............	36	55	42	94
B: favourable economic development........	23	32	26	58

Thus, if the region achieves a favourable rate of economic growth in the coming decade, present plans would fall short of capacity needs by 1.5 million tons of paper (of which half a million tons newsprint) and one million tons of pulp (of which just over half mechanical). These figures could well be exceeded if exceptionally rapid development took place, e.g., if some of the rapid growth rates of recent years were achieved. Should, however, economic growth be limited to the bare minimum rates we have assumed in "A", then the probable gap would still be 600,000 tons for paper and 300,000 tons for pulp. Only in the case of chemical pulp would the gap be nearly closed.

All these figures rest on the assumption that it will be possible in 1965 to import pulp and paper on the recent scale.

Does this mean that in the event of only minimum economic growth being achieved there is any danger of chemical pulp capacity becoming over-expanded? No, for several reasons—some of which are evident from a perusal of graph 5, which illustrates some of the data in table 17 and also presents a "stage" analysis (based on the most recent information available) of the projects listed in table 13.

First, relatively few of the projects listed are as yet completed or under construction. Many have, it is true, reached the advanced planning stage, but a very large number are still only at the stage of preliminary study. Clearly, to assume that all these projects will reach fruition, is to take a very optimistic view.

Secondly, it is very probable that the minimum rates of economic growth assumed will be exceeded; they have of course been exceeded during the years 1950-54.

Thirdly, as the comparison between needs and prospective capacity has shown, the lag is greatest in mechanical pulp. Hitherto mechanical pulp has been made only from softwoods, and though the region is by no means lacking in softwood resources, these are localized.

[9] The position that would arise if neither pulp nor paper were imported has not been discussed. For self-sufficiency, not only would additional pulp and paper capacity be required to replace present imports, but further pulp capacity would be required to make up the paper no longer imported. In that situation the total capacity deficit would be as follows:

	A Minimum economic growth	B Favourable economic development
	(thousand tons annually)	
Newsprint.....................	575	790
Other paper and board...........	660	1,285
Mechanical pulp.................	640	915
Chemical pulp..................	520	935

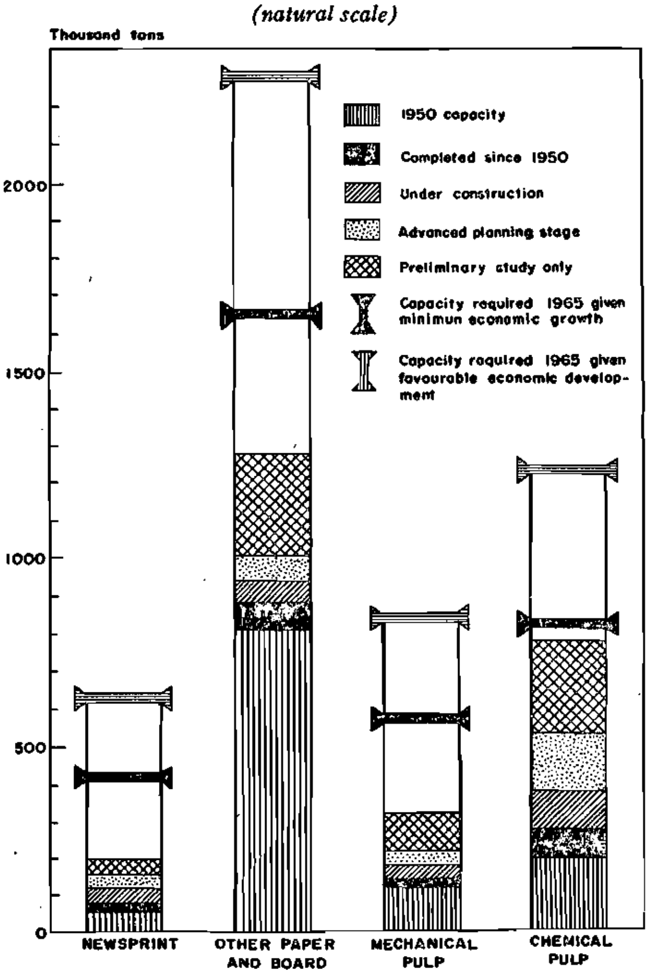
Unless the efforts to obtain from tropical woods an economic substitute for mechanical pulp are crowned with success,[10] it will be necessary to replace mechanical pulp by chemical pulp in certain uses. Furthermore, countries with an abundance of bagasse but scarce wood supplies may well use chemical bagasse pulp instead of mechanical pulp in such products as newsprint. For these reasons it may be expected that chemical pulp needs in 1965 will be higher than has been estimated here, and mechanical pulp needs correspondingly lower.

Graph 5

LATIN AMERICAN PULP AND PAPER CAPACITY IN 1965: NEEDS AND PLANS

(assuming no decline in pulp and paper imports)

(natural scale)



[10] See paper 3.13, *The use, in newsprint, of bleached cold soda pulps from certain mixtures of Latin American hardwoods,* by G. H. Chidester and K. J. Brown.

Finally, the whole of this discussion has dealt with the needs of the region as whole in relation to the region's aggregate plans. But in general specific additions to production will be absorbed in the local national market and will not become available to other markets within the region. Thus those countries whose capacity plans come nearest to satisfying their local needs will enjoy a more rapid increase in consumption standards; other countries will not necessarily find their situation improved.

For these reasons the high figure (94 per cent) of prospective chemical pulp capacity in relation to minimum future needs is largely illusory. Present plans for expanding capacity lag behind expected requirements for all categories of pulp and paper, although certainly the lag is most marked in mechanical pulp and newsprint.

5. THE OTHER DEFICIT REGIONS

Latin America is not the only region which has always looked to the traditional pulp and paper producing centres for the satisfaction of part of its paper needs. All the other less developed regions—the Near, Middle and Far East, and Africa—have imported a substantial part of their requirements from Europe and North America; and even Oceania (mainly Australia and New Zealand), where consumption standards are relatively high, has always been and still remains largely dependent on imports. A recent review[10] of the prospects in these regions compared the probable increase in paper requirements up to 1960-62 with the additions to local capacity which might be realized by that date. The conclusions are summarized in the following table:

Thus, even were all the projects at that time under consideration to be realized by 1960-62 (and subsequent progress reports suggest that this would be taking an excessively optimistic view) the aggregate deficit in these regions would rise by over 300,000 tons, including 100,000 tons of newsprint. These figures exclude China and Japan, the tacit assumption being that these two countries will be able to take care of their own rising needs. In Japan both paper production and paper consumption are

[11] UN/FAO: *World Pulp and Paper Resources and Prospects,* New York, 1954.

Table 19

COMPARISON BETWEEN ESTIMATED INCREASE IN PAPER REQUIREMENTS AND ESTIMATED INCREASE IN PAPER CAPACITY IN CERTAIN REGIONS, 1950–52 TO 1960–62

(thousand tons a year)

Region	*Imports 1950–52*	*Regional production 1950–52*	*Estimated additional capacity by 1960–62*	*Estimated increase in demand by 1960–62*	*Increase in deficit as compared with 1950–52*
Far East (excluding China and Japan)	375	190	392	465	73
Near and Middle East	74	27	68	49	−19
Africa	360	90	128	260	132
Oceania	388	287	179	325	146
TOTAL—FOUR REGIONS	1,197	594	767	1,099	332
Of which:					
Newsprint	428	51	219	325	106
Other paper and board	769	543	548	774	226

rising extremely rapidly. But her pulp and paper industries face very difficult raw material problems, so serious that Japan cannot be counted upon to make any substantial contribution towards reducing the deficit in the rest of the region. In China, too, paper consumption is rising rapidly, and the indications are that domestic supplies will require to be supplemented by imports for some time to come.

This brief summary of the situation in other regions therefore suggests that, first, there is little prospect of Latin America procuring pulp or paper imports other than from her traditional supply sources; secondly, that the rising gap between requirements and the ability to satisfy those requirements from domestic sources in Latin America will be paralleled by a similar evolution in the other regions of the world today deficit in pulp and paper.

6. Conclusions and perspectives

This review of Latin American pulp and paper prospects leads to the following conclusions:

By 1965 the region's paper needs will have at least doubled as compared with 1948-52. Given favourable economic development, the region's paper needs would be considerably higher.

Many projects for expanding the region's capacity are under construction, at the planning stage, or being studied. Even if all were realized, they would not satisfy the expected increase in demand.

Unless capacity rises much faster than is at present contemplated, only a steep rise in pulp and paper imports will permit the region's paper needs to be fully met.

There is little likelihood that the region will be able to import on the scale required, or that quantities of this order will be available for export to Latin America in the traditional producing centres, especially as needs are rising faster than capacity in other regions of the world, also today deficit regions, which look to Europe and North America for supplies.

Every effort should therefore be made to step up the rate at which new capacity is being developed, both by pressing forward those projects already under study which prove practicable and by exploring further possibilities.

One of the most urgent problems is to develop sources of cheap mechanical pulp, or pulps capable of replacing mechanical pulp, for the manufacture of newsprint.

Latin America, then, in common with all the other deficit regions of the world, is faced with the prospect of achieving a remarkable expansion of indigenous pulp and paper production, or of securing a considerable increase in pulp and paper imports, or of being content with depressed standards of paper consumption. These are not, of course, mutually exclusive alternatives. But to the extent that additional supplies, be they from domestic or foreign sources, fail to be forthcoming, by that margin will paper consumption fall short of the levels which may be considered appropriate to the stage of material and cultural progress reached in the region.

It must be conceded that an underconsumption of paper does not involve any spectacular consequences. There are a hundred and one economies and improvisations which can soften the impact of a paper shortage. The fact that so few categories of paper are, in the last analysis, consumption goods tends to obscure the consequences of inadequate paper supplies. The newspaper buyer buys not newsprint but news. If newsprint is scarce and dear, the citizen is less well informed than he otherwise might be; the functioning of all democratic processes is impaired. Printing paper is the carrier of education, science and culture. Perhaps no government has yet tottered because the supply of textbooks in the schools was inadequate, yet no one will gainsay the fact that a shortage of printing paper can wreak incalculable harm. It is nonsense to campaign against illiteracy if printing and writing papers are not available in sufficient quantities. Commodities will get produced, distributed and consumed whether or not plentiful supplies of packing and wrapping papers and boards are to be had. But distribution will be less efficient, less hygienic, more costly. In many end-uses, especially in industry and building, there are plenty of commodities which can take the place of paper and board. Frequently, however, they involve a heavier call on either labour, or resources, or both.

A steadily rising standard of paper consumption, therefore, must be regarded as part and parcel of any advance in living standards, on both the material and cultural planes. This has long been recognized by Latin American Governments, all of which have sought means of placing more abundant supplies of paper at the disposal of their peoples. The main conclusion to be drawn from this paper is that these efforts must not be relaxed.

It was stated earlier that Latin America cannot hope to secure from abroad the increased quantities of paper which would be necessary if legitimate needs are to be satisfied. This is true; it is doubtful whether the traditional sources will have supplies on that scale available for export, and it is even more doubtful whether Latin American countries will be able to set aside means of payment. Nevertheless, imports into the region will increase; and in all probability their pattern will change. The many papers submitted to this meeting make it clear that, in spite of the progress being made in fostering indigenous production of paper, the problem of achieving a substantial increase in Latin American newsprint production is a long way from being solved. The reasons are partly technical, partly economic. Technically, the region possesses conifers which are suitable for newsprint. Recently it has become possible to make newsprint from bagasse. Several plantation woods can be made into newsprint. So far, however, the way to use the region's greatest resources, mixed tropical woods, for newsprint manufacture has not been discovered. Many Latin American markets are small, and the minimum economic size for newsprint manufacture is much greater than for most paper categories. Newsprint production does not offer a return on the capital invested as attractive as that offered by most other forms of paper.

For these and other reasons, therefore, the region's need of newsprint imports will increase. Can this need be met? Certainly European and Canadian suppliers would have a greater interest in fostering the Latin American market if they could feel sure that this trade would not be subject to interruption, e.g., by rapid switches in import programmes. Given the prospect of a stable and enduring market, capacity in the traditional producing countries would adjust itself to take care of that market. There are of course uncertainties on the other side too. Only a fraction of the world trade in newsprint is free. Leaving aside the considerable volume of direct producer-consumer ties, much of the trade passes in long-term bulk contracts. From time to time the spot market, on which the small consumers largely depend, is invaded by the large consumers, and small buyers even in Europe and North America, let alone in Latin America, have seen supplies sucked away by the large consumers, or have found difficulty in securing the supplies they needed at reasonable prices. It is conceivable that an extension of co-operative purchasing on the part of Latin American newsprint consumers, coupled with longer term contract arrangements (with or without price provisions) would help to shield them against a repetition of these difficulties.

The problem of securing a rapid and substantial increase in Latin American newsprint output is likely to prove the most difficult of all problems in the pulp and paper field. For many years to come the region will need increasing quantities of newsprint from overseas.

Import needs of kraft papers may also increase, since this is another paper category where the economies of large-scale operations are very considerable, and hence where small markets do not attract investors. There are certain types of speciality papers, particularly industrial papers, which will come to be needed in increasing quantities, though not yet in quantities which warrant the establishment of local production. Finally, though the region's paper production will grow in size and diversity of output, it is probable that increasing amounts of long-fibre conifer pulps will be needed for mixing with domestic pulps.

Undoubtedly the immensity of the potential future market in Latin America will act as a great stimulus on the development of domestic production. It is essential, however, that forward planning, whether on the part of Governments or of private individuals and corporations, should not lose touch with realities. In the critical paper boom years, 1950-51, pulp and paper projects sprang up in Latin America like mushrooms. It might have been thought that wherever there existed a fibrous material that was potentially pulpable, the possibility existed of making and selling paper at a handsome profit. Many of the projects advanced were incapable of standing up to a moment's critical examination by a qualified team of foresters, pulp engineers and economists. Investors were ready, willing and able to undertake risks; for the most part they sought in vain for the objective, many-sided advice that would enable them to gauge the risks involved.

When world paper prices dropped in 1952, the situation was transformed. True, the more hare-brained schemes fell into deserved oblivion. But at the same time, now that pulp and paper investment had lost some of its earlier attraction, several schemes which merited further investigation and serious study were pigeonholed. In point of fact, investment cannot be prompted by transient boom conditions or adjustment troughs; it must be related to a sober assessment of medium- and long-term prospects. Today, perhaps for the first time since the end of the war, it is possible to look into the future with an eye that is neither excessively jaundiced nor excessively enamoured. The forward view need no longer be conditioned by the first flush of post-war reconstruction, by the readjustment uncertainties of the late 1940's, by the fever of the 1950-51 boom, by the anxieties of its aftermath. Though international tension remains high, it is much lower than it has been for several years past. Economically and politically, the world is nearer normality, albeit a hesitant and uncertain normality, than at any time since the end of the war.

These general considerations, together with the estimates and conclusions flowing therefrom set out in this paper, constitute a framework for the discussions at this meeting. They suggest a generally favourable perspective —a situation which calls for a correct blend of enterprise and caution.

For caution, because in the nature of things estimates of potential production costs in a new industry and in a country not highly developed economically must be tentative. This is the reason why, in planning new industries, it will rarely be possible at the outset to rely, even partially, on finding foreign outlets for the indigenous product; the manifold risks and uncertainties of overseas selling constitute additional arguments. Export industries will arise in due course, but they will arise because new industries prove themselves in practice capable not only of satisfying domestic demand, but also of feeling their way with increasing confidence into neighbouring markets.

For enterprise, because without enterprise it seems highly probable that Latin America will have to be content with standards of paper consumption which must constitute a drag on the region's economic and cultural development.

PAPER FOR PRINTING AND WRITING: TENTATIVE FORECASTS OF DEMAND IN 1955, 1960 AND 1965*

INTELLIGENCE UNIT OF *The Economist*, LONDON, at the special request of the United Nations Educational, Scientific and Cultural Organization (UNESCO)

The Economist Intelligence Unit was asked by UNESCO to prepare forecasts of demand for (*a*) newsprint and (*b*) printing paper—other than newsprint—and writing paper, in the years 1955, 1960 and 1965, in all countries and territories of the world where demand for either one of these two groups of commodities is expected to be at least 50 tons yearly before 1965.

In the preparation of such estimates, special consideration was given to the following factors:

(i) *Demographic trends.* Here an examination was made of the present level of population, the rate of growth of population in recent years, and the probable

* A brief summary of the original paper (ST/ECLA/CONF.3/L.2.1) which was published by the UNESCO Clearing House, Department of Mass Information, as Report No. 12.

change in the absolute numbers and the age structure of the population.

(ii) *Trends in literacy.* Where data was available, a study was made of the trend towards the elimination of illiteracy in the country concerned. This trend was then associated with the likely change in the demographic trends.

(iii) *The trend of domestic paper production.* The possibility of demand being either partly or entirely met by domestic production was considered to be one of the important factors influencing the level of consumption in a given area, since it would free a particular country or territory from eventual marketing or foreign exchange problems.

(iv) *Probable fluctuations in income.* For certain countries, it was possible to relate paper consumption to the present levels of over-all or *per capita* national incomes in real terms; then an estimate was made to establish the probable trend of real income during the period under consideration in order to determine, at least to some extent, the probable levels of future demand.

In short, the methods used were basically non-statistical in the sense that no elaborate statistical relationships were established nor correlations attempted. The relevant variations were considered to be so numerous and their long-term trends so uncertain that the results of any complex statistical analysis would have been of doubtful value. In fact, a careful examination and assessment of the importance of the relevant factors relating to each country or territory was felt to be the only method likely to produce worth-while results.

The figures in the table below are the result of the analysis made. Country-by-country forecasts are given only for America, and in particular Latin America. Lack of data on the consumption of "other printing and writing paper" prevented forecasts being made for Cuba, Honduras and Uruguay. In the case of Argentina, it was difficult to suggest estimates of future demand for (*a*) newsprint and (*b*) other printing and writing paper because the "true" level of demand in post-war years is not exactly known. In particular the forecasts of future demand for newsprint are speculative and may well prove to be inadequate. They should be interpreted with caution.

Table 1

PAPER FOR PRINTING AND WRITING: TENTATIVE FORECASTS OF DEMAND IN 1955, 1960 AND 1965

(*thousand tons*)

	Newsprint			Other printing and writing paper		
	1955	1960	1965	1955	1960	1965
Argentina	170	220	270	90	110	130
Bolivia	3.2	3.6	4.3	1.2	1.5	2
Brazil	140	175	220	85	105	135
Chile	27	30	35	14	17	20
Colombia	20	24	30	9	13	17
Costa Rica	2.5	3.2	4.2	0.8	1.2	2
Cuba	38	47	56	..	..	..
Dominican Republic	1	1.8	3.2	0.4[a]	0.8[a]	1.2[a]
Ecuador	6.5	9	14	2.2	2.6	3.4
El Salvador	3.5	5	6.8	0.5	1.2	2.8
Guatemala	2.5	3.5	4.5	1.5	2	2.5
Haiti	0.4	0.7	1.2	0.1[a]	0.2[a]	0.4[a]
Honduras	0.6	0.8	1.2	..	..	..
Mexico	82	100	125	44	55	70
Nicaragua	0.9	1.3	1.8	0.5	0.8	1.1
Panama	2.6	3.6	4.9	0.9	1.4	2.1
Paraguay	0.6	0.8	1.3	0.5	0.6	0.9
Peru	13	16	20	6	7	9
Uruguay	24	28	34	..	..	..
Venezuela	13	18	26	15	19	26
LATIN AMERICA	551	691	863	317	396	502
United States	5,800	6,500	7,250	4,400	4,950	5,600
Canada	375	425	510	200	230	270
Alaska, Puerto Rico and others	16	23	32	4	4	5
AMERICA	6,742	7,640	8,657	4,921	5,580	6,377
EUROPE (excluding USSR)	2,864	3,411	3,914	2,647	3,137	3,675
ASIA (excluding USSR)	826	1,096	1,408	693	985	1,358
USSR	570	700	1,000	425	525	700
AFRICA	118	144	179	123	150	187
OCEANIA	280	318	382	127	155	190
WORLD	11,400	13,310	15,540	8,940	10,530	12,490

[a] Excluding writing paper.

CONSUMPTION TRENDS IN WRAPPING, PACKING AND INDUSTRIAL PAPERS AND PAPERBOARD[1]

Louis T. Stevenson

Introduction

The development of the use of wrapping, packaging papers, paperboard and industrial papers in the United States, the world's largest consumer of these papers both in absolute volume and *per capita*, indicates patterns of growth which may foreshadow those likely to develop in other regions if they follow an evolution similar to that which has occurred in the United States. This paper discusses growth trends in the United States in the hope that a study of these may be helpful to the pulp and paper industry in Latin America.

Growth in paper and board consumption in the United States has been made possible by favourable developments in several related fields. The remarkable expansion of advertising and the national distribution of prepackaged goods of all sorts has led to an astonishing increase in the consumption of packing and wrapping grades of paper and board, a consumption conditioned by the movement of population away from the country to the city, where many foodstuffs come in packages.

Food packaging has developed enormously in the last forty years, and in many cases paper and paperboard have developed the field almost without competition from other products. The size of the market has led to a gradual development of mechanized packing; this has helped reduce costs by enabling the packages to come off the machines sealed and ready to be packed in shipping containers or for unit sales. The development of the chain store has fostered unit sale packaging as has the growth of the "supermarket" for foods. In fact, without packaging in paper and paperboard, the "supermarket" as it is today could not exist.

Types of papers and paperboards

Before describing trends in the use and production of the major grades of wrapping, packaging and industrial papers and paperboard, it may be as well to differentiate between industrial papers and other grades.

Industrial papers are papers which are used in making industrial products, of which they form an integral part. An example is "cable paper" used as insulation in the manufacture of electric cables.

Wrapping and packaging papers include wrapping papers of various kinds, bag papers, shipping sack papers, all papers used to protect commodities while being stored and delivered.

Paperboard is a broad classification of generally thick and heavy paper also used to protect commodities during storage and delivery, of which sub-classifications are *container-board, folding boxboard* (including food board) and *set-up boxboard*.

Trend patterns for the major grades of papers

A. *Paperboard*

The largest group of papers, in terms of tonnage, is paperboard, consumption of which reached over 12 million tons in 1953. The pattern of consumption from 1899 through 1953 indicates an annual growth of 5 per cent.

Container-board is made into shipping containers, generally the corrugated type. Production has more than trebled in twenty years, from 2 million tons in 1934 to over 6 million tons in 1953. These containers have successfully competed with wooden cases, boxes, barrels, etc.

Folding boxboard, generally used in making folding boxes and other flexible containers, has grown steadily more important, production rising from less than one million tons in 1934 to about 2,300,000 in 1953.

Set-up boxboard, a non-bending board used in making rigid boxes, has moved upward but very slightly. Both folding and set-up boxboards are made from waste paper combined with virgin chemical wood pulp.

Food board, used for packaging foods such as milk, ice cream, butter and frozen foods, is a fairly recent development. Growth was moderate up to 1948 but since that year output has more than doubled, reaching a million tons in 1953.

B. *Coarse paper group*

The coarse paper group includes wrapping paper, bag paper, shipping sack paper and converting paper. Consumption of shipping sack paper, generally a kraft paper grade, after setbacks in 1949 and 1952 has continued to grow, if only slightly. Of the other groups each is divided into kraft, glassine, greaseproof and vegetable parchment, and "other", the latter being principally made from sulphite pulp, jute and miscellaneous fibres.

Glassine, greaseproof and vegetable parchment papers are mostly used for food wrapping, as are *waxed papers*. Production of the former group (which has met with severe competition from transparent cellulose wrappings) had shown little recent change, but the tonnage of waxing stock produced has increased from 124,000 tons in 1937 to 433,000 tons in 1952.

Upward trends are also evident in the consumption of multi-wall shipping sacks and various special industrial papers.

C. *Building papers and boards*

This group includes sheathing paper, saturating and dry roofing felts, floor covering, auto felts, asbestos paper, insulation boards and several types of hardboards. Since the low year of 1932, building board production, although erratic, has shown a decidedly upward trend.

Future demand

The phenomenal rise in *per capita* consumption of both paperboard and coarse paper indicates that new uses have constantly been found for these products. If past rates of growth continue consumption may be expected to be almost double in the next twenty-two years. However, it should be borne in mind that past success limits future opportunities of displacing other materials.

[1] The original paper (ST/ECLA/CONF.3/L.2.2), of which this is a summary version, includes five tables and thirteen charts illustrating the growth in U.S. production of various paper and board categories.

Today some wooden shipping containers are enlisting paperboard by laminating it to plywood and thus making a composite of the two rivals in this race. On the other hand, paperboard is invading the large field of shipping containers for fruit and vegetable packing. Improved qualities of water resistance are giving impetus to this movement. Fungicides incorporated in the board to retard mould are being used. In the field of packaging papers, various kinds of coatings are being used to give the sheet needed characteristics for special applications. Polyethylene coatings have been used on food wrapping papers, for example.

The extensive facilities available in the industry, including research institutions for the development of product applications and new uses, augur well for success. Among the many new and recent applications may be listed the following: pressure sensitive tape, toxic-coated papers for flies and insects, heat-sealing papers, duplex sheets of fibre and paper or cloth and paper, and many other products made by treating or combining paper with various chemicals. Rust-resistant paper and water- and vapour-resistant papers and fibre-board shipping containers are finding a widening field of application. Chidester mentions "an interesting new idea is the use of expanded paper honeycomb to line railroad car bottoms for carrying bagged citrus fruits. It provides both cushioning and ventilation. Paper honeycomb is being considered for use in strong light-weight pallets for shipment".[2] Sturdy structural building members, made up from cross-laminated corrugated kraft board, seem to offer good possibilities for use in the construction of dwellings.

[2] G. H. Chidester, "New and Improved Paper Products", *Paper Industry*, Chicago, December 1953.

The possible new applications of paper and board packaging are infinite in their variety. Their capitalization by the industry depends upon practical developments and is a matter of research and application, a field in which the industry has in the past been eminently successful.

Summary and conclusions

The tremendous growth in the consumption of packaging paper and board in the United States has been due largely to mass-marketing techniques, including national advertising, standardized packaging and display techniques. Paperboard has lent itself readily to this through its ability to carry both the advertising message and the product. The growth of the chain stores and supermarkets has at once facilitated and been made possible by these developments. Paper and board have played an important role in this revolution in distribution. Economy of packaging, safety in transportation and encouragement of impulse buying have been important factors. *Per capita* consumption is rising, and with increasing population the rise in consumption is expected to continue.

A projection of past trends indicates a demand in 1965 of over 17 million tons for paperboard and almost 5 million tons for coarse paper. Whether these levels of consumption will be realized depends upon the continued development of new uses. If manufacturers aggressively continue their research and development programmes these figures may well be attained.

WORLD TRENDS IN CONSUMPTION OF NEWSPRINT, OTHER PRINTING PAPER AND WRITING PAPER*

United Nations Educational, Scientific and Cultural Organization

Newsprint

Between 1928-30 and 1950-51, world newsprint consumption expanded from an average yearly level of 6,340,000 tons to 9,283,000 tons.

In 1931-33, owing to the depression, the average level of world consumption dropped to 5,786,000 tons. It then rose from 6,508,000 tons in 1934 to 8,095,000 tons in 1937, but dropped to 6,801,000 tons with the recession which took place in 1938.

From 1939 onwards, as a consequence of the Second World War, world newsprint consumption dropped from 7,071,000 tons in the first year of the war to 4,549,000 tons in 1944.

From 1945 to 1951 increasing production gradually made it possible, as the world economic position recovered in the post-war period, to close the gap which had existed between supply and demand since 1939. It was only in 1949, however, when 8,464,000 tons of newsprint were consumed, that the pre-war yearly high of 8,095,000 tons in 1937 was surpassed.

The yearly average increase in world newsprint consumption from 1934 through 1937, when ground which had been lost during the depression of the early 1930's was being regained, was close on 600,000 tons. The average yearly increase which took place in the post-war immediate period of recovery (1945 through 1950), was approximately 760,000 tons.

As shown in table 1, Latin American newsprint consumption increased, between 1929 and 1947, in every year when the world figure advanced.[1] Moreover, Latin American newsprint consumption increased in five years between 1929 and 1947 when aggregate world consumption dropped; these years being 1932, 1939, 1941, 1943 and 1944.

Excepting Second World War years, the only years between 1929 and 1947 when the Latin American figure dropped were 1930, 1931 and 1938, when recessions in the United States affected the economy of several Latin American countries. While Latin America failed to show an increase in consumption in 1948, 1949 and 1950, this

* A highly condensed version of the original paper (ST/ECLA/CONF.3/L.2.4), which was also published by the UNESCO Clearing House, Department of Mass Information, as Reports Nos. 10 and 11.

[1] As used here, the term "Latin America" is taken to include all countries and territories in the Americas other than Canada, the United States and Alaska.

was not due to a decrease in aggregate demand but a consequence of the world newsprint shortage and of restrictions on imports made necessary in several countries by "hard" currency shortages. Excluding Argentina, which was perhaps the country most affected by the newsprint shortage, Latin America showed the following increases in consumption over the previous year: 13,000 tons in 1948, 5,000 tons in 1949, 17,000 tons in 1950 and 30,000 tons in 1951. Average yearly growth of Latin American newsprint consumption in 1947-51 (excluding Argentina), was 17,000 tons. The volume of demand for newsprint which remained unfilled in Latin America during this period is, however, not known exactly.

Table 1

WORLD AND LATIN AMERICAN NEWSPRINT CONSUMPTION, 1928–51

Year	World: Consumption (thousand tons)	World: Difference over preceding year (thousand tons)	Latin America: Consumption (thousand tons)	Latin America: Difference over preceding year (thousand tons)	Per cent of world total (%)
1928	6,132	.....	230	....	3.7
1929	6,527	+395	243	+13	3.7
1930	6,360	−167	238	− 5	3.7
1931	5,961	−399	214	−24	3.6
1932	5,663	−298	220	+ 6	3.9
1933	5,734	+ 71	222	+ 2	3.9
1934	6,508	+774	262	+40	4.0
1935	6,776	+268	274	+12	4.0
1936	7,332	+556	289	+15	3.9
1937	8,095	+763	345	+56	4.3
1938	6,801	−1,294	269	−76	4.0
1939	7,071	−270	308	+39	4.4
1940	6,279	−792	288	−20	4.6
1941	5,854	−425	299	+11	5.1
1942	5,276	−578	229	−70	4.3
1943	4,907	−369	249	+20	5.1
1944	4,549	−358	287	+38	6.3
1945	4,871	+322	310	+23	6.4
1946	6,276	+1,405	377	+67	6.0
1947	6,987	+711	395	+18	5.7
1948	7,645	+658	389	− 6	5.1
1949	8,464	+819	390	+ 1	4.6
1950	9,110	+646	389	− 1	4.3
1951	9,456	+346	432	+43	4.6

Table 2 shows the distribution, according to regions, of world newsprint consumption in 1928-51.

All the "low" figures shown on the table for the period 1928-39 occurred between 1928 and 1931, and all the "high" figures between 1935 and 1939, with the exception of the "low" and "high" figures for the United States and Canada together, which occurred in 1928 and 1939, respectively.

The Second World War vastly changed the pattern of world newsprint distribution, the average figures for 1940-45 being, in comparison with those for 1928-39, as follows:

Increases	%	Decreases	%	No Change
United States and Canada	16.8	Europe	15.6	South Central Asia
Latin America	1.4	Far East	1.3	South-East Asia
Near and Middle East	0.1	Oceania	0.5	
		USSR	0.6	
		Africa	0.2	

During the period 1946-51, the newsprint purchasing position of United States consumers remained strong in comparison with that of consumers in other parts of the world, mainly owing to the division of world trade into "soft" and "hard" currency areas. The average percentage of world newsprint supplies consumed in the different areas in 1946-51, as compared with the 1928-39 average, was as follows:

Increases	%	Decreases	%
United States and Canada	14.0	Europe	15.0
Latin America	1.2	Far East	1.6
USSR	0.9	Oceania	0.2
South Central Asia	0.3		
South-East Asia	0.2		
Near and Middle East	0.1		
Africa	0.1		

The above figures would seem to indicate that the main trends in world newsprint distribution in the post-war years have been:

(1) A tendency for the combined United States and Canadian share of world supply to recede slowly.

(2) A lasting contraction, in comparison with pre-war, in the share of world supply taken by Europe (excluding USSR).

(3) A stable consumption, on the long-term average, in Oceania, of approximately 2.5 per cent of the total world supply.

(4) A long-term tendency for the under-developed areas of the world and for the USSR to take a larger share of world newsprint supply.

An examination of the growth of newsprint consumption in 1950-51 over pre-war (1935-39) in the various under-developed regions furthermore shows that, despite the world newsprint shortage and "hard" currency shortages, this expansion has been 118 per cent in the Near and Middle East, 100 per cent in South Central Asia and in Latin America (excluding Argen-

Table 2

NEWSPRINT CONSUMPTION BY REGIONS AS A PERCENTAGE OF WORLD CONSUMPTION

(*per cent*)

Region	1928–39 Low	1928–39 High	1928–39 Average	1940–45 Average	1946–51 Low	1946–51 High	1946–51 Average
United States and Canada	43.4	55.7	49.2	66.0	60.9	65.0	63.2
Latin America	3.6	4.4	3.9	5.3	4.3	6.0	5.1
Europe (excl. USSR)	31.1	39.6	35.5	19.9	19.1	22.2	20.5
Near and Middle East	0.1	0.2	0.1	0.2	0.1	0.3	0.2
South Central Asia	0.3	0.5	0.4	0.4	0.5	0.8	0.7
South-East Asia	0.3	0.5	0.3	0.3	0.3	0.6	0.5
Far East	3.3	5.4	4.6	3.3	2.6	4.1	3.0
Oceania	1.8	3.0	2.6	2.1	1.5	3.3	2.4
USSR	2.1	3.5	2.6	2.0	2.2	4.2	3.5
Africa	0.6	1.0	0.8	0.6	0.8	1.1	0.9

tina) and 80 per cent in the USSR; figures which compare with an increase of 67 per cent in aggregate United States and Canadian consumption.

PRINTING PAPER (OTHER THAN NEWSPRINT) AND WRITING PAPER

Only incomplete statistics are available on the world's consumption of other printing paper and writing paper. Nevertheless, consumption outside the people's republics may be roughly estimated to have been as follows from 1947 to 1951:[2]

	Tons
1947	6,000,000
1948	6,200,000
1949	6,200,000
1950	7,000,000
1951	7,800,000

The above data would put the average yearly increase in world consumption (excluding the people's republics) at approximately 450,000 tons from 1947 to 1951.

[2] The term "people's republics" is taken here to include: Albania, Bulgaria, continental China, Czechoslovakia, German Democratic Republic, Hungary, Korea (North), Mongolian People's Republic, Poland, Romania, USSR and Yugoslavia.

However, as consumption gains appear to have been much greater in 1950 and 1951 than in 1947-49, and as the time series over which data are available is very short, it appears difficult to draw any definite conclusions in this respect.

Data on Latin American consumption of other printing paper and writing paper is only available for the years 1947 to 1951, and this excluding, for lack of information, consumption in the Bahama Islands, Barbados, Bermuda, British Honduras, British Guiana, Cuba, Guadeloupe, Honduras, Jamaica, Netherlands Antilles, Windward Islands and Uruguay. The incomplete figures are:

	Tons
1947	202,000
1948	182,000
1949	187,000
1950	216,000
1951	234,000

These figures suggest that Latin America consumes between 3 and 4 per cent of the printing paper (other than newsprint) and writing paper used in the world (excluding the people's republics).

III. Economic aspects of pulp and paper manufacture from Latin American tropical and sub-tropical hardwoods

ECONOMIC ASPECTS OF PULP AND PAPER MANUFACTURE FROM LATIN AMERICAN TROPICAL AND SUB-TROPICAL HARDWOODS[1]

SECRETARIAT

The present paper, intended to serve as a basis for discussion of the problems of manufacturing pulp and paper from mixed tropical and sub-tropical woods in Latin America, summarizes the more important information and conclusions contained in Secretariat papers 3.01 to 3.04 and in documents 3.1 to 3.14. The summary is by no means complete; only the more important aspects are dealt with. These are grouped as follows:

A. Aspects of tropical forestry

B. Pulping processes and pulp quality

C. Industrial problems

D. Future developments

A. ASPECTS OF TROPICAL FORESTRY

Features of the tropical forests

1. The tropical and sub-tropical virgin forests, unlike the temperate coniferous and broad-leaved forests, are composed of a large variety of species from a great number of tree families. The species composition often changes over quite short distances, depending on soil conditions, access to water, etc., so that the pattern of the forest composition is extremely heterogeneous.

2. The physical and chemical properties vary within wide limits, not only as between species, but even for a given species in different localities. Hence density, for example, may be as low as 0.075 and as high as 1.35. Some species may be difficult to bark; others cannot be chipped, while still others—because of high density and silica content—may not even burn. Several species have a high content of gum and other extractives, while some are highly poisonous.

3. Tree size varies considerably in a virgin tropical forest, but a high proportion of the total volume consists of large-sized trees with diameters of 60 to 70 cm and over. On the other hand, heavy understory (brush, lianas) is quite a common feature of tropical forests and can make wood extraction difficult.

4. Several wood species, especially those of low density, undergo rapid decay after felling as a result of bacterial, fungoid and insect attack, particularly during the rainy season. Thus it is impossible to store wood for long periods, either in the forest or at the mill.

5. Contrary to what is often believed, the soil in many of the Latin American tropical forests is of low inherent fertility. Large areas of forest in the lower Amazon basin, for example, have a very thin and poor sandy topsoil; this, if exposed by a clear cut, is very sensitive to heavy rain and drought. Preventive measures to avert soil degradation are therefore necessary.

Problems of extraction

6. As most of the trees are large sized, extraction and transport require heavy mechanical equipment and a good road network. This contrasts with conditions in Scandinavia, for example, where smaller-sized trees permit extraction to be carried out with lighter equipment (snow sledges, etc.).

7. Since the timber cannot generally be stored for more than a few weeks, wood extraction must be conducted on a round-the-year basis. Depending on soil conditions and topography, this may give rise to technical difficulties during the rainy reason, calling for the construction of a permanent, all-weather, road network.

8. Floating, a cheap and convenient means of transport extensively used in Scandinavia and North America, is generally ruled out in tropical forests because many of the species do not float.

9. Labour productivity in the forest will probably be lower than in North America or Scandinavia, partly because of the high temperature and humidity, especially during the rainy season.

B. PULPING PROCESSES AND PULP QUALITY

Processes

10. It has been established that, because of its great tolerance to bark and extractives (tannin), the most suitable method for chemical pulping of mixed species is the sulphate (or sulphur-soda) process. This has the further advantage of producing stronger pulps than other commercial processes.

11. The pulping conditions for mixed tropical species do not differ much from the normal conditions employed for chemical pulping of temperate broad-leaved species. The pulping conditions (time, temperature, sulphidity, etc.) must be so chosen as to cope with the most resistant woods. Experience has shown, however, that a mixture of species varying greatly in composition may be successfully pulped by the sulphate (or sulphur-soda) process.

12. Since pulp mills operating on mixed tropical woods must usually be located far from industrial markets, it follows that for the production of bleached qualities chlorine, which is difficult and costly to transport, will have to be produced at the mill site. Unless market conditions definitely favour the selling of caustic soda produced simultaneously with the chlorine, the pulping

[1] Originally issued as ST/ECLA/CONF.3/L.3.0.

process should be based on sulphur and caustic soda as make-up chemicals (sulphur-soda process).

13. The production of mechanical pulp from *mixed* tropical species by the conventional grinding process is not feasible. There are also doubts—which, however, may be proved wrong—about the applicability of the chemi-groundwood process to such mixtures. The only processes which seem to offer a solution are the disk-refining processes, with pre-treatment of the wood by steam or chemicals (Defibrator and cold soda processes).

14. The conventional grinding process may be applied in those cases where a large percentage of the forest stand is composed of a single light-weight species, for instance *Cecropia*.

15. The most promising for the production of newsprint-type groundwood from *mixed* species is the cold caustic soda process. This method should be taken into consideration as a supplementary process in any integrated pulp and paper project as a means of producing cheap pulp for blending with chemical pulp in those paper qualities which normally contain mechanical pulp.

16. For the production of board grade pulps from mixed tropical woods, the Defibrator process with chemical pre-treatment seems to offer practical possibilities.

Pulp quality

17. Just as the physical and chemical properties of tropical woods vary between wide limits, so do their fibre characteristics. The average fibre length, however, is on the whole higher than for temperate broad-leaved woods.

18. Laboratory tests, and limited industrial experience, have provided sufficient evidence to show that a wide range of papers can be successfully made from tropical mixed woods. Blending with long-fibred (coniferous) pulp is necessary only where high tear and folding resistance is required, e.g., for first strength wrapping papers and kraft liner. Sheet formation properties are excellent so that the pulp is especially suited —in blends—for the manufacture of book, printing and fine papers.

C. Industrial problems

Problems of establishing mills in undeveloped regions

19. Distances to markets are often great, transport means lacking, and labour may have to be brought in from outside; industrial services and community facilities will usually not exist already. In short, a new mill in a tropical region must usually be planned to be self-sufficient.

20. Very heavy investment will normally be required in transport means to handle the large tonnages which pass in and out of a pulp and paper mill; in an industrialized area a new project will as a rule be able to make use of existing facilities.

21. Even where processing chemicals (saltcake, sulphur, limestone) are to be found near the prospective mill site, these resources will usually have to be specially developed. High freight rates will make it necessary for bleaching chemicals (especially chlorine) to be produced at the mill site.

22. Skilled labour, if locally available at all, will be of a lower standard. Wear and tear will be higher. Obtaining replacement parts and effecting repairs may occasion hold-ups. Though labour will normally be cheaper, this advantage will be partly offset by lower productivity.

Investment and production costs

23. Capital needs for fixed investment will be higher in undeveloped countries, as a consequence of the need for heavy forest investment, of the need to create community facilities, transport means and mill services, and because of the higher cost of constructing the mill itself.

24. The investment required for forest operations in tropical regions is an appreciable item of the total capital needs. Contrary to what is usually claimed, however, the cost of establishing general community facilities —although it may be high in absolute terms—does not represent a very high proportion of the total.

25. For mills in undeveloped regions the curve of investment cost per unit of mill capacity descends more steeply as mill size increases than for mills in industrialized areas. Thus the incentive to establish larger units will be more pronounced in the former case.

26. For these reasons, and also because interest rates will be higher, a mill in an undeveloped region will call for a much heavier investment than would one of the same size in an industrialized area, while the product will have to bear much heavier capital costs.

27. The pattern of production cost will thus differ, capital charges being heavier, as also chemical costs generally speaking, while pulpwood and labour costs will be lower. For small mill sizes production costs will compare unfavourably with those in industrialized areas, but production cost will fall more steeply as mill size increases. The incentives for integrated operations will be stronger, and there would seem to be economic possibilities in partly integrated operations, a relatively small paper mill section being combined with a larger pulp mill size.

28. There is a considerable difference between paper-converting costs in a non-integrated mill and in an integrated mill section, especially for small units. Therefore the establishment of a new pulp mill in an undeveloped area should, if possible, be integrated with a paper section to convert at least part of its production.

D. Future developments

29. The heavy investment, and the complex problems to be faced, in establishing a mill in a tropical area make it essential that preliminary planning should be thorough and carefully phased. Only air photography combined with surface sampling can give, at a reasonable cost, sufficiently precise information concerning the forest resources. Other aspects—extraction schemes, water, power, chemicals, transport, etc.—must be explored with equal care. The risks involved make it extremely advisable not to skimp time and money in the preliminary planning stages.

30. As planning proceeds, it will become possible to formulate provisional estimates of investment and production costs. It will be found that both fall off more steeply (per unit of output) as mill size increases than they do for projects in industrialized areas. This fact has to be weighed against the information available concerning the size and pattern of the potential market in

determining the optimum size, and production programme, of the project.

31. The corresponding estimate of production cost must then be carefully assessed before a decision to proceed is taken. The assessment must take into account alternative sources of supply in the markets aimed at, making allowances for freight, duties, quality differences, continuity of supply, etc.

32. In the particular models examined in preparation for this meeting, a provisional assessment indicates that the erection of a mill based on mixed tropical woods in the Yucatán is feasible; it is possible that a site other than the one selected might offer advantages. In Amapá, however, the prospects seem less attractive at first sight, though further investigation might lead to a revision of this preliminary judgement.

LATIN AMERICAN TROPICAL AND SUB-TROPICAL HARDWOODS AS A SOURCE OF PULP AND PAPER[1]

SECRETARIAT

LATIN AMERICA'S FOREST WEALTH

The preliminary results of the Food and Agriculture Organization's 1953 World Forest Inventory show that the Latin American region contains more forest wealth, in terms of area, than any other region:

Region	*Area of forest (million hectares)*	*Percentage of world total (per cent)*
Latin America	927	23.7
Africa	801	20.5
Union of Soviet Socialist Republics	743	19.0
North America	656	16.7
Asia	567	14.5
Europe	136	3.5
Pacific area	85	2.1
WORLD TOTAL	3,915	100.0

In spite of this forest wealth, Latin America (which consumes about 3 per cent of the world's paper) produces little more than 1.5 per cent of the world's paper and less than 1 per cent of total world wood pulp production. In fact, for forest products generally, in spite of some important exports (e.g., Paraná pine and Central American hardwoods), the region is on balance an importing region.

Of the total forest area, less than 40 per cent (around 340 million hectares) are today accessible. Of the accessible forests, only a quarter (89 million hectares) are today in use, the remaining three-fourths being still unexploited. Some particulars of forest areas in each country are given in end-tables A and B.

About 11 million hectares of the forests in use are conifers, leaving 77 million hectares for all hardwoods. Assuming—very conservatively—an annual gross increment per hectare of 3 m³, this would correspond to 231 million m³ annually (with bark) in all the hardwood forests in use in the region. It is believed that yearly fellings are around 170 million m³—well below the growth figure.

Moreover, not all the broad-leaved forests in use are tropical and sub-tropical forests; it is estimated that about 13 million hectares consist of temperate hardwood forests. Thus today well under 70 million hectares of Latin America's 800 million or so hectares of tropical and sub-tropical broad-leaved forests are being exploited. As was pointed out above, the majority of the unexploited forests are as yet inaccessible; for example only a fourth of Brazil's 480 million hectares of forest are today accessible, while accessible forests in Peru account for only 15 million hectares out of a total forest area of 70 million hectares.

These figures are eloquent of the region's potential, a potential that steadily becomes nearer realization as population grows, economies develop and communications spread. This paper considers the tropical and sub-tropical forests the most extensive of the region's forest resources, and some of the problems they pose when their exploitation for pulp and paper is being contemplated.

FEATURES OF THE TROPICAL AND SUB-TROPICAL FORESTS

Tropical and sub-tropical evergreen and deciduous hardwood stands in Latin America cover more than 800 million hectares; they thus account for about nine-tenths of all the region's forests. Brazil alone has three and a half times more forest area than has Europe, which produces annually 10 million tons of pulp. Argentina, Colombia and Peru together possess about the same area of forests as the United States of America; the United States of America produces 15 million tons of pulp annually. Bolivia's forest area is as great as that of Finland and Sweden together; the latter two countries produce more than 5 million tons of wood pulp a year. Moreover, these 800 million hectares of forest in Latin America could produce, on a sustained yield basis, some 2,400 to 2,800 million m³ of roundwood annually, that is to say, about twice as much wood as is felled each year in the whole world.

These very crude comparisons of areas, pulp production and fellings are striking; they suggest quite fantastic figures for Latin America's potential supply of pulpwood and other industrial wood. They have little meaning however, since they fail to take into account either the location, composition, and types of the forests, or the paper-making values of the woods they contain. The mere existence of a forest does not imply the possibility of establishing a pulp plant. What the pulp and paper maker needs is a sufficient supply of suitable raw material within economic reach of one or more consuming centres.

Of the 800 million hectares, less than 70 millions have so far been utilized. Their exploitation, which has only recently included pulp, has followed a pattern very different from that in broad-leaved forests in the northern

[1] Originally issued as ST/ECLA/CONF.3/L.3.01.

hemisphere—because of their special, and contrasting, characteristics.

First and foremost is the immense variety of tree families and species found there; generally speaking the tropical forests of Latin America are less heterogeneous than those of Central West Africa, where, for example, over 600 species are found in the rain forests of the Ivory Coast alone. Nevertheless, the Latin American forests are highly heterogeneous. In the *terra firma* region of the Amazon territory eighty-seven species, were found in a single hectare, while another sample in this region gave forty-six different species having a diameter of more than 30 cm. On the other hand, there are, especially in the sub-tropical regions, areas where only one or two species occur; this is the case in Argentina and Paraguay, where quebracho is found in more or less pure stands. Another species flourishing in pure stands, though usually in small areas, is *Cecropia (cetico* or *guarumo* or *imbaúba)*; this tree is common to practically all the second-growth forests of Latin America, where the virgin stands have been clear cut or where land has been abandoned following banana plantations. *Cecropia* grows very rapidly and has excellent pulping qualities, for both chemical and mechanical pulps.[2]

Forests in more or less pure stands are, however, exceptional and in general both tropical and sub-tropical forests in Latin America are composed of an immense variety of species. The species composition often changes very clearly within quite small areas, so that a heterogeneous species pattern in one area may give way, within a few kilometres, to an equally heterogeneous but completely different pattern. It need hardly be stated that variation in species composition complicates pulping procedures. This heterogeneity affords a great contrast with the broad-leaved stands of the northern hemisphere, where over very large areas the probability of finding more than ten to twenty species is very small.

A second important feature of these tropical forests is the extraordinarily wide variation in density, as well as in physical and chemical qualities, of the species found therein. In European broad-leaved forests the specific gravity may range from 0.4 (poplar) to 0.8 (oak) but in the tropical forests of Latin America it can range from 0.075 (balsa) to 1.35 (quebracho). Moreover, even a single species may vary considerably in density from place to place; for example, balsa may have a specific gravity as low as 0.075 and as high as 0.48. On the whole heavy woods predominate, especially in the virgin tropical rain forests, so that the average specific gravity of the woods encountered is usually well above that in the temperate forests. This higher density of tropical woods also gives rise to certain problems in pulping.

Thirdly, where tropical forests have normally been exploited hitherto, only certain species have been extracted; the bulk of the timber, having little or no commercial value, has been left standing. An example from Ecuador shows the contrast with extraction methods in the temperate zones where all tree species find a market. Of the 2,140 species which have been identified in the forests of Ecuador, only 480 are known to be used anywhere in the country, and only 220 ever reach the principal towns. Of these, only twenty-three species have been found suitable for export while only six have been exported in any quantity. In the region of the Caura river valley in Venezuela there are some ten species which have a current economic value, but only three or four trees of these species are found per hectare. While growth is high in the tropical rain forests, often exceeding 15 m^3 per hectare, the "economic growth" (i.e., of the commercial species only) is often no more than 2 m^3. The selective cutting hitherto practised does not, of course, allow of intensive logging operations. High extraction and transportation costs render the marketing of any but precious hardwoods prohibitive. Frequently, only a veneer log of 50 cm minimum diameter is cut, the rest of the tree remaining in the forest.

A fourth characteristic of these forests is the density of the stands. The understory is often very thick and complex, with monocotyledons and numerous vines growing up to the top of even the largest trees. The dense understory of uneconomic species not only increases logging costs but also impedes the natural regeneration of the useful species.

These characteristics help to explain why only limited exploitation of hardwood forests in the tropical regions of Latin America has taken place so far. Moreover, it has to be borne in mind that in many areas the climate, though good for vegetation, is very uncongenial, involving high temperature with very heavy seasonal rainfall and high humidity throughout the year. The population is thinly spread and local labour, though comparatively cheap, is not very efficient. Wood storage also presents many problems, because the stored timber is heavily attacked by micro-organisms which destroy the cellulose. This is why Latin America, in spite of its immense forest resources, is on balance a forest products importing region (imports of industrial wood and its products exceed exports by some 2 million m^3). This is why, until quite recently, hundreds and even thousands of species of various densities and diverse technical properties were not made use of at all.

This was the situation in the past, and it remains to a large extent the situation today. But certain important changes, which had already started before the Second World War, are now taking place with increasing rapidity. The experience which has already been gained and the research which is at present being carried out offer the prospect of a more rational utilization accompanied by an increasing economic return.

Problems of exploitation

More and more of these forests are coming under tropical forest management, which aims at gradually converting these stands, consisting of good and low-quality timber of all sizes and dimensions, into forests containing a larger proportion of high quality indigenous species. The silvicultural methods adopted to reach this goal differ from place to place, but experience has shown that it is in fact possible to obtain an adequate stocking of commercially useful species. Contrary to what is often believed, the soil of these forests is often of low inherent fertility, and the humus cover, not normally thick, deteriorates very rapidly on exposure; the soil is sensitive to heavy rainfall and drought and, once damaged, recovers slowly. For instance, in many parts of the Amazon region one clear cut changes the soil into deep dry sand; it can take decades of prodigious effort to establish new forests on this degraded soil. Clear cutting followed by the replanting of the species desired is not therefore a method which can be recommended under all

[2] See papers 3.7, *Pulpwood from Peruvian "cetico" (Cecropia)*, by the Banco de Fomento Agropecuario del Perú, and 3.11, *The pulping of Peruvian cetico for the manufacture of newsprint*, by Batineyret (Batignolles-Chatillon and Ateliers Neyret Beylier).

circumstances. Natural regeneration is usually to be preferred, supplemented by planting if there are not enough seed trees. This conversion of heterogeneous tropical forests into stands with commercial species predominating requires a great deal of work; in French West Africa it has been estimated that this transformation calls for fifty working days per hectare, distributed, of course, over several years. Improvement of the growing stock by silvicultural measures is thus a slow process, involving intensive management.

Fortunately, developments in wood utilization are drawing attention to the potentialities of these forests. There is an increasing tendency to seek methods of using the woods they contain in the pattern in which they are found. In the years following the war many new species, which previously were scarcely known beyond their native habitats, appeared on the international market. Though often greeted at first with scepticism, they gained in favour as they properties became known and some of them have now won a permanent place in the world hardwood market. This, of course, is only a partial solution, since the market for tropical saw and veneer logs is limited, easily saturated and takes only the best qualities.

The economic utilization of all or most of the species and sizes in the tropical and sub-tropical forests can be achieved on any considerable scale only by the mass production of semi-finished or finished forest products *in situ*.

Research on the possibilities of using tropical broad-leaved species for pulp and paper began in the 1930's and has been intensified since the war. Though industrial experience is still limited it is already clear that pulps of mixed tropical woods are capable of satisfying many of the needs of national markets. It is not necessary to confine attention to low-density species; all but the very hard species can be pulped economically. Unduly great variations in density certainly give rise to difficulties, but from the pulping point of view it is necessary to distinguish only three or four broad classes, for example, specific gravity below 0.5, from 0.5 to 0.7 and above 0.7, thus ensuring that each pulping charge possesses a "homogenized heterogeneity". In fact, mixtures of species give better results than single species.

No complex mixtures of Latin American tropical species have as yet been pulped on an industrial scale, but laboratory tests have been very successful. Research in British Guiana has shown that mixtures of hardwoods in the proportions in which they are found in the forests give good pulp which can be used as a raw material to produce practically every grade of paper except, those requiring high strength. A test of fifty-six commercial and non-commercial species from tropical forests in Surinam showed that only one species was unsuitable for pulping and that mixtures of species from the wet as well as from the dry forests gave good paper qualities. Twenty-one Amazon species (from Amapá) have been tested in mixtures by Industrias Klabin do Paraná, with successful results.[3] This parallels the successful experiments carried out by a pilot plant in French West Africa on the simultaneous cooking of up to twenty-five species (which are similar to those encountered in the Amazon valley). Tests with the most common tropical hardwoods of Yucatán, Mexico, give satisfactory results, both for single species and in mixed cooking.

These few examples show that it is technically possible to pulp many of the Latin American tropical species, often in the proportions in which they occur in the forests. The problem is solved on the laboratory scale and the next stage, the erection of pilot plants for the pulping of tropical mixtures, may be contemplated: the principal objective is to determine the economic conditions for supplying a large pulping establishment. Much hard work and research will clearly be necessary before any particular project can be embarked upon. But there is no doubt that the tropical and sub-tropical broad-leaved forests of Latin America do constitute an immense reserve of pulpwood for the future.

In many cases economic exploitation of tropical forests for pulp alone would not utilize all species, and a combination of forest products industries would therefore seem desirable. The most logical procedure, where marketing and other conditions make it possible, would be to combine pulp and paper manufacture with sawmill and plywood plants, since the latter mainly use large-size logs of high-density woods; combination with fibreboard manufacture can also be contemplated. Such combinations would enable virtually all species and dimensions to be turned to industrial use (including use as fuel) and selective felling could thus be avoided. Intensive logging with mechanized equipment would then become possible, while problems of regeneration and management would be simplified. New areas, where commercial species are too scattered for economic exploitation under present conditions, could be opened up. Some beginnings of such an integration can be noted in several Latin American countries, e.g., in Colonia in Yucatán, where modern sawmills, plywood plants and other forest products industries serve to exploit the tropical broad-leaved forests. This, however, has been directed only to the mechanical utilization of wood; chemical processing of roundwood would provide new possibilities for an integrated exploitation of the forest crop.

Conclusion

The tropical and sub-tropical forests of Latin America represent the world's greatest store of forest wealth. As yet over three-fifths of the total area is beyond the reach of economic exploitation, while less than one-tenth is actually being exploited.

The composition of these forests presents a number of problems for exploiting them for pulp. The technical problems may today be considered largely solved—certainly on the laboratory scale the main difficulties have been overcome. The remaining problems are principally economic and environmental. There are strong reasons for believing that these, too, can be successfully solved, though the immediate future is likely to be a period of trial and experiment.

The final goal in tropical forest exploitation must be the full utilization of all or most of the species. Much research has yet to be done to reach this goal. For this reason it is to be hoped that the Central Forestry Research Institute, recommended by the Latin American Forestry Commission, will soon become a reality; an institute of this kind could play an important part in helping to expand pulp and paper production.

Experience gathered so far shows how important it

[3] See paper 3.10, *Preliminary results of the pulping of some Brazilian tropical and sub-tropical hardwoods*, by L. Rys and others.

is to select a site which satisfies the many different prerequisites for pulp and paper production in the most economic way. But it need not be assumed that, for a project to be successful, its final product must necessarily be able to complete in price and quality on the international pulp and paper market.

Table A

FORESTED AREA AND ACCESSIBLE FORESTS

Country	All forests: Total area	All forests: As percentage of land area	All forests: Forest area per inhabitant	Accessible forests: Total	Accessible forests: For use
	(thousand hectares)	(per cent)	(hectares)	(thousand hectares)	(thousand hectares)
Argentina	70,000	25.2	3.9	60,000	10,000
Bolivia	47,000	44.0	14.5	6,000*	4,000*
Brazil	480,195	56.7	8.6	120,048	30,012
British Guiana	18,100	84.2	54.4	3,600	260
British Honduras	2,050	89.1	28.5	1,530	1,010
Chile	16,360	22.1	2.8	6,895	6,595
Colombia	69,000	61.5	5.7	62,000	411
Costa Rica	3,925	78.3	4.6	2,350	1,600
Cuba	3,463	30.2	0.7	2,585[a]	2,000*
Dominican Republic	3,438	68.7	1.6	3,007[b]	1,000*
Ecuador	12,000	43.6	3.6	2,500	500
El Salvador	721	36.8	0.4	479	94
French Guiana	8,747	97.2	336.4	400[a]	400
Guatemala	6,568	61.7	2.3	3,068	1,500*
Haiti	1,700[c]	61.3*	0.5*	1,600[c]	1,600*
Honduras	4,873	42.3	3.3	3,873*	3,000*
Mexico	25,856	13.1	1.0	24,563	4,500
Nicaragua	6,450	47.1	5.9	1,502	1,502
Panama	5,270	69.8	7.2	1,181	1,181
Paraguay	20,906	54.0	14.3	6,272	5,017
Peru	70,000	62.0	7.9	15,000	5,000
Surinam	11,721	84.4	51.6	1,000	10
Uruguay	486	2.8	0.2	486	486
Venezuela	36,500*	40.6*	7.1*	12,000*	7,000*
COUNTRIES LISTED	925,329	45.9	5.6	341,939	88,678

* Unofficial figures.
[a] Accessible productive forests only.
[b] Accessible and inaccessible productive forests.
[c] Includes brushlands.

Table B

FORESTS IN USE: COMPOSITION AND REMOVALS

Country	Total forests in use	Composition: Conifers	Composition: Conifers as percentage of forests in use	Removals: All species	Removals: Conifers	Removals: Non-conifers	Removals: Industrial wood	Removals: Fuel wood
	(thousand hectares)	(thousand hectares)	(per cent)	(thousand m³ without bark)				
Argentina	10,000	250	2	12,150	150	12,000	3,150	9,000
Bolivia	4,000*	—	0	7,180	—	7,180	130	7,050
Brazil	30,012	4,800	16	89,255	3,700*	85,555*	5,340	83,915
British Guiana	260	—	0	260	—	260	110	150
British Honduras	1,010	148	15	79	38	41	64	15
Chile	6,595	403	6	4,070	595*	3,475*	1,950	2,120
Colombia	411	—	0	8,860	—	8,860	2,300	6,560
Costa Rica	1,600	—	0	430	—	430	250*	180*
Cuba	2,000*	200*	10*	1,026	30*	996	213	813
Dominican Republic	1,000*	400*	40*	330	185*	145*	170	160
Ecuador	500	—	0	4,500	—	4,500	1,000	3,500
El Salvador	94	—	0	750*	—	750*	250*	500*
French Guiana	400	—	0	37	—	37	21	16
Guatemala	1,500*	800*	53*	462	208	254	162	300
Haiti	1,600*	100*	6*	7,500	30	7,470	50	7,450
Honduras	3,000*	600*	20*	2,540	960*	1,580*	540	2,000
Mexico	4,500	2,500	56	2,492	2,298	194	688	1,804
Nicaragua	1,502	750*	50	300*	160*	140*	200*	100*
Panama	1,181	—	0	1,690	—	1,690	45	1,645
Paraguay	5,017	—	0	1,980	—	1,980	550	1,430
Peru	5,000	—	0	1,360	—	1,360	70	1,290
Surinam	10	—	0	325	—	325	125	200
Uruguay	486	9	2	1,100	90	910	130	870
Venezuela	7,000*	—	0	280	—	280	245	35
COUNTRIES LISTED	88,678	10,960	12	148,856	8,444	140,412	17,753	131,103

* Unofficial figures.
— Nil or negligible.

AMAPA-YUCATAN: A STUDY OF HYPOTHETICAL PULP AND PAPER MILLS BASED ON TROPICAL MIXED WOODS[1]

SECRETARIAT

CONTENTS

INTRODUCTION

Scope and method of the study

The most extensive reserves of fibrous material in Latin America lie in the tropical forests. So far, however, no experience has been gained in this region in the use of the tropical forests as a source of raw material for paper. Though some experience has been acquired in other parts of the world—notably in the Bimbresso mill on the Ivory Coast—it cannot be said that the economic feasibility of enterprises based on tropical woods has been conclusively demonstrated.

To facilitate an assessment of the economic possibilities of manufacturing pulp and paper from tropical woods in Latin America the Secretariat has therefore undertaken a study of hypothetical pulp and paper mills in two different areas.

So that costs may be compared with those prevailing in traditional pulp and paper manufacturing regions a similar study of hypothetical mills in Sweden was commissioned from Karlstads Mekaniska Werkstad A. B., Sweden, and is reported separately in paper 3.1.[2]

The present paper summarizes the work carried out and the calculations made, and presents some conclusions and findings. The first part of the paper, which includes a number of text tables, two maps and numerous graphs, contains a general account of the work carried out, summarizes the calculations, results and conclusions; then follows a series of end-tables (A1-A56), containing the detailed calculations of the mill projects, mainly in tabular form; and finally detailed production cost estimates for different products and mill sizes are given in end-tables B57 to B68.

For reasons which are explained below, the study deals mainly with sulphate pulp and integrated mills, though a short reference is made to the manufacture of cold caustic soda pulps. In order to make the comparisons as complete as possible, a fairly wide range (from 50 to 300 tons daily) of mill capacities has been investigated. Separate calculations were made throughout the range for pulp mills, but for integrated mills and non-integrated paper mills primary data were assembled for only two mill sizes; 50 and 100 tons per day. The mathematical relationships between cost and mill size presented in paper 3.03, however, made it possible to extend the comparison and estimates also to other mill sizes. Consequently, the estimates made in this study cover all mill sizes between 50 and 300 tons daily capacity.

Definitions and background material used in the study

(1) Throughout the study weights and measures are given in the metric system; currency, unless otherwise stated, is in United States dollars. Weight of pulp is given in tons of *air-dry* material (90 per cent).

(2) Local currencies have been converted to dollars at the following rates: 12.50 Mexican pesos = 1 dollar (official rate); 32.00 Brazilian cruzeiros = 1 dollar (parity rate established by the Banco Nacional do Desenvolvimento Econômico, Brazil); 5.18 Swedish kronor = 1 dollar (official rate). Where these rates are departed from (as, in some instances, in the background papers) the alternative rates, and the reasons for adopting them, are given.

(3) The terms "sulphate process" and "sulphate mill" are used in this study to indicate the straight sulphate process using saltcake as makeup chemical, as well as the process (mill) using caustic soda and sulphur, generally referred to as the "sulphur/soda process".

(4) The term "cold caustic soda" process refers to the process developed by Forest Products Laboratory, Madison, Wisconsin; this consists of treating wood chips with cold caustic soda liquor, followed by refining in disk mills.

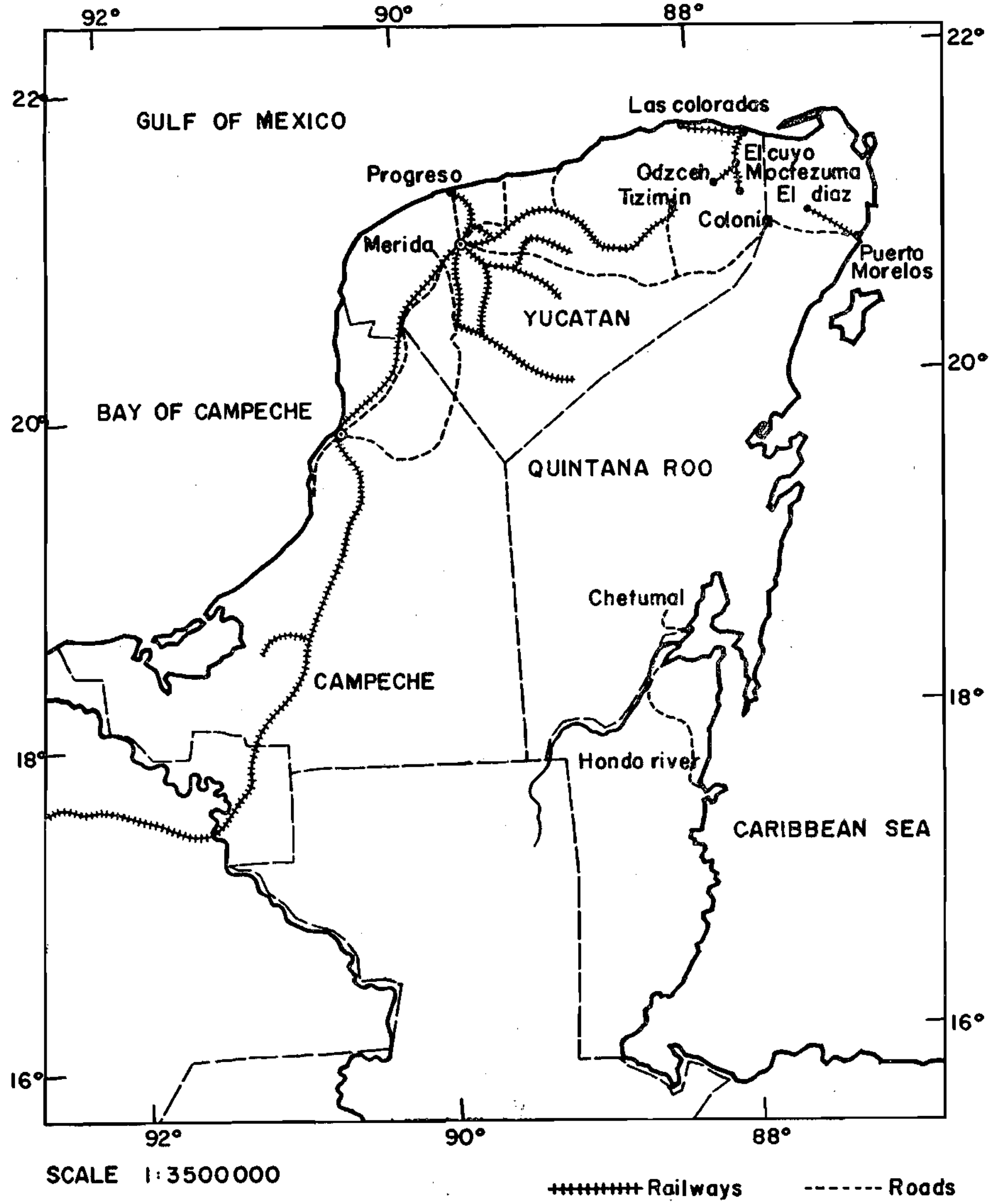
(5) The term "paper converting" for integrated mills used in connexion with cost of investment or produc-

[1] Originally issued as ST/ECLA/CONF.3/L.3.02.

[2] *Influence of Mill Size and Integration upon Investment and Cost in Pulp and Paper Manufacture.*

Map 1

Site for the Yucatán mills



tion refers to the difference between integrated operation and the production of dried pulp.

(6) Throughout the paper numbers in brackets refer to the relevant end-tables.

The following background papers and material have been used in the study:

3.03 *Mill size, integration, location. A study of investment and production costs in hypothetical pulp and paper mills,* by the secretariat.

3.1 *Influence of mill size and integration upon investment and cost,* by Karlstads Mekaniska Werkstad A. B., Sweden.

3.5 *Wood extraction and transportation in tropical regions,* by Pierre Allouard, Centre Technique Forestier Tropical, France.

3.8 *Pulping of Latin American Woods,* by G. H. Chidester, Chief, Division of Pulp and Paper, Forest Products Laboratory, U.S. Department of Agriculture, U.S.A.

3.10 *Preliminary Results of the Pulping of Some Brazilian Tropical and Sub-Tropical Hardwoods,* by L. Rys, A. Boenisch, W. Overbeck and A. Schwarz, Industrias Klabin do Paraná de Celulose S.A., Brazil.

3.13 *The Use in Newsprint of Bleached Cold Soda Pulps from Certain Mixtures of Latin American Hardwoods,* by G. H. Chidester, Chief, Division of Pulp and Paper, Forest Products Laboratory, U.S. Department of Agriculture.

6.7 *Economics of Waste Liquor Recovery and Burning in the Sulphate and Sulphite Processes,* by Gustaf Edling, Vice-President of the Swedish Steam Users Association.

Section I

Location

Forest areas and mill sites selected

For the purpose of this study it was decided to select two areas of tropical mixed forests displaying, if possible, differences in forest types as well as in those environmental and local conditions which could affect the cost of installation and production. The area should also —on the basis of a preliminary judgement—offer at least some prospects of later implementation to warrant the cost and effort involved.

Two areas which seemed to qualify according to the above criteria were the Yucatán peninsula of Mexico and the Territory of Amapá in the lower Amazon. An additional advantage was that certain information was already available regarding topography, soil, forest types, wood species, etc., in these two areas.

The Yucatán mill site

The Yucatán peninsula (see map 1) is to a large extent covered by tropical mixed woods which form extensive blocks of unbroken tropical dry forests. The terrain is usually flat and the forest relatively easy to penetrate. The place selected as possible mill site for this study is Colonia, Yucatán, situated in the north-east corner of the peninsula, about 37 km from the small harbour of El Cuyo.

There were several reasons for this choice, of which the following deserve mention:

(*a*) The forest is already under exploitation (though for valuable species only) by a lumber and plywood manufacturing firm—Maderera del Tropico, S.A. This company has also made a preliminary investigation into the possibilities of establishing a pulp and paper mill.

(*b*) The extension and composition of the forest areas around this mill site are known in a general way, though not in detail, while pulping tests of the main species have been carried out by the Forest Products Laboratory in Madison.

(*c*) The mill site is near the coast and is fairly well situated from the point of view of transport.

(*d*) Fresh water is easy to find in abundant quantities from natural wells "cenotes" near the mill.

The site has, however, one serious drawback—the possibilities of disposing of effluent from the mill. As there is no surface water whatsoever in this part of the peninsula, the mill would have to either dump the effluent in one of the "cenotes" or build a pipeline to the coast. Whether the first alternative is feasible or not can be determined only by a special investigation of the groundwater flow. It may be that all "cenotes" in the area are connected by an underground stream and could, in consequence, be contaminated by the effluent. For this study it has been provisionally assumed that the effluent could be disposed of in the first way described.

At this point, it should be mentioned that alternative, and probably better, mill sites exist in the south-east part of the peninsula. A preliminary inspection of an area in the State of Quintana Roo near the Hondo River (which forms the border between Mexico and British Honduras) and about 40 to 50 km upstream from Chetumal has shown that conditions for the establishment of a pulp and paper mill probably are better than at Colonia, Yucatán; the forest stand is richer (probably twice the quantity of wood per unit area), the trees are less branchy and twisted, the river is navigable up to the mill site, etc.

The Amapá mill site

The area chosen for the second field study was the Territory of Amapá in Brazil. Amapá (see map 2) is situated at the mouth of the river Amazon; it is bordered in the south by this river, in the east by the Atlantic, and in the north by French Guiana. The capital is Macapá, almost on the equator. Along the Atlantic coast, the forests are completely devastated up to a distance of 100 to 200 km from the sea, but the interior of the territory is covered with rich stands of tropical rain forest. Some of the reasons for the choice of this area were:

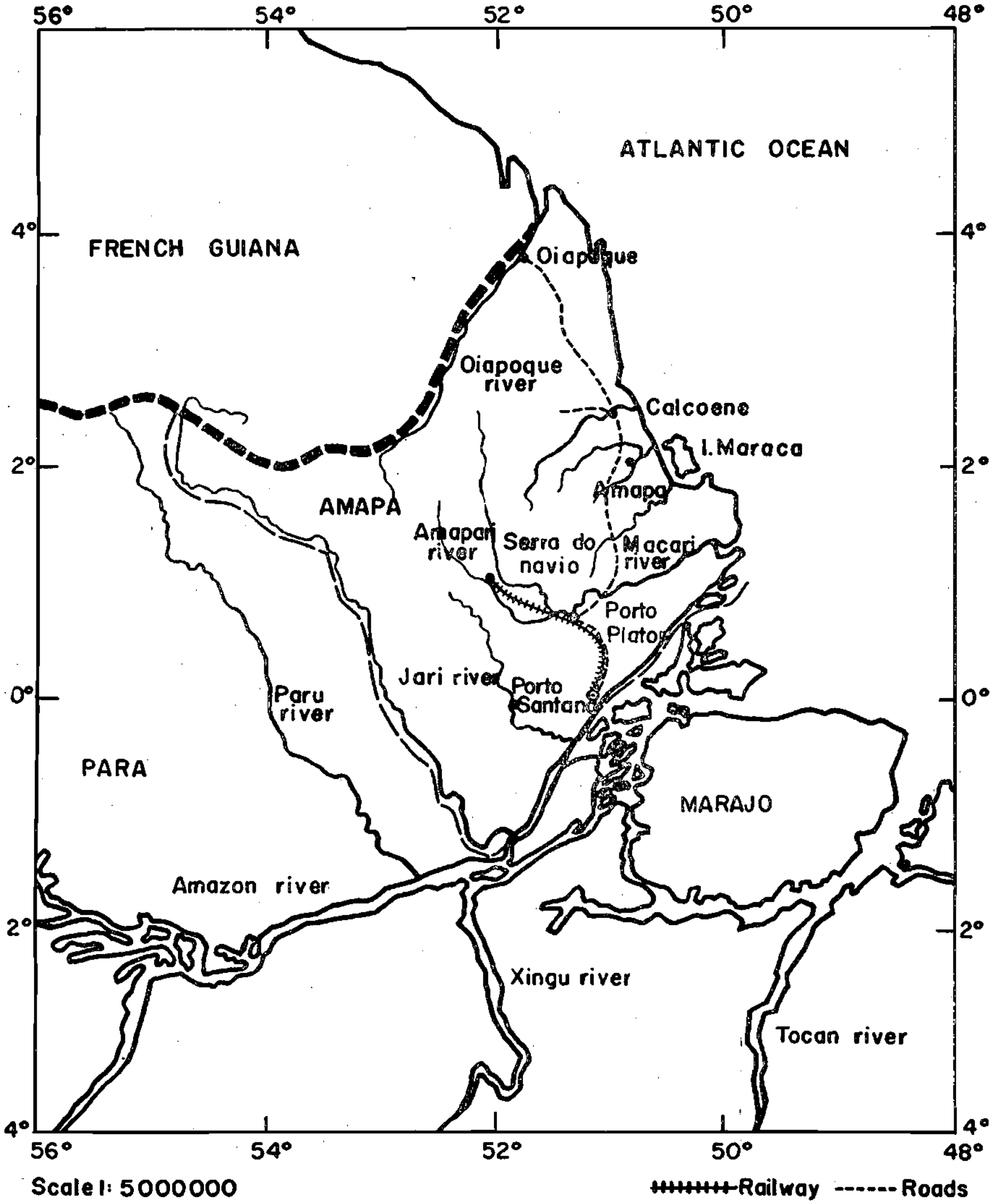
(*a*) The territory is presently undergoing rapid economic development.

(*b*) A manganese ore deposit of considerable extension has been found at Serra do Navio in the centre of the State. To exploit this deposit, a railway line from Porto Santana (close to Macapá) to the mines is under construction. About 100 to 120 km from the port (Santana) this railway line will pass close to the river Araguari, which can easily supply the necessary quantities of fresh water.

(*c*) In the Araguari river—about 40 km downstream from the site selected—a power dam is to be constructed.

Map 2

Site for the Amapá mills



(*d*) A preliminary aerial survey of the region has revealed that rich forests, apparently easy to penetrate, are located south of the river Araguari and close to the river Amapari.

The actual site selected was Porto Platon, 10 km upstream from Porto Grande on the Araguari river. This location has certain drawbacks of which the following are the most important.

In the Territory of Amapá there are no known deposits of limestone; this therefore would have to be brought in from outside—in this case from a deposit about 450 km upstream the river Amazon.

The region is sparsely populated and difficulties may arise in securing the necessary number of workmen for the mill and forest operations.

Additional surveys which have been carried out since this present study was undertaken give rise to some doubts as to whether the area contains enough timber in easily accessible closed stands to supply a mill of more than about 60,000 tons capacity. These doubts, if confirmed, would of course jeopardize the realization of a project at Amapá even if it proved practicable on other grounds. Since, however, the main object of this paper is expository, the material assembled is presented on the assumption that there would be no difficulty in securing adequate timber supplies for all mill sizes.[3]

Section II

Wood extraction and transport

Basic assumptions and data[4]

It has been assumed that forest operations would be carried out on a sustained yield basis with a rotation of forty years—a rotation which might, when dealing with faster growing species, be shortened to thirty years. "Clear-felling"[5] is assumed, since experience has shown this to be the most practicable mode of exploiting tropical forests, both from the silvicultural and cost points of view. There would, of course, be a management plan, regulating the shape, location and extent of the areas exploited so as to facilitate natural regeneration both by seeds and coppice. Five to seven years after clear-cutting, selection would be carried out to leave only those species suitable for pulping. *Cecropia* ("kochlé" or "imbauba") and other fast-growing species might be an exception, since in this period they may have attained pulpwood size.

No account has been taken of the many species which could be exported as timber or whose conversion to other uses could accord them a value higher than their pulpwood value. In so far as these species could be converted to other uses, they would improve the profitability of the enterprise. In the present paper, however, they have been considered rather as conferring a margin of safety on the pulpwood cost calculations or as a potential realizable only if and when the proposed pulp mill is integrated with other forest industries.

It has been assumed, conservatively, that only half the wood in the forest could be used for pulp, the remainder serving as fuelwood, though clearly fuelwood needs would depend on the type and size of mill. On the other hand, only a small allowance has been made for the separate handling and storing of individual pulpwood species or groups of species, since laboratory tests have shown the relative unimportance—within certain colour and density limits—of the composition of wood mixtures.

Costs of extraction and transport have been allocated as between pulpwood and fuelwood, but those costs which would necessarily have to be incurred to extract pulpwood at all (e.g., preparatory work, road-building and silvicultural operations) have been charged entirely to pulpwood.

The calculations are based on tons of green wood (i.e., 60 per cent dry substance) with bark, and it has been assumed, again conservatively, that four tons of wood will yield one ton of pulp.

The Yucatán forest, composed of stands of average height 20-25 m—rarely straight and mostly branchy—contains about 100 tons of wood per hectare. Since this estimate,[6] though it excludes lianas and shrubs, includes trees of all diameters, it is assumed that one hectare would yield 40 tons of pulpwood and an equal amount of fuelwood or, on a forty-year rotation, one ton per year.[7] The dense Amapá forest, composed of straight trees, contains an estimated 200 tons of wood per hectare. It is assumed that one hectare will yield 100 tons each of pulpwood and fuelwood, or 2.5 tons of pulpwood per year.[8]

This determines the areas, set out in the following table, required to supply pulp mills of different sizes. For Yucatán the areas have been stepped up by a quarter to allow for agricultural activities and for the exploitation of certain valuable woods (mainly cedar).

Table 1

Supply areas for different mill sizes

	Mill capacity in daily tons			
	50	*100*	*200*	*300*
Annual pulpwood requirements (thousand tons)	60	120	240	360
Supply areas of Yucatán (thousand hectares)	75	150	300	450
Supply area Amapá (thousand hectares)	24	48	96	144

No problem of sufficient, readily accessible forest area arises in the Yucatán case. For the Amapá project, however, it was assumed either that there would be enough flat lands in the Porto Platon neighbourhood to supply

[3] Because exposition is the main purpose of this paper, there is discussion of non-integrated paper mills of all sizes. In fact, of course, there can be no question of siting a *non-integrated* paper mill either in Amapá or Yucatán; it is assumed that such mills, whether in Mexico or Brazil, would be located near the paper consuming centres.

[4] Since it is believed that the forest operations aspect of the present study will be of special interest to readers, there being very little literature available on schemes of wood extraction for pulping from tropical forests, this aspect has been dealt with in much more detail in the present paper than have other important aspects. It is hoped that the notes included will also serve to guide the reader through the voluminous background material appended.

[5] To be exact, it is assumed that all the pulpwood will be extracted, and all the fuelwood required by the mill. The latter quantity will depend on the operations carried out. Remaining trees will be killed by bark-stripping.

[6] Inventories taken by Maderera del Trópico, S.A.

[7] Assuming 300 working days per year.

[8] Estimates by the FAO Mission to the Amazon indicated a stand per hectare, excluding trees of less than 15 cm. diameter, of 250 m³.

all mill sizes or, alternatively, that for the 360,000-ton forest operation (300-ton daily capacity mill) only, it would be necessary to supplement supplies from proximate sources by pulpwood from more distant areas or from logging camps located along the projected railroad to Serra do Navio. These two possibilities for the largest forest operation are referred to later in this paper as Alternative 1 and Alternative 2 respectively.

Investigations carried out since this study was completed have revealed that the *easily* exploitable area near Porto Platon is in the order of 60,000 hectares, i.e., sufficient to cover (on the basis of the assumptions made) no more than a 120,000-ton forest operation. However, as explained in Section I, calculations have nevertheless been presented for all sizes, since they throw light on wood extraction and transportation problems in the Amazon generally. It should be noted that they are very extensive forests elsewhere in the lower Amazon basin, as flat and as dense as those surrounding Porto Platon. It is believed that the conclusions reached will be valid for these forests also.

Forest units and central administration

Experience gained in similar operations suggests that it is advisable to divide the area of operations into units producing annually 60,000 tons of pulpwood each, plus whatever fuelwood may be necessary. These units will be independent so far as equipment, secondary roads, haulage trails, minor repair shops and forest extraction personnel are concerned. Thus the field equipment and man-power required for a mill will be proportional to the number of these units required for the forest operations.[9]

A central administration[10] will take care of operations and service facilities common to all units, e.g., building and maintaining primary roads, unit to mill transport, repairs that call for a central machine shop, silviculture, housing, health and recreation.

General preparatory work

(a) *Aerial photography and preliminary reconnaissance.* The extreme variability of the tropical forest and sometimes the difficulty of penetrating it make aerial photographs indispensable for preliminary reconnaissance, for inventories, and for planning forest operations. Preliminary reconnaissance helps to determine the areas to be included in the supply perimeter, areas to be devoted to agriculture or cattle rearing, areas for workers' settlements, areas for timber exploitation, etc. It affords a basis for organizing the cuts and laying out the road network. Preliminary inventories can be taken by combining 1 per cent ground sampling with interpretation of air photographs.

No costs for these items were charged against the Amapá project, since photographs already existed covering the entire locality.[11] For Yucatán, the cost of aerial survey is estimated at 0.25 Mexican pesos per hectare, or 25,000 pesos for the 60,000-ton forest operation, while, for the same operation, ground sampling is estimated to cost 125,000 pesos.[12]

(b) *Trial of working methods.* A small-scale trial of working methods is desirable before large amounts of equipment are purchased. In Yucatán this will be facilitated by the presence of an existing enterprise already exploiting the forest. The cost of this pilot test is estimated at $40,000 both in Yucatán and at Amapá.[13]

The road network

Before describing the forest operations and going into details of equipment and personnel, it is necessary to consider the road network necessary to extract the wood and convey it to the mill.

For the sake of simplicity particulars are given only for the Amapá project, and all that follows relates only to Amapá unless expressly stated otherwise. The full calculations for both Amapá and Yucatán are given in the end-tables.

(a) *Primary roads* connect the mill with the units, cutting across the latter to form a network of roughly parallel lines at 5 to 10 km intervals. The intervals will depend on roadbuilding costs, the roughness of the land, climatic conditions, and the density and wood content of the forest. They will be permanent, all-weather roads, surfaced with gravel or laterite; sections may be asphalted if traffic and cost considerations make this necessary or desirable.[14] They will have banking and semi-permanent bridges so that the gullies may be crossed throughout the year.[15]

The total length of the primary network has been calculated by taking the basic requirement of 1 km for each 500 to 1,000 hectares served, adding 20 per cent as allowance for transversal sections and also an allowance for additional sections necessary to ensure permanent linkage between the mill and the forest units. This last element depends on the shape of the units.

The calculation gives 80 km of primary roads per unit of forest operations,[16] i.e., for the extraction of 60,000 tons of pulpwood annually. The lengths required for the other scales of operation are proportional, save in the case of Alternative 2 for the 360,000-ton operation, where the length is 580 km (against 480 km for Alternative 1) because exploitation is extended beyond the area of immediate access.

The cost of primary roads has been considered as a permanent investment, amortized and charged to pulp-

[9] Unit administration: coupe manager, five yard foremen, ten operation foremen, one accountant, four clerks. Skilled and unskilled labour needs are discussed below.

[10] Central administration: forest director (except for smallest mill), assistant director, administrative assistant, plus a number of foremen, accountants, clerks and messengers which increases slightly with mill size.

[11] These were interpreted by Mr. Dammis Heinsdijk (Surinam Forestry Department), Member of the FAO Mission to the Amazon. In general, work already carried out by the FAO Mission greatly simplifies these aspects of the Amapá operations.

[12] Aerial survey costs rise proportionally with mill size, ground survey costs (including interpretation and sampling) rather less than proportionally, e.g., 250,000, 450,000 and 625,000 pesos for 120,000-; 240,000-; and 360,000-ton operations respectively.

[13] Equipment required: Yucatán—D4 caterpillar tractor with arch, 5-ton diesel truck with 4-wheel trailer, self-driven crane and hoist. Amapá—D6 and D4 caterpillar tractors and truck.

[14] All the primary network is asphalted in the case of Yucatán.

[15] Primary roads for Amapá to be built as follows: stumps, etc., removed to width of 9 m; convex understructure 7 m wide built so that lower point is 10 cm above natural land level; necessary material brought by bulldozer from points at least 2 m from road; levelling and forming with motorgrader; six months' waiting period until land settles; new levelling with motorgrader and two months' wait; spreading of 25-cm layer of laterite gravel extracted with scraper; new levelling with motorgrader; felling 15-m strips on either side of road (as part of exploitation); permanent wooden bridges, etc., where necessary.

[16] Variations in the area of the forest units compensated by different intervals between the primary roads.

wood. It has been assumed that a team of two D8 or D6 caterpillar tractors, with bulldozers and semi-trailers, one large motorgrader, three skilled and twelve unskilled men can build 100 m of primary road in one day. The cost per km has thus been estimated at $340[17] plus 22,200 cruzeiros[18] or a combined total of $1,034. This gives, for the 60,000-ton operation, a total cost of $82,700. Costs for the other operations are in strict proportion, save that Alternative 2 for the largest gives $595,400 against $496,200 for Alternative 1.

Assuming the primary network is to be completed in four years, this implies a daily advance in roadbuilding of 67-133-266 m and 400 m (Alternative 1) or 480 m (Alternative 2) for operations in ascending order. In practice this means one, two, three, four or five teams, with the completion time adjusted to ensure the teams are fully occupied. The costs given include the building of bridges and banking equipment, spares and maintenance, and fuel, but exclude amortization of the equipment (taken into account globally in the amortization of all forest operations equipment).

Primary road maintenance requires yearly about 12 per cent of the work per km needed for construction, the team being the same but with lighter graders and D6 tractors. Maintenance would require, for each thousand tons of pulpwood, 1.6 team-days, i.e., 3.2 D6 tractor-days, 1.6 light grader-days, 8.0 skilled and 19.2 unskilled man-days; this item is charged entirely to pulpwood.

(b) *Secondary roads* intersect the primary roads at roughly kilometre intervals; each km of secondary road thus serves 100 hectares. Though built to withstand truck traffic even in the rainy season, they will be temporary, designed to last only for the period of exploitation of the area they serve.[19]

The cost of building secondary roads has been charged entirely to pulpwood, and has been estimated on the assumption that a team of two D6 tractors (occasionally one), with bulldozers and semi-trailers, one large motorgrader, four skilled and twelve unskilled workers, can build 200 m in one day. Since 1 km of road serves 100 hectares containing 10,000 tons of pulpwood, the work of building secondary roads per thousand tons of pulpwood is 1 D6 tractor day, 0.5 motorgrader days, 1 skilled and 6 unskilled man-days.

A similar team, using light motorgraders, can on average repair 800 m of secondary road in one day. Maintenance cost of secondary roads (charged to both pulpwood and fuelwood) is estimated therefore on the basis of 0.25 D6 tractor days, 0.125 motorgrader-days, 0.5 skilled and 1.5 unskilled man-days per thousand tons of wood.

(c) *Haulage trails* will be opened by hand at the rate of about 1 km for 2 hectares of forest operations. Intended primarily for tractor traffic, whenever possible they should accommodate trucks so as to reduce haulage distances, which would normally vary from 0 to 500 m. So far as possible long hauls will be carried out in the dry months, extraction being concentrated in areas close to primary and secondary roads in the rainy season.[20] Haulage trails will be opened by haulage teams, and equipment and man-power requirements are discussed below under haulage.

Organization of forest operations

Here again the description of the basis on which costs were computed is confined to Amapá. There are important differences between the Amapá and Yucatán estimates, arising mainly from the higher mechanization and lower labour consumption in Amapá. These differences are pointed out in end-tables A1-A7 and A28-A34, to which reference should be made for full details of both the Amapá and Yucatán estimates:

(a) *"Quadrillage", inventory, and marking operations.* Cuts at Amapá will be delimited by the contours of the small hills and valleys, so that the usefulness of quadrillage (dividing the area into plots of 100 by 100 m) is arguable.[21] However, the establishment of km lines would be necessary for inventory taking; brushwood clearing (the principal item of cost in the "quadrillage" operation) would be necessary for tree-marking anyway; and "quadrillage" offers a useful means of checking labour output and yield per hectare. The "quadrillage" operations consist of:

Opening up kilometric lines by tachymeter and compass, and placing concrete posts at every kilometre; One operator and ten labourers can do 5 km a day, serving 250 hectares. Since a hectare yields 100 tons of pulpwood, requirements per thousand tons of pulpwood are 0.04 skilled and 0.4 unskilled man-days. The cost is charged entirely to pulpwood.

Opening up hectometric lines with stakes and pickets; One foreman and five labourers do 5 km a day (25 hectares). Requirements, therefore, per thousand tons of pulpwood, 0.4 skilled and 2.0 unskilled man-days.

Painting and numbering of trees at every 100 metres; One specialist and two labourers can do 5 km a day (25 hectares). Requirements, therefore, per thousand tons of pulpwood, 0.4 skilled and 0.8 unskilled man-days.

Thus total requirements for "quadrillage" operations, per thousand tons of pulpwood, are 0.84 skilled and 3.2 unskilled man-days.

An inventory, taken on the basis of the quadrillage plots, should also give an indication of the land configuration and the presence of watercourses. Though an inventory of the whole exploitation area may not be required, since the principal costs—brush clearing and tree-marking—must be incurred in any case, clearly a total inventory could furnish very valuable information at little extra expense. The inventories would, of course, prove useful if lumber exploitation is subsequently undertaken.

The inventory operations consist of:

Brush clearing; at a third of a hectare per man, per day this means thirty unskilled man-days per thousand tons of pulpwood.

The inventory proper: a team of one specialist and ten labourers can cover 10 hectares a day. Thus requirements per thousand tons of pulpwood are one skilled and ten unskilled man-days.

[17] Mainly spares and imported fuel.

[18] Wages and salaries.

[19] Constructed in Amapá, in a similar way to the primary roads, but with the following modifications: width only 5 m; embankments only to diminish gradients; one levelling with motorgrader only; 10-cm layer of laterite gravel, suppressed where possible; temporary bridges.

[20] This will enable the average haul to be reduced to 125 m. See discussion under haulage.

[21] In Yucatán the land is completely flat.

Tree-marking; carried out by the inventory team, with 50 per cent more labour. Per thousand tons of pulpwood, therefore, an additional 0.5 skilled and 5 unskilled man-days.

This gives per thousand tons of pulpwood, for all quadrillage, inventory and marking operations, 2.34 skilled and 48.2 unskilled man-days. Of the former, 0.4 (from the painting and numbering team) would be second category skill. All these costs are charged to pulpwood.

(b) *Felling and bucking.* Exploitation will be by "clear-felling" in strips,[22] small-diameter wood (below 35 cm) being felled first. Bucking into 7-m and 9-m lengths (the most economic for bucking and loading operations) would be by hand at the felling site.[23]

Felling and bucking (both by hand) will be carried out by a two-man team, capable of felling and bucking 10 tons per day. A foreman assisted by two labourers would supervise fifty such teams. Thus requirements per thousand tons of wood are two skilled and 204 unskilled man-days; the cost is charged to fuelwood and pulpwood in the proportions cut and used. The cutting or killing of unused trees is regarded as a silvicultural cost and charged to pulpwood.

(c) *Haulage.* Secondary roads will service 500-m strips on either side. In the dry season the outer halves of these strips will be exploited, and trucks will enter the forest on the haulage trails. In the rainy season, trucks will be confined to the secondary roads, and the inner halves of the strips will be exploited. In both seasons, therefore, the average haul will be 125 m.

The small-sized wood (about a third of the total volume) and the large-sized wood (over 35-cm diameter) are considered separately. For the former a team will consist of a D4 tractor, driver and assistant, ten men to open trails[24] and clean out the land after felling, and four haulers. This team has a capacity of 70 tons a day in the six months' dry season, and 40 tons during the rainy season, an average through the year of 55 tons. For the large diameter wood, a D6 tractor with the same team, but with only five trail-openers will have a capacity of 100 tons a day in the dry season and 60 tons a day in the rainy season, an average through the year of 80 tons. Thus a D4 team and a D6 team, together with three men to sort and cord the wood at the truck loading site, will together handle daily 135 tons. Truck personnel aided by the wood sorters will load the trucks.

Requirements, therefore, per thousand tons of wood (pulpwood or fuelwood), are 7.4 D4 tractor-days, 7.4 D6 tractor-days, 30 skilled and 208 unskilled man-days.

(d) *Transport* of the wood to the mill will be carried out by type 5-6T trucks; furnished with a one-axle trailer for the 7-m and 9-m logs, each truck will carry 9 tons in the dry season and 7 tons in the rainy season, an average truckload of 8 tons. Trucks carrying small-sized wood will be provided with small self-driven 1.5-ton cranes, others will have a two-cable hoist. For the four forest operation sizes, average transport distances to the mill, estimated from the layout of the exploitation areas, will be 8, 12, 20 and 28 km, respectively. Allowing one hour on each round trip for loading and unloading, the numbers of truck-days per thousand tons of wood have been calculated as follows:[25]

Table 2

TRANSPORT REQUIREMENTS

	Annual wood tonnage (thousand tons)			
	60	*120*	*240*	*360 (Alt. 1)*
Daily wood tonnage (tons)	200	400	800	1,200
Average round trip distance (km)	16	24	40	56
Daily trips per truck	5	5	4	3
Truck-days required	5	10	25	50
Truck-days per thousand tons of wood	25	25	31	42
Trucks required (adding 20 per cent for contingencies)	6	12	30	60

Each truck will be manned by a driver (skilled) and assistant (unskilled). In addition there will be a fleet personnel. Hence, for the four different sizes of forest operations in ascending order, the labour requirements will be 60, 60, 75 and 100 man-days respectively; in each case half the labour will be skilled.

The possibility of using the railroad now being constructed has been investigated only for Alternative 2 of the largest mill, in respect of distant pulpwood. Since local conditions favour the construction of permanent roads, other means should be employed only as a last resort and every effort should be made to maintain road transport in the rainy season. In exceptional circumstances the railroad could be used (truck cranes loading the wagons) and reserve tractors employed for long-distance hauling.[26]

(e) *Silvicultural work* is charged entirely against pulpwood. As pointed out earlier, non-pulpwood species not used as fuelwood will have to be killed by circular bark-stripping. A team of two labourers can do this at the rate of 0.3 hectares a day. Assuming no fuelwood is extracted, this work would require sixty-six unskilled man-days per thousand tons of pulpwood. This is the maximum, the minimum (corresponding to clear-felling) being zero. To afford a safety margin, the maximum has been included in the calculations.

Five to ten years after felling, fast-growing pulpable species such as *Cecropia* will be cut, while at the same time selective thinning will be carried out to leave species suitable for pulpwood or other uses. A team of one skilled and four unskilled workers could do this work at the rate of 0.5 hectares per day. Requirements, therefore, per

[22] It is assumed that trees used neither for pulpwood nor fuelwood will be killed by circular bark-stripping to avoid an undesirable composition of the forest in the second rotation.

[23] Logs over 50-cm diameter, however, would be bucked into lengths and split at the mill before chipping.

[24] One man can open about 33 m of trail a day and do the corresponding cleaning. Since a hectare has about 500 m of trail and contains 100 tons of wood, ten men will do the opening for the 70 tons which represents a day's work for a D4 tractor team.

[25] Strictly speaking, the first line of this table relates to a "transport" operation, rather than a "forest" operation, of the size indicated. The smallest mill will require 60,000 tons of pulpwood; how much fuelwood it requires will depend on the processes undertaken in the mill. The per thousand tons cost of transporting fuelwood will be the same as that for transporting pulpwood *for a given mill size,* since the cost varies only with the quantity to be transported and the distance it has to be carried. It is assumed that, for silvicultural reasons, fuelwood will be taken out evenly over the area exploited.

[26] It should be pointed out that in the cost estimates haulage has been included at the same figure in the two alternatives for the largest operation; in fact a slightly higher figure ought to have been included for Alternative 2.

thousand tons of pulpwood, are twenty skilled and eighty unskilled man-days.

Total labour and equipment needs

The labour requirements (in man-days per thousand tons of wood) to be costed against the wood extracted in the Amapá operations are added together in the following table, which covers all the operations discussed except general preparatory work and primary roads (regarded as permanent investment and charged against wood as amortization), and transport (discussed below).

Table 3

TOTAL LABOUR NEEDS (EXCEPT FOR TRANSPORT) DIRECTLY CHARGEABLE TO WOOD EXTRACTED

(*man-days per thousand tons of wood*)

	Pulpwood			*Fuelwood*		
	Skilled workers			*Skilled workers*		
Activity	*First category skill*	*Second category skill*	*Labourers*	*First category skill*	*Second category skill*	*Labourers*
Maintenance of primary roads.........	4.00	4.00	19.20	4.00	4.00	19.20
Quadrillage, inventory and tree-marking	1.94	0.40	48.20	—	—	—
Construction of secondary roads.......	1.00	1.00	6.00	—	—	—
Maintenance of secondary roads.......	0.25	0.25	1.50	0.25	0.25	1.50
Felling and bucking..................	—	2.00	204.00	—	2.00	204.00
Haulage............................	15.00	15.00	208.00	15.00	15.00	208.00
Silvicultural work...................	20.00	—	145.00	—	—	—
Miscellaneous (shops, either transport, unforeseen, etc.)..................	32.81	92.35	118.10	2.15	48.75	27.30
TOTAL	75.00	115.00	750.00	21.40	70.00	460.00

All these labour requirements are directly proportional to the wood extracted and independent of the size of the forest operation. To the total must be added labour requirements for transport; these vary with the size of the forest operation, as follows:

Table 4

LABOUR NEEDS FOR TRANSPORT

(*man-days per thousand tons of wood*)

	Size of forest operation (thousand tons)			
	60	*120*	*240*	*360 (Alt. 1)*
Skilled, first category (drivers)....	30	30	37.5	50
Unskilled (helpers)..............	30	30	37.5	50

By applying labour needs per thousand tons of wood to the different sizes of forest operation it is possible (assuming 300 working days a year) to compute the labour force required. These figures are given in end-table A30, along with estimates of personnel for central and field administration, wages, salaries, and total cost of labour force and administrative personnel.[27]

On the basis of the estimates of total personnel, making assumptions as to the housing needs of different categories, total housing requirements were computed; details of the housing schemes are given in end-tables A31 (Amapá) and A4 (Yucatán).

To arrive at an estimate of investment in equipment it is necessary to aggregate equipment needs. The following items in table 5 vary directly with the volume of wood extracted.

To these items must be added trucks for transport (the number of these varies with the scale of operations; 6, 12, 30 and 60 5-ton trucks for the four cases considered) and equipment for primary road construction (details of which were given earlier in this section). To the resulting totals has been added a number of sundry vehicles (cars, jeeps, etc.) and 15 per cent has then been added for miscellaneous equipment. Full details of the

[27] Corresponding information for Yucatán is shown in end-table A3.

Table 5

EQUIPMENT NEEDS ACCORDING TO THE VOLUME OF WOOD EXTRACTED

(*equipment-days per thousand tons of wood*)

	Pulpwood				*Fuelwood*		
	Tractor D6	*Tractor D4*	*Large grader*	*Small grader*	*Tractor D6*	*Tractor D4*	*Small grader*
Maintenance of primary roads....	3.20	—	—	1.60[a]	—	—	—
Construction of secondary roads...	1.00	—	0.50	—	—	—	—
Maintenance of secondary roads...	0.25	—	—	0.13	0.25	—	0.13
Haulage......................	7.40	7.40	—	—	7.40	7.40	—
TOTAL	11.85	7.40	0.50	1.73	7.65	7.40	0.13[a]

[a] Charged to pulpwood in the subsequent computations, since fuelwood requires, even in the case of the largest operation, only a fraction of the services of a small grader.

calculations are given, for Amapá, in end-table A29 and, for Yucatán, in end-table A2.

Investment and total cost of wood

Total investment requirements for forest operations are summarized in end-tables A28 (Amapá) and A1 (Yucatán). An item has been added for sundry and unforeseen expenses, while working capital has been reckoned as the value of two months' production for Amapá[28] and one month's for Yucatán.

An estimate of the cost of both pulpwood and fuelwood for all the forest extraction schemes now becomes possible. It is assumed that half the forest yield is of pulpwood quality. Labour costs are derived from the requirements estimates which have been outlined. Estimates are made of operational expenses such as fuel, repairs, and replacement parts. The investment costs are amortized at various rates: thirty years for the cost of preparatory work and primary road construction; twenty years for the housing scheme; four years for tractors, and six years for trucks and other vehicles. Interest on both investment and working capital is charged at the rate of 8 per cent.

These computations lead to the following final pulpwood and fuelwood costs for the various forest operations at each site:

Table 6

ESTIMATED WOOD COSTS: AMAPÁ AND YUCATÁN

(dollars per ton)

Size of the forest operation (in thousands of tons per year)	*Amapá*		*Yucatán*	
	Pulpwood	*Fuelwood*	*Pulpwood*	*Fuelwood*
60	8.50	4.51	5.55	2.35
120	8.11	4.57	5.36	2.42
240	8.08	4.81	5.37	2.51
360 (Alt. 1)	8.38	5.23	5.51	2.69
360 (Alt. 2)	8.89	5.73	—	—

For both sites, as the size of operations increases, the fuelwood cost rises—more steeply for Amapá than for Yucatán. The curve of pulpwood cost, in both cases, is U-shaped. Since actual pulpwood and fuelwood requirements of the pulp and paper mills projected will depend on the commodity produced (bleached or unbleached pulp) and on the degree of integration, the estimated wood costs for different projects were arrived at by interpolation from graphs based on the figures in the above table. (A33-34, A6-7).

These variations in wood requirements for different types of mills are, of course, accompanied by variations in the investment required as well as in wood costs. No adjustment, however, was made to take into account the differences in pulpwood requirements for various processes and degrees of integration: first, because the adjustment would be very complex, and, secondly, because the differences in pulpwood requirements are in any case very small. Fuelwood consumption, however, varies considerably with the type of product and the degree of integration, and an adjustment was therefore made. Since the principal item in the investment costs for fuelwood is housing, this item was adjusted by interpolating on a graph connecting labour force with the size of forest operations (A34 and A7).

[28] A precautionary measure arising from the fact that Amapá, not having paved roads, may not be assured of a completely continuous wood supply. It is realized, however, that a two-months' pulpwood stock would probably involve deterioration due to climatic conditions.

Section III

PROCESSES AND EQUIPMENT

Processes

The sulphate process is the most generally applicable process for the production of chemical pulps. Because of its flexibility and tolerance to decayed wood and bark it can be applied to mixtures of different wood species. (See Papers 3.8 and 3.10). Sulphate pulps also generally have better strength properties than chemical pulps produced by other processes. Finally, in a modern sulphate pulp mill, by burning the waste liquor, a high percentage of the processing chemicals is recovered and processing steam generated in quantities sufficient to meet requirements.

For these reasons, the sulphate process has been selected for the chemical pulp production in the hypothetical mill projects. For the production of unbleached pulp a straight sulphate process using saltcake as make-up chemical is foreseen, whereas bleached pulp qualities will be produced by the sulphur/soda process, in which case caustic soda would be produced in an electrolytic plant at the mill site and sulphur added to the white liquor. The reason for choosing the sulphur/soda process when bleached pulps are to be produced is that prohibitive freight rates make it necessary to manufacture chlorine at the mill site in an electrolytic plant; this produces a quantity of caustic soda about equal to that of chlorine and roughly in balance with the process requirements. Naturally, where conditions are favourable, the caustic soda produced may be sold on the open market, using saltcake instead as make-up chemical; this would not call for any major changes in the pulp-mill equipment.

Time and lack of sufficient data has prevented a full study of the possibilities of producing mechanical type pulps from mixed tropical woods. Reference is, however, made later in the paper to the use of the *cold caustic soda process.* The main reasons for this choice are:

(a) There are strong reasons for believing that the operation of the ordinary mechanical process on a mixture of even a few wood species will meet with great technical difficulties.

(b) Only a very limited number of low-density broad-leaved woods have proved suitable for producing a mechanical pulp with acceptable strength characteristics.[29]

(c) There is also reason to believe that the production of mechanical pulp from several different wood species using the chemi-groundwood process will present technical difficulties. This judgement may be proved wrong by further investigations.

(d) Preliminary tests on a mixture of six different tropical wood species using the cold caustic soda process have shown encouraging results regarding the possibilities of producing mechanical type pulps for newsprint.

[29] An important exception is *Cecropia.* This species occurs in fairly pure stands, mainly as second growth, in some Latin American tropical forests; it has proved suitable for grinding. See Paper 3.11, *The Pulping of Peruvian cetico for the manufacture of newsprint.*

Equipment

It is impossible within the scope of this report to give a detailed specification of the equipment and machinery visualized for the different operations and mill sections. The following comments are of a summary character only and are given merely to describe the general set-up of the mill.

(a) *Log-yard and wood preparation department.* Besides mechanical equipment for handling the logs, the following machinery is also included:

Barking equipment of the friction type (Waterous type barkers)

Bark presses for de-watering and recovery of bark[80]

Splitting equipment for large-size logs

Multi-knife chippers and chip-screening equipment

Very little information or experience is available concerning the barking of mixed tropical woods. The best equipment can be selected only after careful experiments with the woods to be used at each particular mill site; it seems likely, however, that the most versatile equipment is the hydraulic barker.

It is claimed that new developments and designs of centrifugal pulp cleaners (centri-cleaners, etc.) make it possible to produce good quality pulp (especially bleached qualities) from unbarked broad-leaved woods. If this should prove possible it will mean a considerable saving in investment and in operating costs which in most cases will probably not be offset by the higher consumption of chemicals. Obviously the suitability of this method needs to be carefully checked in each case, and for the purpose of this study barking equipment has therefore been included.

(b) *Digester and diffuser departments.* The digesters are of the stationary type with forced circulation of the liquor and indirect heating. The better circulation obtained by this system as against the direct-cooking installations is of great importance for the pulp quality when dealing with mixed species.

The washing of the brown stock will be carried out in diffusers. The choice between this older system and a modern multi-stage filter washing can be taken only after a careful analysis has been made of installation costs, costs of chemicals, labour and fuel, as well as the operational skill of the personnel.

(c) *Screening departments.* These are of modern design including high frequency vibratory screens.

(d) *Bleaching department.* A modern five-stage bleaching operation is provided for.

(e) *Electrolytic plant.* The choice between mercury or diaphragm cells for the production of caustic soda and chlorine is to a large extent influenced by market considerations. If caustic soda is to be marketed, the choice will probably be in favour of mercury cells, since they produce alkali of higher concentration and purity. Diaphragm cells, on the other hand, generally require less investment and call for lower operational skill. Because of its greater versatility, a mercury cell plant has been selected for the purpose of this study.

[80] Although bark presses are included, no account has been taken of the fuel value of the bark for lack of sufficient data regarding quantity, fuel value, minimum water content, etc. See also following section on chemicals and fuels.

(f) *Pulp-drying machine department.* The pulp-drying machine department is equipped with a Kamyr wet lap machine and a fan dryer (FLAKT dryer).

(g) *Evaporation plant and soda recovery.* This section consists of a multiple effect Swenson evaporation installation and modern spray-type stationary furnace for soda recovery.

(h) *Lime reburning.* Rotary kilns for the reburning of lime sludge are foreseen in all cases except the mills of 50 tons daily capacity in the Yucatán project. In this case it was omitted because it was supposed that a lime-kiln of this size would carry capital costs per ton too heavy to enable it to compete with the low market price of lime in Yucatán. However, it will be seen from end-table A10 that this assessment proved to be wrong; the installation of a lime-kiln would be an economic proposition for the smallest mill size also. Choice of fuel for the kiln is discussed in the section "Chemicals and fuels".

(i) *Mill services.* The steam and power stations are designed so that the mill shall be completely self-sufficient, using wood as additional fuel.

The mechanical workshop includes cast iron and soft metal foundries.

Section IV

Chemicals and fuels

Consumption of chemicals

The mills producing unbleached pulp qualities will use saltcake as make-up chemical; consumption is estimated at 90 kg per ton of pulp. For bleached qualities caustic soda and sulphur are used, and the consumption for digestion is estimated at 70 kg of caustic and 23 kg of sulphur, with an additional 20 kg of caustic and 2 kg of sulphur plus 70 kg of chlorine for the bleaching operation (A9). To produce these quantities of caustic soda and chlorine in the electrolytic plant, 145 kg of salt, calculated from the quantity of caustic soda produced, will be required. A surplus of 10 kg of chlorine will be obtained which may be converted to hydrochloric acid. Alternatively, if there is no market for hydrochloric acid, production in the electrolytic plant may be based on the chlorine requirements, in which case an additional 18 kg of saltcake will be required. For the purpose of this study the first alternative has been chosen but no profit on the production of hydrochloric acid has been assumed.

Consumption of lime for causticising is estimated at 260 kg per ton of unbleached pulp. For bleached qualities an additional 30 kg will be needed, giving a total consumption of 290 kg. For mills reburning the lime sludge the consumption of make-up limestone is 30 and 90 kg respectively (A9).

The consumption of sizing materials in the paper mills naturally depends on the qualities of paper produced and may vary within wide limits. Two standard grades of paper have been selected for the purpose of this study, one grade of unbleached wrapping paper and one of bleached printing or writing paper. The consumption of sizing materials has been estimated as follows:

	Bleached paper	*Unbleached paper*
Rosin size	20 kg/ton	30 kg/ton
Alum	30 "	45 "
China clay	60 "	—
Total	110 "	75 "

Supply possibilities and cost

(a) *Amapá.* It has been assumed that limestone and salt are the only chemicals which would be supplied from local sources; limestone from Monte Elegre (about 450 kilometres up the River Amazon) and salt from the north-eastern part of the country (Recife). Other chemicals and sizing materials would be imported, probably from the United States as return cargo on ships taking manganese ore from Santana (A35).

(b) *Yucatán.* Limestone, salt, sulphur and rosin will be suppied from local sources, other chemicals imported from the United States (A8).

Prices of imported chemicals are those valid in April 1954 and quoted f.o.b. United States ports. To these prices have been added the estimated freight rates and handling costs, plus an additional 15 per cent as a nominal import duty.

The following table shows the estimated cost of chemicals for the Amapá and Yucatán projects compared with the United States prices in April 1954:

Table 7

ESTIMATED COST OF CHEMICALS AT MILL SITE IN AMAPÁ AND YUCATÁN COMPARED WITH US MARKET PRICES

(dollars per ton)

	Limestone	*Saltcake*	*Salt*	*Sulphur*	*Aluminium sulphate*	*China clay*	*Rosin*
Amapá	15.00	47.20	25.50	61.00	76.40	42.00	276.50
Yucatán	4.00	47.20	8.00	51.00	76.00	41.40	179.00
US market price..	4.00	21.00	10.00	33.00	46.00	16.00	220.00

Fuels

To obtain self-sufficiency in heat and power additional fuel is required over and above the fuel obtained from the black liquor. Further quantities are also needed for the reburning of lime sludge.

It has previously been stated that the forest extraction scheme is based on the conservative assumption that only 50 per cent of the woods could be used for pulping. A small percentage of the remainder consists of valuable and marketable species, leaving a large part of the total stand (probably about 45 per cent) with no value other than as fuel. It therefore follows that the additional fuel requirements of the mill should, if possible, be met by making use of this remaining wood.

From a technical viewpoint the utilization of wood fuel for steam (and power) production is quite feasible although it would probably require the sorting out of certain species (i.e., those with high density and silica content) which are difficult to chip or burn.

In the case of lime reburning, the use of wood fuel instead of fuel oil would involve not only technical inconveniences but also considerably higher investments, manpower, repair costs, etc., and lower yield. For this purpose, therefore, fuel oil has been preferred (A10, A36).

End-table A11 gives detailed calculations of the fuel requirements in the different projects; these are summarized in the following table:

Table 8

CONSUMPTION OF ADDITIONAL FUELS (1,000 TONS PER ANNUM)

(For comparison, the fuelwood consumption is also expressed as a percentage of the pulpwood consumption)

	Mill size, tons/day							
	50		*100*		*200*		*300*	
	Unbleached	*Bleached*	*Unbleached*	*Bleached*	*Unbleached*	*Bleached*	*Unbleached*	*Bleached*
Pulp mills								
Fuel oil or	0.78[a]	0.87[a]	1.56	1.74	3.12	3.48	4.68	5.22
Fuelwood.....................	5.25	20.0	10.5	39.9	21.0	79.8	31.5	119.7
Percentage of pulpwood........	10	33	10	33	10	33	10	33
Integrated mills								
Fuel oil or	0.83	0.92	1.65	1.85	3.30	3.69	4.95	5.54
Fuelwood.....................	22.5	39.0	45.0	78.0	90.0	156.0	135.0	234.0
Percentage of pulpwood........	40	63	40	63	40	63	40	63
Non-integrated mills								
Fuel oil......................	5.55	5.78	11.1	11.6	22.2	23.1	33.3	34.7

[a] Refers to Amapá only, as no lime reburning was envisaged in the case of Yucatán.

From the above it will be seen that the consumption of fuelwood is considerably less than that of pulpwood. Expressed as a percentage of pulpwood consumption, it is 10 for unbleached pulp, about 33 for bleached pulp, 40 for unbleached and 60 for bleached papers. Since bark (which amounts to about 10 per cent of the pulpwood quantity) could probably be de-watered and burned, actual fuelwood requirements may even be lower than stated; thus a pulp mill producing unbleached qualities would be completely self-sufficient as regards fuel, except for the oil needed for lime reburning.

It follows that if only half the standing timber is used as pulpwood, considerable quantities of wood from the first cutting will be left on the ground to rot. The situation would, however, be quite different when the mill starts to operate on wood from the second growth since it is likely that a much higher percentage of these stands will be suitable for pulping.

Power

The electric power required for the mill operation will be generated from steam; by bleeder turbines in a quantity corresponding to the factory's consumption of low-pressure steam and by condenser turbines for the balance (A11). Electricity required for the community will be produced by a diesel-generator set, thus affording a maximum of flexibility.

Section V

ADMINISTRATION, SUPERVISION AND LABOUR

The administration and supervision of a pulp and paper mill in an undeveloped area will not differ much from that required in a mill in one of the traditional pulp-producing countries. A high standard will be required in the technical staff, however, partly because local labour will have to be trained, partly because, even when trained, it is unlikely to reach the same standard of efficiency as may be expected in a country with longer industrial experience. The need for highly qualified technical staff will be especially felt during the running-in period of the mill, particularly since it will be operating on non-traditional materials. Problems which in a well-established pulp region could be speedily referred to outside specialists will, in an undeveloped region, require a solution on the spot if costly stand-stills are to be avoided. For these reasons it will usually be necessary in an undeveloped region to acquire the assistance of foreign technicians—certainly until local labour and supervisory personnel have been trained. In this study, for both Amapá and Yucatán, the same administrative and supervisory staff has been envisaged as is usually employed in Scandinavian mills, and the salaries of the higher officers have been set in line with European standards (A12 and A37-38).

Although labour productivity in both Amapá and Yucatán is probably higher than in some other undeveloped regions of the world, it is likely to be lower than in Scandinavian countries, partly for reasons of climate. The number of workmen for both the Amapá and Yucatán mills has therefore been increased over the figures given for the Swedish project. An extra allowance has been made for Amapá arising from the need to handle and split large-size logs. Labour requirements for mill operations in the three hypothetical projects are summarized in the end-tables A13-A15 and A39-A41):

Table 9

COMPARISON OF LABOUR REQUIREMENTS FOR MILL OPERATION AND SERVICES

(*numbers*)

	Mill size, tons/day							
	50		*100*		*200*		*300*	
	Unbleached	*Bleached*	*Unbleached*	*Bleached*	*Unbleached*	*Bleached*	*Unbleached*	*Bleached*
Pulp mills								
Amapá	159	189	203	238	275	321	345	405
Yucatán	121	148	148	178	187	228	240	291
Sweden	95	117	116	144	147	182	194	233
Integrated mills								
Amapá	236	271	334	374	—		—	
Yucatán	195	220	279	309	—		—	
Sweden	164	186	233	276				
Non-integrated paper mills								
Amapá	133		203		—		—	
Yucatán	133		203		—		—	
Sweden	111		176					

The *total* number of employees (including administration and supervison personnel, industry and forest workers, as well as workmen required in community services) is given in the tables (A20, A47).

Table 10

TOTAL NUMBER OF EMPLOYEES IN THE AMAPÁ AND YUCATÁN MILLS

	Mill size, tons/day							
	50		*100*		*200*		*300*	
	Unbleached	*Bleached*	*Unbleached*	*Bleached*	*Unbleached*	*Bleached*	*Unbleached*	*Bleached*
Pulp mills								
Amapá	470	550	785	880	1,400	1,570	2,040	2,275
Yucatán	600	700	1,100	1,200	2,030	2,250	2,960	3,280
Integrated mills								
Amapá	570	650	945	1,050	—	—	—	—
Yucatán	710	810	1,290	1,460	—	—	—	—

Comparing tables (A20, A47) it will be seen that only a small number of employees are absorbed in actual mill operation; forest workers account for the overwhelming majority of the labour force.

The lower figures for total employees at the Amapá mills reflect the higher degree of mechanization in the forest operations.

Section VI

Transport

Considerable tonnages of various materials have to be transported to and from a pulp and paper mill. The following table shows the quantities involved for integrated mills in Amapá and Yucatán producing bleached paper:

Table 11

ANNUAL TONNAGES OF MATERIALS TO BE TRANSPORTED TO AND FROM INTEGRATED MILLS PRODUCING BLEACHED PAPER [a]

	Mill size, tons/day			
	50	100	200	300
Integrated mills				
Fuel oil	900	1,900	3,700	5,500
Chemicals	5,800	11,600	23,100	34,700
Finished products	15,000	30,000	60,000	90,000
Sub-total	21,700	43,500	86,800	130,200
Pulpwood and wood fuel	103,000	205,500	411,000	616,500
TOTAL	124,700	249,000	497,800	746,700

[a] Rounded figures.

These figures show the magnitude of the transport problem involved. As will be seen from the table, the total tonnage of materials to be handled is more than eight times the quantity of finished products alone.

The transport of pulpwood and fuelwood (which account for more than 80 per cent of the total) has been dealt with in section II, and the discussion here is limited to the transport of chemicals, fuel oil and finished goods only. The problem of transporting these other items is by no means insignificant. In a 60,000-ton integrated mill, for instance, the quantity of materials to be shipped or received amounts to about 300 tons daily, corresponding to some ten to twenty medium-size railway cars. "Moreover, taking into account that regular daily transport of the same tonnage could never be realized, the transport system must be developed to cope with peak loads which may be considerably higher than the daily rate mentioned above."[31]

It will thus be realized that, especially for larger mill sizes, a well-developed system both for internal and external transport is required. The internal transport system, which forms an integral part of the layout and design of the mill, will not be dealt with here. It should only be mentioned that railway-lines on the mill site have been included in both the Amapá and Yucatán projects.

In the Amapá mill projects all external transport will be carried out on the railway-line that connects the Port of Santana with Serra do Navio. As mentioned previously, this line will pass close to the suggested mill site at Porto Platon. Moreover, since a modern port will be established at Santana, facilities will be limited in the case of Amapá, to the construction of a short connecting railway-line from the mill site to the main line.

The situation in Yucatán is different, as outside transport means have to be developed specially for the mill project; they include the construction of a railway-line from Colonia to the small port of El Cuyo[32] as well as port facilities for vessels of 1,000 tons maximum capacity.[33]

Section VII

Capital requirements

The estimated total capital requirements for the various mill projects are recorded in end-tables A24-A25 and A51-A52, along with an analysis of investments for the separate mill sections (A22-A23, A49-A50). Reference is also made to a comparison and discussion of these data in Paper 3.03.[34]

In this section, a short explanation of the principles employed in calculating the capital requirements will be presented, followed—for the convenience of the reader—by a summary of total capital requirements for the different projects.

By way of illustration, the capital requirements for a non-integrated sulphate mill of 60,000 tons annual (200 tons daily) capacity, producing bleached qualities, are discussed below with reference to the table on page 77.

Table 12 serves to illustrate both the principles followed in working out the estimates, and the differences in capital needs arising from locational factors.

The same general basis for the estimates of capital requirements has been used in all the case studies (e.g., it has been assumed that the machinery is supplied by the same manufacturer). The following main differences—arising from locational factors—between the Swedish and the Amapá/Yucatán projects should be noted.

(*a*) Investment in forest operations is not included in the Swedish project since the forests are already opened and the project may usually depend—at least for part of its pulpwood needs—on the supply from local forest owners (see Paper 3.03).

(*b*) In the Swedish project electric power will be generated by bleeder turbines in a quantity corresponding to the factory's requirement of low-pressure steam; additional power needs will be purchased from outside. The Amapá and Yucatán mills, however, are designed for complete self-sufficiency.

The capital items in table 12 are grouped to show the *investments*, as distinct from *capital* items,[35] and also the amount of *foreign* currency (items 1, 2, 3 and 11) required to establish the Amapá and Yucatán mills.

For a detailed analysis of the various items reference

[31] *World Pulp and Paper Resources and Prospects*, UN/FAO Publication, New York, 1954.

[32] The existing decauville line will not be able to cope, certainly not with transport from the larger mills.

[33] It is assumed that the mills will produce for the Mexican market only, in which case most of the products will be shipped to Veracruz.

[34] *Mill size, Integration, Location—A study of Investment and Production Costs in hypothetical pulp and paper mills*, by the Secretariat.

[35] Strictly speaking, items Nos. 11 and 12 are investment items which should be charged proportionately to all other investments.

Table 12

CAPITAL REQUIREMENTS FOR NON-INTEGRATED SULPHATE MILLS OF 60,000 TONS ANNUAL CAPACITY PRODUCING BLEACHED PULP

Mill project	*Sweden*	*Yucatán*	*Amapá*
1. Machinery, freight, administration during erection period, etc.	7,916	9,365	9,522
2. Forest equipment	—	1,073	1,508
3. Engineering fees, etc.	440	600	715
TOTAL	8,356	11,038	11,745
4. Excavation, erection of machinery, buildings, chests, etc.	3,378	1,900	4,309
5. Railway-lines, port, etc.	579	1,545	799
6. Forest preparatory work and primary roads	—	1,524	371
7. Housing project, factory	483	340	911
8. Housing project, forest department	—	1,693	2,451
9. Contingencies	164	480	426
10. General community investments	—	1,470	1,610
TOTAL	4,604	8,952	10,877
11. Capital costs during erection period } Foreign exchange	—	1,325	1,409
12. } Local currency	972	1,075	1,307
13. Working capital—factory	1,900	1,700	2,360
14. Working capital—forest department	—	130	412
TOTAL	2,872	4,230	5,488
15. GRAND TOTAL	15,832	24,220	28,110
16. Estimated amount of foreign exchange required		12,363	13,154
17. Percentage foreign exchange of total capital required		50.1	46.8

is made to the end-tables: the following are summary notes only.

Item 1. This includes production machinery as well as machinery for mill services, estimated ocean freight in the case of Amapá/Yucatán, and administration during the erection period.[36]

Item 2. See end-tables already quoted.

Item 3. Engineering fees are calculated as a percentage of mill investment (items 1, 3, 4, 5, 7 and 9): in the Swedish project, 3.5; in Amapá 4.5 and in Yucatán 5 per cent. The higher figure for Yucatán arises from difficulties envisaged in waste effluent disposal and the construction of railway-line and harbour.

Item 4. Building construction costs are estimated in Yucatán at $8 and in Amapá at $18 per cubic metre of building volume. The volumes are taken from figures in background Paper No. 3.1.

Item 5. See end-tables.

Item 6. See end-tables A1, A28.

Items 7 and 8. It has been considered necessary to provide permanent housing of a reasonable standard for all personnel including forest workers. For details of estimated unit costs, etc., see end-tables A4, A18-19, A31, A45-46.

Item 9. Contingencies are supposed to cover only the cost of additional and unforeseen machinery. The figures of capital requirements cannot therefore be used as a basis for the financing scheme of the project; an additional safety margin must be added to safeguard against any increases in machinery costs, etc., which may take place during the period from negotiating the scheme until the mill is ready to start operations. (In the cost estimates discussed later in this paper contingencies are included to cover an eventual increase in capital costs.)

[36] It is supposed that the erection of the Amapá/Yucatán mills would be on a management contract basis signed with a foreign company.

Item 10. General community investments include the establishment of schools, hospital, parks, amusement facilities, etc., for all employees. The total number of inhabitants has been calculated by assuming that one out of every five inhabitants is employed in the mill or the forest operation (A20, A47).

Items 11 and 12. These capital items, which strictly speaking are *investment* costs, consist of the interest charges on capital required during the "building" period. They are calculated on the assumption that capital needs will accrue proportionately during a period of three years. A 5 per cent rate of interest is assumed for the Swedish project, and 8 per cent for the Amapá/Yucatán projects.

Item 13. Working capital for mill operation in the Amapá/Yucatán projects is calculated at the value of four months' production (A24-27, A51-54).

Item 14. Working capital for forest operation is estimated at one month's production value in Yucatán and two months' in Amapá (A1, A28).

In Paper 3.03 the influence of locational factors on capital investment is discussed. The following short discussion summarizes, referring to table 10, some of the main conclusions.

The cost of production machinery, etc. (item 1), differs very little in the three projects. The main differences arise from higher transport costs to the Amapá/Yucatán mill sites and the higher investments there in steam and power plants. The actual mill investment (items 1, 3, 4 and 9)[37] shows greater differences; this is because of differences in construction costs—Sweden 12.96, Yucatán 12.35 and Amapá 14.97 million dollars.

The investment in forest operations (items 2, 6 and 8) is an appreciable item of the total capital; this item,

[37] Including planning of site, buildings and erection of machinery, but excluding housing, railways and port.

for reasons already explained, does not appear in the Swedish project. For the Amapá/Yucatán 60,000-ton integrated mills it amounts to 16-18 per cent of the total investment.

The investments required to establish transport facilities in Yucatán and Amapá do not reflect the general conditions which may be expected in undeveloped regions since the mill sites selected are particularly favourable. As explained in paper 3.03, this investment item will often be so high as to rule out entirely any small-scale pulp and paper project.

General community investments are less important than is usually claimed; in the case of a 60,000-ton non-integrated mill they represent only about 6 per cent of the total capital.

Capital costs during the erection period are surprisingly high—about 6 per cent in the Swedish and 11 per cent of total requirements in the Amapá/Yucatán projects. They are possibly estimated on the high side since capital needs will probably accumulate at a faster rate at the end of the period.

The following table summarizes the total capital requirements for all the mill projects. The figures for integrated mills and non-integrated paper mills are calculated by using the straight-line relationship between investment and mill capacity established in paper 3.03.

Table 13

TOTAL CAPITAL REQUIREMENTS

(thousands of dollars)

	Mill size, tons/day							
	50		*100*		*200*		*300*	
	Unbleached	*Bleached*	*Unbleached*	*Bleached*	*Unbleached*	*Bleached*	*Unbleached*	*Bleached*
Pulp mills								
Sweden	7,130	8,705	9,475	11,540	13,280	15,830	17,925	21,015
Yucatán	10,190	12,160	14,245	16,725	20,905	24,220	28,600	32,855
Amapá	11,820	14,330	16,220	19,320	23,880	28,110	33,150	38,610
Integrated mills								
Sweden	10,315	12,015	14,720	16,640	23,500	26,000	32,500	35,000
Yucatán	13,915	15,845	20,135	22,700	32,500	36,500	45,000	50,000
Amapá	15,505	17,890	22,250	25,470	36,000	41,000	49,500	56,000
Non-integrated paper mills								
Sweden	6,275	6,395	9,010	9,220	14,500	15,000	20,000	20,500
Yucatán	7,685	7,795	10,565	10,725	16,500	16,500	22,000	22,500
Amapá	8,775	8,940	12,380	12,630	19,500	20,000	27,000	27,500

Finally, the figures set out make it abundantly clear how heavy is the *over-all* investment required to establish a project in an undeveloped region. For example, a 60,000-ton non-integrated pulp mill producing bleached qualities established in the Amapá region would require a total capital investment of about $28 million, or $140,000 per ton of daily capacity; the corresponding figures for Yucatán and Sweden are, roughly, $120,000 and $80,000 per daily ton. This point needs to be specially emphasized, since all too frequently the figures for investment per daily ton quoted in the literature and in the Press relate to *mill* investment only. Table 12 shows that, in the case of the Amapá project, *mill* investment represents only half of the total capital requirements.

Finally, the difference in the investment required to establish a paper mill section in an integrated mill in an undeveloped country as compared with an industrialized country is quite small (as may be seen by the difference between the pulp and integrated mill figures in table 13); this, as is pointed out in paper 3.03, means that the arguments in favour of integrated operations are stronger in undeveloped regions that in industrialized countries.

Section VIII

PRODUCTION COSTS

Production cost estimates have been worked out for the three hypothetical projects in Sweden, Yucatán and Amapá; they are recorded in end-tables B57-B68.

This section includes:

(*a*) Some explanations of a general nature referring to all cost data sheets;

(*b*) Specific observations on some of the cost items—not previously dealt with in this study;

(*c*) A summary comparison of production costs for the different projects and mill sizes.

Cost estimates have been prepared for bleached and unbleached *air-dry* pulp produced in mills of four different capacities: 15,000, 30,000, 60,000, and 90,000 tons per year. Production costs for bleached and unbleached papers in integrated mills and paper-converting costs have been calculated for the two smallest mill sizes only. However, it has been possible, without making detailed calculations, to extend the estimates to the larger mill sizes by making use of the straight-line relationship between annual (or daily) production costs and mill size established in paper 3.03.

All cost estimates are based on 300 working days per year. Practice on this point varies from one country to another. In the United States and Canada, for example, the mills are usually run on a round-the-year basis, with only a couple of days' interruption for major repair work. In Sweden the common practice is to operate the mills for 285 days only; i.e., standstill on Sundays, statutory and annual holidays. However, since capital cost is one of the largest items in the total cost of production and can be considerably reduced by more rational use of machinery and installations, there has been a tendency in recent years to change over to the North American practice. This means, however, an increased labour force as well as heavier wear on machinery and equipment.[38] Whether round-the-year or some shorter operation is more profitable for mills in Amapá/Yucatán can only be determined by a careful analysis of all factors involved. One point in favour of the 300-day operation here adopted for Amapá/Yucatán is that, because of climatic conditions and the lower average operational skill of the workmen, round-the-year operations may result in unusually high wear and tear on the machinery leading to breakdowns. For the sake of comparison a 300-day operation has also been selected for the hypothetical mill in Sweden.

All estimates include a contingency item (margin of safety) calculated at 5 per cent of the total cost (excluding contingencies).

Notes on specific cost items

In the Swedish project pulpwood consumption (stated in cubic metres loose measure) and costs are taken from paper 3.1. They represent typical figures for a mill situated in the inland area of Central Sweden. In the case of Amapá and Yucatán the consumption is estimated on the assumption that the pulpwood (wet) contains 40 per cent moisture of total weight and 10 per cent bark on dry wood. Unit costs of pulpwood (and fuelwood) are taken from end-tables A5-A7 and A32-A34.

Consumption and unit costs of chemicals in the Swedish project are according to figures in paper No. 3.1; in Amapá/Yucatán they are taken from end-tables A8-A9 and A35-A36. The item "miscellaneous materials" (which includes clothing, felts, wires, etc., and lubricating oil) is, for the Swedish project, taken from paper 3.1; for Amapá/Yucatán it is estimated by the Secretariat.

Operating expenses in the Swedish mill are according to paper 3.1. For details of quantities and unit costs in the Amapá/Yucatán projects reference is made to the end-tables. In Yucatán an extra allowance of 50 per cent on the labour costs has been made in view of the present low salaries in the region.

Factory administration and supervision: see paper 3.1 and end-tables.

Insurance is included in overhead costs in the Swedish project; in Amapá/Yucatán it is calculated at 1 per cent per annum of the value of machinery, buildings, and spare parts.

[38] On the last point opinions differed considerably during the meeting; the majority claimed that wear on machinery is actually less in continuous operation.

Different depreciation rates have been applied for the Swedish and for the Amapá/Yucatán projects to allow for differences in climatic conditions, operational skill, etc., as follows:

	Sweden	*Amapá/Yucatán*
Machines, engineering fees, unforeseen expenses	15 years	10 years
Buildings, chests, etc.	25 "	20 "
Port, railways, etc.	40 "	30 "

Interest on fixed capital is charged at a rate of 5 per cent for the Swedish and 8 per cent for the Amapá/Yucatán projects.[39] It should be observed that interest on capital requirements for forest operations is charged to the cost of pulpwood and fuelwood respectively.

The capital costs incurred during the "building" period (dealt with in the previous section) are amortized during a ten-year period; they are calculated at 5 and 8 per cent respectively on half the *total* capital during three years.[39]

Interest on working capital is calculated at 6 and 8 per cent respectively for the Swedish and the Amapá/Yucatán projects.

General community expenses: for details see end-tables.

The relative importance of the various items in the total cost of production is dealt with in paper 3.03. In this connexion it should only be emphasized that the most important item in the mill costs is capital charges, which—in the case of Amapá/Yucatán—in a mill of 200-ton daily capacity producing bleached pulp, accounts for 40-50 per cent of the total plus an additional 10 included in the cost of pulpwood. For smaller mill capacities the figure is still higher; in larger mills slightly lower.

The following table shows the estimated production costs per ton of pulp and paper. They are taken from the cost estimates at the end of this study, except for production costs in 200- and 300-ton integrated mills; these are calculated from the hyperbolic cost functions (see paper 3.03).

The table shows that the production costs are lower in Yucatán than in Sweden, whereas in Amapá they

[39] It is assumed that this capital will be amortized over a certain period and consequently the interest is calculated on half the capital. This is not strictly correct since it assumes simple instead of compound interest but it is generally accepted for this kind of estimate.

Table 14

PRODUCTION COSTS OF PULP AND PAPER IN THE THREE HYPOTHETICAL PROJECTS

(Dollars per ton of air-dry product)

	Mill size							
	50 tons		*100 tons*		*200 tons*		*300 tons*	
	Unbleached	*Bleached*	*Unbleached*	*Bleached*	*Unbleached*	*Bleached*	*Unbleached*	*Bleached*
Pulp								
Sweden	124.00	147.30	99.60	119.10	86.70	102.80	83.60	98.60
Yucatán	122.10	144.10	90.50	105.70	72.60	84.10	68.20	78.70
Amapá	160.50	193.10	120.10	144.90	97.70	117.80	92.70	111.90
Paper								
Sweden	170.70	195.20	140.60	161.00	125.60	143.90	120.50	138.20
Yucatán	175.30	197.20	134.30	150.50	113.80	127.15	107.00	119.40
Amapá	231.90	265.80	181.40	207.10	156.20	177.80	147.70	168.00

are considerably higher, especially for the smaller mill capacities. It will also be seen from the table that the influence of mill size upon cost of production is much more pronounced in the case of the Amapá/Yucatán mills than in the Swedish project; consequently the incentive to establish larger mill capacities is higher in Amapá/Yucatán than in Sweden (see paper 3.03).

Since production costs at the mill do not of themselves determine the viability of a project, they are not discussed here in that context. This aspect is dealt with below, in section IX, which contains a general assessment of the projects.

Before proceeding to this assessment, however, some observations on the question of integration should be made. The following table shows the converting costs for unbleached paper in integrated and non-integrated mills.

Table 15

PAPER CONVERTING COSTS IN INTEGRATED AND NON-INTEGRATED MILLS

(Dollars per ton of unbleached paper)

	Mill size, tons per day			
	50	100	200	300
Sweden				
Integrated mills......	46.70	41.00	38.90	36.90
Non-integrated mills..	72.80	57.30	49.60	47.00
Yucatán				
Integrated mills......	53.20	43.80	41.20	38.80
Non-integrated mills..	92.00	69.20	57.80	54.00
Amapá				
Integrated mills......	71.40	61.30	58.50	55.00
Non-integrated mills..	120.90	93.80	80.25	75.70

As is to be expected, table 15 shows that the converting costs in non-integrated mills are considerably higher than in an integrated operation. This is more clearly seen from the table below, which shows the difference as a percentage of the cost in integrated mills.

Table 16

PERCENTAGE BY WHICH CONVERTING COST FOR UNBLEACHED PAPER IN NON-INTEGRATED MILLS EXCEEDS THAT IN INTEGRATED MILLS

	Mill size, tons per day			
	50	100	200	300
Sweden..............	56	40	28	27
Yucatán.............	73	58	40	39
Amapá..............	69	53	37	38

The difference is less pronounced in the Swedish than in the Amapá/Yucatán projects, or, expressed in general terms: the incentive towards integration is higher in undeveloped regions than in the industrialized countries.

Furthermore, the cost of converting increases rapidly with a decrease in mill capacity. This is perhaps better illustrated by the following table, which gives the percentage rise in cost as mill size decreases.

This table reveals an additional point which is worth observing; as size decreases, the cost increase is much more rapid for non-integrated than for integrated mills. This bears out the statement made in paper 3.03 regarding the possibility of establishing small-size paper-mill sections combined with a larger-scale pulp mill within an integrated operation.

Table 17

PERCENTAGE RISE IN PAPER-CONVERTING COST AS MILL SIZE DECREASES

	Mill size, tons per day			
	300	200	100	50
Sweden				
Integrated mills........	—	5	11	27
Non-integrated mills....	—	6	22	55
Yucatán				
Integrated mills.........	—	6	13	37
Non-integrated mills....	—	7	28	70
Amapá				
Integrated mills........	—	6	11	30
Non-integrated mills....	—	6	24	60

Section IX

AN ASSESSMENT

The basis for comparison

Having established production costs it now becomes possible to present a provisional assessment of the two hypothetical projects based on mixed tropical forests. It should be emphasized that this appraisal is provisional, since the calculations are based on several assumptions which, on closer examination, may be subject to revision. It is nevertheless presented since it is believed that certain general conclusions regarding the economic possibilities of producing pulp from mixed tropical woods in Latin America may legitimately be drawn.

Before evaluating the economic feasibility of the projects a few summary notes on the possible uses of the pulp are given below.

It may be stated with confidence that sufficient evidence has now accumulated to show that a wide range of paper products can be manufactured from sulphate pulps made from tropical mixed forests; some qualities from a 100 per cent furnish, some from blends containing varying percentages of coniferous pulp to give the necessary strength characteristics.

Unbleached pulp may be used up to 100 per cent in second strength wrapping papers, which would probably find a good market outlet in most countries in Latin America. Blended with smaller quantities of coniferous pulp, paper qualities may be produced with strength characteristics approaching those required for first strength wrappings. Bleached pulp qualities could be used in high percentages (or exclusively) for the manufacture of writing and printing papers. Rayon pulp—not considered in this study—can be produced exclusively from tropical woods.[40]

Regarding the suitability of Yucatán wood species, reference is made to the tests commissioned by Maderera del Tropico S.A. from the Forest Products Laboratory, Madison;[41] as to Amapá, a selection of twenty-one

[40] FAO Forestry and Forest Products Study No. 6, April 1953.
[41] Not presented at this meeting. The results of these tests confirm some of the main points mentioned above.

species has been tested by Industrias Klabin S.A., Monte Alegre, Brazil, with promising results.[42]

Finally, it should also be mentioned that tests of the suitability of some selected Yucatán species for producing ground-wood-type pulp by the cold caustic soda process have been made. These tests[43] have indicated the possibility of manufacturing newsprint-type papers from selected mixed species, mainly of the types which are dominant in the second growth of the forest.

The various papers submitted to this Meeting suggest that, provided that pulp from mixed tropical woods can be produced at a reasonable cost, this pulp will also find a market, as will those papers capable of being manufactured from it.

Basis for economic assessment of the projects

The economic feasibility of a project is utlimately determined by production cost and market price of product. While production cost may be determined with a reasonable degree of accuracy, the expected market price is often very difficult to estimate. This is especially true for pulp and paper which, during the last decade, have experienced wide price fluctuations. The problem is further complicated by the rather long time (three years or more) required to establish a new pulp and paper mill; by the time the mill starts to produce, the market prices ruling may be very different from those which were employed as a basis to determine the economic prospects of the scheme.

As mentioned earlier in this paper, it has therefore been considered sounder to use as a basis of comparison the estimated production costs in a new mill established in one of the traditional pulp-producing countries, e.g., in Scandinavia. To this cost has been added sales expenses, a reasonable profit,[44] freight rate and a nominal import duty of 15 per cent on the c.i.f. value. As coniferous pulp is of higher quality and more versatile, it was considered necessary to make a quality adjustment; a deduction of 10 per cent, to create a price incentive for the buyer, was therefore made to arrive at what may be termed a "nominal market value".

It still had to be decided, however, which mill size should be selected in the Swedish project as a basis of comparison. The average mill size in the Scandinavian countries today is probably about 100 to 150 tons per day. The tendency in recent years, however, has been towards the establishment of larger units, both in the building of new projects and by extending older mills. It was therefore decided to choose a 200-ton mill as a basis for establishing the "nominal market values".

The following table shows the "nominal market values" which have been used as a basis of comparison with the "gross sales values" of pulp and paper from the hypothetical mills in Yucatán and Amapá. As will be seen from table 18, these prices are fairly consistent with the present market prices.

To establish the gross sales values of the hypothetical mills in Yucatán and Amapá, a similar procedure has been followed as for the Swedish project. To the net sales value at mill (mill cost plus sales expenses) has been added a nominal profit of 10 per cent on the "project" investment[45] plus the estimated freights to Veracruz and Rio de Janeiro respectively. The values are given in table 19 on page 82.

[42] See paper 3.10, *Preliminary results of the pulping of some Brazilian tropical and sub-tropical hardwoods* by L. Rys and others.

[43] Commissioned from the Forest Products Laboratory, paper 3.13, *The use, in newsprint, of bleached cold soda pulps from certain mixtures of Latin American hardwoods.*

[44] Calculated at 10 per cent of the "mill investment", i.e., total capital requirement minus working capital investment in forest operations and capital costs during erection.

[45] "Project" investment refers to total capital requirements minus working capital and capital costs during building period.

Table 18

NOMINAL MARKET VALUES

Used as basis for comparison with "gross sales values" of pulp and paper from the hypothetical mills in Yucatán and Amapá

(dollars per ton)

	Unbleached pulp	*Bleached pulp*	*Unbleached paper*	*Bleached paper*
For the Yucatan project				
"Net sales value" from 200-ton hypothetical mill in Sweden	88.70	104.80	128.10	146.40
Profit, 10 per cent on mill investment	18.00	21.60	32.50	35.80
Freight from Sweden to Veracruz	18.00	18.00	22.00	22.00
C.I.F.-VALUE	124.70	144.40	182.60	204.20
"Nominal" import duty, 15 per cent on c.i.f.-value	18.70	21.70	27.40	30.60
Deduction for quality difference, 10 per cent	14.30	16.60	21.00	23.50
NOMINAL MARKET VALUE	129.10	149.50	189.00	211.30
For the Amapá project				
"Net sales value" from 200-ton hypothetical mill in Sweden	88.70	104.80	128.10	146.40
Profit, 10 per cent on mill investment	18.00	21.60	32.50	35.80
Freight from Sweden to Rio de Janeiro	20.00	20.00	24.00	24.00
C.I.F.-VALUE	126.70	146.40	184.60	206.20
"Nominal" import duty, 15 per cent on c.i.f.-value	19.00	22.00	27.70	30.90
Deduction for quality difference, 10 per cent	14.60	16.80	21.20	23.70
NOMINAL MARKET VALUE	131.10	151.60	191.10	213.40

Table 19

GROSS SALES VALUES

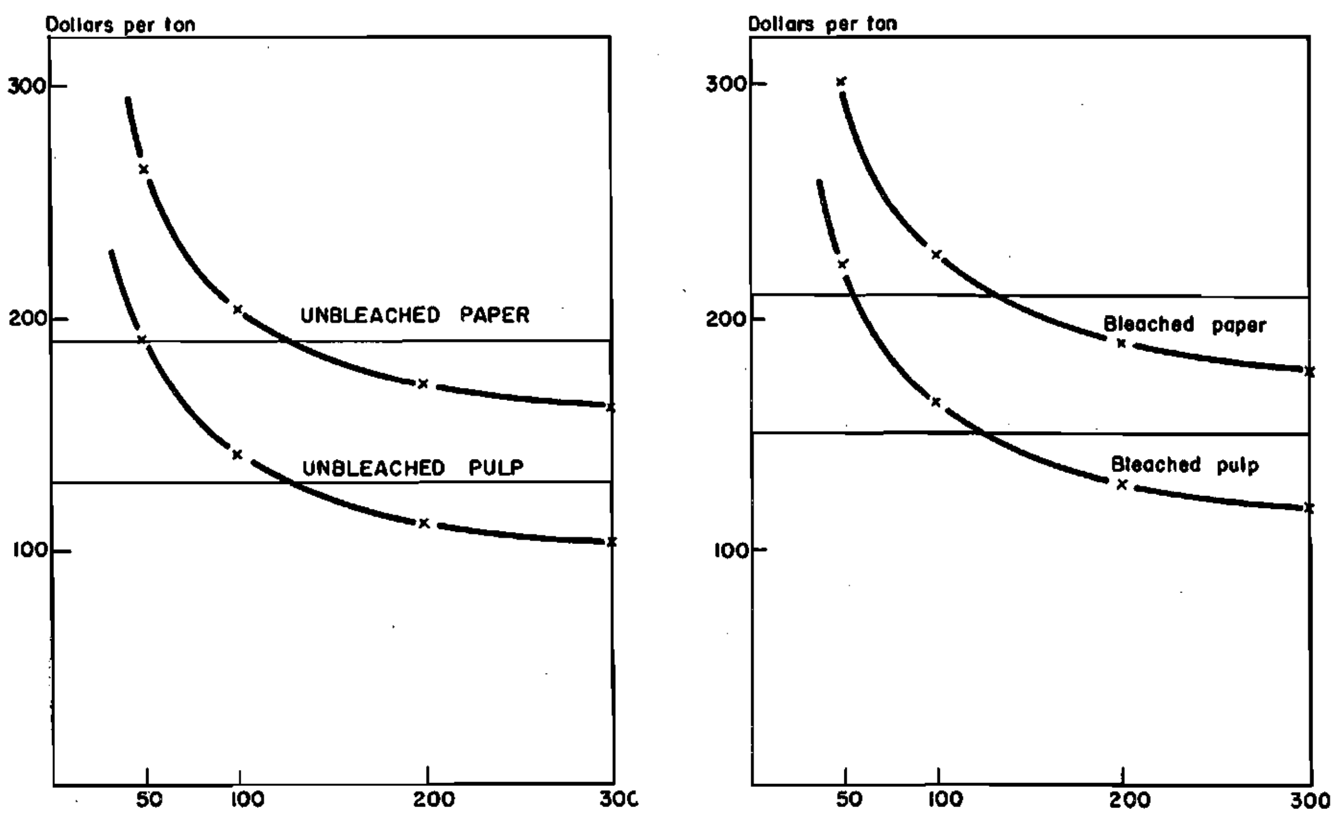
PULP AND PAPER FROM HYPOTHETICAL MILLS IN YUCATÁN AND AMAPÁ

(dollars per ton)

	Mill size, tons per day							
	50		*100*		*200*		*300*	
	Unbleached	*Bleached*	*Unbleached*	*Bleached*	*Unbleached*	*Bleached*	*Unbleached*	*Bleached*
Yucatán project								
Pulp: "Net sales value" at mill	124.20	146.20	92.10	107.30	73.80	85.30	68.20	79.70
Profit, 10 per cent on "project" investment	56.90	67.90	39.50	46.40	28.80	33.30	26.10	30.00
Freight to Veracruz	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
GROSS SALES VALUE	191.10	224.10	141.60	163.70	112.60	128.60	104.30	119.70
Paper: "Net sales value" at mill	178.80	200.70	136.80	153.00	115.00	128.50	108.10	120.50
Profit, 10 per cent on "project" investment	77.50	88.30	55.80	62.90	44.70	50.00	41.10	46.00
Freight to Veracruz	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
GROSS SALES VALUE	268.30	301.00	204.60	227.90	171.70	190.50	161.20	178.50
Amapá project								
Pulp: "Net sales value" at mill	164.00	196.70	122.60	147.40	99.70	119.80	94.50	113.70
Profit, 10 per cent on "project" investment	65.00	78.90	44.20	52.60	32.10	37.70	29.50	34.30
Freight to Rio de Janeiro	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
GROSS SALES VALUE	244.00	290.60	181.80	215.00	146.80	172.50	139.00	163.00
Paper: "Net sales value" at mill	235.90	269.80	184.40	210.10	158.70	180.30	150.10	170.30
Profit, 10 per cent on "project" investment	84.80	97.90	60.30	69.00	48.30	54.80	44.00	48.10
Freight to Rio de Janeiro	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
GROSS SALES VALUE	338.70	385.70	262.70	297.10	225.00	253.10	212.10	236.40

Chart I

YUCATÁN PROJECT: COMPARISON OF "GROSS SALES VALUES" WITH "NOMINAL MARKET VALUES"



Mill size, tons per day

Horizontal lines indicate "nominal market values"

In order to facilitate a comparison between tables 18 and 19, the results are presented in graphical form and the charts are referred to below:

The assessments

Yucatán

As will be seen from chart I, the hyperbolic curves of "gross sales value" in the Yucatán mill intersect the line representing the "nominal market value" at a point corresponding to a mill size of 120 tons per day or 36,000 tons per year. Furthermore the intersect point is on the fairly steep slope of the curve and an increase of mill size to 200 tons per day, for instance, will give an appreciable additional profit.

It may therefore be concluded that—judged according to the criteria of comparison used in this study—the Yucatán mill project is economically feasible and attractive provided that market considerations allow for the installation of a mill of larger capacity than 120 tons per day.

To exemplify this conclusion, some calculations relating to an integrated project with a mixed production programme are presented below. This project, which is the same as shown in paper 3.03, has been arbitrarily chosen, without any particular study of actual marketing possibilities, and is presented only by way of illustration.

The following production and sales programme is assumed:

	Production, tons/year	*Sales volume, tons/year*
Unbleached pulp	15,000	8,600
Bleached pulp	30,000	14,200
Unbleached paper	6,000	6,000
Bleached paper	15,000	15,000

The sales quantities have been determined on the assumption that the paper production is based entirely on chemical pulp; one ton of paper/1.06 tons of chemical pulp.

Total capital requirement is calculated at $24.8 million (using the straight line relationship explained in paper 3.03). "Project investments"—used to calculate "nominal profit" over and above the interest charges—are estimated in the same way as follows:

	Million dollars
Investment for unbleached pulp production	14.5
Investment for bleaching department	2.1
Investment for paper-mill section	4.0
TOTAL "NET INVESTMENT"	20.6

On the basis of the hyperbolic cost functions, the production costs of the different products have been calculated in paper 3.03. Using these cost figures it is possible to estimate the "gross sales values" and to compare them with the normal market values in order to determine the economic viability of the scheme:

Table 20

AN EXAMPLE OF COST AND SALES DATA FOR AN INTEGRATED MILL IN YUCATÁN

(*dollars*)

	Unbleached pulp	*Bleached pulp*	*Unbleached paper*	*Bleached paper*
Mill net cost	78.80	93.80	127.10	142.60
Sales expenses (estimated)	2.00	2.00	3.20	3.20
Profit 10 per cent on "project investment"				
Pulp section	32.20	32.20	32.20	32.20
Bleaching department	—	7.00	—	7.00
Paper-mill section	—	—	19.00	19.00
Freight to Veracruz	10.00	10.00	12.00	12.00
Gross sales value	123.00	145.00	193.50	216.00
"Nominal market value"	129.10	149.50	189.00	211.30
Difference per ton	+6.10	+4.50	−4.50	−4.70
Annual difference	+52,500	63,900	−27,000	−70,500
TOTAL ANNUAL DIFFERENCE[a]		+18,900		

[a] Note: this calculation includes 8 per cent on project investment *and* 10 per cent profit. Moreover, the mill size chosen is slightly above (for pulp) and considerably below (for paper) the "meeting point"—the intersection of the gross sales value curve with the "nominal market value" line.

These figures underline the two important conclusions reached in this study:

(*a*) The production of pulp and paper from mixed tropical woods in Yucatán (and in other areas where similar conditions prevail) is—judged on the basis of the criterion employed in this study—economically feasible in mill units of fairly limited size (larger than 35,000—40,000 tons);

(*b*) The integration of smaller size paper-mill sections with a larger pulp mill is economically possible.

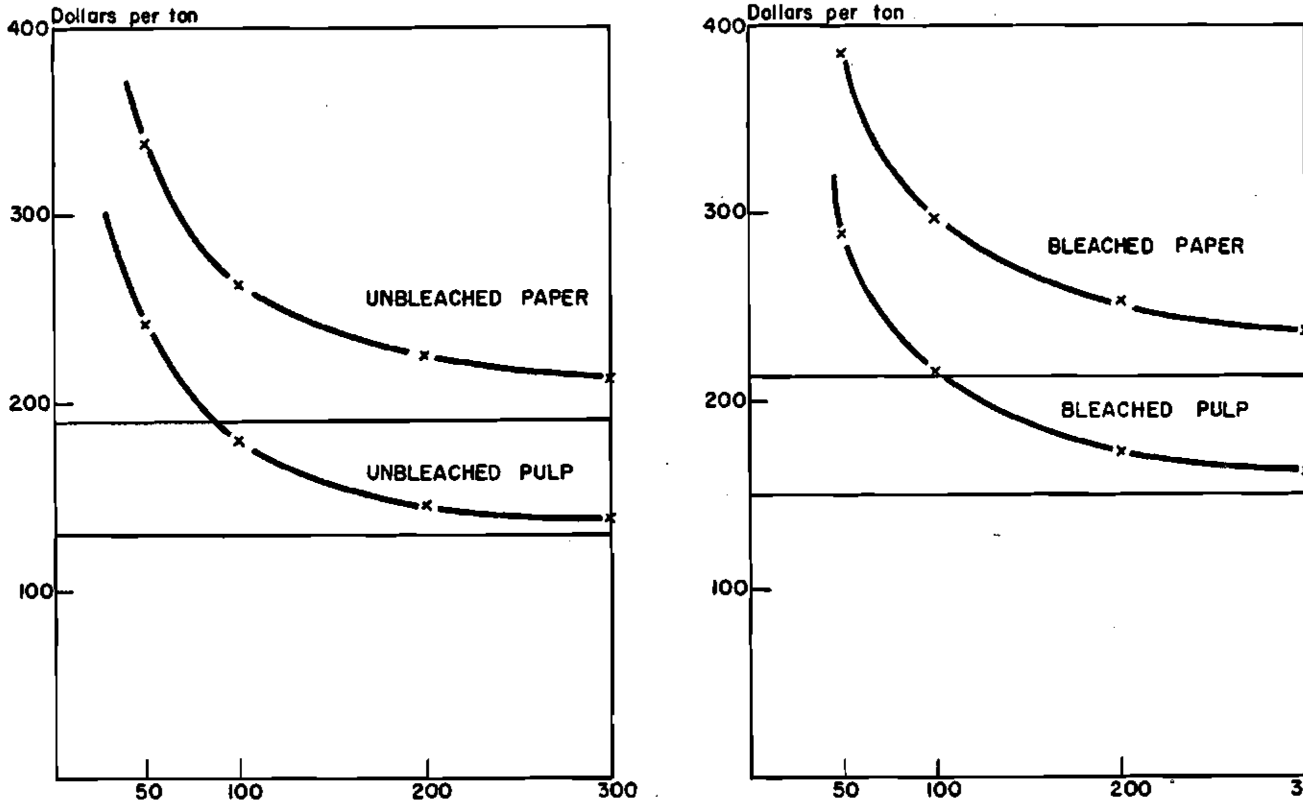
At the same time it must be emphasized that at this stage the project is still hypothetical; additional economic and technical investigation would be required before a final "go-ahead" order could be given. Moreover, the present study should be supplemented by a similar investigation of at least one alternative mill site, for instance near Chetumal, where conditions may be even more favourable than at Colonia Yucatán. Such a study should also include further tests and economic investigations concerning the possibility of producing groundwood-type pulps from low-density second growth species in the region.

Amapá

A comparison of the hyperbolic curves of gross sales value in the Amapá with the estimated "nominal market values" (see chart II) shows that, throughout the range of mill sizes investigated, production costs exceed "nominal market values" for both pulp and paper, for bleached and unbleached qualities. At the maximum mill size (90,000 tons), the excess falls to around $8-11 per ton for bleached and unbleached pulps, but the margin on both paper qualities is $21-23.

Chart II

AMAPÁ PROJECT: COMPARISON OF "GROSS SALES VALUES" WITH "NOMINAL MARKET VALUES"



Mill size, tons per day
Horizontal lines indicate "nominal market values"

This would suggest that, provided the various assumptions on which the estimates of production cost have been built up are sound, a project of the kind outlined cannot offer any financial attraction. It is true that in proceeding to these estimates every effort has been made to ensure that the most cautious view shall be taken. Indeed, the "safety margins" in the final figures may well exceed the differences just quoted. This, however, in no way modifies the conclusions reached, first—because for a smaller-sized mill—which is naturally a more realistic project in an undeveloped region when account is taken of marketing possibilities—the differences are greater than those quoted; and secondly, the "safety margins" must be retained in the estimates to offset any unforeseen expenditures or under-estimates.

This being said, however, it must be pointed out that there is at least one aspect of the Amapá production cost estimates which may be considered vulnerable. If closer investigation cast doubt on this particular assumption, the adoption of an alternative assumption might perhaps lead to a fairly considerable amendment in the estimated production costs, conceivably of a sufficient order of magnitude to warrant a reassessment of the project.

Nearly all the locally incurred costs in the Amapá project have been converted to dollars at the parity rate calculated by the Banco Nacional do Desenvolvimento Econômico, Brazil, namely, 32 cruzeiros to one dollar. The free market rate is 50-55 cruzeiros to the dollar. Now clearly the latter rate is not the appropriate one to apply in translating locally incurred costs. At the same time it is no easy matter to decide what is the appropriate rate to apply. But the application of any other rate would have a considerable effect on the final production cost. For example, if in the case of a 60,000-ton mill making bleached pulp, applying the free market rate instead of the parity rate would reduce labour costs (including the labour content of the pulpwood cost) by some $8 per ton; it would reduce the cost of local capital by $10 to $12; it would also affect, though to a minor extent, certain other items. The aggregate effect of all these changes could imply a reduction in the final dollar cost per ton of somewhere between $20 and $30. While the free market rate is not applicable, any rate intermediate between the free market rate and parity rate assumed would also imply a reduction, though a proportionately less reduction, in the final dollar cost per ton. And the reduction implied might necessitate a revision in the assessment made above.

The Territory of Amapá—because of its transport facilities and rapid economic development—seems, at first sight, to offer the best possibilities in the region for the development of a pulp and paper industry. In view of the heavy investments which would normally be required to establish the necessary transport means to a mill located elsewhere in the area—a disadvantage that could probably not be offset by lower labour costs, richer forests, etc.—the following conclusion seems inescapable. Since it is unlikely that a much more favourable location for a pulp and paper mill than Porto Platon could be found elsewhere in the lower Amazon region, it follows that—unless a reassessment of the Amapá project proves the present appraisal to be wrong—the whole area does not seem to offer attractive possibilities for the establishment of pulp and paper industries at the present time. In any case there is no doubt that a mill project—if at all feasible—must be a large-size unit, probably with a production capacity of at least 90,000 tons per year.

This may seem disappointing, and it should therefore again be emphasized that the assessment is *conditional* and that a different set of assumptions (parity rate, etc.) and another "standard" of comparison (different import duties, etc.) might well lead to a different conclusion.

In addition to the qualifications which have already been referred to, a new point of some importance emerged in the course of the Meeting's discussions on this item of the agenda. Representatives of both the FAO Forestry Mission in the Amazon and of the government of the Federal Territory of Amapá pointed out that the forest extraction scheme envisaged for the Amapá model (*a*) over-estimated the costs of wood extraction, and (*b*) assumed an excessive rotation period. If the assumptions made in arriving at cost estimates for the hypothetical Amapá mill were revised to take account of current experience in the Amazon region, a marked reduction in the "cost of pulpwood" item might ensue; this in itself might be of sufficient magnitude to justify a revision of the provisional assessment given above.

A final note of caution, however; any mill project in an undeveloped area, especially if it is based on a non-traditional raw material, needs not only careful analysis of all cost factors involved but also technical investigations, large-scale tests of raw materials, etc., all of which involve large expenses. This initial capital outlay is imperative, especially in the case of new processes or processing techniques. Moreover, because a large-scale pulp and paper mill calls for very heavy investment, the need to safeguard against possible failures makes a cautious —even extremely conservative—assessment advisable.

Table A1

YUCATÁN PROJECT

INVESTMENT: FOREST OPERATION

(thousand Mexican pesos)

	(Quantity of wood, tons per year)							
	60,000		*120,000*		*240,000*		*360,000*	
	Pulpwood	*Fuelwood*	*Pulpwood*	*Fuelwood*	*Pulpwood*	*Fuelwood*	*Pulpwood*	*Fuelwood*
General preparatory work.........	650	—	800	—	1,050	—	1,250	—
Primary roads....................	4,500	—	9,000	—	18,000	—	27,000	—
Equipment........................	3,000	2,095	5,420	4,190	10,665	8,700	17,300	14,060
Unforeseen and sundry expenses[a]...	725	145	1,355	290	2,645	600	4,025	975
Working capital[b]................	345	150	690	315	1,400	660	2,170	1,055
Housing..........................	4,790	1,885	9,410	3,755	18,665	7,440	27,925	11,160
TOTAL	14,010	4,275	26,675	8,550	52,425	17,400	79,670	27,250
Equivalent thousands of dollars..	1,121	342	2,134	684	4,194	1,392	6,374	2,180

[a] Including spare parts for various equipment.
[b] One month's production.

Table A2

YUCATÁN PROJECT

ESTIMATES OF EQUIPMENT REQUIREMENTS: FOREST OPERATION

(thousand Mexican pesos except where otherwise stated)[a]

	Quantity of wood (tons per year)							
	60,000		120,000		240,000		360,000	
	Pulpwood	Fuelwood	Pulpwood	Fuelwood	Pulpwood	Fuelwood	Pulpwood	Fuelwood
Secondary roads								
Grader	160 (1)	—	160 (1)	—	320 (2)	—	320 (2)	—
Crusher	100 (1)	—	200 (2)	—	300 (3)	—	500 (5)	—
D7	—	—	—	—	200 (2)	—	600 (3)	—
Clearance								
D4 with arch	700 (5)	700 (5)	1,400 (10)	1,400 (10)	2,800 (20)	2,800 (20)	4,200 (30)	4,200 (30)
Transport								
5-ton trucks with trailer	500 (5)	500 (5)	1,000 (10)	1,000 (10)	2,000 (20)	2,000 (20)	3,500 (35)	3,500 (35)
Splitting saw	200 (1)	—	200 (1)	—	200 (1)	200 (1)	400 (2)	400 (2)
Sundry vehicles	150 (5)	60 (2)	300 (10)	120 (4)	600 (20)	240 (8)	900 (30)	360 (12)
Sundry equipment (15 per cent)	270	190	490	380	960	780	1,560	1,270
SUB-TOTAL	2,080	1,450	3,750	2,900	7,380	6,020	11,980	9,730
Price increase due to change in rate of exchange	920	645	1,670	1,290	3,285	2,680	5,320	4,330
TOTAL	3,000	2,095	5,420	4,190	10,665	8,700	17,300	14,060
Equivalent thousands of dollars	240	168	434	335	853	696	1,384	1,125

[a] Figures in parentheses denote number of units required.

Table A3

YUCATÁN PROJECT

PERSONNEL: FOREST OPERATION

(thousand Mexican pesos except where otherwise stated)

	Salary per man	Quantity of wood (tons per year) 60,000 Pulpwood No.	Salaries	Fuelwood No.	Salaries	120,000 Pulpwood No.	Salaries	Fuelwood No.	Salaries	240,000 Pulpwood No.	Salaries	Fuelwood No.	Salaries	360,000 Pulpwood No.	Salaries	Fuelwood No.	Salaries
Central administration																	
Forest director	75	—	—	—	—	1	75	—	—	1	75	—	—	1	75	—	—
Assistant director	60	1	60	—	—	—	—	—	—	1	60	—	—	1	60	—	—
Administrative assistant	40	1	40	—	—	1	40	—	—	—	—	—	—	1	40	—	—
Foremen (cutting, delivery, checking)	15	2	30	1	15	2	30	1	15	3	45	1	15	4	60	2	30
Accountant	25	1	25	—	—	1	25	1	25	2	50	1	25	2	50	2	50
Clerks and typists	8	3	24	1	8	4	32	2	16	6	48	4	32	8	64	4	32
Messengers, etc.	3	2	6	2	6	4	12	2	6	5	15	4	12	6	18	5	15
		10	185	4	29	13	214	6	62	18	293	10	84	23	367	13	127
Field administration																	
Coupe managers	25	1	25	—	—	2	50	—	—	4	100	1	25	6	150	2	50
Yard foremen	18	5	90	1	18	10	180	2	36	20	360	3	54	30	540	5	90
Operation foremen	15	10	150	2	30	20	300	4	60	40	600	7	105	60	900	10	150
Accountant	15	1	15	—	—	2	30	—	—	4	60	—	—	6	90	—	—
Clerks	8	4	32	2	16	8	64	4	32	16	128	8	64	24	192	12	96
		21	312	5	64	42	624	10	128	84	1,248	19	248	126	1,872	29	386
Field personnel																	
Skilled workers (drivers, etc.)	6	65	390	16	96	130	780	32	192	260	1,560	64	384	390	2,340	96	576
Unskilled labour	4	320	1,280	150	600	640	2,560	300	1,200	1,280	5,120	600	2,400	1,920	10,240	900	3,600
		385	1,670	166	696	770	3,340	332	1,392	1,540	6,680	664	2,784	2,310	12,580	996	4,176
TOTAL		416	2,167	175	789	825	4,178	348	1,582	1,642	8,221	693	3,116	2,459	14,819	1,038	4,689
Equivalent thousands of dollars			173		63		334		127		658		249		1,186		375

Table A4

YUCATÁN PROJECT

HOUSING SCHEME: FOREST OPERATION

(*thousand Mexican pesos*)

	Unit cost per man	Quantity of wood (tons per year) 60,000 Pulpwood	60,000 Fuelwood	120,000 Pulpwood	120,000 Fuelwood	240,000 Pulpwood	240,000 Fuelwood	360,000 Pulpwood	360,000 Fuelwood
Central administration									
Forest director	50	—	—	50	—	50	—	50	—
Assistant director	40	40	—	—	—	40	—	40	—
Administrative assistant	35	35	—	35	—	—	—	35	—
Foremen (cutting, delivery, checking)	25	50	25	50	25	75	25	100	50
Accountant	25	25	—	25	25	50	25	50	50
Clerks and typists	15	45	15	60	30	90	60	120	60
Messengers, etc.	8	15	15	30	15	40	25	50	30
Field administration									
Coupe managers	25	25	—	50	—	100	25	150	50
Yard foremen	20	100	20	200	40	400	60	600	100
Operation foremen	20	200	40	400	80	800	140	1,200	200
Accountant	20	20	—	40	—	80	—	120	—
Clerks	15	60	30	120	60	240	120	360	180
Field personnel									
Skilled workers (drivers, etc.)	15	975	240	1,950	480	3,900	960	5,850	1,440
Unskilled labour	10	3,200	1,500	6,400	3,000	12,800	6,000	19,200	9,000
TOTAL		4,790	1,885	9,410	3,755	18,665	7,440	27,925	11,160
Equivalent thousands of dollars		383	151	753	300	1,493	595	2,234	893

Table A5

YUCATÁN PROJECT

COST OF WOOD

(*Mexican pesos per ton*)

	Quantity of wood (tons per year) 60,000 Pulpwood		60,000 Fuelwood		120,000 Pulpwood		120,000 Fuelwood		240,000 Pulpwood		240,000 Fuelwood		360,000 Pulpwood		360,000 Fuelwood	
Labour																
Unskilled labour	21.30		10.00		21.30		10.00		21.30		10.00		21.30		10.00	
Skilled workers	6.50		1.60		6.50		1.60		6.50		1.60		6.50		1.60	
Supervisory and general administrative personnel	8.30	36.10	1.55	13.15	7.00	34.80	1.58	13.18	6.45	34.25	1.38	12.98	6.25	34.05	1.42	13.02
Operational expenses																
Fuel, repairs and spare parts	6.20	6.20	4.55	4.55	6.70	6.70	5.40	5.40	7.85	7.85	6.45	6.45	9.20	9.20	7.90	7.90
Capital expenditure																
Amortization general investment	3.30		0.08		3.10		0.08		3.00		.08		3.00		0.09	
Amortization equipment	10.00		7.00		9.05		7.00		8.90		7.25		9.60		7.80	
Amortization housing	4.00		1.57		3.90		1.56		3.88		1.55		3.88		1.55	
Interest on investment capital	9.35		2.85		8.95		2.85		8.75		2.90		8.85		3.03	
Interest on working capital	0.46	27.11	0.20	11.70	0.46	25.46	0.21	11.70	0.47	25.00	0.22	12.00	0.48	25.81	0.23	12.70
TOTAL		69.41		29.40		66.96		30.28		67.10		31.43		69.06		33.62
Equivalent dollars		5.55		2.35		5.36		2.42		5.37		2.51		5.52		2.69

Chart A6

YUCATÁN PROJECT: COST OF PULPWOOD

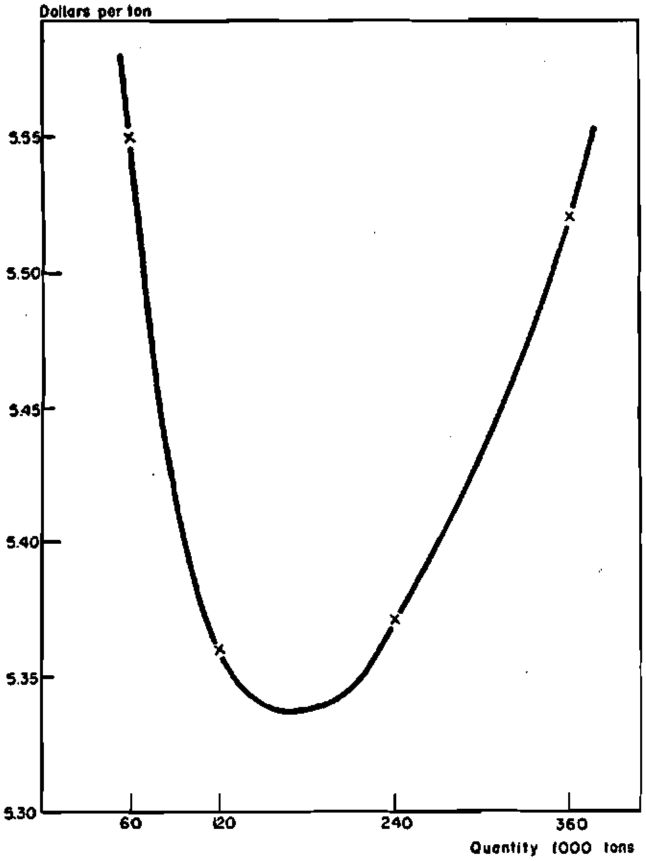
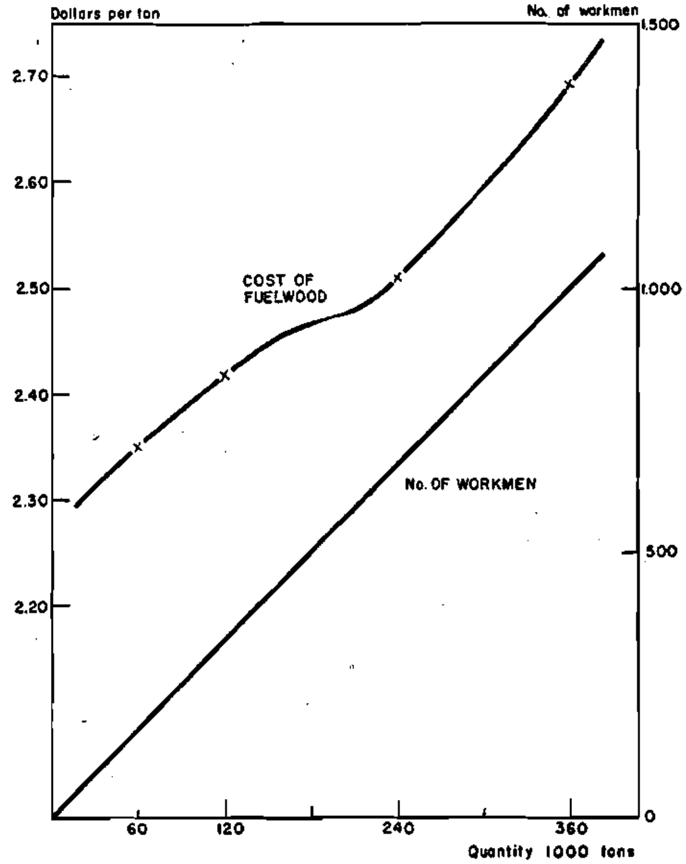


Chart A7

YUCATÁN PROJECT: COST OF FUELWOOD AND NUMBER OF WORKMEN FOR FUELWOOD EXTRACTION



A8

YUCATÁN PROJECT

Cost and supply possibilities of chemicals and fuel

1. *Limestone*

The whole of the Yucatán peninsula is formed by a stratum of limestone covering geological formations of older age. There would probably be no difficulty in finding limestone deposits of sufficient size and reasonably good quality in the vicinity of a mill site. For the purpose of this study it has been assumed that the transport distance would be a maximum of 20 km.

Estimated cost at mill site:	*Mexican pesos per ton*	*Dollars per ton*
Mining cost	25.00	2.00
Transport cost including loading	25.00	2.00
TOTAL COST AT MILL	50.00	4.00

2. *Lime*

A 50 ton/day mill producing unbleached pulp would buy quicklime in the open market. The price in Tizimin (40 km from Colonia) in February 1954 was 30 Mexican pesos per m³ (480 kg) (1 dollar= 8.65 Mex. pesos in February 1954).

Estimated cost at mill site:	*Mexican pesos per ton*	*Dollars per ton*
Price at Tizimin	62.50	7.25
Transport and loading costs	37.50[a]	3.00
TOTAL COST AT MILL	100.00	10.25

[a] 1 dollar = 12.50 Mex. pesos.

3. *Saltcake*

This is available in Mexico in various places, but production is not sufficient to cover the country's needs. Furthermore, the deposits are in the north-west of the country, which means that transportation would be difficult and costly. In February 1954, the price in Mexico City was about 450-500 Mexican pesos per ton, or $52-$58 at the exchange rate valid at that time.

For this "project" therefore, it has been assumed that saltcake would be imported from the United States.

Estimated cost at mill site:	*Mexican pesos per ton*	*Dollars per ton*
Price, f.o.b. New York (April 1954)	262.50	21.00
Freight New York to El Cuyo	250.00	20.00
Unloading and transport to mill	37.50	3.00
Import duty 15 per cent	40.00	3.20
TOTAL COST AT MILL	590.00	47.20

4. *Salt*

This is at present produced at Las Coloradas about 40 km from El Cuyo. The price (February 1954) in Colonia was 100 Mexican pesos per ton, or $11.50. It seems probable, however, that this price could be reduced for a large-scale operation. In the present study it has been reckoned that this price would be maintained.

	Mexican pesos per ton	*Dollars per ton*
Estimated cost at mill site	100.00	8.00

5. *Sulphur*

The probable source of supply for the Yucatán project would be the deposits at San Cristobal, on the eastern coast of the isthmus of Tehuantepec, where operations should begin in the middle of 1954 (200,000 tons/year). No information about price, however, was available, and therefore the calculations have been based on the price of imported sulphur, excluding import duties and expenses.

Estimated cost at mill site:	*Mexican pesos per ton*	*Dollars per ton*
Price, f.o.b. Gulf-ports (April 1954)	412.50	33.00
Freight, Gulf-port to El Cuyo	187.50	15.00
Unloading and transport to mill	37.50	3.00
TOTAL COST AT MILL	637.50	51.00

A8 (continued)

6. *Aluminium sulphate, china clay and barium sulphate*

Lacking sufficient information about local supply possibilities prices have been calculated on the basis of those prevailing for imported materials in April 1954. It seems probable, however, that kaolin as well as barium sulphate of reasonably good quality could be supplied from sources within the country.

Cost of paper-making chemicals[a]

		F.o.b. price	Freight US-El Cuyo	Freight El Cuyo-mill	Import duty 15%	Total cost of mill site
Aluminium sulphate	Dollars	46.00	20.00	3.00	7.00	76.00
	Mex. pesos	575.00	250.00	37.00	86.00	948.00
China clay	Dollars	16.00	20.00	3.00	2.40	41.40
	Mex. pesos	200.00	250.00	37.00	30.00	517.00
Barium sulphate	Dollars	60.00	20.00	3.00	9.00	92.00
	Mex. pesos	750.00	250.00	37.00	113.00	1,150.00

[a] All figures per metric ton.

7. *Rosin*

This is produced in Mexico. The estimated price (February 1954) in Mexico City was about 2,000 Mexican pesos per ton.

Estimated cost at mill site:	Mexican pesos per ton	Dollars per ton
Price in Mexico City	2,000	160.00
Estimated freight to Tizimin from Mexico City	200	16.00
Estimated freight Tizimin to Colonia	37.50	3.00
TOTAL COST AT MILL	2,237.50	179.00

8. *Fuel oil*

Price in February 1954 was 8.3 centavos per litre in Campeche, and 13.5 centavos in Colonia. These prices correspond to 95 and 145 Mexican pesos per ton or $11.50 and $16.70 respectively (1 dollar=8.65 Mex. pesos). It was estimated that by transporting larger quantities via El Cuyo the price in Colonia could be brought down to 108 Mexican pesos per ton.

	Mexican pesos per ton	Dollars per ton
Estimated cost at mill site	108.00	12.50

9. *Wood fuel*

See *Charts A6* and *A7* on page 89.

A9

YUCATÁN PROJECT

Consumption of chemicals pulp mill

For the production of unbleached pulp saltcake would be used as make-up chemical whereas in the case of bleached pulp make-up chemicals would be caustic soda (from an electrolytic plant at mill site) plus sulphur, which would be added to the white liquor. Estimated consumption of saltcake is 90 kg per ton of unbleached pulp. For bleached pulp the estimated consumption of processing and bleaching chemicals per ton is as follows:

	Caustic soda	Sulphur	Chlorine
	(all figures in kg)		
For digestion	70	23	—
For bleaching	20	2	70
TOTAL	90	25	70

Counting with a 90 per cent yield in the electrolytic plant this quantity of caustic soda corresponds *to 145 kg of NaC1* which would give a surplus of about 10 kg of chlorine which may be converted to hydrochloric acid. Alternatively the electrolytic plant might be dimensioned to suit the consumption of chlorine in which case about 18 kg of saltcake would be needed as additional make-up chemical. Consumption of sulphur would be reduced by 4 kg and salt by 15 kg.

All units would be equipped with rotary kilns for reburning of lime sludge except the 50 ton-day unit, which would purchase burnt lime in the open market. Consumption of limestone in the mills having reburning kilns is estimated at about 6 per cent of the dry feed to the kiln, corresponding to about 11-12 per cent of the actual lime consumption in the cooking process which is estimated at 260 kg. An additional 30 kg of lime would be required for bleaching.

Consequently the consumption of lime or limestone per ton of pulp would be as follows:

	Unbleached pulp	Bleached pulp
	(all figures in kg)	
Without reburning of lime	260 (lime)	290 (lime)
With reburning	30 (limestone)	90 (limestone)

SUMMARY

Total consumption of chemicals in tons per year for the various mill sizes would be as follows:

	Mill size							
	50 tons/day		100 tons/day		200 tons/day		300 tons/day	
	Unbleached	Bleached	Unbleached	Bleached	Unbleached	Bleached	Unbleached	Bleached
Saltcake	1,350	—	2,700	—	5,400	—	8,100	—
Lime	3,900	4,350	—	—	—	—	—	—
Limestone	—	—	900	2,700	1,800	5,400	2,700	8,100
Salt	—	2,200	—	4,350	—	8,700	—	13,000
Sulphur	—	380	—	750	—	1,500	—	2,250
TOTAL TONS/YEAR	5,250	6,930	3,600	7,800	7,200	15,600	10,800	23,350
or alternatively:								
Saltcake	—	270	—	540	—	1,080	—	1,620
Lime	—	4,350	—	—	—	—	—	—
Limestone	—	—	—	2,700	—	5,400	—	8,100
Salt	—	1,950	—	3,900	—	7,800	—	11,700
Sulphur	—	320	—	630	—	1,260	—	1,710
TOTAL TONS/YEAR	—	6,890	—	7,770	—	15,540	—	23,130

Table A10

YUCATÁN PROJECT

Reburning of Lime sludge

All cost figures in dollars per ton of burnt lime.
Calculations based on a production of 7,500 tons/year.

Item	*Quantity*	*Cost per unit*	*With fuel oil*	*With wood fuel*
Lime sludge	—	—	—	—
Limestone	110 kg	0.004	0.44	—
Limestone	165 kg	0.004	—	0.66
Fuel oil	200 kg	0.0125	2.50	—
Wood fuel	1.37 tons	2.50	—	3.43
Electric power	25 kWh	0.015	0.38	—
Electric power	40 kWh	0.015	—	0.60
Labour, man/hours	1.05	0.20	0.21	—
Labour, man/hours	3.15	0.20	—	0.63
Repair	—	—	0.50	1.00
Depreciation and interest (10 years, 8 per cent on $100,000 and $130,000 respectively)	—	—	1.73	2.25
		TOTAL COST PER TON OF LIME	5.76	8.57

Conclusions:

(*a*) For the Yucatán project an oil-fired kiln has been selected.

(*b*) It might also be worth while installing a reburning kiln in the case of the 50 tons/day pulp mill, as expected cost per ton of lime is about 5.76+1.75=$7.51 per ton compared with a market price of about $10.25.

Table A11

HEAT AND POWER BALANCE FOR PULP AND PAPER MILLS: AMAPÁ AND YUCATÁN

(All figures per ton of product)

	Bleeding pressure	*Pulp mills*				*Integrated paper mills*				*Non-integrated paper mills*			
		Unbleached		*Bleached*		*Unbleached*		*Bleached*		*Unbleached*		*Bleached*	
	kg/cm²	*1,000 kcal*	*kWh*	*1,000 kcal*	*kWh*	*1,000 kcal*	*kWh*	*1,000 kcal*	*kWh*	*1,000 kcal*	*kWh*	*1,000 kcal*	*kWh*
Heat for evaporation	2.6	750		750		750		750					
" " cooking	8.5	1,070		1,160		1,070		1,160					
" " bleaching	2.0			800				800					
" " drying	2.0	865		865		1,750		1,750		1,750		1,750	
" " miscellaneous	2.0	200		200		250		250		150		150	
Total power required			485		910		900		1,375		575		625
Turbine, bleeding		480	415	645	560	645	560	810	700	380	325	380	325
Turbine, condensing		180	70	910	350	880	340	1,750	675	650	250	780	300
TOTAL HEAT CONSUMPTION		3,545		5,330		5,345		7,270		2,930		3,060	
Produced by recovery unit		2,970		3,230		2,970		3,230		—		—	
Produced by fresh steam		575		2,100		2,375		4,040		2,930		3,060	
Additional fuel required [a]													
Fuel oil (kg)		70		265		300		510		370		385	
(or alternatively) Wood fuel (kg)		350		1,330		1,500		2,600					

[a] Excluding lime reburning.

Notes: Heat requirements are taken from papers 3.1 and 6.12 but evaporation heat is raised from 725,000 to 750,000 and the item "Miscellaneous" is added.

Table A12

YUCATÁN PROJECT

(thousand Mexico pesos, except where otherwise stated)

	Mill size															
	Administration and supervision personnel: pulp mill								*Administration and supervision: integrated mill*				*Administration and supervision personnel: non-integrated paper mill*			
	50 tons/day		*100 tons/day*		*200 tons/day*		*300 tons/day*		*50 tons/day*		*100 tons/day*		*50 tons/day*		*100 tons/day*	
	No.	*Total salaries /year*	*No.*	*Total salaries /year*	*No.*	*Total salaries /year*	*No.*	*Total salaries /year*	*No.*	*Total salaries /year*	*No.*	*Total salaries /year*	*No.*	*Total salaries /year*	*No.*	*Total salaries /year*
Managing director	1	85	1	95	1	110	1	120	1	85	1	85	1	85	1	95
Mill manager		—		—	1	75	1	80	1	70	1	70	1	70	1	70
Mill superintendent	1	50	1	55	1	60	1	70			1	50	1	50	1	55
Assistant mill superintendent		—		—	1	40	1	40	1	40	1	40				
Chief chemist	1	30	1	30	1	35	1	40	1	30	1	30	1	30	1	30
Superintendent workshops	1	30	1	30	2	60	2	70	2	70	2	70	1	35	2	60
Shift foremen	3	54	3	54	3	54	6	108	6	108	6	108	3	54	3	54
Foremen	4	60	4	60	5	84	6	99	5	75	6	90	4	60	4	60
Shift chemists	3	36	3	36	3	36	3	36	3	36	3	36				
Laboratory assistants	2	11	2	11	3	16	4	22	2	11	3	17	2	11	2	11
Draftsmen	1	15	2	30	3	45	4	60	2	30	3	45	1	15	2	30
Secretary	1	30	1	30	1	35	1	40	1	30	1	30	1	30	1	30
Chief accountant	1	25	1	25	1	30	1	35	1	25	1	25	1	25	1	25
Office clerks and typist	5	40	8	64	10	75	12	90	6	48	10	80	5	40	8	64
Storekeeper	1	15	1	15	1	18	1	18	1	12	1	12	1	12	1	12
Assistant storekeepers and clerks	2	16	2	16	3	24	4	30	2	16	3	24	2	16	2	16
Porters	3	12	3	12	3	12	3	12	3	12	3	12	3	12	3	12
Messengers	2	6	2	6	3	9	4	12	3	9	4	12	2	6	3	9
TOTAL ANNUAL SALARIES: MEX. PESOS	(32)	515	(36)	569	(46)	818	(56)	982	(41)	707	(51)	836	(30)	551	(36)	633
Equivalent thousands of dollars		41.2		45.5		65.4		78.6		56.6		66.9		44.1		50.6

Table A13

YUCATÁN PROJECT

NUMBER OF WORKMEN: PULP MILL

	Mill size															
	Per 8 hours								*Per day*							
	50 tons		*100 tons*		*200 tons*		*300 tons*		*50 tons*		*100 tons*		*200 tons*		*300 tons*	
	Unbl.	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*
Log yard	6	6	6	6	8	8	10	10	12	12	12	12	16	16	20	20
Wood prep. dept.	3	4	4	5	4	8	5	10	6	8	8	10	8	16	10	20
Digester dept.	3	3	3	3	3	3	4	4	9	9	9	9	9	9	12	12
Diffuser dept.	1	1	1	1	2	2	3	3	3	3	3	3	6	6	9	9
First screening dept.	1	1	2	2	3	3	4	4	3	3	6	6	9	9	12	12
Bleaching dept.	—	1	—	1	—	1	—	1	—	3	—	3	—	3	—	3
Electrolytic plant and bleach liquor dept.	—	4	—	5	—	6	—	8	—	12	—	15	—	18	—	24
Second screening dept.	—	1	—	1	—	1	—	1	—	3	—	3	—	3	—	3
Pulp drying machine	4	4	5	5	8	8	12	12	12	12	15	15	24	24	36	36
Pulp store	2	2	3	3	4	4	4	4	6	6	9	9	12	12	12	12
Causticizing dept.	1	1	2	2	2	2	3	3	3	3	6	6	6	6	9	9
Evaporation plant	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
Soda recovery	3	3	3	3	3	3	5	5	9	9	9	9	9	9	15	15
Lime recovery and transport	1	1	1	1	1	1	2	2	3	3	3	3	3	3	6	6
Chemical stores	—	—	—	—	—	—	—	—	2	4	1	2	1	2	1	2
Water purification and pump station	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
General service	—	—	—	—	—	—	—	—	8	10	12	15	16	20	20	25
Transport workers	—	—	—	—	—	—	—	—	10	10	15	15	20	20	25	25
Repair shop	—	—	—	—	—	—	—	—	20	23	25	28	30	34	35	40
Boiler house	2	2	2	2	3	3	3	3	6	6	6	6	9	9	9	9
Power house	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
TOTAL									121	148	148	178	187	228	240	291
No. skilled workmen ex total									50	61	56	66	62	72	69	87
Annual salaries:																
(Skilled labour 6,000 pesos)								Thousand pesos	584	714	702	844	870	1,052	1,098	1,338
(Unskilled labour 4,000 pesos)								Thousand dollars	46.7	57.1	56.2	67.5	69.6	84.2	87.8	107.0

Table A14

YUCATÁN PROJECT

NUMBER OF WORKMEN: INTEGRATED MILL

	Mill size							
	Per 8 hours				*Per day*			
	50 tons/day		*100 tons/day*		*50 tons/day*		*100 tons/day*	
	Unbleached	*Bleached*	*Unbleached*	*Bleached*	*Unbleached*	*Bleached*	*Unbleached*	*Bleached*
Log yard	6	6	6	6	12	12	12	12
Wood prep. dept.	3	4	4	5	6	8	8	10
Digester dept.	3	3	3	3	9	9	9	9
Diffuser dept.	1	1	1	1	3	3	3	3
First screen dept.	1	1	2	2	3	3	6	6
Bleaching dept.	—	1	—	1	—	3	—	3
Electrolytic plant and bleach liq. prep.	—	4	—	5	—	12	—	15
Second screen dept.	—	1	—	1	—	3	—	3
Causticizing dept. and lime kiln	1	1	2	2	3	3	6	6
Evaporation plant	1	1	1	1	3	3	3	3
Soda recovery	3	3	3	3	9	9	9	9
Chemical stores	—	—	—	—	2	4	2	4
Beater room	1	1	2	2	3	3	6	6
Size prep. dept.	1	1	2	2	3	3	6	6
Paper machine	6	9	6	9	18	18	27	27
Re-reelers	3	3	6	6	9	9	18	18
Duplex cutter	2	2	4	4	4	4	8	8
Balers	—	—	—	—	4	4	6	6
Reel packers	—	—	—	—	3	3	6	6
Re-reelers for small reels	—	—	—	—	1	1	2	2
Sorters	—	—	—	—	25	25	40	40
Transport workers	—	—	—	—	20	20	30	30
Water purification plant and pump station	1	1	1	1	3	3	3	3
Oilers	1	1	2	2	3	3	6	6
Miscellaneous	—	—	—	—	10	10	14	14
Boiler house	2	2	2	2	6	6	6	6
Power house	1	1	1	1	3	3	3	3
Repair shop	—	—	—	—	30	33	40	45
TOTAL					195	220	279	309
No. skilled workmen ex total					83	96	106	119
Annual salaries: (Skilled 6,000 pesos) (Unskilled 4,000 pesos) (Sorters 3,000 pesos)				Thousand pesos	921	1,047	1,288	1,430
				Thousand dollars	73.7	83.8	103	114

Table A15

YUCATÁN PROJECT

NUMBER OF WORKMEN: NON-INTEGRATED PAPER MILL

	Mill size			
	Per 8 hours		*Per day*	
	50 tons/day	*100 tons/day*	*50 tons/day*	*100 tons/day*
Pulp store	—	—	4	5
Bale pulping	1	2	3	6
Beater dept.	1	2	3	6
Size prep. dept.	1	2	3	6
Paper machine	6	9	18	27
Reelers	3	6	9	18
Duplex cutter	2	4	4	8
Balers	—	—	4	6
Reel packers	—	—	3	6
Re-reelers for small reels	—	—	1	2
Sorters	—	—	25	40
Transport workers	—	—	12	18
Water purification plant and pump station	1	1	3	3
Oilers	1	2	3	6
Miscellaneous work	—	—	9	12
Boiler house	2	2	6	6
Power house	1	1	3	3
Repair shop	—	—	20	25
TOTAL			133	203
No. skilled workmen ex total			60	78
Annual salaries: (Skilled 6,000 pesos) (Unskilled 4,000 pesos) (Sorters 3,000 pesos)		Thousand pesos	625	928
		Thousand dollars	50.0	74.2

Table A16

YUCATÁN PROJECT

MEXICAN PESOS PER TON OF PULP

	Labour cost per ton of unbleached pulp								*Labour cost per ton of bleached pulp*							
	Mill size								*Mill size*							
	50 tons/day		*100 tons/day*		*200 tons/day*		*300 tons/day*		*50 tons/day*		*100 tons/day*		*200 tons/day*		*300 tons/day*	
Operating																
Skilled	31	12.40	35	7.00	38	3.80	43	2.87	42	16.80	45	9.00	48	4.80	58	3.87
Unskilled	38	10.12	48	6.40	67	4.47	101	4.50	47	12.50	61	8.13	89	5.95	126	5.68
TOTAL	69	22.52	83	13.40	105	8.27	144	7.37	89	29.30	106	17.13	137	10.75	184	9.55
Man hrs	11.04		6.64		4.20		3.84		14.24		8.48		5.48		4.91	
Mill services																
Skilled	9	3.60	9	1.80	9	0.90	9	0.45	9	3.60	9	1.80	9	0.90	9	0.45
Unskilled	23	6.14	31	4.13	43	2.87	52	2.31	27	7.18	35	4.66	48	3.20	58	2.57
TOTAL	32	9.74	40	5.93	52	3.77	61	2.76	36	10.78	44	6.46	57	4.10	67	3.02
Man hrs	5.12		3.20		2.08		1.63		5.76		3.52		2.28		1.79	
Repair																
Skilled	10	4.00	12	2.40	15	1.50	17	1.13	10	4.00	12	2.40	15	1.50	20	1.33
Unskilled	10	2.67	13	1.73	15	1.00	18	0.80	13	3.47	16	2.13	19	1.26	20	0.89
TOTAL	20	6.67	25	4.13	30	2.50	35	1.93	23	7.47	28	4.53	34	2.76	40	2.22
Man hrs	3.20		2.00		1.20		0.93		3.68		2.24		1.36		1.07	
TOTAL	121	38.93	148	23.46	187	14.54	240	12.06	148	47.55	178	28.12	228	17.61	291	14.79
Man hrs	19.3		11.8		7.5		6.3		23.7		14.4		9.2		7.8	
Equivalent dollars		3.11		1.88		1.16		0.96		3.80		2.25		1.41		1.18

1 dollar = Mex. pesos 12.50.

Table A17

YUCATÁN PROJECT

LABOUR COST PER TON OF PAPER

(Cost figures in Mexican Pesos per ton of paper)

	Mill size											
	Non-integrated mill				*Integrated mill—Unbleached*				*Integrated mill—Bleached*			
	50 tons/day		*100 tons/day*		*50 tons/day*		*100 tons/day*		*50 tons/day*		*100 tons/day*	
	No.	*Cost*	*No.*	*Cost*	*No.*	*Cost*	*No.*	*Cost*	*No.*	*Cost*	*No.*	*Cost*
Operating												
Pulp section:												
Skilled	—	—	—	—	24	9.60	27	5.40	36	14.40	39	7.80
Unskilled	—	—	—	—	24	6.36	29	3.85	32	8.50	40	5.33
Paper section:												
Skilled	38	15.20	56	11.20	32	12.80	45	9.00	32	12.80	45	9.00
Unskilled	17	4.52	39	5.18	16	4.25	39	5.18	16	4.25	39	5.18
Sorters	22	4.40	35	3.50	22	4.40	35	3.50	22	4.40	35	3.50
TOTAL	77	24.12	130	19.88	118	37.41	175	26.93	138	44.35	198	30.81
Man hrs	12.32		10.40		18.88		14.00		22.08		15.84	
Mill services												
Skilled	12	4.80	12	2.40	12	4.80	15	3.00	12	4.80	15	3.00
Unskilled	24	6.38	36	4.78	35	9.30	49	6.53	37	9.85	51	6.80
TOTAL	36	11.18	48	7.18	47	14.10	64	9.53	49	14.65	66	9.80
Man hrs	5.76		3.84		7.52		5.12		7.84		5.28	
Repair												
Skilled	10	4.00	10	2.00	15	6.00	19	3.80	16	6.40	20	4.00
Unskilled	10	2.66	15	2.00	15	4.00	21	2.80	17	4.53	25	3.33
TOTAL	20	6.66	25	4.00	30	10.00	40	6.60	33	10.93	45	7.33
Man hrs	3.20		2.00		4.80		3.[illegible]		5.28		[illegible].60	
TOTAL	133	41.96	203	31.06	195	61.51	279	43.06	220	69.93	309	47.94
Man hrs/ton	21.3		16.2		31.2		22.3		35.1		24.7	
Equivalent dollars		3.36		2.48		4.92		3.44		5.59		3.84

1 dollar = Mex. pesos 12.50.

Table A18

YUCATÁN PROJECT

HOUSING PROJECT: PULP MILL

(*thousand Mexican pesos except where otherwise stated*)

	Unit cost per man	Mill size: 50 tons/day Unbl.	50 tons/day Bl.	100 tons/day Unbl.	100 tons/day Bl.	200 tons/day Unbl.	200 tons/day Bl.	300 tons/day Unbl.	300 tons/day Bl.
Managing director	70	70	70	70	70	70	70	70	70
Mill manager	50	—	—	—	—	50	50	50	50
Mill superintendent	40	40	40	40	40	40	40	40	40
Assistant superintendent	35	—	—	—	—	35	35	35	35
Chief chemist	35	35	35	35	35	35	35	35	35
Superintendent workshop	30	30	30	30	30	60	60	60	60
Foremen	25	175	175	175	175	200	200	300	300
Shift chemist, laboratory assistant and draftsmen	15	90	90	105	105	135	135	165	165
Secretary	35	35	35	35	35	35	35	35	35
Chief accountant	30	30	30	30	30	30	30	30	30
Office clerks and typists	15	75	75	120	120	150	150	180	180
Storekeepers, assistant storekeepers and clerks	15	45	45	45	45	60	60	75	75
Porters and messengers	8	40	40	40	40	50	50	55	55
Sub-total: administration and supervising personnel	—	665	665	725	725	950	950	1,130	1,130
Skilled workmen	20	1,000	1,220	1,120	1,320	1,240	1,440	1,380	1,740
Unskilled workmen	12	852	1,044	1,104	1,344	1,500	1,872	2,052	2,448
TOTAL	—	2,517	2,929	2,949	3,389	3,690	4,262	4,562	5,318
Equivalent thousand dollars	—	201	234	236	271	295	341	365	425

Table A19

YUCATÁN PROJECT

HOUSING PROJECT: INTEGRATED MILL

(*thousand Mexican pesos, except where otherwise stated*)

	Unit cost	Mill size: 50 tons/day Unbl. No.	50 tons/day Unbl. Total	50 tons/day Bl. No.	50 tons/day Bl. Total	100 tons/day Unbl. No.	100 tons/day Unbl. Total	100 tons/day Bl. No.	100 tons/day Bl. Total
Managing director	70	1	70	1	70	1	70	1	70
Mill manager	50	1	50	1	50	1	50	1	50
Mill superintendent	40		—		—	1	40	1	40
Assistant mill superintendent	35	1	35	1	35	1	35	1	35
Chief chemist	35	1	35	1	35	1	35	1	35
Superintendent mechanical workshop	30	1	30	1	30	1	30	1	30
Superintendent electrical workshop	30	1	30	1	30	1	30	1	30
Foremen	25	11	275	11	275	12	300	12	300
Shift chemists	15	3	45	3	45	3	45	3	45
Laboratory assistants and draftsmen	15	4	60	4	60	6	90	6	90
Secretary	35	1	35	1	35	1	35	1	35
Chief accountant	30	1	30	1	30	1	30	1	30
Office clerks, typists, storekeepers, etc.	15	9	135	9	135	14	210	14	210
Porters and messengers	8	6	50	6	50	7	55	7	55
Sub-total: administration and supervision personnel	—	—	880	—	880	—	1,055	—	1,055
Skilled workmen	20	83	1,700	96	1,920	106	2,120	119	2,380
Unskilled workmen	12	90	1,080	102	1,224	138	1,656	155	1,860
Sorters	—	22	—	22	—	35	—	35	—
TOTAL	—	—	3,620	—	4,024	—	4,831	—	5,295
Equivalent thousand dollars	—	—	290	—	322	—	386	—	424

Table A19 (continued)

HOUSING PROJECT: NON-INTEGRATED PAPER MILL

	Unit cost	Mill size: 50 tons/day No.	Total	100 tons/day No.	Total
Managing director	70	1	70	1	70
Mill manager	50	1	50	1	50
Mill superintendent	40	1	40	1	40
Chief chemist	35	1	35	1	35
Superintendent workshops	30	1	30	2	60
Shift foremen	25	3	75	3	75
Foreman, finishing dept.	25	1	25	1	25
Foremen, workshops and transport	25	3	75	3	75
Laboratory assistants and draftsmen	15	3	45	4	60
Secretary	35	1	35	1	35
Chief accountant	30	1	30	1	30
Office clerks and typists	15	5	75	8	120
Storekeeper, assistant storekeepers and clerks	15	3	45	3	45
Porters and messengers	8	5	40	6	50
Sub-total, administration and supervision personnel	—	—	670	—	770
Skilled workmen	20	60	1,200	78	1,560
Unskilled workmen	12	51	612	90	1,080
Sorters	—	22	—	35	—
TOTAL: Paper mill	—	—	2,482	—	3,410
Equivalent thousand dollars	—	—	199	—	273

Table A20

YUCATÁN PROJECT

GENERAL COMMUNITY EXPENSES

The following are estimates only, and based on the assumption that for every 1,000 inhabitants of the community, 200 will be actually employed in forest or mill services. Housing projects for these workmen are calculated separately and charged to the mill and the forest department respectively.

INVESTMENT COSTS

(*Investment figures in thousands of dollars*)

	Number of inhabitants: 1,000	2,000	4,000	8,000	16,000
Community roads, parks, etc.	90	160	280	520	900
Housing for teachers, doctors and workmen	16	32	60	110	185
Schools	8	16	30	50	80
Hospital (15 beds/1,000)	10	20	35	60	70
Amusement facilities	20	40	70	120	200
Shops, restaurants, etc.	10	20	35	60	70
Water system	6	12	20	35	60
Electricity	14	25	45	80	150
Contingencies	16	25	45	85	135
TOTAL INVESTMENT	190	350	620	1,120	1,850

ANNUAL CAPITAL COSTS

Dollars

	Number of inhabitants: 1,000	2,000	4,000	8,000	16,000
Depreciation, community roads, etc.	3,000	5,400	9,500	19,500	30,000
Depreciation, houses, schools, hospitals, shops, restaurants, etc.	3,200	6,400	11,500	20,000	30,000
Depreciation, water system, power plant	2,000	3,700	6,500	11,500	21,000
Total depreciation	8,200	15,500	27,500	51,000	81,000
Interest, 8 per cent, first year	15,200	28,000	49,600	89,600	148,000
Interest, average	7,600	14,000	24,800	44,800	74,000
TOTAL AVERAGE COST	15,800	29,500	52,300	95,800	155,000

Table A20 (continued)

ANNUAL OPERATING EXPENSES

Dollars

	Number of inhabitants				
	1,000	*2,000*	*4,000*	*8,000*	*16,000*
Repairs of roads, parks, etc.	2,300	4,000	7,000	13,000	22,000
Repairs of schools, hospitals, etc.	1,400	2,900	5,000	8,700	12,500
Electricity supply	3,500	6,500	12,500	22,000	42,000
Water	500	1,000	1,800	3,400	6,500
Salaries, teachers, doctors, etc.	13,000	26,000	49,000	92,000	160,000
Contingencies	2,300	4,000	6,700	12,900	22,000
TOTAL	23,000	44,400	82,000	152,000	265,000
TOTAL ANNUAL COSTS	38,800	73,900	134,300	247,800	420,000

COMMUNITY EXPENSES PER TON OF PRODUCT

	Capacity tons/day	*No. of workmen*	*Total inhabitants*	*Annual expenses (thousand dollars)*	*Dollars per ton*
Pulp mill, unbleached	50	600	3,000	102	6.80
Pulp mill, unbleached	100	1,100	5,500	165	5.50
Pulp mill, unbleached	200	2,030	10,150	303	5.05
Pulp mill, unbleached	300	2,960	14,800	400	4.45
Pulp mill, bleached	50	700	3,500	117	7.80
Pulp mill, bleached	100	1,200	6,000	192	6.40
Pulp mill, bleached	200	2,250	11,250	328	5.45
Pulp mill, bleached	300	3,280	16,400	425	4.70
Integrated mill, unbleached	50	710	3,550	125	8.35
Integrated mill, unbleached	100	1,290	6,450	205	6.85
Integrated mill, bleached	50	810	4,050	137	9.15
Integrated mill, bleached	100	1,460	7,300	230	7.65
Non-integrated paper mill[a]	50	165	825	—	—
Non-integrated paper mill	100	240	1,200	—	—

[a] Non-integrated paper mill should be established near main consuming centres, where community facilities are already established.

Note: Number of workmen include forest operations, administration and supervision personnel, etc.

Chart A21

YUCATÁN PROJECT: GENERAL COMMUNITY EXPENSES

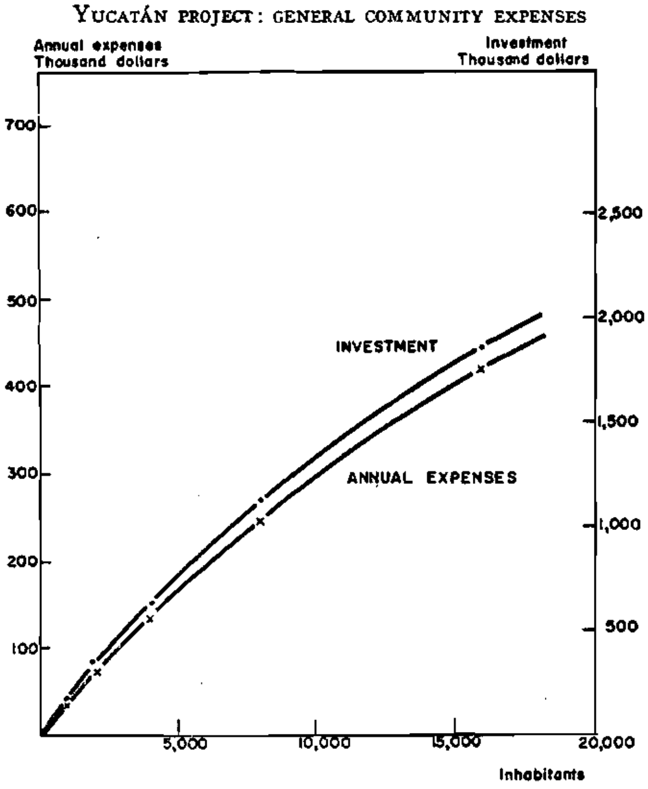


Table A22

YUCATÁN PROJECT

INVESTMENTS, PULP MILL

(thousand dollars)

	Mill size							
	50 tons/day		*100 tons/day*		*200 tons/day*		*300 tons/day*	
	Unbleached	*Bleached*	*Unbleached*	*Bleached*	*Unbleached*	*Bleached*	*Unbleached*	*Bleached*
1. Log yard	100	100	115	115	125	125	230	230
2. Wood prep. dept. and chip silos	310	310	435	435	540	540	735	735
3. Digester and diffuser depts	380	380	435	435	690	690	965	965
4. First screening dept	205	205	355	355	510	510	660	660
5. Bleaching dept	—	250	—	360	—	470	—	580
6. Electrolytic plant and bleach liq. prep	—	525	—	640	—	735	—	830
7. Salt store	—	4	—	5	—	6	—	7
8. Second screening dept	—	77	—	120	—	160	—	212
9. Pulp drying machine dept	275	275	450	450	825	825	1,190	1,190
10. Pulp store	12	12	15	15	17	17	19	19
11. Evaporation plant and soda recovery	795	795	1,000	1,000	1,220	1,220	1,830	1,830
12. Sulphate store	12	12	15	15	17	17	19	19
13. Causticizing dept	212	212	405	405	575	575	760	760
14. Piping between the different buildings	58	68	77	92	106	121	126	140
15. Electrical motors and cables	116	145	190	230	330	375	445	500
16. Insulation material and woodwork	17	20	23	26	30	34	37	41
17. Water purif. plant and pump station	130	130	190	190	345	345	450	450
18. Steam and power station	500	595	600	750	675	950	735	1,095
19. Machinery in repair shop	155	155	175	175	190	190	210	210
20. Machinery in fire station	25	25	25	25	25	25	25	25
21. Laboratory equipment	15	15	20	20	20	20	20	20
22. Office equipment	20	20	25	25	30	30	40	40
23. Excavation and planning of site	125	130	170	180	235	250	310	330
24. Cost of freight	265	290	350	375	485	510	685	735
25. Cost of erection	200	250	270	365	370	485	560	710
26. Administration during erection	62	62	100	100	140	140	160	160
27. Cost of buildings, chests, etc	970	1,210	1,170	1,410	1,600	1,900	2,170	2,550
28. Houses for staff and workmen (pulp mill)	200	235	235	270	295	340	365	425
29. Railway lines on mill site and to port	1,215	1,215	1,255	1,255	1,295	1,295	1,330	1,330
30. Port	100	100	200	200	250	250	300	300
31. Unforeseen expenses	131	148	160	192	205	250	274	327
32. Engineering fees	345	430	440	520	555	600	750	875
TOTAL INVESTMENT	6,950	8,400	8,900	10,750	11,700	14,000	15,400	18,300
Equivalent thousands of Mexican pesos	87,000	105,000	111,000	134,000	146,000	175,000	193,000	229,000

Items 1-16: Costs are taken from Karlstads cost summary, and converted to dollars at a rate of 1 dollar=5.18 Sw. Cr., and to Mex. pesos at a rate of 1 Sw. Cr.=2.42 Mex. pesos.

Item 17: This cost item has been raised by 35 per cent in view of (*a*) the fact that water would be supplied from artesian wells, and (*b*) the hardness of the groundwater.

Item 18: This item has been increased by the following amounts due to increase in boiler capacity and turbine/genrator, in order to attain self-sufficiency in power supply to electrolytic plant (only for bleached pulp):

	Mill size, tons/day			
	50	*100*	*200*	*300*
Power; kw	750	1,500	3,000	4,500
Additional costs: dollars:				
Boiler	15,000	25,000	35,000	40,000
Turbine/generator	25,000	50,000	90,000	125,000
TOTAL	40,000	75,000	125,000	165,000

Items 19-22: From Karlstads cost summary.

Item 23: Costs for 50-ton unit in Karlstads summary are apparently wrong. They have been corrected to 750 and 775,000 Sw. Cr. respectively.

Item 24: Estimated freight rates for additional machinery in steam and power plant have been added.

Item 25: As calculated by Karlstads but additional cost for power plant added.

Item 26: According to information received in Colonia Yucatán, cost of construction will vary between 150-200 pesos per m² floor area, i.e., about 50 pesos/m³ or $6. In view of the present price increase in Mexico, we have added 33 per cent, which gives a total cost of construction of $8 per m³. Building volumes are taken from Karlstads figures.

Item 27: As given by Karlstads.

Item 28: See Housing Project.

Item 29: Railway-lines on factory site calculated according to Karlstads figures. Construction cost for railway Colonia Yucatán-El Cuyo (37 km), estimated at $30,000 per km.

Item 30: Estimated figures applied to local conditions. Port facilities only for vessels of 1,000 tons maximum capacity.

Table A23

YUCATÁN PROJECT

INVESTMENTS: NON-INTEGRATFD AND INTEGRATED PAPER MILL

(thousand dollars)

	Non-integrated mill		Integrated mill			
			50 tons/day		100 tons/day	
	50 tons/day	100 tons/day	Unbleached	Bleached	Unbleached	Bleached
1. Pulp mill machinery	—	—	2,016	2,874	2,761	3,886
2. Paper mill machinery	1,930	2,900	1,850	1,850	2,820	2,820
3. Electrical motors	145	232	240	270	395	425
4. Piping between the different buildings	30	40	87	97	117	130
5. Insulation material and woodwork	17	23	33	35	43	45
6. Water purification plant and pump station	100	125	185	185	335	335
7. Boiler house and steam turbine dept.	515	650	680	760	810	980
8. Machinery in repair shop	155	175	175	175	195	195
9. Machinery in fire station	23	23	23	23	23	23
10. Laboratory equipment	15	15	20	20	20	20
11. Office equipment	20	23	23	23	29	29
12. Excavation and planning of site	60	100	160	165	220	230
13. Cost of freight	115	155	370	385	465	485
14. Cost of erection	115	155	290	350	385	485
15. Administration during erection	54	93	105	105	180	180
16. Cost of buildings, chests, etc.	805	1,160	1,230	1,460	1,720	1,970
17. Houses for staff and workmen	200	275	290	320	385	425
18. Railway-lines on mill site and to port	1,215	1,215	1,255	1,255	1,295	1,295
19. Port	100	200	200	200	250	250
20. Engineering fees	275	400	470	540	640	720
21. Unforeseen expenses	111	141	163	223	247	302
TOTAL COST	6,000	8,100	9,865	11,315	13,335	15,230
Equivalent thousands of Mex. pesos	75,000	101,000	123,000	141,000	167,000	190,000

Items 1-5: Costs are taken from Karlstads cost summary.

Item 6: Costs have been increased by 35 per cent over the Karlstads estimates.

Item 7: This item has been increased by the following amounts due to increase in boiler capacity and turbine/generator, in order to attain self-sufficiency in power supply.

	Mill size, tons/day					
	Non-integrated		Integrated mill			
	50	100	50		100	
			Unbl.	Bl.	Unbl.	Bl.
Power, kw	750	1,500	850	1,650	1,700	3,300
Incr. in boiler, dollars	25,000	45,000	30,000	45,000	45,000	90,000
Turb/generator, dollars	45,000	85,000	50,000	90,000	90,000	180,000
TOTAL	70,000	130,000	80,000	135,000	135,000	270,000

Items 8-15: From Karlstads figures.

Item 16: Calculated from building volumes and a construction cost of \$8 per m³.

Item 17: See housing project.

Item 18: Railway-lines on factory site from Karlstads figures. Railway to El Cuyo estimated at \$30,000 per km.

Item 19: Estimated for local conditions. Port facilities for vessels of 1,000 tons maximum capacity.

Table A24
YUCATÁN PROJECT
CAPITAL REQUIREMENTS: PULP MILLS
(thousand dollars)

	Mill size							
	50 tons/day		100 tons/day		200 tons/day		300 tons/day	
	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.
1. Machinery, freight, erection, etc.	3,989	5,062	5,440	6,903	7,500	9,365	10,211	12,493
2. Forest equipment	240	300	469	544	913	1,073	1,464	1,719
3. Engineering fees, etc.	340	430	440	520	555	600	748	875
TOTAL	4,569	5,792	6,349	7,967	8,968	11,038	12,423	15,087
4. Buildings, chests, etc.	970	1,210	1,170	1,410	1,600	1,900	2,170	2,550
5. Railway-lines, port, etc.	1,315	1,315	1,455	1,455	1,545	1,545	1,630	1,630
6. Forest prep. work and primary roads	412	412	784	784	1,524	1,524	2,260	2,260
7. Housing project, factory	200	235	235	270	295	340	365	425
8. Housing project, forest dept.	383	433	778	853	1,548	1,693	2,310	2,534
9. Contingencies	191	213	269	311	420	480	602	674
10. General community investment	490	575	820	880	1,360	1,470	1,770	1,880
TOTAL	3,961	4,393	5,511	5,963	8,292	8,952	11,107	11,953
11. Capital costs (during foreign build- }	545	695	760	955	1,075	1,325	1,490	1,810
12. ing period) and local currency }	475	525	660	715	995	1,075	1,330	1,435
TOTAL	1,020	1,220	1,420	1,670	2,070	2,400	2,820	3,245
13. Working capital, factory	610	720	910	1,060	1,460	1,700	2,070	2,370
14. Working capital, forest dept.	30	35	55	65	115	130	180	200
TOTAL	640	755	965	1,125	1,575	1,830	2,250	2,570
15. GRAND TOTAL	10,190	12,160	14,245	16,725	20,905	24,220	28,600	32,855
16. Amount foreign exchange *ex* grand total	5,114	6,487	7,109	8,922	10,043	12,363	13,913	16,897
Percentage	50.0	53.3	49.1	53.3	48.0	50.1	48.6	51.4

Table A25
YUCATÁN PROJECT
CAPITAL REQUIREMENTS: PAPER MILLS
(thousand dollars)

	Mill size, tons/day					
	Non-integrated		Integrated mills			
	50	100	50		100	
			Unbl.	Bl.	Unbl.	Bl.
1. Machinery, freight, adm. during erection, etc.	3,119	4,454	5,807	6,800	8,223	9,553
2. Forest equipment	—	—	300	353	559	649
3. Engineering fees	275	400	470	540	640	720
TOTAL	3,394	4,854	6,577	7,693	9,522	10,922
4. Excavation, erection, buildings, chests, etc.	980	1,415	1,680	1,975	2,325	2,685
5. Railway-lines, port, etc.	1,315	1,415	1,455	1,455	1,545	1,545
6. Forest prep. work and primary roads	—	—	412	412	784	784
7. Housing project: factory	205	280	295	325	390	425
8. Housing project: forest dept.	—	—	429	464	849	914
9. Contingencies	105	135	220	286	360	425
10. General community exp.	—	—	550	630	950	1,165
TOTAL	2,605	3,245	5,041	5,547	7,203	7,943
11. Capital costs during building period } Foreign ex.	403	586	789	924	1,143	1,310
12. } Local ex.	313	390	605	665	864	953
TOTAL	716	976	1,394	1,589	2,007	2,263
13. Working cap.: factory	970[a]	1,490[a]	870	980	1,340	1,500
14. Working cap.: forest dept.	—	—	33	36	63	72
TOTAL	970	1,490	903	1,016	1,403	1,572
GRAND TOTAL	7,685	10,565	13,915	15,845	20,135	22,700
Amount of foreign exchange *ex* grand total	3,797	5,430	7,366	8,617	10,665	12,232
Percentage foreign exchange *ex* grand total	49.4	51.4	52.9	54.4	53.0	53.9

[a] Refers to unbleached qualities.

Table A26

YUCATÁN PROJECT

CAPITAL COSTS: PULP MILL

1. *Depreciation*[a]

Investment: Machinery, engineering fees, unforeseen exp. .... 10 years
Buildings, chests, etc. .... 20 years
Port, railways, etc. .... 30 years

	Mill size, tons/day							
	50		*100*		*200*		*300*	
	Unbl.	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*
Machinery, pulp mill [b]	3,144	4,122	4,405	5,718	6,215	7,805	8,731	10,653
Machinery, mill services	845	940	1,035	1,185	1,285	1,560	1,480	1,840
Buildings, chests, etc.	970	1,210	1,170	1,410	1,600	1,900	2,170	2,550
Housing project	200	235	235	270	295	340	365	425
Railway-lines and port	1,315	1,315	1,455	1,455	1,545	1,545	1,630	1,630
Unforeseen expenses	131	148	160	192	205	250	276	327
Engineering fees	345	430	440	520	555	600	748	875
TOTAL (thousand dollars)	6,950	8,400	8,900	10,750	11,700	14,000	15,400	18,300
Capital cost: (dollars per ton pulp)								
Machinery, pulp mill	20.95	27.50	14.70	19.10	10.35	13.00	9.70	11.85
Machinery, mill services	5.65	6.25	3.45	3.95	2.15	2.60	1.65	2.05
Buildings, chests, etc.	3.25	4.05	1.95	2.35	1.35	1.60	1.20	1.40
Housing project	0.65	0.80	0.40	0.45	0.25	0.30	0.20	0.25
Railway, port	2.90	2.95	1.60	1.60	0.85	0.85	0.60	0.60
Unforeseen expenses	0.85	1.00	0.55	0.65	0.35	0.40	0.30	0.35
Engineering fees	2.25	2.85	1.50	1.75	0.90	1.00	0.85	0.95
TOTAL	36.50	45.40	24.15	29.85	16.20	19.75	14.50	17.45

[a] Depreciation on forest equipment charged to cost of pulpwood.
[b] Including freight, erection, etc.

2. *Amortisation of capital costs during erection*

It is assumed that the investment capital accrues proportionately during the first three years, which is time estimated for the mill to get into operation.

Rate of interest: 8 per cent.

	Mill size, tons/day							
	50		*100*		*200*		*300*	
	Unbl.	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*
Capital required[a]: thousand dollars	8,530	10,185	11,860	13,930	17,260	19,990	23,530	27,040
Capital cost: thousand dollars	1,030	1,220	1,420	1,670	2,070	2,400	2,820	3,245
Dollars per ton during 10 years	6.85	8.15	4.75	5.55	3.45	4.00	3.15	3.60

3. *Interest on fixed capital* [b]

Rate of interest: 8 per cent.

	Mill size, tons/day							
	50		*100*		*200*		*300*	
	Unbl.	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*
First year	37.05	44.80	23.75	28.65	15.60	18.65	13.70	16.25
Average during depr. period	18.50	22.40	11.90	14.30	7.80	9.30	6.85	8.10

4. *Interest on working capital* (in mill operation)

Working capital is estimated as being equivalent to the value of 4 months' production.

	Mill size, tons/day							
	50		*100*		*200*		*300*	
	Unbl.	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*
Value: dollars per ton	122	144	91	106	73	85	69	79
4 months' prod. value: thousand dollars	610	720	910	1,060	1,460	1,700	2,070	2,370
Interest per ton of pulp	3.30	3.85	2.40	2.80	1.95	2.25	1.85	2.10

Table A26 (continued)

5. *Insurance*

Insurance is calculated at 1 per cent of machinery, buildings and spare parts (5 per cent of machinery).

	Mill size, tons/day							
	50		*100*		*200*		*300*	
	Unbl.	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*
Yearly expense: thousand dollars	56.3	67.3	70.7	87.7	97.1	120.0	131.9	160.0
Dollars per ton of pulp	3.75	4.50	2.35	2.90	1.60	2.00	1.45	1.75

Total capital costs per ton of pulp

	Mill size, tons/day							
	50		*100*		*200*		*300*	
	Unbl.	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*
Depreciation	36.50	45.40	24.15	29.85	16.20	19.75	14.50	17.45
Amortisation of capital costs	6.85	8.15	4.75	5.55	3.45	4.00	3.15	3.60
Interest, fixed capital	18.50	22.40	11.90	14.30	7.80	9.30	6.85	8.10
Interest, working capital	3.30	3.85	2.40	2.80	1.95	2.25	1.85	2.10
Insurance	3.75	4.50	2.35	2.90	1.60	2.00	1.45	1.75
TOTAL	68.90	84.30	45.55	55.40	31.00	37.30	27.80	33.00

[a] See capital requirements.
[b] Interest on capital required for forest operations is charged to cost of pulpwood.

Table A27

YUCATÁN PROJECT

CAPITAL COSTS: INTEGRATED AND NON-INTEGRATED PAPER MILLS

1. *Depreciation*

Machinery, engineering fees and unforeseen expenses .... 10 years
Buildings, chests, etc. .... 20 years
Port, railways, etc. .... 30 years

Capital required:

	Mill size, tons/day					
	Non-integrated		*Integrated mill*			
	50	*100*	*50*		*100*	
			Unbl.	*Bl.*	*Unbl.*	*Bl.*
Machinery pulp and paper mill	2,466	3,698	5,151	6,129	7,386	8,686
Machinery mill services	828	1,011	1,106	1,188	1,412	1,582
Buildings, chests, etc.	805	1,160	1,230	1,460	1,720	1,970
Housing project	200	275	290	320	385	425
Railway and port	1,315	1,415	1,455	1,455	1,545	1,545
Engineering fees	275	400	470	540	640	720
Unforeseen expenses	111	141	163	223	247	302
TOTAL (thousand dollars)	6,000	8,100	9,865	11,315	13,335	15,230
Capital cost: (Dollars per ton of pulp)						
Machinery pulp and paper mill	16.45	12.30	34.34	40.86	24.62	28.95
Machinery mill services	5.50	3.35	7.35	7.90	4.70	5.25
Buildings, chests, etc.	2.70	1.95	4.10	4.90	2.85	3.30
Housing project	0.65	0.45	0.95	1.05	0.65	0.70
Railway and port	2.90	1.60	3.25	3.25	1.70	1.70
Engineering fees	1.85	1.35	3.15	3.60	2.15	2.40
Unforeseen expenses	0.75	0.45	1.10	1.50	0.80	1.00
TOTAL	30.80	21.45	54.24	63.06	37.47	43.30

Table A27 (continued)

2. *Amortisation of capital costs during erection*

It is assumed that the investment capital accrues proportionately during three years, the estimated time required before the mill begins operating.

Rate of interest: 8 per cent.

	Mill size, tons/day					
	Non-integrated		*Integrated mill*			
	50	*100*	*50*		*100*	
			Unbl.	*Bl.*	*Unbl.*	*Bl.*
Capital required: thousand dollars	6,000	8,100	11,617	13,240	16,725	18,860
Capital cost	720	972	1,394	1,589	2,007	2,263
Dollars per ton during 10 years	4.80	3.24	9.29	10.60	6.69	7.54

3. *Interest on fixed capital*

Rate of interest: 8 per cent.

	Mill size, tons/day					
	Non-integrated		*Integrated mill*			
	50	*100*	*50*		*100*	
			Unbl.	*Bl.*	*Unbl.*	*Bl.*
First year	32.00	21.60	52.61	60.53	35.56	40.63
Average during depr. period	16.00	10.80	26.30	30.27	17.78	20.32

4. *Interest on working capital*

Working capital estimated as being equivalent to value of 4 months' production.

	Mill size, tons/day							
	50		*100*		*50*		*100*	
	Unbl.	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*
Value: dollars per ton	194	216	149	165	174	196	134	150
Production value: thousand dollars	970	1,080	1,490	1,650	870	980	1,340	1,500
Interest	5.20	5.80	4.00	4.40	4.65	5.25	3.55	4.00

5. *Insurance*

Insurance calculated at 1 per cent of machinery, buildings and spare parts (5 per cent of machinery).

	Mill size, tons/day					
	50	*100*	*50*		*100*	
			Unbl.	*Bl.*	*Unbl.*	*Bl.*
Yearly expense: thousand dollars	44.7	63.8	83.9	97.7	118.4	136.7
Dollars per ton of pulp	3.00	2.10	5.60	6.50	3.95	4.55

Total capital costs per ton of paper

	Mill size, tons/day					
	50	*100*	*50*		*100*	
			Unbl.	*Bl.*	*Unbl.*	*Bl.*
Depreciation	30.80	21.45	54.24	63.06	37.47	43.30
Amortisation of capital	4.80	3.24	9.29	10.60	6.69	7.54
Interest, fixed capital	16.00	10.80	26.30	30.27	17.78	20.32
Interest, working capital	5.20[a]	4.00[a]	4.65	5.25	3.55	4.00
Insurance	3.00	2.10	5.60	0.50	3.95	4.55
TOTAL	59.80	41.59	100.08	115.68	69.44	79.71
For bleached quality add	0.60	0.40				
	60.40	41.99				

[a] Refers to unbleached pulp.

Table A28

AMAPÁ PROJECT

INVESTMENT: FOREST OPERATION

	Quantity of wood, tons per year											
	60,000 tons				120,000 tons				240,000 tons			
	Pulpwood		Fuelwood		Pulpwood		Fuelwood		Pulpwood		Fuelwood	
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
General preparatory work	40	—	—	—	40	—	—	—	40	—	—	—
Primary roads	27	1,776	—	—	54	3,552	—	—	109	7,104	—	—
Equipment	334	—	218	—	624	—	435	—	1,223	—	914	—
Working capital [a]	27	1,964	17	950	52	3,768	36	1,910	104	7,520	78	3,934
Unforeseen and sundry expenses—10 per cent	43	374	23	95	77	732	47	191	148	1,462	99	393
Housing	—	17,072	—	8,901	—	33,306	—	17,734	—	66,744	—	36,162
TOTAL	471	21,186	258	9,946	847	41,358	518	19,835	1,624	82,830	1,091	40,489
Thousand dollars	1,133		569		2,139		1,137		4,211		2,356	

	Quantity of wood, tons per year							
	(Alternative 1) 360,000 tons				(Alternative 2) 360,000 tons			
	Pulpwood		Fuelwood		Pulpwood		Fuelwood	
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
General preparatory work	40	—	—	—	40	—	—	—
Primary roads	163	10,656	—	—	196	12,787	—	—
Equipment	1,927	—	1,484	—	2,167	—	1,723	—
Working capital [a]	166	11,579	128	6,264	192	11,738	154	6,395
Unforeseen and sundry expenses—10 per cent	230	2,224	161	626	259	2,453	188	640
Housing	—	102,140	—	56,598	—	102,140	—	56,598
TOTAL	2,526	126,599	1,773	63,488	2,854	129,118	2,065	63,633
Thousand dollars	6,483		3,756		6,889		4,052	

[a] Two months' production.

Note: (A) = thousand dollars.
(B) = thousand cruzeiros.

Table A29

AMAPÁ PROJECT

ESTIMATES OF EQUIPMENT REQUIREMENTS: FOREST OPERATION

(figures in thousands of dollars except where otherwise stated)[a]

	Quantity of wood, tons per year									
	60,000		*120,000*		*240,000*		*(Alternative 1) 360,000*		*(Alternative 2) 360,000*	
	Pulpwood	*Fuelwood*	*Pulpwood*	*Fuelwood*	*Pulpwood*	*Fuelwood*	*Pulpwood*	*Fuelwood*	*Pulpwood*	*Fuelwood*
Grader (small)	28(2)	—	28(2)	—	28(2)	—	42(3)	—	42(3)	—
Grader (large)	—	—	22(1)	—	44(2)	—	66(3)	—	66(3)	—
Caterpillar D8[b]	64(2)	—	96(3)	—	160(5)	—	224(7)	—	224(7)	—
Caterpillar D6	96(4)	96(4)	192(8)	192(8)	384(16)	384(16)	576(24)	576(24)	720(30)	720(30)
Caterpillar D4	48(3)	48(3)	96(6)	96(6)	192(12)	192(12)	288(18)	288(18)	352(22)	352(22)
5-ton trucks with accessories	39(6)	39(6)	78(12)	78(12)	195(30)	195(30)	390(60)	390(60)	390(60)	390(60)
Sundry vehicles	15(5)	6(2)	30(10)	12(4)	60(20)	24(8)	90(30)	36(12)	90(30)	36(12)
Sundry equipment 15 per cent	44	29	82	57	160	119	251	194	283	225
TOTAL	334	218	624	435	1,223	914	1,927	1,484	2,167	1,723

[a] Figures in parentheses denote number of units required.

[b] Required only during the period of construction of primary roads.

Table A30

AMAPÁ PROJECT

PERSONNEL: FOREST OPERATION

(figures in thousands of cruzeiros except where otherwise stated)

		Quantity of wood, tons per year							
		60,000				*120,000*			
		Pulpwood		*Fuelwood*		*Pulpwood*		*Fuelwood*	
	Salary per man	*No.*	*Salaries*	*No.*	*Salaries*	*No.*	*Salaries*	*No.*	*Salaries*
Central administration									
Forest director	420	—	—	—	—	1	420	—	—
Assistant director	312	1	312	—	—	—	—	—	—
Administrative assistant	216	1	216	—	—	1	216	—	—
Foremen	84	2	168	1	84	2	168	1	84
Accountant	132	1	132	—	—	1	132	1	132
Clerks, typists	42	3	126	1	42	4	168	2	84
Messengers	14.4	2	28.8	2	28.8	4	57.6	2	28.8
		10	982.8	4	154.8	13	1,161.6	6	328.8
Field administration									
Coupe manager	180	1	180	—	—	2	360	—	—
Yard foremen	96	5	480	1	96	10	960	2	192
Operation foremen	72	10	720	2	144	20	1,440	4	288
Accountant	72	1	72	—	—	2	144	—	—
Clerks	48	4	192	2	96	8	384	4	192
		21	1,644	5	336	42	3,288	10	672
Field personnel									
Unskilled labour	24	156	3,744	98	2,352	312	7,488	196	4,704
Skilled workers, 1st category	60	21	1,260	10	600	42	2,520	20	1,200
Skilled workers, 2nd category	36	23	828	14	504	46	1,656	28	1,008
		200	5,832	122	3,456	400	11,644	244	6,912
	TOTAL	231	8,458.8	131	3,946.8	455	16,093.6	260	7,912.8

		Quantity of wood, tons per year							
		240,000				*360,000*			
		Pulpwood		*Fuelwood*		*Pulpwood*		*Fuelwood*	
	Salary per man	*No.*	*Salaries*	*No.*	*Salaries*	*No.*	*Salaries*	*No.*	*Salaries*
Central administration									
Forest director	420	1	420	—	—	1	420	—	—
Assistant director	312	1	312	—	—	1	312	—	—
Administrative assistant	216	—	—	—	—	1	216	—	—
Foremen	84	3	252	1	84	4	336	2	168
Accountant	132	2	264	1	132	2	264	2	264
Clerks, typists	42	6	252	4	168	8	336	4	168
Messengers	14.4	5	72	4	57.6	6	86.4	5	72
		18	1,572	10	441.6	23	1,970.4	13	672
Field administration									
Coupe manager	180	4	720	—	—	6	1,080	—	—
Yard foremen	96	20	1,920	4	384	30	2,880	6	576
Operation foremen	72	40	2,880	8	576	60	4,320	12	864
Accountant	72	4	288	—	—	6	432	—	—
Clerks	48	16	768	8	384	24	1,152	12	576
		84	6,576	20	1,344	126	9,864	30	2,016
Field personnel									
Unskilled labour	24	630	15,120	398	9,552	960	23,040	612	14,688
Skilled workers, 1st category	60	90	5,400	46	2,760	150	9,000	84	5,940
Skilled workers, 2nd category	36	92	3,312	56	2,016	138	4,968	84	3,024
		812	23,832	500	14,328	1,248	37,008	780	23,562
	TOTAL	914	31,980	530	16,113.6	1,397	48,842.4	823	26,250

Table A31

AMAPÁ PROJECT

HOUSING SCHEME: FOREST OPERATION

(thousand cruzeiros)

		Quantity of wood, tons per year							
		60,000		*120,000*		*240,000*		*360,000*	
	Unit cost per man	*Pulp-wood*	*Fuel-wood*	*Pulp-wood*	*Fuel-wood*	*Pulp-wood*	*Fuel-wood*	*Pulp-wood*	*Fuel-wood*
Central administration									
Forest director	256	—	—	256	—	256	—	256	—
Assistant director	182	182	—	—	—	182	—	182	—
Administrative assistant	176	176	—	176	—	—	—	176	—
Foremen	128	256	128	256	128	384	128	512	256
Accountant	144	144	—	144	144	288	144	288	288
Clerks, typists	77	231	77	308	154	462	308	616	308
Messengers	42	84	84	168	84	210	168	252	210
		1,073	289	1,308	510	1,782	748	2,282	1,062
Field administration									
Coupe manager	160	160	—	320	—	640	—	960	—
Yard foremen	144	720	144	1,440	288	2,880	576	4,320	864
Operation foremen	128	1,280	256	2,560	512	5,120	1,024	7,680	1,536
Accountant	112	112	—	224	—	448	—	672	—
Clerks	77	308	154	616	308	1,232	616	1,848	924
		2,580	554	5,160	1,108	10,320	2,216	15,480	3,324
Field personnel									
Unskilled labour	58	9,048	5,684	18,096	11,368	36,540	23,084	55,680	35,496
Skilled workers, 1st category	103	2,163	1,030	4,326	2,060	9,270	4,738	15,450	8,652
Skilled workers, 2nd category	96	2,208	1,344	4,416	2,688	8,832	5,376	13,248	8,064
		13,419	8,058	26,838	16,116	54,642	33,198	84,378	52,212
	TOTAL	17,072	8,901	33,306	17,734	66,744	36,162	102,140	56,598

Table A32

AMAPÁ PROJECT

COST OF WOOD

(dollars per ton)

	Quantity of wood, tons per year							
	60,000 tons							
	Pulpwood				*Fuelwood*			
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
Labour								
Unskilled labour	—	62.40			—	39.20		
Skilled workers, 1st category	—	21.00			—	10.00		
Skilled workers, 2nd category	—	13.80			—	8.40		
Central and field administration	—	43.80	—	141.00	—	8.20	—	65.80
Operational expenses								
Fuel, repairs and spare parts	1.09	12.60	1.09	12.60	0.74	8.40	0.74	8.40
Capital expenditure								
Amortization, gral. investment	0.06	1.19			0.01	0.05		
Amortization, equipment	1.25	—			0.80	—		
Amortization, housing	—	14.20			—	7.40		
Interest on investment capital	0.30	12.80			0.16	6.00		
Interest on working capital	0.04	2.62	1.65	30.81	0.02	1.27	0.99	14.72
			2.74	184.41			1.73	88.92
TOTAL DOLLARS			8.50				4.51	

Table A32 (continued)

	Quantity of wood, tons per year — 120,000 tons							
	Pulpwood				Fuelwood			
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
Labour								
Unskilled labour	—	62.40			—	39.20		
Skilled workers, 1st category	—	21.00			—	10.00		
Skilled workers, 2nd category	—	13.80			—	8.40		
Central and field administration	—	37.00	—	134.20	—	8.35	—	65.95
Operational expenses								
Fuel, repairs and spare parts	1.09	12.10	1.09	12.10	0.79	8.75	0.79	8.75
Capital expenditure								
Amortization, gral. investment	0.05	1.19			0.01	0.05		
Amortization, equipment	1.17	—			0.80	—		
Amortization, housing	—	13.90			—	7.40		
Interest on investment capital	0.26	12.50			0.16	5.97		
Interest on working capital	0.03	2.51	1.51	30.10	0.02	1.27	0.99	14.69
			2.60	176.40			1.78	89.39
TOTAL DOLLARS			8.11				4.57	

Note: (A) = dollars.
(B) = cruzeiros.

	Quantity of wood, tons per year — 240,000 tons							
	Pulpwood				Fuelwood			
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
Labour								
Unskilled labour	—	63.00			—	39.80		
Skilled workers, 1st category	—	22.50			—	11.50		
Skilled workers, 2nd category	—	13.80			—	8.40		
Central and field administration	—	33.90	—	133.20	—	7.45	—	67.15
Operational expenses								
Fuel, repairs and spare parts	1.15	12.20	1.15	12.20	0.91	9.55	0.91	9.55
Capital expenditure								
Amortization, gral. investment	0.04	1.19			0.01	0.05		
Amortization, equipment	1.13	—			0.84	—		
Amortization, housing	—	13.90			—	7.50		
Interest on investment capital	0.25	12.51			0.17	6.09		
Interest on working capital	0.03	2.50	1.45	30.10	0.02	1.31	1.04	14.95
TOTAL DOLLARS			2.60	175.50			1.95	91.65
			8.08				4.81	

	Quantity of wood, tons per year — (Alternative I) 360,000 tons							
	Pulpwood				Fuelwood			
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
Labour								
Unskilled labour	—	64.00			—	40.80		
Skilled workers, 1st category	—	25.00			—	16.50		
Skilled workers, 2nd category	—	13.80			—	8.40		
Central and field administration	—	32.90	—	135.70	—	7.45	—	73.15
Operational expenses								
Fuel, repairs and spare parts	1.26	13.10	1.26	13.10	1.04	10.50	1.04	10.50
Capital expenditure								
Amortization, gral. investment	0.04	1.19			0.02	0.06		
Amortization, equipment	1.17	—			0.86	—		
Amortization, housing	—	14.20			—	7.85		
Interest on investment capital	0.26	12.80			0.18	6.35		
Interest on working capital	0.04	2.57	1.51	30.76	0.03	1.39	1.09	15.65
			2.77	179.56			2.13	99.30
TOTAL DOLLARS			8.38				5.23	

Table A32 (continued)

	Quantity of wood, tons per year (Alternative 2) 360,000 tons							
	Pulpwood				Fuelwood			
	(A)	(B)	(A)	(B)	(A)	(B)	(A)	(B)
Labour								
Unskilled labour	—	64.00			—	40.80		
Skilled workers, 1st category	—	25.00			—	16.50		
Skilled workers, 2nd category	—	13.80			—	8.40		
Central and field administration	—	32.90	—	135.70	—	7.45	—	73.15
Operational expenses								
Fuel, repairs and spare parts	1.48	15.25	1.48	15.25	1.26	12.65	1.26	12.65
Capital expenditure								
Amortization, gral. investment	0.05	1.41			0.02	0.06		
Amortization, equipment	1.33	—			1.04	—		
Amortization, housing	—	14.20			—	7.85		
Interest on investment capital	0.30	13.05			0.21	6.35		
Interest on working capital	0.04	2.61	1.72	31.27	0.03	1.42	1.30	15.68
			3.20	182.22			2.56	101.48
TOTAL DOLLARS			8.89				5.73	

Note: (A) = dollars.
(B) = cruzeiros.

Chart A33

AMAPÁ PROJECT: COST OF PULPWOOD

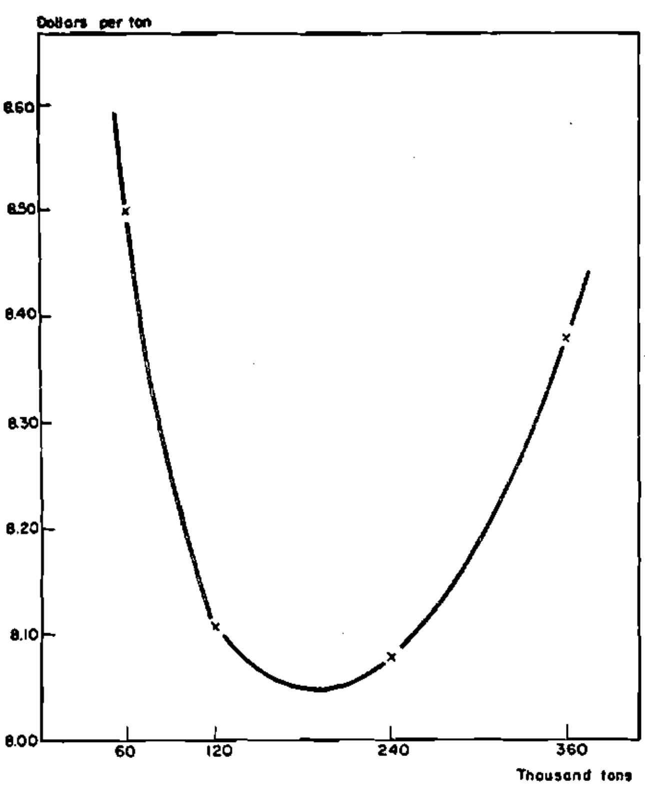


Chart A34

AMAPÁ PROJECT: COST OF FUELWOOD AND NUMBER OF WORKMEN FOR FUELWOOD EXTRACTION

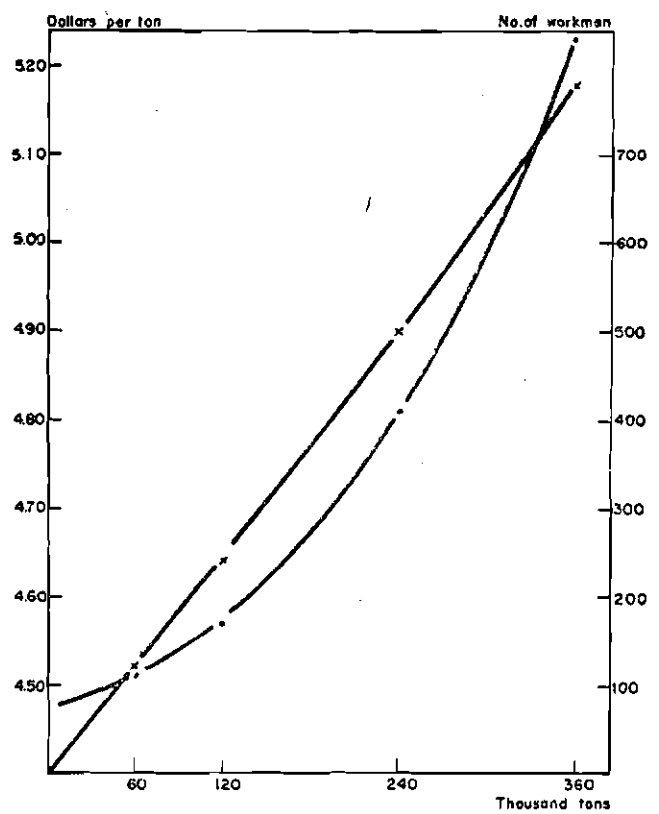


Table A35

AMAPÁ PROJECT

COST AND SUPPLY POSSIBILITIES OF CHEMICALS AND FUEL

1. *Limestone*

Limestone deposits of reasonable proportions and quality are unknown in the region of Amapá. The nearest deposit which could be taken into account is near Monte Alegre, about 450 km up the Amazon river from Macapá.

Estimated cost at mill site:	*Dollars per ton*	*Cruzeiros per ton*
Mining cost	2.00	64.00[a]
Transport to Monte Alegre	2.00	64.00[a]
River transport to Porto Santana	8.00	256.00[a]
Railway transport to Platon	3.00	96.00[a]
TOTAL COST AT MILL	15.00	480.00

2. *Saltcake*

None available in the area, and the mill would have to depend on imports. In view of the large shipments of manganese ore (200,000 tons yearly) from Porto Santana to the United States, return freight would be low.

Estimated cost at Mill site:	*Dollars per ton*	*Cruzeiros per ton*
Price, f.o.b. N.Y. (April 1954)	21.00	1,714[b]
Freight (estimated)	20.00	640[a]
Freight, Santana to Porto Platon	3.00	96[a]
Import duty 15 per cent	3.20	100[a]
TOTAL COST AT MILL	47.20	2,550

3. *Sulphur*

There is at present no production of sulphur in the country worth mentioning, thus any pulp would have to depend on imports.

Estimated cost at Mill site:	*Dollars per ton*	*Cruzeiros per ton*
F.o.b. price (U.S. Gulf port, April 1954)	33.00	1,765[c]
Freight, U.S. Porto Santana	20.00	640[a]
Freight, Santana to Porto Platon	3.00	96[a]
Import duty 15 per cent	5.00	160[a]
TOTAL COST AT MILL	61.00	2,661

4. *Salt*

Produced in the north-east of the country. April 1954 price in the São Paulo area was 1,000 cruzeiros per ton, or $32 at parity rate of exchange. The price at Porto Santana would be lower, and is estimated at 700 cruzeiros per ton or $22.40. Price at mill site may be estimated at $25.50 or about 800 cruzeiros.

5. *Aluminium sulphate, china clay*

		F.o.b.	*Freight U.S.-Santana*	*Freight Santana mill*	*Import duty*	*Total cost at mill*
Aluminium sulphate	Dollars	46.00	20.00	3.50	6.90	76.40
	Cruzeiros	2,460[b]	640[a]	112[a]	221[a]	3,433
China clay	Dollars	16.00	20.00	3.50	2.50	42.00
	Cruzeiros	856[b]	640[a]	112[a]	80[a]	1,688

6. *Rosin*

Would probably have to be imported.

Estimated cost at mill:	*Dollars per ton*	*Cruzeiros per ton*
F.o.b. price (April 1954)	220	11,770[b]
Freight, U.S. to Porto Santana	20	640[a]
Freight, Porto Santana to Porto Platon	3.50	112[a]
Import duty 15 per cent	33	1,056[a]
TOTAL COST AT MILL	276.50	13,578

7. *Fuel oil*

Imported. April 1954 price was 860 cruzeiros per ton, or $36 at the exchange rate for category I (1 dollar=24 cruzeiros). Price at mill site is estimated at $40 or 960 cruzeiros per ton.

8. *Wood fuel*

See *Charts A33* and *A34* on page 111.

[a] Parity rate of exchange 1 dollar = 32.00 cruzeiros.

[b] Category IV commodity, rate of exchange 1 dollar = 81.50 cruzeiros.

[c] Category III commodity, rate of exchange 1 dollar = 53.50 cruzeiros.

Table A36

AMAPÁ PROJECT

REBURNING OF LIME SLUDGE

All cost figures in dollars per ton of burnt lime.
Calculation based on a production of 7,500 tons/year.

Item	*Quantity*	*Cost per unit*	*With fuel oil*	*With wood fuel*
Lime sludge		—	—	—
Limestone	110 kg	0.015	1.65	
Limestone	165 kg	0.015		2.50
Fuel oil	200 kg	0.040	8.00	
Wood fuel	1.37 tons	4.50		6.15
Electric power	25 kWh	0.015	0.38	
Electric power	40 kWh	0.015		0.60
Labour, man/hours	1.05	0.60	0.63	
Labour, man/hours	3.15	0.60		1.90
Repairs			0.60	1.20
Depreciation and interest, 10 years, 8 per cent			1.90	2.45
TOTAL COST PER TON OF LIME			13.16	14.80

Conclusions:

(*a*) For the Amapá project an oil-fired kiln has been selected.

(*b*) Lime reburning kiln should also be installed for the 50-ton unit, as expected cost of lime 13.16 + 1.90 = 15.06 is less than anticipated market price.

Table A37

AMAPÁ PROJECT
ADMINISTRATION AND SUPERVISORY PERSONNEL: PULP MILL
(thousand cruzeiros)

	Mill size							
	50 tons/day		*100 tons/day*		*200 tons/day*		*300 tons/day*	
	Salary		*Salary*		*Salary*		*Salary*	
	No.	*Cr./Yr.*	*No.*	*Cr./Yr.*	*No.*	*Cr./Yr.*	*No.*	*Cr./Yr.*
Managing director	1	600	1	670	1	775	1	850
Mill manager	–	—	–	—	1	530	1	570
Mill superintendent	1	360	1	400	1	430	1	500
Assistant mill superintendent	–	—	–	—	1	290	1	290
Chief chemist	1	220	1	220	1	240	1	290
Superintendent mech. workshop	1	220	1	220	1	220	1	240
Superintendent electr. workshop	–	—	–	—	1	220	1	240
Shift foremen production	3	288	3	288	3	288	6	596
Foreman, mech. workshop	1	96	1	96	1	96	2	192
Foreman, electr. workshop	1	96	1	96	1	96	1	96
Foremen, boilerhouse	–	—	–	—	1	115	1	115
Foremen, wood yard	1	96	1	96	1	115	1	115
Foremen, transport	1	96	1	96	1	115	1	115
Shift chemists	3	234	3	234	3	234	3	234
Laboratory assistants	2	84	2	84	3	104	4	126
Draftsmen	1	96	2	192	3	240	4	286
Secretary	1	220	1	220	1	255	1	290
Chief accountant	1	180	1	180	1	220	1	240
Office clerks and typist	5	210	8	336	10	400	12	460
Storekeeper	1	96	1	96	1	115	1	115
Assistant storekeeper and clerks	2	84	2	84	3	120	4	144
Porters	3	87	3	87	3	87	3	87
Messengers	2	30	2	30	3	45	4	60
TOTAL ANNUAL SALARIES—Cr.	(32)	3,393	(36)	3,725	(46)	5,350	(56)	6,251
Equiv. thousands of dollars		106.0		116.4		167.2		195.3

Table A38

AMAPÁ PROJECT
(figures in thousands of cruzeiros, except where otherwise stated)[a]

	Mill size							
	Administration and supervisory: integrated mill				*Administration and supervisory personnel: non-integrated paper mill*			
	50 tons/day		*100 tons/day*		*50 tons/day*		*100 tons/day*	
	No.	*Total salaries /year*	*No.*	*Total salaries /year*	*No.*	*Total salaries /year*	*No.*	*Total salaries /year*
Managing director	1	600	1	600	1	600	1	670
Mill manager	1	450	1	450	1	450	1	450
Mill superintendent	–	—	1	360	1	360	1	400
Assistant superintendent	1	300	1	300	–	—	–	—
Chief chemist	1	220	1	220	1	220	1	220
Superintendent workshops	2	480	2	480	1	240	2	440
Shift foremen	6	576	6	576	3	288	3	288
Foremen	5	480	6	576	4	384	4	384
Laboratory assistants	2	84	3	122	2	84	2	84
Draftsmen	2	192	3	238	1	96	2	192
Secretary	1	220	1	220	1	220	1	220
Chief accountant	1	220	1	220	1	180	1	180
Shift chemists	3	234	3	234	–	—	–	—
Office clerks and typists	6	252	10	400	5	210	8	336
Storekeepers	1	84	1	84	1	84	1	84
Assistant storekeepers and clerks	2	84	3	120	2	84	2	84
Porters	3	90	3	90	3	87	3	87
Messengers	3	45	4	60	2	30	3	45
TOTAL ANNUAL SALARIES	(41)	4,611	(51)	5,350	(30)	3,617	(36)	4,164
Equiv. thousands of dollars		144.1		167.2		113.0		130.1

[a] 1 dollar = 32.00 cruzeiros.

Table A39

AMAPÁ PROJECT

NUMBER OF WORKMEN: PULP MILL

	Mill size, tons/day															
	Per 8 hours								*Per day*							
	50				*100*				*50*				*100*			
	Unbl.		*Bl.*		*Unbl.*		*Bl.*		*Unbl.*		*Bl.*		*Unbl.*		*Bl.*	
	(1)	*(2)*	*(1)*	*(2)*	*(1)*	*(2)*	*(1)*	*(2)*	*(1)*	*(2)*	*(1)*	*(2)*	*(1)*	*(2)*	*(1)*	*(2)*
Log yard	10	2	10	2	12	2	12	2	20	4	20	4	24	4	24	4
Wood prep. department	4	2	6	2	5	2	8	3	8	4	12	4	10	4	16	6
Digester department	3	1	3	1	3	1	3	1	9	3	9	3	9	3	9	3
Diffuser department	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
First screening department	1	1	1	1	2	1	2	1	3	3	3	3	6	3	6	3
Bleaching department	–	–	1	1	–	–	1	1	–	–	3	3	–	–	3	3
Electrolytic plant and bleaching prep.	–	–	4	1	–	–	5	2	–	–	12	3	–	–	15	6
Second screen department	–	–	1	1	–	–	1	1	–	–	3	3	–	–	3	3
Pulp drying machine	5	2	5	2	8	2	8	2	15	6	15	6	24	6	24	6
Pulp store	3	1	3	1	4	1	4	1	9	3	9	3	12	3	12	3
Causticizing department	1	1	1	1	2	1	2	1	3	3	3	3	6	3	6	3
Evaporation plant	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
Soda recovery	4	1	4	1	4	1	4	1	12	3	12	3	12	3	12	3
Lime recovery and transport	2	1	2	1	4	1	4	1	6	3	6	3	12	3	12	3
Chemical stores	–	–	–	–	–	–	–	–	3	1	4	1	3	1	4	1
Water purification and pump station	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
General services	–	–	–	–	–	–	–	–	10	1	12	1	14	1	16	1
Transport workers	–	–	–	–	–	–	–	–	15	–	15	–	20	–	20	–
Repair shop	–	–	–	–	–	–	–	–	25	12	30	14	30	15	35	18
Boiler house	3	1	3	1	3	1	3	1	9	3	9	3	9	3	9	3
Power house	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
NO. OF WORKMEN (total and skilled)									159	61	189	72	203	64	238	81

Annual salaries:		Per day 50 Unbl.	Per day 50 Bl.	Per day 100 Unbl.	Per day 100 Bl.
thousand cruzeiros:	Skilled	2,196	2,592	2,304	2,916
	Unskilled	2,352	2,808	3,386	3,768
thousand dollars:	Skilled	68.6	81.0	72.0	91.1
	Unskilled	73.5	89.3	105.8	119.3

	Mill size, tons/day															
	Per 8 hours								*Per day*							
	200				*300*				*200*				*300*			
	Unbl.		*Bl.*		*Unbl.*		*Bl.*		*Unbl.*		*Bl.*		*Unbl.*		*Bl.*	
	(1)	*(2)*	*(1)*	*(2)*	*(1)*	*(2)*	*(1)*	*(2)*	*(1)*	*(2)*	*(1)*	*(2)*	*(1)*	*(2)*	*(1)*	*(2)*
Log yard	16	4	16	4	20	4	20	4	32	8	32	8	40	8	40	8
Wood prep. department	6	2	10	3	8	3	16	3	12	4	20	6	16	6	32	6
Digester department	3	1	3	1	4	1	4	1	9	3	9	3	12	3	12	3
Diffuser department	2	1	2	1	3	1	3	1	6	3	6	3	9	3	9	3
First screening department	3	2	3	2	4	2	4	2	9	6	9	6	12	6	12	6
Bleaching department	–	–	2	1	–	–	2	1	–	–	6	3	–	–	6	3
Electrolytic plant and bleaching prep.	–	–	6	2	–	–	8	2	–	–	18	6	–	–	24	6
Second screen department	–	–	1	1	–	–	1	1	–	–	3	3	–	–	3	3
Pulp drying machine	12	3	12	3	16	4	16	4	36	9	36	9	48	12	48	12
Pulp store	5	1	5	1	6	1	6	1	15	3	15	3	18	3	18	3
Causticizing department	3	1	3	1	4	1	4	1	9	3	9	3	12	3	12	3
Evaporation plant	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
Soda recovery	6	1	6	1	6	1	6	1	18	3	18	3	18	3	18	3
Lime recovery and transport	6	1	6	1	8	2	8	2	18	3	18	3	24	6	24	6
Chemical stores	–	–	–	–	–	–	–	–	4	1	5	1	4	1	5	1
Water purification and pump station	2	1	2	1	2	1	2	1	6	3	6	3	6	3	6	3
General services	–	–	–	–	–	–	–	–	18	2	22	2	25	3	30	3
Transport workers	–	–	–	–	–	–	–	–	25	–	25	–	35	–	35	–
Repair shop	–	–	–	–	–	–	–	–	40	20	45	22	45	22	50	25
Boiler house	4	2	4	2	4	2	4	2	12	6	12	6	12	6	12	6
Power house	1	1	1	1	2	1	2	1	3	3	3	3	6	3	6	3
NO. OF WORKMEN (total and skilled)									275	83	320	99	345	94	405	109

Annual salaries:		Per day 200 Unbl.	Per day 200 Bl.	Per day 300 Unbl.	Per day 300 Bl.
thousand cruzeiros:	Skilled	2,990	3,560	3,380	3,924
	Unskilled	4,608	5,328	6,024	7,104
thousand dollars:	Skilled	93.4	111.4	105.8	122.6
	Unskilled	144.0	166.5	188.3	222.0

(1) Total number.
(2) Skilled workers.

Table A40

AMAPÁ PROJECT

NUMBER OF WORKMEN: INTEGRATED MILL

	Mill size, tons/day															
	Per 8 hours								Per day							
	50				100				50				100			
	Unbl.		Bl.		Unbl.		Bl.		Unbl.		Bl.		Unbl.		Bl.	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Log yard	10	2	10	2	12	2	12	2	20	4	20	4	24	4	24	4
Wood prep. department	4	2	6	2	5	2	8	3	8	4	12	4	10	4	16	66
Digester department	3	1	3	1	3	1	3	1	9	3	9	3	9	3	9	3
Diffuser department	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
First screening department	1	1	1	1	2	1	2	1	3	3	3	3	6	3	6	3
Bleaching department	–	–	1	1	–	–	1	1	–	–	3	3	–	–	3	3
Electrolytic plant and bleach liq. prep.	–	–	4	1	–	–	5	2	–	–	3	3	–	–	3	3
Second screening department	–	–	1	1	–	–	1	1	–	–	12	3	–	–	15	6
Causticizing department and lime kiln	3	2	3	2	6	2	6	2	9	6	9	6	18	6	18	6
Evaporation plant	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
Soda recovery	4	1	4	1	4	1	4	1	12	3	12	3	12	3	12	3
Chemical stores									4	1	5	1	5	1	6	1
Beater room	1	1	1	1	2	1	2	1	3	3	3	3	6	3	6	3
Size prep. department	1	1	1	1	2	1	2	1	3	3	3	3	6	3	6	3
Paper machine	6	3	6	3	9	4	9	3	18	9	18	9	27	12	27	12
Re-reelers	3	3	3	3	6	4	6	4	9	9	9	9	18	12	18	12
Duplex cutter	2	2	2	2	4	4	4	4	4	4	4	4	8	8	8	8
Balers									6	–	6	–	10	–	10	–
Reel packers									6	–	6	–	10	–	10	–
Re-reelers for small packers									1	1	1	1	2	2	2	2
Sorters									25	3	30	3	40	5	45	5
Transport workers									25	–	25	–	35	–	35	–
Water purification plant and pump station	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
Oilers	1	1	1	1	2	2	2	2	3	3	3	3	6	6	6	6
General services									12	1	14	1	16	1	18	1
Boiler house	3	1	3	1	3	1	3	1	9	3	9	3	9	3	9	3
Power house	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
Repair shop									35	17	40	20	45	22	50	25
TOTAL									236	92	271	104	334	113	374	130

Annual salaries:				Per day 50 Unbl.	Per day 50 Bl.	Per day 100 Unbl.	Per day 100 Bl.
Skilled labour	36,000 Cr.		Thousand cruzeiros	6,636	7,590	9,402	10,296
Unskilled labour	24,000 Cr.		Thousand dollars	207.4	237.2	293.8	321.8
Sorters	18,000 Cr.						

(1) Total number.
(2) Skilled workers.

Table A41

AMAPÁ PROJECT

NUMBER OF WORKMEN: NON-INTEGRATED PAPER MILL

	Mill size					
	Per 8 hours		Per day			
	50 tons/day	100 tons/day	50 tons/day		100 tons/day	
			Total	Skilled	Total	Skilled
Pulp store	–	–	4	1	5	1
Bale pulping	1	2	3	3	6	3
Beater department	1	2	3	3	6	6
Size preparation department	1	2	3	3	6	3
Paper machine	6	9	18	9	27	12
Reelers	3	6	9	6	18	12
Duplex cutter	2	4	4	4	8	8
Balers	–	–	4	4	6	4
Reel packers	–	–	3	–	6	–
Re-reelers for small reels	–	–	1	1	2	2
Sorters [a]	–	–	25	3	40	5
Transport workers	–	–	12	–	18	–
Water purification plant and pump station	1	1	3	3	3	3
Oilers	1	2	3	3	6	3
General services	–	–	9	–	12	–
Boiler house	2	2	6	3	6	3
Power station	1	1	3	3	3	3
Repair shop	–	–	20	10	25	10
TOTAL			133	(59)	203	(78)

Annual salaries (rates as in previous table): Thousand cruzeiros 3,756 — 5,598
Thousand dollars 117.4 — 174.9

[a] For bleached qualities additional 5 sorters required.

Table A42

AMAPÁ PROJECT

LABOUR COST PER TON OF UNBLEACHED PULP

(*all cost figures in cruzeiros per ton of pulp*)[a]

	Mill size							
	50 tons/day		100 tons/day		200 tons/day		300 tons/day	
Operating:								
Skilled	39	93.6	39	46.8	49	29.4	57	22.8
Unskilled	55	88.0	85	68.0	122	48.8	159	42.4
TOTAL	94	181.6	124	114.8	171	78.2	216	65.2
Man/hours	15.04		9.92		6.84		5.76	
Mill services:								
Skilled	10	24.0	10	12.0	14	8.4	15	6.0
Unskilled	30	48.0	39	31.2	50	20.0	69	18.4
TOTAL	40	72.0	49	43.2	64	28.4	84	24.4
Man/hours	6.40		3.92		2.56		2.24	
Repair:								
Skilled	12	28.8	15	18.0	20	12.0	22	8.8
Unskilled	13	20.8	15	12.0	20	8.0	23	6.1
TOTAL	25	49.6	30	30.0	40	20.0	45	14.9
Man/hours	4.00		2.40		1.60		1.20	
TOTAL	159	303.2	203	188.0	275	126.6	345	104.5
Man/hours	25.44		16.24		11.00		9.20	
Equiv. dollars		9.48		5.88		3.96		3.27

[a] 1 dollar = 32.00 cruzeiros.

Table A43

AMAPÁ PROJECT

LABOUR COST PER TON OF BLEACHED PULP

(*all cost figures in cruzeiros per ton of pulp*)[a]

	Mill size							
	50 tons/day		100 tons/day		200 tons/day		300 tons/day	
Operating:								
Skilled	48	115.2	53	63.6	63	37.8	69	27.6
Unskilled	69	110.4	99	79.2	144	57.6	197	52.5
TOTAL	117	225.6	152	142.8	207	95.4	266	80.1
Man/hours	18.72		12.16		8.28		7.09	
Mill services								
Skilled	10	24.0	10	12.0	14	8.4	15	6.0
Unskilled	32	51.2	41	32.8	54	21.6	74	19.7
TOTAL	42	75.2	51	44.8	68	30.0	89	25.7
Man/hours	6.72		4.08		2.72		2.37	
Repair:								
Skilled	14	33.6	18	21.6	22	13.2	25	10.0
Unskilled	16	25.6	17	13.6	23	9.2	25	6.7
TOTAL	30	59.2	35	35.2	45	22.4	50	16.7
Man/hours	4.80		2.80		1.80		1.33	
TOTAL	189	360.0	238	222.8	320	147.8	405	122.5
Man/hours	30.24		19.04		12.80		10.8	
Equiv. dollars		11.25		6.96		4.62		3.83

[a] 1 dollar = 32.00 cruzeiros.

Table A44

AMAPÁ PROJECT

LABOUR COST PER TON OF PAPER

(all cost figures in cruzeiros per ton of paper)[a]

	Mill size											
	Non-integrated mill				*Integrated mill Unbleached*				*Integrated mill Bleached*			
	50 tons/day		*100 ton/sday*		*50 tons/day*		*100 tons/day*		*50 tons/day*		*100 tons/day*	
	No.	*Cost*	*No.*	*Cost*	*No.*	*Cost*	*No.*	*Cost*	*No.*	*Cost*	*No.*	*Cost*
Operating:												
Pulp section: Skilled	—	—	—	—	30	72.0	30	36.0	39	93.6	44	52.8
Unskilled	—	—	—	—	41	65.6	60	48.0	55	88.0	74	59.2
Paper section: Skilled	37	88.8	56	67.2	32	76.8	45	54.0	32	76.8	45	54.0
Unskilled	18	28.8	39	31.2	21	33.6	47	37.6	21	33.6	47	37.6
Sorters	22	26.4	35	21.0	22	26.4	35	21.0	27	32.4	40	24.0
TOTAL	77	144.0	130	119.4	146	274.4	217	196.6	174	324.4	250	227.6
Man hrs/ton		12.32		10.40		23.36		17.36		27.84		20.00
Mill services:												
Skilled	12	28.8	12	14.4	13	31.2	16	19.2	13	31.2	16	19.2
Unskilled	24	38.4	36	28.8	42	67.2	56	44.8	44	70.4	58	46.4
TOTAL	36	67.2	48	43.2	55	98.4	72	64.0	57	101.6	74	65.6
Man hrs/ton		5.76		3.84		8.80		5.76		9.12		5.92
Repairs:												
Skilled	10	24.0	10	12.0	17	40.8	22	26.4	20	48.0	25	30.0
Unskilled	10	16.0	15	12.0	18	28.8	23	18.4	20	32.0	25	20.0
TOTAL	20	40.0	25	24.0	35	69.6	45	44.8	40	80.0	50	50.0
Man hrs/ton		3.20		2.0		5.60		3.60		6.40		4.00
TOTAL	133	251.2	203	186.6	236	442.2	334	305.4	271	506.0	374	343.2
Man hrs/ton		21.28		16.24		37.76		26.72		43.36		29.92
Equivalent dollars		7.85		5.83		13.82		9.54		15.81		10.73

[a] 1 dollar = 32.00 cruzeiros.

Table A45 AMAPÁ PROJECT HOUSING PROJECT: PULP MILL (*thousand dollars*)

	Unit cost per man	Mill size: 50 tons/day Unbl.	50 tons/day Bl.	100 tons/day Unbl.	100 tons/day Bl.	200 tons/day Unbl.	200 tons/day Bl.	300 tons/day Unbl.	300 tons/day Bl.
Managing director	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
Mill manager	8.0	—	—	—	—	8.0	8.0	8.0	8.0
Mill superintendent	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
Assistant superintendent	5.5	—	—	—	—	5.5	5.5	5.5	5.5
Chief chemist	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Superintendent workshops	4.7	4.7	4.7	4.7	4.7	9.4	9.4	9.4	9.4
Foremen	4.0	28.0	28.0	28.0	28.0	32.0	32.0	48.0	48.0
Shift chemist, lab. asst. and draftsmen	2.4	14.4	14.4	16.8	16.8	21.6	21.6	26.4	26.4
Secretary	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Chief accountant	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
Office clerks and typists	2.4	12.0	12.0	19.2	19.2	24.0	24.0	28.8	28.8
Storekeepers, asst. storekeepers and clerk	2.4	2.4	2.4	2.4	2.4	9.6	9.6	12.0	12.0
Porters and messengers	1.3	6.5	6.5	6.5	6.5	8.1	8.1	8.9	8.9
Sub-total: administration and supervisory personnel		100.4	100.4	110.0	110.0	150.6	150.6	179.4	179.4
Skilled workmen	3.2	195.2	230.4	204.8	259.2	265.6	316.8	300.8	348.8
Unskilled workmen	2.0	196.0	238.0	282.0	318.0	384.0	444.0	502.0	592.0
TOTAL		491.6	568.8	596.8	687.2	800.2	911.4	982.2	1,120.2

Table A46 AMAPÁ PROJECT (*figures in thousands of dollars except where otherwise stated*)

	Unit cost	Housing project: integrated mill — 50 tons/day Unbl. No.	50 tons/day Unbl. Total	50 tons/day Bl. No.	50 tons/day Bl. Total	100 tons/day Unbl. No.	100 tons/day Unbl. Total	100 tons/day Bl. No.	100 tons/day Bl. Total	Housing project: non-integrated paper mill — Unit cost	50 tons/day No.	50 tons/day Total	100 tons/day No.	100 tons/day Total
Managing director	11	1	11.0	1	11.0	1	11.0	1	11.0	11	1	11.0	1	11.0
Mill manager	8	1	8.0	1	8.0	1	8.0	1	8.0	8	1	8.0	1	8.0
Mill superintendent	5.7					1	5.7	1	5.7	5.7	1	5.7	1	5.7
Assistant mill superintendent	5.5	1	5.5	1	5.5	1	5.5	1	5.5					
Chief chemist	5.5	1	5.5	1	5.5	1	5.5	1	5.6	5.5	1	5.5	1	5.5
Superintendent workshops	9.4	2	9.4	2	9.4	2	9.4	2	9.4	4.7	1	4.7	2	9.4
Shift foremen										4.0	3	12.0	3	12.0
Foremen	4.0	11	44.0	11	44.0	12	48.0	12	48.0	8.0	4	16.0	4	16.0
Shift chemists	2.4	3	7.2	3	7.2	3	7.2	3	7.2					
Lab. assistant and draftsmen	2.4	4	9.6	4	9.6	6	9.6	6	9.6	2.4	3	7.2	4	9.6
Secretary	5.5	1	5.5	1	5.5	1	5.5	1	5.5	5.5	1	5.5	1	5.5
Chief accountant	4.7	1	4.7	1	4.7	1	4.7	1	5.7	4.7	1	4.7	1	4.7
Office clerks, typists, storekeepers, etc.	2.4	9	21.6	9	21.6	14	33.6	14	33.6	4.8	8	19.2	11	26.4
Porters and messengers	1.3	6	8.1	6	8.1	7	8.9	7	8.9	1.3	5	6.5	6	7.8
Sub-total: administration and supervisory personnel			140.1		140.1		162.6		162.6			106.0		121.6
Skilled workmen	3.2	92	294.0	104	333.0	113	362.0	130	416.0	3.2	58	185.6	78	249.6
Unskilled workmen	2.0	122	244.0	140	280.0	186	372.0	204	408.0	2.0	75	150.0	125	250.0
Sorters	—	22	—	27	—	35	—	40	—	—	22	—	35	—
TOTAL: PAPER MILL			678.1		753.1		896.6		986.6			441.6		621.2

Table A47

AMAPÁ PROJECT

GENERAL COMMUNITY EXPENSES

(all costs in dollars)

The following are estimates only, and based on the assumption that for every 1,000 inhabitants of the community, 200 will be actually employed in forest or mill services. Housing projects for these workmen are calculated separately and charged to the mill and the forest department respectively.

Investment
(thousand dollars)

	Number of inhabitants				
	1,000	*2,000*	*4,000*	*8,000*	*16,000*
Community roads, parks, etc.	110	190	335	625	1,100
Housing for teachers, doctors and workmen	30	60	110	210	350
Schools	15	30	56	95	150
Hospital (15 beds/1,000)	20	40	65	110	130
Amusement facilities	35	70	130	220	375
Shops, restaurants, etc.	20	40	65	110	130
Water system	10	20	35	65	110
Electricity	17	30	55	95	180
Contingencies	23	35	64	125	195
TOTAL INVESTMENT	280	515	915	1,655	2,720

Annual capital costs
(dollars)

	Number of inhabitants				
	1,000	*2,000*	*4,000*	*8,000*	*16,000*
Depreciation, community roads, etc.	3,700	6,300	11,000	21,000	37,000
Depreciation, houses, schools, hospitals, shops, restaurants, etc.	6,000	12,000	21,300	37,200	56,800
Depreciation, water system, power plant	2,700	5,000	9,000	16,000	29,000
TOTAL DEPRECIATION	12,400	23,300	41,300	74,200	122,800
Interest, 8 per cent, first year	22,400	41,200	73,200	132,400	217,600
Interest, average	11,200	20,600	36,600	66,200	108,800
TOTAL AVERAGE COST	23,600	43,900	77,900	140,400	231,600

Annual operating expenses
(dollars)

	Number of inhabitants				
	1,000	*2,000*	*4,000*	*8,000*	*16,000*
Repairs of roads, parks, etc.	4,100	7,200	12,000	23,000	40,000
Repairs of schools, hospitals, etc.	2,500	5,200	9,000	16,000	22,500
Electricity supply	7,000	13,000	25,000	44,000	84,000
Water	600	1,200	2,200	4,000	7,500
Salaries, teachers, doctors, etc.	32,000	65,000	120,000	230,000	400,000
Contingencies	4,800	8,400	13,800	25,000	46,000
TOTAL	51,000	100,000	182,000	342,000	600,000
TOTAL ANNUAL COSTS	74,600	143,900	259,900	482,400	831,600

Community expenses per ton of product

	Capacity tons/day	*No. of workmen*	*Total inhabitants*	*Annual expenses (thousand dollars)*	*Dollars per ton*
Pulp mill, unbl.	50	470	2,350	165	11.00
Pulp mill, unbl.	100	785	3,925	255	8.50
Pulp mill, unbl.	200	1,400	7,000	425	7.08
Pulp mill, unbl.	300	2,040	10,200	600	6.67
Pulp mill, bl.	50	550	2,750	187	12.47
Pulp mill, bl.	100	880	4,400	280	9.33
Pulp mill, bl.	200	1,570	7,850	465	7.75
Pulp mill, bl.	300	2,275	11,375	660	7.33
Integrated mill, unbl.	50	570	2,850	192	12.80
Integrated mill, unbl.	100	945	4,725	300	10.00
Integrated mill, bl.	50	650	3,250	218	14.53
Integrated mill, bl.	100	1,050	5,250	328	10.93
Non-integrated paper mill[a]	50	180	900	—	—
Non-integrated paper mill	100	260	1,300	—	—

[a] Non-integrated paper mill should be established near main consuming centres, where community facilities are already established.

Chart A48

AMAPÁ PROJECT: GENERAL COMMUNITY EXPENSES

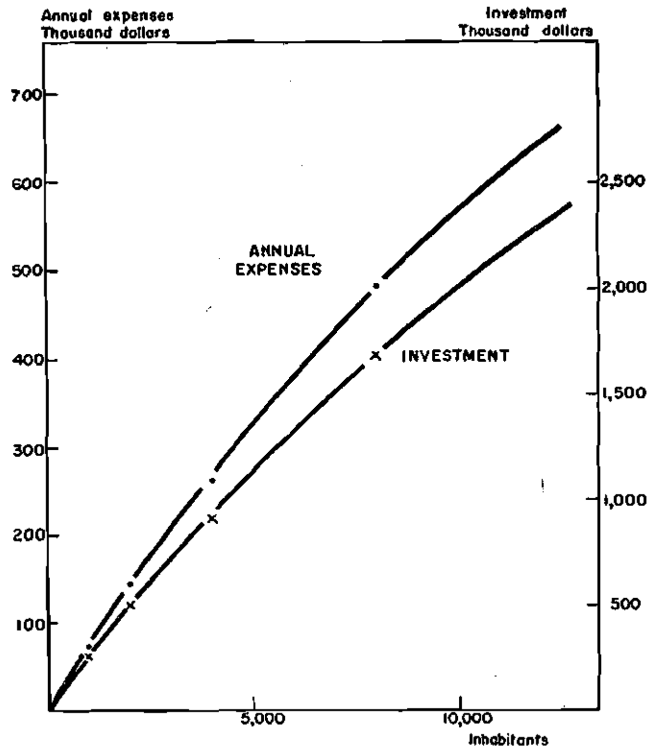


Table A49

AMAPÁ PROJECT

INVESTMENTS: PULP MILL

(thousand dollars)

	Mill size							
	50 tons/day		*100 tons/day*		*200 tons/day*		*300 tons/day*	
	Unbl.	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*
1. Log yard	100	100	115	115	125	125	230	230
2. Wood prep. department and chip silos	310	310	435	435	540	540	735	735
3. Digester and diffuser departments	380	380	435	435	690	690	965	965
4. First screening department	205	205	355	355	510	510	660	660
5. Bleaching department		250		360		470		580
6. Electrolytic plant and bleach liquid prep.		525		640		735		830
7. Salt store		4		5		6		7
8. Second screening department		77		120		160		212
9. Pulp drying machine department	275	275	450	450	825	825	1,190	1,190
10. Pulp store	12	12	15	15	17	17	19	19
11. Evaporation plant and soda recovery	795	795	1,000	1,000	1,220	1,220	1,830	1,830
12. Sulphate store	12	12	15	15	17	17	19	19
13. Causticizing department	212	212	405	405	575	575	760	760
14. Piping between different buildings	58	68	77	92	106	121	126	140
15. Electrical motors and cables	116	145	190	230	330	375	445	500
16. Insulation material and woodwork	17	20	23	26	30	34	37	41
17. Water purification plant and pump station	100	100	146	146	265	265	346	346
18. Steam and power station	500	565	600	700	675	840	735	945
19. Machinery in repair shop	155	155	175	175	190	190	210	210
20. Machinery in fire station	25	25	25	25	25	25	25	25
21. Laboratory equipment	15	15	20	20	20	20	20	20
22. Office equipment	20	20	25	25	30	30	40	40
23. Excav. and planning of site	160	166	218	230	301	320	397	422
24. Cost of freight, ocean	265	290	350	375	485	510	685	735
Cost of freight, local	60	65	80	85	110	115	150	160
25. Cost of erection	250	313	338	456	463	606	700	888
26. Administ. during erection	80	80	129	129	181	181	206	206
27. Cost of buildings, chests, etc.	2,200	2,744	2,654	3,198	3,639	4,309	4,922	5,783
28. Houses for staff and workers (pulp mill)	492	569	597	687	800	911	982	1,120
29. Railway-lines on mill site	750	750	775	775	799	799	821	821
30. Engineering fees	380	475	485	570	610	715	820	960
31. Unforeseen expenses	136	148	158	186	202	254	275	321
TOTAL INVESTMENT	8,080	9,870	10,290	12,480	13,770	16,510	18,350	21,720

Table A50

AMAPÁ PROJECT

INVESTMENTS: NON-INTEGRATED AND INTEGRATED PAPER MILL

(*thousand dollars*)

	Mill size					
	Non-integrated mill		Integrated mill			
			50 tons/day		100 tons/day	
	50 tons/day	100 tons/day	Unbleached	Bleached	Unbleached	Bleached
1. Pulp-mill machinery	—	—	2,104	2,960	2,929	4,054
2. Paper-mill machinery	1,930	2,900	1,850	1,850	2,820	2,820
3. Electrical motors and cables	145	232	240	270	395	425
4. Piping between diff. buildings	30	40	87	97	117	130
5. Insulation material and woodwork	17	23	33	35	43	45
6. Water purification plant and pump station	70	88	130	130	235	235
7. Boiler house and steam turbine department	515	650	680	760	810	980
8. Machinery in repair shop	155	175	175	175	195	195
9. Machinery in fire station	23	23	23	23	23	23
10. Laboratory equipment	15	15	20	20	20	20
11. Office equipment	20	23	23	23	29	29
12. Excavation and planning of site	60	100	160	165	220	230
13. Cost of freight, ocean	115	155	370	385	465	485
Cost of freight, local	25	35	85	90	110	115
14. Cost of erection	145	195	366	441	485	612
15. Administration during erection	70	121	136	136	233	233
16. Cost of buildings, chests, etc.	1,800	2,594	2,750	3,265	3,846	4,405
17. Houses for staff and workmen	422	607	678	753	897	987
18. Railway-lines on mill site	750	750	775	775	799	799
19. Engineering fees	300	440	530	600	700	790
20. Unforeseen expenses	103	134	160	222	249	308
TOTAL COST	6,710	9,300	11,375	13,175	15,620	17,920

Table A51

AMAPÁ PROJECT

CAPITAL REQUIREMENTS: PULP MILLS

(*thousand dollars*)

	Mill size							
	50 tons/day		100 tons/day		200 tons/day		300 tons/day	
	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.
1. Machinery, freight, erection, etc.	4,122	5,184	5,621	7,064	7,730	9,522	10,510	12,715
2. Forest equipment	352	406	662	768	1,300	1,508	2,040	2,362
3. Engineering fees, etc.	380	475	485	570	610	715	820	960
TOTAL	4,854	6,065	6,768	8,402	9,640	11,745	13,370	16,037
4. Buildings, chests, etc.	2,200	2,744	2,654	3,198	3,629	4,309	4,922	5,783
5. Railway lines	750	750	775	775	799	799	821	821
6. Forest prep. work and primary roads	123	123	205	205	371	371	536	536
7. Housing project, factory	492	569	597	687	800	911	982	1,120
8. Housing project, forest dept.	557	626	1,089	1,224	2,182	2,451	3,336	3,746
9. Contingencies	187	191	257	285	390	426	587	638
10. General community investments	590	670	900	1,000	1,460	1,610	2,020	2,200
TOTAL	4,899	5,773	6,477	7,376	9,616	10,877	13,204	14,844
11. Capital costs during erection period: foreign currency	582	728	812	1,008	1,157	1,409	1,604	1,924
12. Capital costs during erection period: local currency	587	694	781	888	1,152	1,307	1,595	1,777
TOTAL	1,169	1,422	1,593	1,896	2,309	2,716	3,189	3,701
13. Working capital, factory	800	960	1,200	1,440	1,960	2,360	2,790	3,360
14. Working capital, forest dept.	98	110	182	206	355	412	597	668
TOTAL	898	1,070	1,382	1,646	2,315	2,772	3,387	4,028
15. GRAND TOTAL	11,820	14,330	16,220	19,320	23,880	28,110	33,150	38,610
Amount foreign exchange *ex* grand total	5,436	6,793	7,580	9,410	10,797	13,154	14,974	17,961
Percentage foreign exchange *ex* grand total	46.0	47.4	46.7	48.7	45.2	46.8	45.2	46.5

Table A52

AMAPÁ PROJECT

CAPITAL REQUIREMENTS: PAPER MILLS

(*thousand dollars*)

	Mill size, tons/day					
	Non-integrated		Integrated mills			
	50	100	50		100	
	Unbleached	Bleached	Unbleached	Bleached	Unbleached	Bleached
1. Machinery, freight, adm. during erection, etc.	3,105	4,445	5,871	6,864	8,314	9,674
2. Forest equipment	—	—	416	476	788	886
3. Engineering fees	300	440	530	600	700	790
TOTAL	3,405	4,885	6,817	7,940	9,762	11,350
4. Excavation, erection, buildings, chests, etc.	2,030	2,924	3,361	3,961	4,661	5,362
5. Railway lines, etc.	750	750	775	775	799	799
6. Forest prep. work and primary roads	—	—	123	123	205	205
7. Housing project, factory	422	607	678	753	897	987
8. Housing project, forest department	—	—	557	626	1,089	1,224
9. Contingencies	107	138	222	292	364	438
10. General community investments	—	—	192	218	300	328
TOTAL	3,309	4,419	5,908	6,748	8,315	9,343
11. Capital costs during erection period: Foreign exchange	409	586	818	952	1,176	1,363
12. Capital costs during erection period: Local exchange	397	530	709	810	998	1,121
TOTAL	806	1,116	1,527	1,762	2,174	2,484
13. Working capital, factory	1,255[a]	1,960[a]	1,155	1,320	1,810	2,060
14. Working capital, forestry department	—	—	98	120	189	233
TOTAL	1,255	1,960	1,253	1,440	1,999	2,293
15. Grand TOTAL	8,775	12,380	15,505	17,890	22,250	25,470
16. Amount foreign exchange *ex* grand total	3,814	5,471	7,635	8,900	10,938	12,713
Percentage foreign exchange *ex* grand total	43.5	44.2	49.3	49.7	49.2	49.9

[a] Refers to unbleached qualities.

Table A53

AMAPÁ PROJECT

CAPITAL COSTS: PULP MILL

1. *Depreciation*[a]

Capital required: Machinery, engineering, fees, unforeseen expenses ... 10 years
Buildings, chests, etc. ... 20 years
Port, railways, etc. ... 30 years

	Mill size, tons/day							
	50		100		200		300	
	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.
Machinery, pulp mill[b]	3,307	4,304	4,630	5,973	6,525	8,152	9,154	11,129
Machinery, mill services	815	880	991	1,091	1,205	1,370	1,376	1,586
Buildings, chests, etc.	2,200	2,744	2,654	3,198	3,629	4,309	4,922	5,783
Housing project	492	569	597	687	800	911	982	1,120
Railway-lines	750	750	775	775	799	799	821	821
Unforeseen expenses	136	148	158	186	202	254	275	321
Engineering fees	380	475	485	570	610	715	820	960
TOTAL (thousand dollars)	8,080	9,870	10,290	12,480	13,770	16,510	18,350	21,720
Capital cost (Dollars per ton pulp)								
Machinery, pulp mill	22.05	28.69	15.43	19.91	10.88	13.59	10.17	12.37
Machinery, mill services	5.43	5.87	3.30	3.64	2.01	2.28	1.53	1.76
Buildings, chests, etc.	7.33	9.15	4.42	5.33	3.02	3.59	2.73	3.21
Housing project	1.64	1.90	1.00	1.15	0.67	0.76	0.55	0.62
Railway-lines	1.67	1.67	0.86	0.86	0.44	0.44	0.30	0.30
Unforeseen expenses	0.91	1.00	0.53	0.62	0.34	0.43	0.31	0.36
Engineering fees	2.53	3.17	1.62	1.90	1.02	1.19	0.91	1.07
TOTAL	41.56	51.45	27.16	33.41	18.38	22.28	16.50	19.69

Table A53 (continued)

2. *Amortization of capital costs during erection*

It is assumed that the investment capital accrues proportionately during the first three years, which is the time estimated for the mill to get into operation.

Rate of interest: 8 per cent.

	Mill size, tons/day							
	50		100		200		300	
	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.
Capital required:[c] thousand dollars	9,753	11,838	13,245	15,778	19,256	22,622	26,574	30,881
Capital cost: thousand dollars	1,170	1,420	1,589	1,893	2,311	2,715	3,189	3,706
Dollars per ton during 10 years	7.80	9.47	5.30	6.31	3.85	4.53	3.54	4.12

[a] Depreciation of forest equipment charged to cost of pulpwood.
[b] Including freight, erection, etc.
[c] See capital requirements.

3. *Interest on fixed capital* [a]

Rate of interest: 8 per cent.

	Mill size, tons/day							
	50		100		200		300	
	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.
First year	43.09	52.64	27.44	33.28	18.36	22.01	16.31	19.30
Average during depr. period	21.55	26.32	13.72	16.64	9.18	11.01	8.16	9.65

4. *Interest on working capital (in mill operation)*

Working capital is estimated as being equivalent to the value of 4 months' production.

	Mill size, tons/day							
	50		100		200		300	
	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.
Value dollars per ton	160	192	120	144	98	118	93	112
4 months' production value, thousand dollars	800	960	1,200	1,440	1,960	2,360	2,790	3,360
Interest per ton of pulp	4.27	5.12	3.20	3.84	2.61	3.15	2.48	2.98

5. *Insurance*

Insurance is calculated at 1 per cent of machinery, buildings and spare parts (5 per cent of machinery).

	Mill size, tons/day							
	50		100		200		300	
	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.
Yearly exp.: thousand dollars	71.1	88.5	93.3	114.8	128.0	154.7	172.9	205.9
Dollars per ton of pulp	4.74	5.23	3.11	3.83	2.13	2.58	1.92	2.29

Total capital costs per ton pulp

	Mill size, tons/day							
	50		100		200		300	
	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.
Depreciation	41.56	51.45	27.16	33.41	18.38	22.28	16.50	19.69
Amortization of capital costs	7.80	9.47	5.30	6.31	3.85	4.53	3.54	4.12
Interest, fixed capital	21.55	26.32	13.72	16.64	9.18	11.01	8.16	9.65
Interest, working capital	4.27	5.12	3.20	3.84	2.61	3.15	2.48	2.98
Insurance	4.74	5.23	3.11	3.83	2.13	2.58	1.92	2.29
TOTAL	79.92	97.59	52.49	64.03	36.15	43.55	32.60	38.73

[a] Interest on capital required for forest operations charged to cost of pulpwood.

Table A54

AMAPÁ PROJECT

CAPITAL COSTS: INTEGRATED AND NON-INTEGRATED PAPER MILLS

1. *Depreciation*

Machinery, engineering fees and unforeseen expenses ..... 10 years
Buildings, chests, etc. ..... 20 years
Port, railways, etc. ..... 30 years

Capital required:

	Mill size, tons/day					
	Non-integrated		Integrated mill			
	50	100	50		100	
			Unbl.	Bl.	Unbl.	Bl.
Machinery, pulp and paper mill	2,537	3,801	5,431	6,429	7,817	9,149
Machinery, mill services	798	974	1,051	1,131	1,312	1,482
Buildings, chests, etc.	1,800	2,594	2,750	3,265	3,846	4,405
Housing project	442	621	678	753	897	987
Railway	750	750	775	775	799	799
Engineering fees	300	440	530	600	700	790
Unforeseen expenses	103	130	160	222	245	304
TOTAL	6,710	9,310	11,375	13,175	15,616	17,916
Capital cost: (dollars per ton of pulp)						
Machinery, pulp and paper mill	16.91	12.67	36.21	42.86	26.06	30.50
Machinery, mill services	5.32	3.25	7.01	7.54	4.37	4.94
Buildings, chests, etc.	6.00	4.32	9.17	10.88	6.41	7.34
Housing project	1.47	1.04	2.26	2.51	1.50	1.65
Railway	1.67	0.83	1.72	1.72	0.89	0.89
Engineering	2.00	1.47	3.53	4.00	2.33	2.63
Unforeseen expenses	0.69	0.43	1.07	1.48	0.82	1.03
TOTAL	34.06	24.01	60.97	70.99	42.38	48.98

2. *Amortization of capital costs during erection*

It is assumed that the investment capital accrues proportionately during the first three years, which is the time estimated for the mill to get into operation.

Rate of interest: 8 per cent.

	Mill size, tons/day					
	Non-integrated		Integrated mill			
	50	100	50		100	
			Unbl.	Bl.	Unbl.	Bl.
Capital required: thousand dollars	6,710	9,300	12,725	14,685	18,116	20,696
Capital cost	805.2	1,160	1,527	1,762	2,174	2,484
Dollars per ton during 10 years	5.37	3.87	10.20	11.75	7.25	8.28

3. *Interest on fixed capital*

Rate of interest: 8 per cent.

	Mill size, tons/day					
	Non-integrated		Integrated mill			
	50	100	50		100	
			Unbl.	Bl.	Unbl.	Bl.
First year	35.78	24.80	67.87	78.32	48.31	55.19
Average during depr. year	17.89	12.40	33.62	39.16	24.16	27.60

4. *Interest on working capital*

Working capital estimated as being equivalent to value of 4 months' production.

	Mill size, tons/day							
	50		100		50		100	
	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.
Value: dollars per ton	251	284	196	221	231	264	181	206
Production value: thousand dollars	1,255	1,420	1,960	2,210	1,155	1,320	1,810	2,060
Interest 8 per cent	6.80	7.58	5.23	5.90	6.17	7.04	4.83	5.49

Table A54 (continued)

5. *Insurance*

Insurance calculated at 1 per cent of machinery, buildings and spare parts (5 per cent of machinery).

	Mill size, tons/day					
	50	100	50		100	
			Unbl.	Bl.	Unbl.	Bl.
Yearly exp.: thousand dollars	68.7	94.9	120.0	139.0	164.0	188.0
Dollars per ton of pulp	4.58	3.16	8.00	9.27	5.47	6.27

TOTAL CAPITAL COSTS PER TON PAPER

	Mill size, tons/day					
	50	100	50		100	
			Unbl.	Bl.	Unbl.	Bl.
Depreciation	34.06	24.01	60.97	70.99	42.38	48.98
Amortization of capital	5.37	3.87	10.20	11.75	7.25	8.28
Interest, fixed capital	17.89	12.40	33.62	39.16	24.16	27.60
Interest, working capital	6.80 [a]	5.23 [a]	6.17	7.04	4.83	5.49
Insurance	4.58	3.16	8.00	9.27	5.47	6.27
TOTAL	68.70	48.67	118.96	138.21	84.09	96.62
For bleached qualities, add	0.78	0.67				
	69.48	49.34				

[a] Refer to unbleached pulp.

Table A55

SWEDISH PROJECT

CAPITAL COSTS: PULP MILL

(all figures in dollars)

1. *Depreciation*

Machinery, engineering, unforeseen expenses ..... 15 years
Buildings, chests, etc. ..... 25 years
Port, railways, etc. ..... 40 years

	Mill size, tons/day							
	50		100		200		300	
	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.
Investment: thousand dollars								
1. Machinery, pulp mill [a]	3,095	3,892	4,150	5,431	5,842	7,413	8,216	10,064
2. Machinery, mill services	810	829	978	1,006	1,195	1,236	1,365	1,413
3. Buildings, chests, etc.	1,421	1,778	1,602	1,988	2,162	2,645	2,896	3,475
4. Housing project	290	290	386	386	483	483	579	579
5. Railway-lines and port	309	309	444	444	579	579	714	714
6. Unforeseen expenses	75	97	100	125	144	164	180	215
7. Engineering fees	210	250	270	330	365	440	490	575
TOTAL: thousand dollars	6,075	7,445	7,930	9,710	10,770	12,960	14,440	17,035
Depreciation:								
(dollars per ton pulp)								
1. Machinery, pulp mill	13.76	17.30	9.22	12.07	6.49	8.24	6.09	7.45
2. Machinery, mill services	3.60	3.68	2.17	2.24	1.33	1.37	1.01	1.05
3. Buildings, chests, etc.	3.79	4.74	2.14	2.65	1.44	1.76	1.29	1.54
4. Housing project	0.77	0.77	0.51	0.51	0.32	0.32	0.26	0.26
5. Railway-lines and port	0.52	0.52	0.37	0.37	0.24	0.24	0.20	0.20
6. Unforeseen expenses	0.33	0.43	0.22	0.28	0.16	0.18	0.13	0.16
7. Engineering fees	0.93	1.11	0.60	0.79	0.41	0.49	0.36	0.43
TOTAL	23.70	28.55	15.23	18.85	10.39	12.60	9.47	11.09

[a] Including freight, erection, etc.

2. *Amortization of capital costs during erection*

It is assumed that the investment capital accrues proportionately during three years, the estimated time required until the mill is in operation.

Rate of interest: 5 per cent.

	Mill size, tons/day							
	50		100		200		300	
	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.	Unbl.	Bl.
Mill investment: thousand dollars	6,075	7,445	7,930	9,710	10,770	12,960	14,440	17,035
Capital cost	455.6	558.4	594.8	728.3	807.8	972.0	1,083.0	1,277.6
Dollars per ton during 10 years	3.04	3.72	1.98	2.43	1.35	1.62	1.20	1.42

Table A55 (continued)

3. *Interest on fixed capital* [a]

Rate of interest: 5 per cent.

	Mill size, tons/day							
	50		100		200		300	
	Unbl.	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*
Interest first year	20.25	24.82	13.22	16.18	8.97	10.80	8.02	9.46
Interest average	10.13	12.41	6.61	8.09	4.49	5.40	4.01	4.73

[a] Interest on capital required for forest operations is charged to the cost of pulpwood.

4. *Interest on working capital* (mill operation only)

Rate of interest: 6 per cent.
Working capital is estimated as being equivalent to the value of 4 months' production.

	Mill size, tons/day							
	50		100		200		300	
	Unbl.	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*
Value: dollars per ton	120	140	95	110	85	95	80	90
4 months' production value: thousand dollars	600	700	950	1,100	1,700	1,900	2,400	2,700
Interest	2.40	2.80	1.90	2.20	1.70	1.90	1.60	1.80

5. *Insurance* is included in overhead costs

Total capital costs per ton pulp

	Mill size, tons/day							
	50		100		200		300	
	Unbl.	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*
Depreciation	23.70	28.55	15.23	18.85	10.39	12.60	9.47	11.09
Amortization of capital costs	3.04	3.72	1.98	2.43	1.35	1.62	1.20	1.42
Interest, fixed capital	10.13	12.41	6.61	8.09	4.49	5.40	4.01	4.73
Interest, working capital	2.40	2.80	1.90	2.20	1.70	1.90	1.60	1.80
TOTAL	39.27	47.48	25.72	31.57	17.93	21.52	16.28	19.04

Table A56

SWEDISH PROJECT

CAPITAL COSTS: INTEGRATED AND NON-INTEGRATED PAPER MILLS

1. *Depreciation*

Machinery, engineering fees and unforeseen exp. .... 15 years
Buildings, chests, etc. .... 25 years
Port, railways, etc. .... 40 years

	Mill size, tons/day					
	Non-integrated		Integrated mill			
	50	100	50		100	
			Unbleached	*Bleached*	*Unbleached*	*Bleached*
1. Pulp and paper machinery	2,378	3,571	4,872	5,832	7,032	8,320
2. Mill services machinery	732	852	978	1,007	1,195	1,234
3. Buildings, chests, etc.	965	1,351	1,709	2,124	2,516	2,703
4. Housing project	290	386	386	386	483	483
5. Railway and port	290	444	444	444	579	579
6. Engineering	165	235	300	350	420	475
7. Unforeseen expenses	68	91	111	127	155	176
Thousand dollars	4,950	6,930	8,800	10,270	12,380	13,970
Dollars per ton of pulp:						
Machinery	10.57	7.94	21.65	25.92	15.63	18.49
Mill services	3.25	1.89	4.35	4.48	2.66	2.74
Buildings, chests, etc.	2.57	1.80	4.56	5.66	3.09	3.60
Housing project	0.77	0.51	1.03	1.03	0.64	0.64
Railway and port	0.48	0.37	0.74	0.74	0.48	0.48
Engineering	0.73	0.52	1.33	1.55	0.93	1.06
Unforeseen expenses	0.30	0.20	0.49	0.56	0.34	0.39
	18.67	13.23	34.15	39.94	23.77	27.40

Table A56 (continued)

2. *Amortization of capital costs during erection*

It is assumed that the investment capital accrues proportionately during three years, the estimated time required before the mill begins operation.

Rate of interest: 5 percent.

	Mill size, tons/day					
	Non-integrated		Integrated mill			
	50	100	50		100	
			Unbleached	Bleached	Unbleached	Bleached
Capital required: thousand dollars	4,950	6,930	8,800	10,270	12,380	13,970
Capital cost	371.3	519.8	660.0	770.3	928.5	1,048
Dollars per ton during 10 years	2.48	1.73	4.40	5.14	3.10	3.49

3. *Interest on fixed capital*

Rate of interest: 5 per cent.

	Mill size, tons/day					
	Non-integrated		Integrated mill			
	50	100	50		100	
			Unbleached	Bleached	Unbleached	Bleached
First year	16.50	11.55	29.33	34.23	20.63	23.28
Average during depr. period	8.25	5.78	14.67	17.12	10.32	11.64

4. *Interest on working capital* (mill operation only).

Rate of interest: 6 per cent.

Working capital is estimated as being equivalent to the value of 4 months' production.

	Mill size, tons/day							
	50		100		50		100	
	Unbleached	Bleached	Unbleached	Bleached	Unbleached	Bleached	Unbleached	Bleached
Value: dollars per ton	191	215	156	177	171	195	141	162
4 months' prod. value: thousand dollars	955	1,075	1,560	1,770	855	975	1,410	1,620
Interest	3.82	4.30	3.12	3.54	3.42	3.90	2.82	3.24

5. *Insurance* is included in overhead costs

Total capital costs per ton paper

	Mill size, tons/day					
	50	100	50		100	
			Unbleached	Bleached	Unbleached	Bleached
Depreciation	18.67	13.23	34.15	39.94	23.77	27.40
Amortization of capital	2.48	1.73	4.40	5.14	3.10	3.49
Interest, fixed capital	8.25	5.78	14.67	17.12	10.32	11.64
Interest, working capital	3.82[a]	3.12[a]	3.42	3.90	2.82	3.24
TOTAL	33.22	23.86	56.64	66.10	40.01	45.77
For bleached qualities add	0.48	0.42				
	33.70	24.28				

[a] Refers to unbleached pulp.

Table B57

SWEDISH PROJECT

COST ESTIMATES: UNBLEACHED PULP

		Mill capacity															
		50 tons/day				100 tons/day				200 tons/day				300 tons/day			
	Unit	Quantity	Unit cost (dollars)	Cost per ton of pulp (dollars)		Quantity	Unit cost (dollars)	Cost per ton of pulp (dollars)		Quantity	Unit cost (dollars)	Cost per ton of pulp (dollars)		Quantity	Unit cost (dollars)	Cost per ton of pulp (dollars)	
Pulpwood	m³, 1.m	6.7	7.72		51.72	6.7	7.72		51.72	6.7	7.72		51.72	6.7	7.72		51.72
Chemicals																	
Saltcake	kg	100	.0193	1.93		100	.0193	1.93		100	.0193	1.93		100	.0193	1.93	
Limestone	"					47	.0046	.22		47	.0046	.22		47	.0046	.22	
Lime	"	260	.0154	4.04													
Salt	"																
Sulphur	"																
Rosin	"																
Alum	"																
China clay	"				5.97				2.15				2.15				2.15
Miscellaneous materials																	
Clothing, felts, wires				1.55				1.36				1.16				1.16	
Lubricating oil, etc.				.58	2.08			.58	1.94			.58	1.74			.58	1.74
Operating expenses																	
Steam	tons	1.0	2.32	2.32		1.0	2.32	2.32		1.0	2.32	2.32		1.0	2.32	2.32	
Coal	"	–	–	–		.104	14.90	1.55		.104	14.90	1.55		.104	14.90	1.55	
Power	kWh	–	–	–		–	–	–		–	–	–		–	–	–	
Labour				12.23				7.47				4.73				4.17	
Repair and maintenance material				1.54	16.09			1.35	12.69			1.16	9.76			1.16	9.20
Factory adm., supervision and overheads					6.93				4.69				3.28				2.53
Capital costs																	
Depreciation, plant and equipment				23.70				15.23				10.39				9.47	
Amortization of capital costs during erection period				3.04				1.98				1.35				1.20	
Interest on fixed capital				10.13				6.61				4.49				4.01	
Interest on working capital				2.40	39.27			1.90	25.72			1.70	17.93			1.60	16.28
Contingencies					5.99				4.74				4.17				4.03
Less recovery of turpentine and tall-oil (percentage)					−4.05				−4.05				−4.05				−4.05
TOTAL COST AT MILL					124.00				99.60				86.70				83.60
Sales expenses					3.50				2.50				2.00				1.80
ESTIMATED NET SALES VALUE AT MILL					127.50				102.10				88.70				85.40

Table B58

SWEDISH PROJECT

COST ESTIMATES: BLEACHED PULP

		Mill capacity															
		50 tons/day				*100 tons/day*				*200 tons/day*				*300 tons/day*			
	Unit	*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*	
Pulpwood	m³, 1.m	7.4	7.72		57.13	7.4	7.72		57.13	7.4	7.72		57.13	7.4	7.72		57.13
Chemicals																	
Saltcake	kg																
Limestone	”					100	.0046	.46		100	.0046	.46		100	.0046	.46	
Lime	”	290	.0154	4.47													
Salt	”	145	.0087	1.26		145	.0087	1.26		145	.0087	1.26		145	.0087	1.26	
Sulphur	”	25	.0463	1.16		25	.0463	1.16		25	.0463	1.16		25	.0463	1.16	
Rosin	”																
Alum	”																
China clay	”				6.89				2.88				2.88				2.88
Miscellaneous materials																	
Clothing, felts, wires				1.74				1.55				1.26				1.26	
Lubricating oil, etc.				.58	2.32			.58	2.13			.58	1.84			.58	1.84
Operating expenses																	
Power	kWh	350	.00579	2.03		350	.00579	2.03		350	.00579	2.03		350	.00579	2.03	
Steam	tons	2	2.32	4.64		2	2.32	4.64		2	2.32	4.64		2	2.32	4.64	
Coal	”	–	–	–		.116	14.90	1.73		.116	14.90	1.73		.116	14.90	1.73	
Labour				15.06				9.27				5.84				5.00	
Repair and maintenance material				1.74	23.47			1.54	19.21			1.35	15.59			1.35	14.75
Factory adm., supervision and overheads					7.47				4.96				3.40				2.67
Capital costs																	
Depreciation, plant and equipment				28.55				18.85				12.60				11.09	
Amortization of capital costs during erection period				3.72				2.43				1.62				1.42	
Interest on fixed capital				12.41				8.09				5.40				4.73	
Interest on working capital				2.80	47.48			2.20	31.57			1.90	21.52			1.80	19.04
Contingencies					6.98				5.66				4.88				4.73
Less recovery of turpentine and tall-oil (percentage)					−4.44				−4.44				−4.44				−4.44
TOTAL COST AT MILL					147.30				119.10				102.80				98.60
Sales expenses					3.50				2.50				2.00				1.80
ESTIMATED NET SALES VALUE AT MILL					150.80				121.60				104.80				100.40

Table B59

Swedish project

Cost estimates: unbleached and bleached paper, integrated mill

		Mill capacity															
		Unbleached paper								*Bleached paper*							
		50 tons/day				*100 tons/day*				*50 tons/day*				*100 tons/day*			
	Unit	*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*	
Pulpwood	m^3, 1.m	7.10	7.72		54.81	7.10	7.72		54.81	7.8	7.72		60.22	7.8	7.72		60.22
Chemicals																	
Saltcake	kg	106	.0193	2.05		106	.0193	2.05									
Limestone	„					50	.0046	.23						106	.0046	.48	
Lime	„	275	.0154	4.24						306	.0154	4.71					
Salt	„									154	.0087	1.34		154	.0087	1.34	
Sulphur	„									26.5	.0463	1.23		26.5	.0463	1.23	
Sizing materials	„			4.35	10.64			4.35	6.63			4.55	11.83			4.55	7.60
Miscellaneous materials																	
Clothing, felts, wires, etc.				3:38				3.18				3.38				3.18	
Lubricating oil				.87	4.25			.87	4.05			.87	4.25			.87	4.05
Operating expenses																	
Steam, extra	tons	2.5	2.32	5.80		2.5	2.32	5.80		3.5	2.32	8.12		3.5	2.32	8.12	
Coal	„					.110	14.86	1.63						.124	14.86	1.84	
Power	kWh	320	.00579	1.85		320	.00579	1.85		670	.00579	3.88		670	.00579	3.88	
Labour				19.82				14.04				22.66				16.81	
Repair and maintenance material				2.70	30.17			2.32	25.64			2.90	37.56			2.51	33.16
Factory adm., supervision and overheads					10.37				7.04				10.69				7.22
Capital costs																	
Depreciation, plant and equipment				34.15				23.77				39.94				27.40	
Amortization of capital costs during erection period				4.40				3.10				5.14				3.49	
Interest on fixed capital				14.67				10.32				17.12				11.64	
Interest on working capital				3.42	56.64			2.82	40.01			3.90	66.10			3.24	45.77
Contingencies					8.12				6.72				9.26				7.69
Less recovery of turpentine and tall-oil (percentage)					−4.30				−4.30				−4.71				−4.71
Total cost at mill					170.70				140.60				195.20				161.00
Sales expenses					4.00				3.00				4.00				3.00
Estimated net sales value at mill					174.70				143.60				199.20				164.00

Table B60

SWEDISH PROJECT

COST ESTIMATES: UNBLEACHED PAPER

		Mill capacity							
		50 tons/day				100 tons/day			
	Unit	Quantity	Unit cost (dollars)	Cost per ton of pulp (dollars)		Quantity	Unit cost (dollars)	Cost per ton of pulp (dollars)	
Sizing materials					4.45				4.45
Miscellaneous materials									
Clothing, felts, wires				2.10				1.90	
Lubricating oil, etc.				.20	2.30			.20	2.10
Operating expenses									
Steam	tons	3.0	2.32	6.96		3.0	2.32	6.96	
Power	kWh	250	.00579	1.45		250	.00579	1.45	
Labour				12.94				10.36	
Repair and maintenance mat.				1.55	22.90			1.35	20.12
Factory adm., supervision and overheads					6.47				4.02
Capital costs									
Depreciation, plant and equipment				18.67				13.23	
Amortization of capital costs during erection period				2.48				1.73	
Interest on fixed capital				8.25				5.78	
Interest on working capital				3.82	33.22			3.12	23.86
Contingencies					3.46				2.75
TOTAL COST AT MILL (converting costs only)					72.80				57.30

Table B61

YUCATÁN PROJECT

COST ESTIMATES: UNBLEACHED PULP

		Mill capacity															
		50 tons/day				*100 tons/day*				*200 tons/day*				*300 tons/day*			
	Unit	*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*	
Pulpwood, wet	tons	3.6			20.05	3.6	5.41		19.48	3.6	5.35		19.26	[3.6	5.46		19.66
Chemicals																	
Saltcake	kg	90	.0462	4.16		90	.0462	4.16		90	.0462	4.16		90	.0462	4.16	
Limestone	"					30	.004	.12		30	.004	.12		30	.004	.12	
Lime	"	260	.01025	2.67													
Salt	"																
Sulphur	"																
Rosin	"																
Alum	"																
China clay	"			___	6.83			___	4.28			___	4.28			___	4.28
Miscellaneous materials																	
Clothing, felts, wires				2.00				2.00				2.00				2.00	
Lubricating oil, etc.				.50	2.50			.50	2.50			.50	2.50			.50	2.50
Operating expenses																	
Fuel oil	kg	70	.0125	.88		52	.0125	.65		52	.0125	.65		52	.0125	.65	
Fuelwood	tons					.35	2.29	.80		.35	2.30	.80		.35	2.32	.80	
Labour:																	
Operating	man/hrs	11.04	.163	1.80		6.64	.161	1.07		4.20	.157	.66		3.84	.154	.59	
Mill services	"	5.12	.152	.78		3.20	.147	.47		2.08	.144	.30		1.63	.135	.22	
Repairs	"	3.20	.166	.53		2.00	.165	.33		1.20	.167	.20		.93	.161	.15	
Repair and maintenance material				3.00				3.00				2.75				2.50	
Allowance for salary increase				1.55	8.54			.94	7.26			.58	5.94			.49	5.40
Factory adm. and supervision					2.75				1.52				1.09				.87
Insurance					3.75				2.35				1.60				1.45
Capital costs																	
Depreciation, plant and equipment				36.50				24.15				16.20				14.50	
Amortization of capital costs during erection period				6.80				4.73				3.45				3.13	
Interest on fixed capital				18.50				11.90				7.80				6.85	
Interest on working capital				3.30	65.10			2.40	43.18			1.95	29.40			1.85	26.33
General community expenses					6.80				5.50				5.05				4.45
Contingencies					5.78				4.33				3.48				3.26
TOTAL COST AT MILL					122.10				90.40				72.60				68.20
Sales expenses					2.10				1.60				1.20				1.00
ESTIMATED NET SALES VALUE AT MILL					127.20				92.00				73.80				69.20

Table B62

YUCATÁN PROJECT

COST ESTIMATES: BLEACHED PULP

		Mill capacity															
		50 tons/day				100 tons/day				200 tons/day				300 tons/day			
	Unit	*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*	
Pulpwood, wet	tons	4.0	5.55		22.20	4.0	5.36		21.44	4.0	5.37		21.48	4.0	5.51		22.04
Chemicals																	
Saltcake	kg																
Limestone	"					90	.004	.36		90	.004	.36		90	.004	.36	
Lime	"	290	.01025	2.97													
Salt	"	145	.008	1.16		145	.008	1.16		145	.008	1.16		145	.008	1.16	
Sulphur	"	25	.051	1.28		25	.051	1.28		25	.051	1.28		25	.051	1.28	
Rosin	"																
Alum	"																
China clay	"				5.41				2.80				2.80				2.80
Miscellaneous materials																	
Clothing, felts, wires				2.00				2.00				2.00				2.00	
Lubricating oil, etc.				.50	2.50			.75	2.75			.75	2.75			.75	2.75
Operating expenses																	
Fuel oil	kg					58	.125	.73		58	.125	.73		58	.125	.73	
Fuelwood	tons	1.33	2.30	3.06		1.33	2.33	3.10		1.33	2.38	3.17		1.33	2.42	3.22	
Labour:																	
Operating	man/hrs	14.24	.164	2.34		8.48	.162	1.37		5.48	.157	.86		4.91	.155	.76	
Mill services	"	5.76	.149	.86		3.52	.148	.52		2.28	.145	.33		1.79	.134	.24	
Repairs	"	3.68	.163	.60		2.24	.161	.36		1.36	.162	.22		1.07	.168	.18	
Repair and maintenance mat.				3.50				3.50				3.25				3.00	
Allowance for salary increase				1.90	12.26			1.13	10.71			.70	9.26			.60	8.73
Factory adm. and supervision					2.75				1.52				1.08				.86
Insurance					4.50				2.90				2.00				1.75
Capital costs																	
Depreciation, plant, equipment, etc.				45.40				29.85				19.75				17.45	
Amortization of capital costs during erection period				9.13				5.20				4.00				3.61	
Interest on fixed capital				22.40				14.30				9.30				8.10	
Interest on working capital				3.85	79.78			2.80	52.15			2.25	35.30			2.10	31.26
General community expenses					7.80				6.40				5.45				4.70
Contingencies					6.90				5.03				3.98				3.71
TOTAL COST AT MILL					144.10				105.70				84.10				78.60
Sales expenses					2.10				1.60				1.20				1.00
ESTIMATED NET SALES VALUE AT MILL					146.20				107.30				85.30				79.60

Table B63

YUCATÁN PROJECT

COST ESTIMATES: UNBLEACHED AND BLEACHED PAPER, INTEGRATED MILL

		Mill capacity															
		Unbleached paper								Bleached paper							
		50 tons/day				100 tons/day				50 tons/day				100 tons/day			
	Unit	Quantity	Unit cost (dollars)	Cost per ton of pulp (dollars)		Quantity	Unit cost (dollars)	Cost per ton of pulp (dollars)		Quantity	Unit cost (dollars	Cost per ton of pulp (dollars)		Quantity	Unit cost (dollars)	Cost per ton of pulp (dollars)	
Pulpwood, wet	tons	3.8	5.56		21.13	3.8	5.57		20.41	4.25	5.52		23.46	4.25	5.35		22.74
Chemicals																	
Saltcake	kg	95	.0462	4.39		95	.0462	4.39									
Limestone	"					35	.004	.14		305	.01025	3.13		95	.004	.38	
Lime	"	275	.01025	2.82													
Salt	"									153	.008	1.22		153	.008	1.22	
Sulphur	"									26.5	.051	1.35		26.5	.051	1.35	
Rosin	"	30	.179	5.37		30	.179	5.37		20	.179	3.58		20	.179	3.58	
Alum	"	45	.076	3.42		45	.076	3.42		30	.076	2.28		30	.076	2.28	
China clay	"				16.00				13.32	60	.0414	2.48	14.04	60	.0414	2.48	11.29
Miscellaneous materials																	
Clothing, felts, wires				3.00				2.50				3.00				2.50	
Lubricating oil, etc.				.75	3.75			.75	3.25			.75	3.75			1.00	3.50
Operating expenses																	
Fuel oil	kg					55	.0125	.69						61.5	.0125	.77	
Fuelwood	tons	1.5	2.30	3.45		1.5	2.34	3.51		2.6	2.33	6.06		2.6	2.38	6.19	
Labour:																	
Operating	man/hrs	18.88	.158	2.99		14.00	.154	2.15		22.08	.161	3.55		15.84	.155	2.46	
Mill services	"	7.52	.150	1.13		5.12	.148	.76		7.84	.149	1.17		5.28	.148	.78	
Repairs	"	4.80	.167	.80		3.20	.166	.53		5.28	.167	.88		3.60	.164	.59	
Repair and maintenance mat.				3.00				3.00				3.50				3.50	
Allowance for salary increase				2.47	13.84			1.73	12.37			2.80	17.96			1.92	16.21
Factory adm. and supervision					3.77				2.22				3.77				2.23
Insurance					5.60				3.95				6.50				4.55
Capital costs																	
Depreciation, plant and equipment				54.24				37.47				63.06				43.30	
Amortization of capital costs during erection period				9.29				6.69				10.60				7.54	
Interest on fixed capital				26.30				17.78				30.27				20.32	
Interest on working capital				4.65	94.48			3.55	65.49			5.25	109.18			4.00	75.16
General community expenses					8.35				6.85				9.15				7.65
Contingencies					8.38				6.45				9.39				7.17
TOTAL COST AT MILL					175.30				134.30				197.20				150.50
Sales expenses					3.50				2.50				3.50				2.50
ESTIMATED NET SALES VALUE AT MILL					178.80				136.80				200.70				153.00

Table B64

YUCATÁN PROJECT

COST ESTIMATES: UNBLEACHED AND BLEACHED PAPER, NON-INTEGRATED MILL

		Mill capacity															
		Unbleached paper								*Bleached paper*							
		50 tons/day				*100 tons/day*				*50 tons/day*				*100 tons/day*			
	Unit	*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*	
Chemicals																	
Rosin	kg	30	.179	5.37		30	.179	5.37		20	.179	3.58		20	.179	3.58	
Alum	”	45	.076	3.42		45	.076	3.42		30	.076	2.28		30	.076	2.28	
China clay					8.79				8.79	60	.0414	2.48	8.34	60	.0414	2.48	8.34
Miscellaneous materials																	
Clothing, felts, wires				2.00				2.00				2.00				2.00	
Lubricating oil, etc.				.50	2.50			.50	2.50			.50	2.50			.50	2.50
Operating expenses																	
Fuel oil	kg	370	.0125	4.63		370	.0125	4.63		385	.0125	4.81		385	.0125	4.81	
Fuelwood	tons																
Labour:																	
Operating	man/hrs	12.32	.157	1.93		10.40	.153	1.59		12.32	.157	1.93		10.40	.153	1.59	
Mill services	”	5.76	.155	.89		3.84	.148	.57		5.76	.155	.89		3.84	.148	.57	
Repairs	”	3.20	.166	.53		2.00	.160	.32		3.20	.166	.53		2.00	.160	.32	
Repair and maintenance mat.				2.00				1.75				2.00				1.75	
Allowance for salary increase				3.35	13.33			2.49	11.35			3.35	13.51			2.49	11.53
Factory adm. and supervision					2.95				1.69				3.15				1.69
Insurance					3.00				2.10				3.00				2.10
Capital costs																	
Depreciation, plant and equipment				30.80				21.45				30.80				21.45	
Amortization of capital costs during erection period				4.80				3.24				4.80				3.24	
Interest on fixed capital				16.00				10.80				16.00				10.80	
Interest on working capital				5.20	56.80			4.00	39.49			5.80	57.40			4.40	39.89
General community expenses				–				–				–				–	
Contingencies					4.37				3.28				4.40				3.25
TOTAL COST AT MILL					91.70				69.20				92.30				69.30
Sales expenses					3.50				2.50				3.50				2.50
ESTIMATED NET SALES VALUE AT MILL					95.20				71.70				95.80				71.80

Table B65

Amapá project
Cost estimates: unbleached pulp

		Mill capacity															
		50 tons/day				*100 tons/day*				*200 tons/day*				*300 tons/day*			
	Unit	*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*	
Pulpwood, wet	tons	3.6	8.56		30.82	3.6	8.12		29.23	3.6	8.05		28.98	3.6	8.26		29.74
Chemicals																	
Saltcake	kg	90	.0472	4.25		90	.0472	4.25		90	.0472	4.25		90	.0472	4.25	
Limestone	"	30	.015	.45		30	.015	.45		30	.015	.45		30	.015	.45	
Lime	"																
Salt	"																
Sulphur	"																
Rosin	"																
Alum	"																
China clay	"				4.70				4.70				4.70				4.70
Miscellaneous materials																	
Clothing, felts, wires				2.25				2.25				2.25				2.25	
Lubricating oil, etc.				.50	2.75			.50	2.75			.50	2.75			.50	2.75
Operating expenses																	
Fuel oil	kg	52	.040	2.08		52	.040	2.08		52	.040	2.08		52	.040	2.08	
Fuelwood	tons	.35	4.47	1.56		.35	4.48	1.57		.35	4.48	1.57		.35	4.49	1.57	
Labour:																	
Operating	man/hrs	15.04	.378	5.68		9.92	.362	3.59		6.84	.357	2.44		5.76	.354	2.04	
Mill services	"	6.40	.352	2.25		3.92	.344	1.35		2.56	.348	.89		2.24	.339	.76	
Repairs	"	4.00	.388	1.55		2.40	.392	.94		1.60	.394	.63		1.20	.392	.47	
Repair and maintenance mat.				3.50				3.25				3.00				2.75	
Allowance for salary increase					16.62				12.78				10.61				9.67
Factory adm. and supervision					7.07				3.88				2.79				2.17
Insurance					4.74				3.11				2.13				1.92
Capital costs																	
Depreciation, plant and equipment				41.56				27.16				18.38				16.50	
Amortization of capital costs during erection period				7.80				5.30				3.85				3.54	
Interest on fixed capital				21.55				13.72				9.18				8.16	
Interest on working capital				4.27	75.18			3.20	49.38			2.61	34.02			2.48	30.68
General community expenses					11.00				8.50				7.08				6.67
Contingencies					7.62				5.77				4.64				4.40
Total cost at mill					160.50				120.10				97.70				92.70
Sales expenses					3.50				2.50				2.00				1.80
Estimated net sales value at mill					164.00				122.60				99.70				94.50

Table B66

AMAPÁ PROJECT

COST ESTIMATES: BLEACHED PULP

	Unit	Mill capacity															
		50 tons/day				*100 tons/day*				*200 tons/day*				*300 tons/day*			
		Quantity	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*	
Pulpwood, wet	tons	4.0	8.50		34.00	4.0	8.11		32.44	4.0	8.08		32.32	4.0	8.38		33.52
Chemicals																	
Saltcake	kg																
Limestone	"	90	.015	1.35		90	.015	1.35		90	.015	1.35		90	.015	1.35	
Lime	"																
Salt	"	145	.0255	3.70		145	.0255	3.70		145	.0255	3.70		145	.0255	3.70	
Sulphur	"	25	.061	1.53		25	.061	1.53		25	.061	1.53		25	.061	1.53	
Rosin	"																
Alum	"																
China clay	"				6.58				6.58				6.58				6.58
Miscellaneous materials																	
Clothing, felts, wires				2.25				2.25				2.25				2.25	
Lubricating oil, etc.				.50	2.75			.50	2.75			.50	2.75			.50	2.75
Operating expenses																	
Fuel oil	kg	58	.040	2.32		58	.040	2.32		58	.040	2.32		58	.040	2.32	
Fuelwood	tons	1.33	4.48	5.96		1.33	4.49	5.97		1.33	4.52	6.01		1.33	4.57	6.08	
Labour:																	
Operating	man/hrs	18.72	.377	7.05		12.16	.367	4.46		8.28	.360	2.98		7.09	.352	2.50	
Mill services	"	6.72	.350	2.35		4.08	.343	1.40		2.72	.346	.94		2.37	.338	.80	
Repairs	"	4.80	.385	1.85		2.80	.393	1.10		1.80	.389	.70		1.33	.391	.52	
Repair and maintenance mat.				4.00	23.53			3.75	19.00			3.50	16.45			3.25	15.47
Factory adm. and supervision					7.07				3.88				2.79				2.17
Insurance					5.23				3.83				2.58				2.29
Capital costs																	
Depreciation, plant and equipment				51.45				33.41				22.28				19.69	
Amortization of capital costs during erection period				9.47				6.31				4.53				4.12	
Interest on fixed capital				26.32				16.64				11.01				9.65	
Interest on working capital				5.12	92.36			3.84	60.20			3.15	40.97			2.98	36.44
General community expenses					12.47				9.33				7.75				7.33
Contingencies					9.21				6.89				5.61				5.35
TOTAL COST AT MILL					193.20				144.90				117.80				111.90
Sales expenses					3.50				2.50				2.00				1.80
ESTIMATED NET SALES VALUE AT MILL					196.70				147.40				119.80				113.70

AMAPÁ PROJECT

COST ESTIMATES: UNBLEACHED AND BLEACHED PAPER, INTEGRATED MILL

		Mill capacity															
		Unbleached paper								*Bleached paper*							
		50 tons/day				*100 tons/day*				*50 tons/day*				*100 tons/day*			
	Unit	*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars*	*Cost per ton of pulp (dollars)*		*Quantity*	*Unit cost (dollars)*	*Cost per ton of pulp (dollars)*	
Pulpwood, wet	tons	3.8	8.55		32.49	3.8	8.12		30.86	4.25	8.45		35.91	4.25	8.08		34.34
Chemicals																	
Saltcake	kg	95	.0472	4.48		55	.0472	4.48									
Limestone	"	35	.015	.53		35	.015	.53		95	.015	1.43		95	.015	1.43	
Lime	"																
Salt	"									153	.0255	3.90		153	.0255	3.90	
Sulphur	"									26.5	.061	1.62		26.5	.061	1.62	
Rosin	"	30	.2765	8.29		30	.2765	8.29		20	.2765	5.53		20	.2765	5.53	
Alum	"	45	.0764	3.44		45	.0764	3.44		30	.0764	2.29		30	.0764	2.29	
China clay	"				16.74				16.74	60	.042	2.52	17.29	60	.042	2.52	17.29
Miscellaneous materials																	
Clothing, felts, wires				3.00				2.50				3.00				2.50	
Lubricating oil, etc.				1.00	4.00			1.00	3.50			1.00	4.00			1.00	3.50
Operating expenses																	
Fuel oil	kg	55	.040	2.20		55	.040	2.20		61.5	.040	2.46		61.5	.040	2.46	
Fuelwood	tons	1.5	4.47	6.71		1.5	4.49	6.74		2.6	4.49	11.67		2.6	4.52	11.75	
Labour:																	
Operating	man/hrs	23.36	.367	8.58		17.36	.354	6.14		27.84	.364	10.14		20.00	.356	7.11	
Mill services	"	8.80	.350	3.08		5.76	.347	2.00		9.12	.349	3.18		5.92	.346	2.05	
Repairs	"	5.60	.389	2.18		3.60	.389	1.40		6.40	.342	2.19		4.00	.390	1.56	
Repair and maintenance mat.				3.50	26.25			3.50	21.98			4.00	33.64			4.00	28.93
Factory adm. and supervision					9.61				5.57				9.61				5.57
Insurance					8.00				5.47				9.27				6.27
Capital costs																	
Depreciation, plant and equipment				60.97				42.38				70.99				48.98	
Amortization of capital costs during erection period				10.20				7.25				11.75				8.28	
Interest on fixed capital				33.62				24.16				39.16				27.60	
Interest on working capital				6.17	110.96			4.83	78.62			7.04	128.94			5.49	90.35
General community expenses					12.80				10.00				14.53				10.93
Contingencies					11.05				8.66				12.61				9.92
TOTAL COST AT MILL					231.90				181.40				265.80				207.10
Sales expenses					4.00				3.00				4.00				3.00
ESTIMATED NET SALES VALUE AT MILL					235.90				184.40				269.80				210.10

Table B68

AMAPÁ PROJECT

COST ESTIMATES: UNBLEACHED PAPER

		Mill capacity							
		50 tons/day				100 tons/day			
	Unit	Quantity	Unit cost (dollars)	Cost per ton of pulp (dollars)		Quantity	Unit cost (dollars)	Cost per ton of pulp (dollars)	
Chemicals									
Rosin	kg	30	.2765	8.30		30	.2765	8.30	
Alum	"	45	.0764	3.44		45	.0764	3.44	
China clay					11.74				11.74
Miscellaneous materials									
Clothing, felts, wires				2.00				2.00	
Lubricating oil, etc.				.50	2.50			.50	2.50
Operating expenses									
Fuel oil	kg	370	.040	14.80		370	.040	14.80	
Fuelwood	tons								
Labour:									
Operating	man/hrs	12.32	.365	4.50		10.40		3.73	
Mill services	"	5.76	.365	2.10		3.84		1.35	
Repairs	"	3.20	.391	1.25		2.00		.75	
Repair and maintenance mat.				2.00	24.65			1.75	22.38
Factory adm. and supervision					7.53				4.07
Insurance					4.58				3.16
Capital costs									
Depreciation, plant and equipment				34.06				24.01	
Amortization of capital costs during erection period				5.37				3.87	
Interest on fixed capital				17.89				12.40	
Interest on working capital				6.80	64.12			5.23	45.51
General community expenses					–				–
Contingencies					5.78				4.44
TOTAL COST AT MILL					120.90				93.80
Sales expenses					4.00				3.00
ESTIMATED NET SALES VALUE AT MILL					124.90				96.80

MILL SIZE, INTEGRATION, LOCATION:[1] A STUDY OF INVESTMENT AND PRODUCTION COSTS IN HYPOTHETICAL PULP AND PAPER MILLS

THE SECRETARIAT

INTRODUCTION

The following study discusses in general terms the influence of location, mill size and integration on investment and production costs. It deals mainly with sulphate pulp mills and integrated mills, but also refers briefly to newsprint manufacture.

Background material used for the study

The study is largely based on data given in the following background papers:

3.02 *Amapá/Yucatán: A study of hypothetical mills based on tropical mixed woods,* by the secretariat

3.1 *Influence of mill size and integration upon investment and cost,* by Karlstads Mekaniska Werkstads A.B.

3.12 *Economics of newsprint production,* by P. R. Sandwell.

Definitions

1. The terms "sulphate process" and "sulphate mill" are used in this study to indicate either the straight sulphate process (or mill), where saltcake is used as make-up chemical, or the process (mill) using caustic soda and sulphur, generally referred to as the sulphur/soda process.

2. Throughout the study, weights and measures are given in the metric system, and currency in US dollars.

3. The term "paper converting" for *integrated* mills, used in connexion with cost of investment or production, refers to the difference between integrated operation and the production of *dried* pulp.

4. The following symbols are used in the text or mathematical expressions:

Y — for total capital requirement;

y — for capital requirement per ton of daily production capacity;

Z — for daily or annual *cost;*

z — for *cost* per ton of product; and

x — for mill capacity, expressed in tons per day

Part I

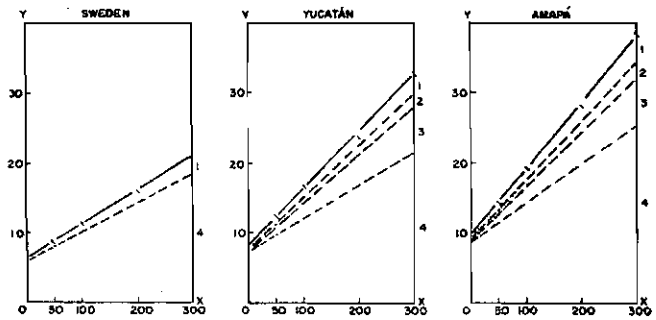
CAPITAL INVESTMENT

A. *Influence of mill size*

The material contained in the background papers reveals a fairly close straight-line relationship between capital investment and mill size for sulphate pulp mills within the capacity range investigated: i.e., from 50 to 300 tons daily capacity.[2] This is illustrated in graph 1, which shows the capital requirements as a function of mill size for hypothetical mills producing bleached sulphate pulp in Sweden, Yucatán (Mexico) and Amapá (Brazil). A similar relationship (not illustrated) obtains for mills producing unbleached pulp. It will be observed that the linear reationship is valid not only for *total* investment in mills producing bleached or unbleached pulp, but also for the main *components* of the total, such as cost of machinery and buildings, forest investment, housing projects and investment in general community facilities. An analysis of the data, taken from secretariat paper No. 3.02, shows that the deviations from the straight line are smaller than the margin of error which may be expected in any estimates of this kind.

Graph 1

CAPITAL REQUIREMENTS AS FUNCTION OF MILL SIZE AND LOCATION
Bleached sulphate pulp
(natural scale)



X=Mill capacity, tons per day
Y=Million dollars

1. Working capital
2. Community investment
3. Forest investment
4. Mill investment, including mill services

A similar relationship, though with a somewhat greater deviation from the straight line, is also found for newsprint mills—from the data given in background paper No. 3.12. The largest difference is found for the smallest mill, i.e., 100 tons daily capacity; it arises from the relatively lower investment in mill services required for this size (graph 2). For the capacity range from 200 to 500 tons per day the deviations are smaller than the margin of error which might be expected.

Although the material presented is limited, it is varied; the linear relationship it reveals between capital requirement and mill size has been considered sufficiently well established to be employed in this study for purposes of preliminary calculations. Accepting this relationship, it becomes possible to calculate the capital required for any mill capacity, providing that the capital requirements for any two mill sizes are known. In this study, therefore, (and in secretariat paper No. 3.02) this procedure has been followed to calculate capital needs for integrated pulp and paper mills and for non-integrated paper mills of capacities over 100 daily tons.

The intercept of the investment line on the Y axis (the C value) represents an amount of capital which is independent of mill size; though it will vary from mill to mill in accordance with location and the commodity to be produced, for a given commodity in a given location it will be constant, whatever the size of the mill. The gradient of the investment line (the k value) represents

[1] Originally issued as ST/ECLA/CONF.3/L.3.03.

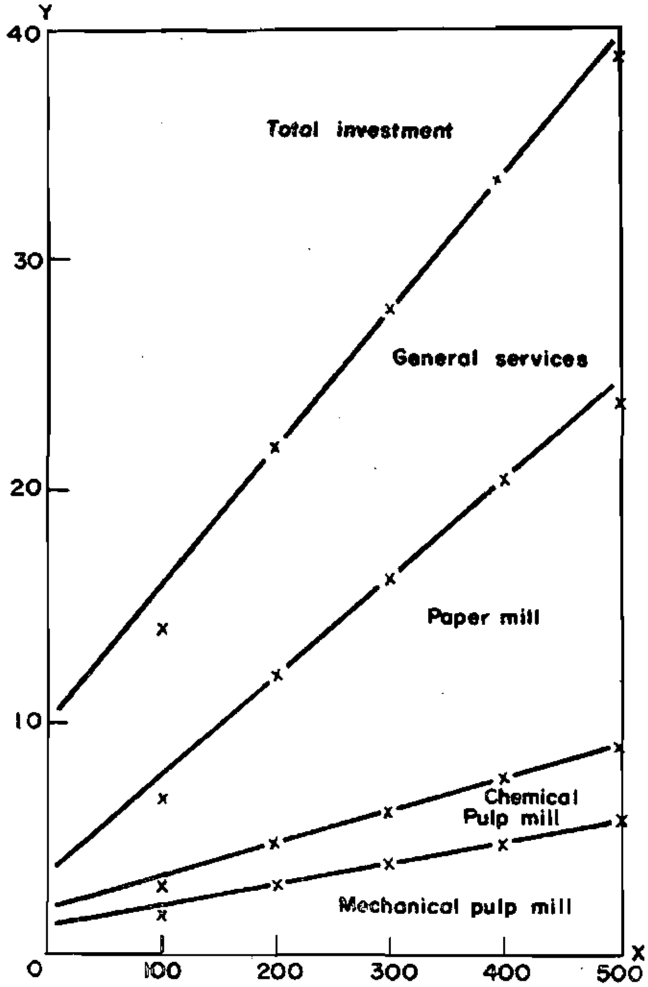
[2] The equations for the investment lines have the general formula: (Eq. 1) $Y = kx + C$

the additional capital required per additional unit of mill capacity; this again is constant, whatever the size of the mill.

Graph 2

NEWSPRINT: COST OF INVESTMENT AS FUNCTION OF MILL SIZE

(natural scale)



X=Mill capacity, daily tons
Y=Million dollars
Data from background paper ST/ECLA/CONF.3/L.3.12

Expressing investment in terms of the capital required per unit of production capacity ($\frac{Y}{x}=y$) the following hyperbolic function results:

$$\text{(Eq. 2)} \quad y=\frac{C}{x}+k$$

This has asymptotes $x=0$ and $y=k$.

The first derivative of this equation shows the change in the amount of capital per unit of capacity required for a given unit increase in capacity at different mill sizes:

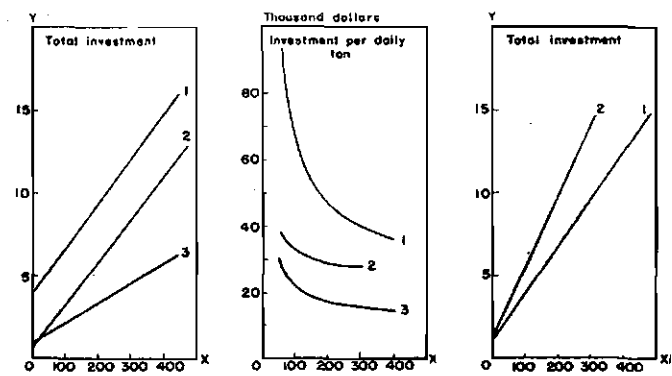
$$\text{(Eq. 3)} \quad \frac{dy}{dx}=\frac{C}{x^2}$$

Thus the capital *saving* (the expression is negative) on each ton of output capacity for a unit increase in capacity falls off inversely with the square of the size for a specific mill location; for a specific mill location it is also related directly to the C value for the investment line. This means that the incentive to establish a larger production unit is greater if the C value is high than if it is low. Mills with high C value investment curves favour the installation of larger units more strongly than do those with low C value investment curves—judged from the point of view of capital costs only. This is illustrated by graph 3, which shows the capital requirement as a function of mill size for sulphate, sulphite and mechanical pulp sections, as well as for paper-mill sections. The centre panel shows that the sulphate section (that with the highest C value on the investment curve) has the steepest fall in capital per daily ton as size increases. The curves of investment per daily ton for sulphite and mechanical pulp sections are much flatter, and hence the incentive to establish larger units, much less. It should also be observed that, contrary to what might be expected, the investment lines for paper-mill sections have low C values. This indicates the possibility of establishing relatively small paper-mill sections in integrated mill operations, without danger of the product having to bear unduly high capital charges as compared with large-scale operations.

Graph 3

COMPARISON OF INVESTMENT AS FUNCTION OF MILL SIZE

(natural scale)



X=Mill capacity, tons per day
Y=Million dollars

1. Sulphate pulp section
2. Sulphite pulp section
3. Mechanical pulp section

1. Newsprint paper mill section, Canada
2. Paper mill section, including services, Sweden

The foregoing discussion relates to the separate mill sections. For a complete installation the C values are additive and it is the total C value (Σ C) which is decisive in determining the economic size (judged from the standpoint of capital costs) for the project as a whole (see appendix 1). In particular, the C value of the capital required for mill services may have a deciding influence on the capital cost per ton of product. This is the case in newsprint production, for example.

Appendices 1 and 2 give in tabular form the capital requirements per daily ton of production capacity for different mills and various sizes, as well as the C and k values for the corresponding hyperbolic functions (Eq. 2).

As a further illustration of the considerable influence of mill size upon capital requirements, table 1 shows the investments per ton of daily production capacity as a percentage of the investment required in the smallest mill.

B. *Influence of integration*

To produce paper in an integrated mill requires an amount of capital smaller than that needed to make paper in separate pulp and paper production units. First, there is a difference in the cost of the actual production machinery needed. Then there are the differences in the amounts of capital required for various other purposes, e.g., for mill services (steam and power station, pump station, etc.), for buildings, for railway lines and port facilities, and so forth. If the forest operations are regarded as an integrated part of the project, this also leads to a difference in the amount of capital required. In this study forest investment has been included in the calculations for the hypothetical mills in Yucatán and Amapá, but not in those for the Swedish project where forest investment appears indirectly—in the pulpwood cost, as the stumpage price paid for pulpwood.

Table 1

CAPITAL REQUIREMENTS PER TON OF DAILY CAPACITY AS PERCENTAGE OF CAPITAL IN 50-TON MILL

(*bleached pulp*)

Mill size, tons per day	*50*	*100*	*200*	*300*
Sweden	100	66	45	40
Yucatán	100	69	50	45
Amapá	100	68	50	45

So far as the actual production machinery is concerned, the main capital items accounting for the difference are as follows:

(1) The cost of the wet machine and pulp dryer;

(2) The cost of baling presses, with auxiliary machinery;

(3) The cost of bale-handling equipment for pulp storage.

These three items at the end of the process in a separate pulp section can be dispensed with in integrated mill operations.

(4) The cost of bale-handling equipment for pulp storage;

(5) The cost of bale-pulping equipment.

These two items at the beginning of the process in a non-integrated paper mill can be dispensed with in integrated mill operations.

An analysis of the investment figures given for the three projects in secretariat paper 3.02 shows that the difference in the cost of the actual production machinery accounts for only a small part of the total difference in investment. The following table, which sets out the differences in investment required for non-integrated paper mills and for paper sections of integrated mills (each of 100 tons daily capacity producing bleached qualities), shows that differences in the cost of actual production machinery account for 17 per cent of the total difference in investment in Sweden, 15 per cent in Yucatán and only 10 per cent in Amapá.

Table 2

CAPITAL REQUIREMENTS FOR NON-INTEGRATED PAPER MILLS AND FOR PAPER-MILL SECTIONS OF INTEGRATED MILLS

(*thousand dollars*)

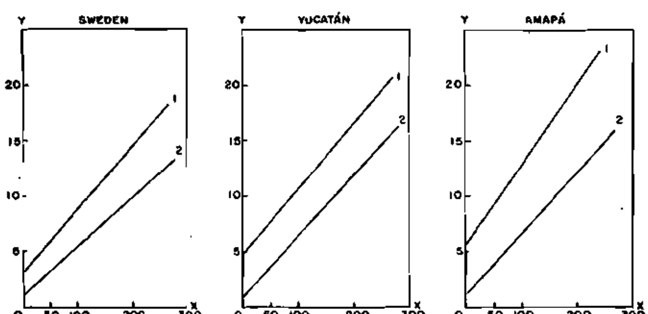
	Sweden		*Yucatán*		*Amapá*	
	Total	*Production machinery only*	*Total*	*Production machinery only*	*Total*	*Production machinery only*
Non-integrated paper mill	9,220	3,571	10,725	3,698	12,630	3,801
Paper-mill section of integrated mill	5,100	2,889	5,975	2,968	6,150	3,176
Difference in investment	4,120	682	4,750	730	6,480	625
Percentage of total difference		17		15		10

The total difference in capital investments for non-integrated and integrated paper manufacture in various mill sizes is illustrated in graph 4 as the difference between the investment lines Nos. 1 and 2.

Graph 4

CAPITAL REQUIREMENTS FOR PAPER MILLS AS FUNCTION OF MILL SIZE AND INTEGRATION

Bleached paper



X=Mill capacity, tons per day 1. Non-integrated paper mills
Y=Investment, million dollars 2. Paper mill section, integrated mills

C. *Influence of location*

In this paper the influence of location on capital requirements will be discussed only in general terms and with particular reference to the differences between establishing pulp and paper mills in an industrially developed area (Sweden) and in less developed areas (Yucatán and Amapá).

Within a given area different sites will offer particular advantages and disadvantages which will affect the amount of capital required, but these intra-area differences are much less important than the inter-area differences arising from completely contrasting environments.

To establish a new mill in an industrially developed area usually requires only a small amount of capital for the forest operations, since as a rule the forests will already have been opened up and transport facilities (railroads, river floating, etc.) developed. Moreover, the project may often depend—at least for part of its pulpwood needs—on the supply from local forest owners. The fact that forest investment can be dispensed with does not necessarily imply a lower cost of production since, as was explained earlier, it does appear indirectly—in the pulpwood cost (stumpage price). In a less developed area the pulpwood cost will be much lower; the stumpage price may even be negligible.

For a mill planned in a virgin area, however, the investment required for forest operations (including preliminary survey, road construction, houses for workmen and supervisory personnel, etc.) is an appreciable item of the total capital. As may be seen from graph 1, forest investment in the Amapá and Yucatán projects ranges from 11 to 20 per cent of the total capital required, depending on the scale of operations—the higher figure corresponding to the larger mill sizes.

Another capital item unnecessary in a developed area but needed in an undeveloped area is for the establishment of general community facilities (schools, hospital, water system, parks, roads, shops, power for lighting, etc.). Contrary to what is often believed, this item does not represent a very high proportion of the total capital. For bleached pulp mills in Amapá and Yucatán it amounts to 5 to 7 per cent of the total.

Transport facilities (railroads, roads, etc.) are a locational factor which is always important and often decisive. In an industrialized area these facilities are usually well developed, and a new mill project may have to face only minor capital investment on this score—to provide connecting roads and railway-lines. The investment required for transport facilities in an undeveloped area may, however, be so great as to rule out a project completely. This fact is not brought out by the Amapá and Yucatán studies, since in both cases favourable sites were selected. In Amapá, for example, railway and port facilities are to be established—independently of the pulp-mill project. Had it been necessary to provide transport means solely for a pulp mill at this particular site, an additional investment of some 8 to 10 million dollars would have been needed—roughly the amount of capital required to establish a minimum size pulp mill (50 tons a day) in this area. Clearly, if an additional investment of this size were necessary any possibility of establishing a small-scale operation would be entirely ruled out. Even for a large mill (300 tons a day) the additional investment would be an important, and perhaps decisive, factor.

A mill in an undeveloped area normally has to provide its own power needs, whereas in an industrially developed area electricity can usually be contracted from public or private power lines in the vicinity.

Other items which add to the capital costs in an undeveloped area are the higher freight rates on machinery, higher engineering and other consultancy fees, and the higher capital costs and expenses incurred during the running-in period. There may be certain offsets; e.g., cheaper local labour and materials may lead to lower investments for buildings, port facilities and the like.

Table 3

TOTAL CAPITAL IN THE YUCATÁN AND AMAPÁ PROJECTS AS PERCENTAGE OF CAPITAL REQUIRED FOR THE SWEDISH MODEL

	Pulp mills		*Integrated mills*	
Mill capacity, tons/day	*50*	*300*	*50*	*300*
Sweden	100	100	100	100
Yucatán	140	157	136	143
Amapá	165	184	153	158

The general effect of all these considerations, however, is to make necessary a much heavier capital requirement for a new mill in an undeveloped area than for one in an industrialized area. This is fully borne out by the comparison between hypothetical mills in Sweden, Amapá and Yucatán given in appendices 1 and 2 and in graph 1. The following table expresses the capital required for the Yucatán and Amapá projects as a percentage of that required for the Swedish model.

Part 2

PRODUCTION COSTS

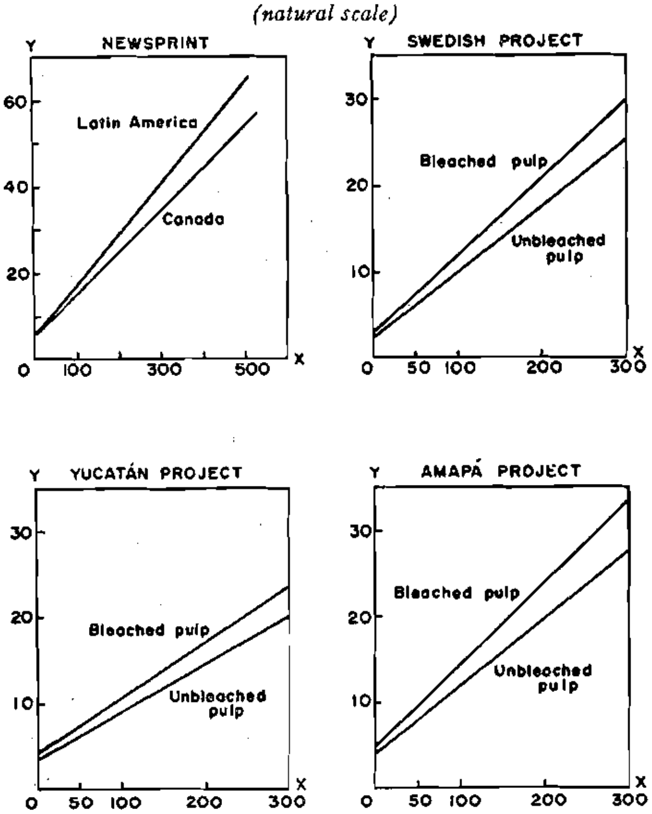
A. *Influence of mill size*

The production cost data given in secretariat paper No. 3.02 shows a close straight-line relationship between daily (or annual) production costs and mill size, similar to that found for capital investment (see graph 5). Except for the smallest mill producing newsprint (100 tons per day), the deviations from the straight line are very slight, generally less than one per cent.

Graph 5

DAILY PRODUCTION COST AS FUNCTION OF MILL SIZE

(natural scale)



X=Mill size, tons per day
Y=Thousand dollars

The daily (or annual) cost as a function of mill capacity can thus be expressed by the general straight-line formula:

(Eq. 4) $$Z = kx + C$$

and the cost per ton by the hyperbolic function

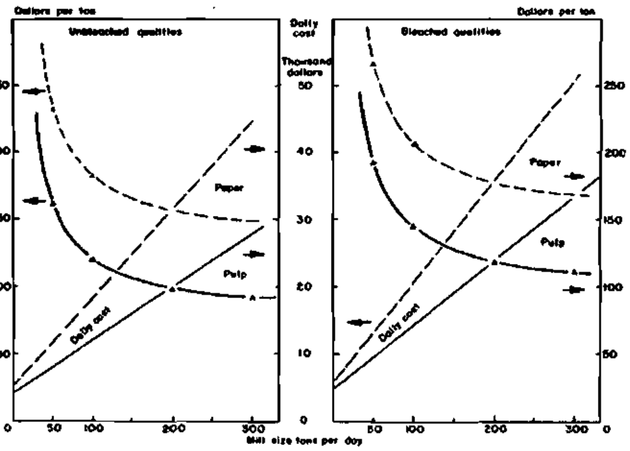
(Eq. 5) $$z = \frac{C}{x} + k$$

The daily cost lines and cost per ton curves are illustrated in graph 6, which presents the data for bleached and unbleached pulp and paper at the Amapá hypothetical mill.

Graph 6

AMAPÁ PROJECT: DAILY PRODUCTION COSTS AND PRODUCTION COST PER TON

(natural scale)



Hyperbolic Cost Functions:

—— pulp $y=\frac{4.006}{x}+78.53$ —— pulp $y=\frac{4.815}{x}+94.67$

- - - paper $y=\frac{4.980}{x}+130.60$ - - - paper $y=\frac{5.810}{x}+147.80$

A. The parallel with the investment investigations continues, since an analysis shows that the separate cost items (except for pulpwood), like the separate capital investment items, are also linear functions of mill size. Within the capacity range investigated, however, the deviations in pulpwood cost from the straight line is not sufficiently large to exert any marked influence on the total cost.[1]

Thus there is:

(Eq. 6) $$z_1+z_2+z_3+\ldots z_n=\sum_1^n\frac{C}{x}+k=\frac{\sum_1^n C}{x}+\sum_1^n k$$

Hence the cost of any separate mill operation, such as bleaching or paper converting, may be calculated for any mill size as the difference between the hyperbolic functions of the combined and the simple operations[2]; for example:

The C value of the daily production cost line, like the C value of the line for capital requirement, is a measure of the incentive to establish larger production units—a high C value favouring large production units.

The production cost C and k values (eq. 5) for hypothetical mills in Sweden, Amapá and Yucatán are tabulated in appendix 3.

Table 4 shows the considerable influence of mill size upon cost of production.[2]

Table 4

PRODUCTION COST IN A MILL OF 300 TONS DAILY CAPACITY EXPRESSED AS PERCENTAGE OF COST IN A MILL OF 50 TONS CAPACITY

	Pulp		*Paper (integrated mill)*	
	Unbleached	*Bleached*	*Unbleached*	*Bleached*
Sweden	67	67	71	71
Yucatán	56	55	61	61
Amapá	58	57	64	63

B. *Influence of integration*

The following brief discussion on the influence of integration is limited to production costs in integrated mills as compared with production in separate units. No reference is therefore made to locational or other factors, which may ultimately decide in favour of the one or the other alternative.

Especially for small mills, a substantial part of the difference in production costs is due to the difference in capital costs. This is illustrated in the table below.

Table 5

DIFFERENCE BETWEEN PAPER CONVERTING COSTS IN NON-INTEGRATED AND INTEGRATED PAPER MILLS (UNBLEACHED PAPER)

(figures in $ per ton)

	50		*300*	
Mill size, tons/day	*Capital costs*	*Total*	*Capital costs*	*Total*
Sweden	15.85	26.10	4.98	9.80
Yucatán	27.42	38.80	7.86	15.00
Amapá	28.34	49.50	6.72	20.20

[1] For larger mill sizes, however, the pulpwood cost may rise steeply due to longer transport distance to mill. This indicates that for a given mill location there is actually an optimum mill size when the increase in pulpwood cost will balance the saving in production cost as mill size increases. The relationship between pulpwood transportation costs and size of forest operation as indicated in this preliminary survey, is, however, too uncertain to warrant a mathematical study of the problem. A rough calculation seems to indicate that the optimum size (from the point of view of production costs only) will, in the case of the Amapá project, lie between 500 and 1,000 tons daily capacity.

[2] This provides a simple way to calculate production costs in mills having a mixed production programme, for instance production costs of unbleached and bleached pulp, as well as unbleached and bleached paper in a mill in Yucatán with the following annual production (constants, C and k from appendix 3):

15,000 tons of unbleached pulp }
30,000 „ „ bleached pulp } 45,000 tons

6,000 „ „ unbleached paper }
15,000 „ „ bleached paper } 21,000 tons

[2] Footnote 2 *continued.*

Cost of unbleached pulp: $z_1=\frac{3,258}{150}+57.08=78.80$ $/ton

Cost of bleached pulp: $z_2=Z_1+\frac{690}{100}+8.17=93.77$ „

Cost of unbleached paper: $z_3=Z_1+\frac{842}{70}+36.22=127.05$ „

Cost of bleached paper: $z_4=Z_2+\frac{722}{70}+38.55=142.63$ „

(Eq. 7) $z_{\text{bleaching}}=z_{\text{bleached pulp}}-z_{\text{unbleached pulp}}$

and hence

(Eq. 8) $$z_{\text{bleaching}}=\frac{C_{\text{bl.}}-C_{\text{unbl.}}}{x}+k_{\text{bl.}}-k_{\text{unbl.}}$$

[3] It should be observed that this study deals strictly with the influence of mill size upon cost of *production*. Market considerations and freight rates may often—especially in undeveloped regions—offset the economic advantages of large-scale operation or limit the size of the mill. In such cases the determination of optimum economic size is difficult as the mill capacities which may be considered fall within the steep slope of the hyperbolic cost function.

The table further shows that the total difference between paper converting costs as between integrated and non-integrated mills is appreciable, especially for small units. This is more easily seen if the difference is set in relation to total cost of paper converting in a non-integrated mill, as in the following table. (See also *graph 7*).

Table 6

DIFFERENCE BETWEEN PAPER CONVERTING COSTS IN NON-INTEGRATED AND INTEGRATED MILLS AS PER CENT OF TOTAL COST IN NON-INTEGRATED MILLS

(*unbleached paper*)

Mill size, tons/day	*50*	*300*
Sweden	36	21
Yucatán	42	28
Amapá	41	27

The two tables 5 and 6, as well as graph 7, amply illustrate the great economic advantage of integration, which, especially for small units, could rarely be offset by counter-balancing factors (such as lower freight rates, sales expenses and interest on stores) for paper mills located in the vicinity of consumption centres. The conclusion is, therefore, that the establishment of a new pulp mill (in an undeveloped area) should, if possible, be integrated with a paper section to convert at least part of its production.

C. *Influence of location*

Before discussing the effect of locational factors on cost of production, it is necessary to consider the relative importance of the various items in the total cost. The following table, giving the various cost items as a percentage of the total, is based on the production costs for bleached pulp in a mill of 200 tons daily capacity.

Table 7

RELATIVE IMPORTANCE OF VARIOUS COST ITEMS IN TOTAL COST OF PRODUCTION

(*figures as percentage of total*)

	Sweden	*Yucatán*	*Amapá*
Pulpwood	56	27[a]	29[a]
Chemicals and miscellaneous materials	5	7	8
Operating expenses and overheads	18	15	19
Capital costs	21	44	37
Community expenses	—	7	7
TOTAL	100	100	100

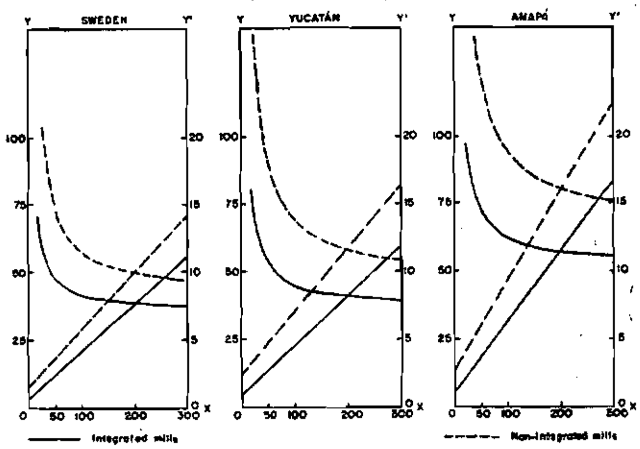
[a] It should be observed that in this figure about 50 per cent represents the cost of labour and supervising personnel for the forest operation, and about 30 to 35 per cent capital costs.

The two most important items are *pulpwood and capital costs*, which together account for about 65 to 75 per cent of the total (77 per cent in Sweden, 71 per cent in Yucatán and 66 per cent in Amapá). In smaller mills the percentage is still higher and in larger mills slightly lower. Looking at these two cost items separately, it is apparent that the pulpwood cost is about 2½ times the capital costs, in the Swedish project, whereas in the Yucatán and Amapá projects the situation is reversed—capital costs being considerably higher than pulpwood costs. The explanation of this fact lies in stumpage price charged to the pulpwood cost in the Swedish project, and higher investments and interest on capital required for the mills in Amapá and Yucatán.

Graph 7

PAPER CONVERTING COST FOR UNBLEACHED PAPER AS FUNCTION OF MILL SIZE, INTEGRATION AND LOCATION

(*natural scale*)



X=Mill size, tons per day
Y=Dollars per ton
Y^1=Daily cost, thousand dollars

In non-integrated pulp mills, *chemicals and miscellaneous materials* (felts, wires, lubricating oil, etc.) together account for only a small percentage of the total cost—varying from 5 per cent in the Swedish project to 8 per cent in Amapá. This is surprising, since in the Amapá project, for example, limestone has to be taken from a deposit 550 km. from the mill site, while saltcake or sulphur has to be imported. It may thus be stated that—contrary to what is generally claimed—the availability of processing chemicals near the mill site would *not*, as a rule, be the *deciding* factor in the viability of a pulp-mill project. This statement is also true—but to a lesser extent—for integrated mills. For a 200-ton integrated mill in Amapá this cost item is 14 per cent of the total cost of production, and in Yucatán 15 per cent.

Operating expenses and overheads, next to pulpwood and capital costs the most important cost items, are together practically the same percentage of the total cost for all mill sizes. This is illustrated in the following table, relating to 200-ton mills producing bleached pulp.

Table 8

OPERATING EXPENSES AND OVERHEADS IN PERCENTAGE OF TOTAL PRODUCTION COSTS

(*bleached pulp*)

Mill size, tons/day	*50*	*100*	*200*	*300*
Sweden	21	21	18	18
Yucatán	14	15	15	15
Amapá	17	17	17	17

As will also be seen from the table, the influence of locational factors is not very great for the larger mill capacities; in the smaller mills the lower cost of labour (and fuelwood) brings down the figure for the Yucatán and Amapá in comparison with the Swedish project.

Finally, table 7 shows that the *community expenses* are of relatively small importance—7 per cent of the total cost. As is the case for operating expenses, the relative importance of this item is practically the same for all mill sizes.

Part 3

Conclusions

Some of the main conclusions drawn from the material presented in this study are summarized below:

(1) Within the capacity range of sulphate mills investigated—that is, from 50 to 300 tons per day—there is a straight-line relationship between total capital investment and annual (or daily) cost of production on the one hand and mill size on the other.

(2) A similar relationship is found also for newsprint mills, sulphite and mechanical pulp-mill sections and paper-mill sections.

(3) The straight-line relationship is valid not only for total investment—or cost—but also for the separate items of these totals.

(4) Investment or production cost per ton of capacity or product is consequently a hyperbolic function of mill size with the general formula y or $z = \frac{C}{x} + k$.

(5) The straight lines and hyperbolic functions provide a simple way of calculating capital requirements or cost of production for any mill capacity, providing the data are known for any two mill sizes. This procedure is especially useful when calculating cost of investment or production in mill projects with alternative and/or mixed production programmes.

(6) The C value of the hyperbolic cost function is a measure of the incentive to establish a larger production unit—a high C value denoting a great incentive.

(7) The influence of mill size upon investment per unit capacity and upon cost of production is very great for sulphate mills, integrated mills and newsprint (high C values). For mills in undeveloped areas the influence is greater than in industrialized countries; consequently, the economic incentive to establish larger units is higher.

(8) A pulp mill established in an undeveloped area requires much heavier capital investment than one in an industrialized region—generally about 50 to 70 per cent higher. A large proportion of this difference is accounted for by investments in forest operations (11 to 20 per cent).

(9) The influence of mill size on paper converting costs is much higher in a non-integrated mill than in an integrated operation. This confirms the economic possibility of establishing small paper-mill sections integrated with larger capacity pulp mills.

(10) The two most important items in the production cost of sulphate pulp are pulpwood and capital costs, which together account for about 65 to 75 per cent of the total—independent of mill location. The relation between the two separate items, however, is quite different for mills in industrialized and undeveloped areas; pulpwood cost being the most important in the first case and capital costs in the second.

(11) The availability of processing chemicals near the mill site would not, as a rule, be the *deciding* factor in the viability of a pulp-mill project, since the cost of this item is only about 5 to 8 per cent of the total cost of production.

(12) Contrary to what is often believed, general community expenses do not represent a high proportion of the total cost of production—usually only between 5 and 8 per cent.

(13) The development of transport facilities generally involves large capital investments—in many cases of such magnitude as to rule out completely any independent pulp and paper project in an undeveloped region.

Appendix 1

Capital requirements per ton of daily capacity pulp mills

(Figures in thousand dollars)

	Mill capacity, tons/day — *Pulp quality* 50		100		200		300		*Constants for hyperbolic function* Unbl.		Bl.	
	Unbl.	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*C*	*k*	*C*	*k*
SWEDEN												
Mill investment[a]	131	160	85	104	58	70	52	61				
Working capacity	12	14	10	11	9	10	8	9				
Total	143	174	95	115	67	80	60	70	4,862	43.63	6,419	48.33
YUCATAN												
Mill investment[a]	160	192	103	124	69	82	61	72				
Forest investment	21	23	20	22	20	21	20	22				
Community	10	12	8	9	7	7	6	6				
Working capacity	13	15	10	11	8	9	8	9				
Total	204	242	141	166	104	119	95	109	6,674	72.68	8,215	81.69
AMAPA												
Mill investment[a]	185	226	119	144	80	96	72	85				
Forest investment	21	23	20	22	19	22	20	22				
Community	12	13	9	10	7	8	7	7				
Working capacity	18	21	14	16	12	14	11	13				
Total	236	283	162	192	118	140	110	127	7,562	84.34	9,480	96.08

[a] Includes mill services, engineering fees, amortization of capital costs during erection and housing scheme.

Appendix 2

CAPITAL REQUIREMENTS PER TON OF DAILY CAPACITY: NON-INTEGRATED AND INTEGRATED PAPER MILLS

(*Figures in thousand dollars*)

	Quality							
	Non-integrated mills				*Integrated mills*			
	Unbleached		*Bleached*		*Unbleached*		*Bleached*	
	Mill capacity, tons/day							
	50	*100*	*50*	*100*	*50*	*100*	*50*	*100*
Sweden	126	90	128	92	206	147	240	166
Yucatán	154	106	156	107	278	201	317	227
Amapá	176	124	179	126	310	223	358	255
	Constants for hyperbolic functions							
	C	*k*	*C*	*k*	*C*	*k*	*C*	*k*
Sweden	3,540	54.70	3,570	56.50	5,910	88.10	7,390	92.50
Yucatán	4,805	57.60	4,865	58.60	7,695	124.40	8,990	137.10
Amapá	5,170	72.10	5,250	73.80	8,760	134.40	10,310	151.60

Appendix 3

HYPERBOLIC COST FUNCTIONS

The functions have the general formula $z = \frac{C}{x} + k$

where z = cost in $ per ton
x = mill capacity in tons per day

	Swedish project		*Yucatan Project*		*Amapá project*	
	C	*k*	*C*	*k*	*C*	*k*
MILL COSTS						
Pulp mill						
1. Unbleached pulp	2,399	75.36	3,258	57.08	4,052	78.73
2. Bleached pulp	2,965	88.55	3,948	65.25	4,865	95.11
3. Bleaching operation (2-1)	566	13.19	690	8.17	813	16.38
Integrated mill						
4. Unbleached paper	3,010	110.50	4,100	93.30	5,050	130.90
5. Bleached paper	3,420	126.80	4,670	103.80	5,870	148.40
Paper converting						
6. Integrated mill, unbleached (4-1)	611	35.14	842	36.22	998	52.17
7. Integrated mill, bleached (5-2)	455	38.25	722	38.55	1,005	53.29
8. Non-integrated mill, unbleached	1,550	41.80	2,280	46.40	2,710	66.70
SALES EXPENSES						
(To calculate net sales value at mill from mill net cost)						
9. Pulp	100	1.50	70	0.80	100	1.50
10. Paper	100	2.00	100	1.50	100	2.00

FORESTRY ASPECTS IN THE PLANNING OF PULP AND PAPER MILLS IN TROPICAL REGIONS[1]

THE SECRETARIAT

INTRODUCTION

It is now well established that the pulping of tropical species, singly or in mixtures, is technically possible. It is not yet established that this is an economic operation, either from the standpoint of producing for the world market, or with the limited aim of satisfying regional or national markets, which naturally offer more favourable prospects. The decentralization of pulp and paper production, making use of tropical species, implies the establishment of complex industries in economically and industrially under-developed regions. This poses a whole series of new problems. Even if the technical problems involved admit of ultimate solution, they can nevertheless give rise to a number of difficulties in the early stages of operation, sending up production costs. The pulps produced may thus find it difficult to compete on world, regional or local markets, especially as they are often of lower quality than those exported from traditional production centres.

Before the establishment of a pulp mill in an under-developed tropical region can be contemplated, it is essential to make sure that the site chosen is not only good

[1] Originally issued as ST/ECLA/CONF.3/L.3.04.

but the best that the area can offer, in order that future production may be able to avail itself of the maximum technical, economic and commercial safeguards. This may seem obvious to the technician. But experience shows that these considerations are often ignored by "prospectors" who, after a brief survey of tropical regions, recommend, without systematic preliminary study, the establishment of pulp mills in certain sites. As often as not the sites are selected merely on the basis of their proximity to forest resources; these, though no doubt extensive, may be completely uninventoried. Costly but often irrelevant laboratory trials may follow. In the light of the results obtained, industrialists are led to believe—in all good faith—that development plans can be made and investors interested in the project. After months—sometimes years—of study carried out on the basis of inaccurate data, it may be found that all the conditions necessary for the installation of a pulp mill are not present, that the whole problem must be studied again from the beginning, and that the time and money spent have been wasted.

Formulating a general plan of inquiry

This paper seeks to define the methodological bases for rationally planning the establishment of new mills in under-developed tropical areas, so that a repetition of the all too frequent errors of the past can be avoided.

The following questions call for study:

(*a*) Is local production of pulp and paper desirable in the given area or region? This is a problem of markets.

(*b*) Is there a sufficient quantity of the principal raw material? Will the forest yield cover the requirements of an industrial unit in the long term? Can this material be supplied to the mill economically? Is the raw material technically suitable?

(*c*) Under what conditions can power, water and secondary raw materials be supplied?

(*d*) Will the pulps or papers produced be sufficiently satisfactory in quantity, quality, and price to ensure their sale under normal conditions?

The replies to these various questions enable a general plan to be formulated, indicating the studies that need to be undertaken.

(1) *Market:*
- (*a*) Present size and pattern;
- (*b*) Future prospects and potential.

(2) *Raw materials:*
- (*a*) Full survey;
- (*b*) Estimate of cost delivered mill site.

(3) *Water supply and effluent disposal*

(4) *Chemicals:*
- (*a*) Can any be produced locally?
- (*b*) Do any need to be imported?

(5) *Fuel and power:*
- (*a*) Alternative sources;
- (*b*) Hydro-electric possibilities.

(6) *Transport:*
- (*a*) Inwards freight }Cost per ton per km
- (*b*) Outwards freight} (or mile).

(7) *Technical suitability of locally produced pulp: preparation of detailed cost estimates*

(8) *Choice of site and various determining factors*

(9) *Staff: personnel:*
- (*a*) Local;
- (*b*) Foreign.

(10) *Finance:*
- (*a*) Local: possible participation in raw material supply;
- (*b*) Foreign: possible participation of company already in business;
- (*c*) Articles of agreement (special care needed);
- (*d*) Effect on economy of country.

(11) *Appreciation of actual production prospects, i.e., conclusions and recommendations*

(12) *Implementation:*
- (*a*) Organization;
- (*b*) Preparation of draft plan;
- (*c*) Inter-industry relationship.

Phases in investigating the raw material

This paper confines itself to a discussion of the preliminary studies which need to be undertaken on the principal raw material, in this case the tropical forest and the mixture of species contained in it.

Four stages may be distinguished:

The first task is to select a broad geographical zone within which, on the basis of general investigations and partial studies, there are *a priori* reasons for believing that suitable conditions exist for the establishment of new pulp industries.

The next stage is to select, within that broad geographical zone, one or more areas worthy of further investigations. This choice will be made on the basis of the general forestry conditions (extent and position of stands) and in the light of topography, transport possibilities, etc.

In each of these areas, detailed studies should next be undertaken so that the advantages and disadvantages of each can be compared; these studies should make it possible to propose one or several definitive sites for the establishment of industrial centres.

Finally, for each projected site, extremely accurate studies should now be made in order to determine production capacity, exploitation and management plans, and the adaptation of industrial techniques to local conditions, with special reference to the qualitative and quantitative composition of the forest.

Choice of general zone. The fundamental importance of this first stage in planning the development and decentralization of pulp and paper production has long been recognized, and FAO has been entrusted by the United Nations Economic and Social Council[1] with the task of carrying out a series of national and regional investigations, aimed at indicating areas suitable for development. The results of this work have been published in a general report,[2] while a joint ECLA/FAO investigation in Latin America has been the subject of a separate report.[3]

These investigations were led by teams of experts, some specializing in raw material aspects, others in ques-

[1] Resolution 374 (XIII), 13/9/51.

[2] UN/FAO *World Pulp and Paper Resources and Prospects,* New York, 1954.

[3] UN/FAO *Possibilities for the Development of the Pulp and Paper Industry in Latin America,* Sales No. 1953.II.G.2.

tions of industrial transformation; clearly, it is not possible to dissociate these two aspects in studies of this kind.

This first stage is not dwelt upon in this paper, since general conclusions have already been published. The data and information contained in the above-mentioned reports enable an *entrepreneur* — after taking into account special political, financial and national considerations—to narrow his choice.

Selection of the most favourable areas in the zone. This selection will be made on the basis of two sets of criteria: (*a*) general forest conditions and (*b*) topographical conditions affecting exploitation, delivery of raw material to the factory and dispatch of finished products. The first set of conditions can be ascertained only after an inventory has been made of the forest wealth of the area. Theoretically, this inventory should, of course, be as accurate and as complete as possible. In dealing with so vast an area, however, the degree of precision attained is bound to leave something to be desired. It may be necessary to be content with a general map, with some topographical and forest detail, interpreted by technicians conversant witth the zone and its vegetation.

Aerial photographs on a 1:40,000 scale can provide the required information, but this kind of inventory, carried out systematically over a large area, is a very long and costly operation and therefore needs to be kept within strict limits. For this reason, the first task must be to search out, study and interpret all the existing documentation on the zone. This will include:

General, topographical and botanical maps at varying scales;

Aerial photographs of certain parts of the zone, even if taken for very different reasons from the one at present under consideration (in nearly every country, aerial photographs were taken by either the national air force concerned, the U. S. Army Air Force or the Royal Air Force during the last World War. After appropriate representations have been made, these may be placed at the disposal of investigators; they will, after study and interpretation, prove extremely useful);

Inventories of certain types of stands growing in the zone; sundry botanical studies;

Studies and analyses made by various specialized institutes on the zone's species.

This initial work is indispensable; if it is well done, valuable time will be saved and new and costly studies avoided.

The next task is to bring together and co-ordinate the various elements of this preliminary investigation, since they have up to now been collected, interpreted and studied separately. All this work has been useful—indeed indispensable—but it must nevertheless be recognized that in most cases only incomplete information will have so far been acquired. By means of large-scale air photographs and rapid surface survey, investigations should now be extended to those areas as yet unsurveyed which, according to other information available, seem of interest from the terrain or forest point of view. The preliminary work will have made it possible to limit new studies to the strict minimum.

A study of all the documentation, both previously collected data and information newly acquired, should now permit the selection of the most favourable areas in the zone for the eventual installation of a pulp mill. These should be areas:

(*a*) Where the necessary general conditions for the installation of a sizeable industry are satisfied;

(*b*) Where the principal raw material seems to be present in sufficient quantities to cover future industrial operations, at least over the medium term;

(*c*) Where it seems possible to carry out economically the exploitation, extraction and transport of the raw material to the mill, and dispatch of finished products to centres of consumption, manufacture or export.

Comparative studies for selecting the site. In the investigations so far, the main emphasis will have been laid on wood supplies as the principal factor governing the choice of site, but studies on the possibility of supplying the mill with water, power and various other materials should not have been neglected. In this new stage, these other aspects assume greater importance. Site selection will be made on the basis of a study of all the factors involved, not merely of the forestry aspect which has dominated the earlier phases of the investigations.

It is not easy to lay down with any exactness the studies that need to be undertaken to enable the best site to be selected, and indeed the particular studies needed will vary from case to case. They should, however, be mainly focused on those aspects which previous inquiries have shown to be specially favourable or unfavourable. They may need to include, in certain instances, more intensive aerial or surface inventories, to enable the volume and composition of the forest to be more accurately assessed.

Detailed study of the site selected. Finally, quantitative and qualitative studies must be undertaken to establish the following points:

(*a*) Production capacity of the contemplated mill;

(*b*) Processing methods to be adopted, whether for the treatment of single species or mixtures;

(*c*) Medium- and long-term plans for the exploitation and management of the forest in the area.

These three elements are essential for an exact economic study of production conditions. Only when these points have been established will it be possible to draw up mill plans and make preliminary estimates of production costs, capital requirements and profitability.

The studies which have just been outlined call for the assembling of a great deal of quantitative and qualitative information, requiring not only investigations on the terrain and detailed laboratory tests, but also trials on an industrial or semi-industrial scale.

Forest inventories will provide the following quantitative data, by type of stand:

(i) Productive forest areas;

(ii) Total volume of standing timber;

(iii) Volume analysed by species or by groups of species, the species groups appropriate being determined after taking into account work already carried out in other regions where similar conditions obtain;

(iv) Volume of each species or group analysed by either age or diameter classes.

These inventories cannot, of course, be carried out with the same degree of accuracy as it is usual to expect in temperate regions. The only practicable course is to combine aerial photography with sufficiently intensive surface sampling.

In the tropical forest, generally speaking, photographs on a 1:20,000 scale will provide information which, supplemented by rapid ground surveys, will enable types of stands to be defined and delineated. Next, suitable sample plots must be selected on which to carry out botanical studies and measurements to arrive at average volumes. These figures, applied to the total areas for each type of stand, will enable estimates to be prepared of total volumes.

If something is already known about the forest—for example, if it is known to be of a less heterogeneous type, with certain species dominant—the work of surface sampling can be reduced or accelerated. In such a case, 1:10,000 scale photographs obtained from additional air surveys will provide fairly exact data on the species composition and distribution and on tree heights. It should, however, be stressed that in the typical heterogeneous equatorial forest it will rarely be possible to obtain precise data by aerial photography alone; ground survey will normally be an indispensable part of any inventory.

Laboratory tests must be carried out to provide information on the relevant physical and chemical properties of the dominant species and of groups of species to be used in a mixture. Here it is essential that the sampling should follow strict lines if the results are to be of any value. Precise rules and safeguards, which cannot be discussed in detail in this short paper, have been laid down in this field. It may be expected that the following tests on prepared samples will have to be undertaken in specialized laboratories:

(i) Studies of the relevant physical and chemical characteristics of each dominant or important species;

(ii) Systematic studies on pulping (*a*) each dominant species, and (*b*) various mixtures of species.

Laboratory tests and industrial trials. Finally, studies must be undertaken to determine the pulping process to be used (or to establish methods of applying a process already in use elsewhere). These studies will fall into three phases:

(i) Determining the process;

(ii) Establishing the best mixture, taking into account: (*a*) the technical necessity of minimum selection from the natural mixture; (*b*) the economic need to make full use of the forest, taking fuel requirements into consideration; (*c*) the quality of the pulp desired; and (*d*) power, water, fuel and chemical consumption;

(iii) Determining the industrial conditions under which the pulp would be used: (*a*) trials on high-speed paper-machines; (*b*) quality trials; and (*c*) trials of mixtures with classic pulps.

These tests should be started in the laboratory to set technical norms, and continued at a pilot plant or on a semi-industrial scale to confirm the results of the laboratory tests and to secure supplementary data of an economic nature.

Conclusion

The forestry problems which arise when planning a pulp and paper mill in the tropics are clearly complex and difficult to resolve. Some may doubt whether all the studies here described are, in fact, necessary. It must, of course, be conceded that the plan of inquiry outlined above is in a sense a maximum programme. Though all the information obtained will prove useful, even essential, in planning a new industry, not all of it is vital for working out a draft scheme.

One of the main problems is to time the sequence of investigations correctly. Less could be done, and the investigations thus speeded up. But the danger of telescoping the stages in order to gain a few months' time is that problems may have to be faced later which normally would have arisen when the mill was first conceived.

If any justification were needed for this insistence on comprehensive studies, it would be found in the statement with which this paper started: though the problem of pulping heterogeneous mixtures of tropical species may be considered as solved on the technical plane, the practical application of these techniques on an economic basis has yet to come. Success is likely only if the maximum number of favourable conditions are found to coexist in the sites selected. Hence all the necessary safeguards must be taken in selecting these sites. Since raw material is undoubtedly the most important factor, it needs to be studied as carefully as possible along the lines indicated in this paper.

INFLUENCE OF MILL SIZE AND INTEGRATION ON INVESTMENT AND COST[1]

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The size of a pulp and/or paper mill, i.e., the daily production capacity, has, as every pulp and paper technician knows, a great influence on the capital investment required and on the cost of production. An understanding of this influence is of very great importance when new pulp and paper industries are being planned. For this reason, a series of special estimates have been prepared.

Table 1 shows the different capital investments required for non-integrated sulphate kraft pulp mills of 50, 100, 200 and 300 tons daily capacity; separate figures are given for bleached and unbleached pulp manufacture.

[1] Originally issued as ST/ECLA/CONF.3/L.3.1.

The table shows that investment does not rise proportionately with production capacity. For example, the percentage rise in investment in doubling capacity from 100 to 200 tons is less than that in doubling capacity from 50 to 100 tons a day. Nor does a given absolute rise in capacity (say 100 to 200, and 200 to 300 daily tons) imply a similar rise in investment, either in absolute or in percentage terms.

This is because as mill size increases, for most of the machinery concerned, what is needed is larger machines rather than more of them; this means lower capital costs per unit of capacity for machinery, for excavation and planning, for erection, freight, buildings, etc.

Tables 2 and 3 present data for integrated pulp and paper mills and for non-integrated paper mills respectively. Comparing these, it will be noted that, for a doubling of capacity from 50 to 100 tons per day, machinery costs in the paper mill or in the paper mill section rise by 50 per cent; in the pulp-mill section they rise only by 40 per cent. In the paper mill the possibilities of stepping up capacity by increasing machine size (as distinct from adding new machines) are more limited than in the pulp mill. Therefore, higher production involves a bigger percentage rise in machinery cost in the paper mill than in the pulp mill.

Tables 4 to 6 show estimated manufacturing costs, for different sized mills, at pulp mills and at non-integrated and integrated paper mills respectively.

An increase in capacity is attended by a much less than proportionate increase in the labour force required, as table 7 shows. For unbleached kraft pulp mills, a 300 per cent increase in capacity (from 50 to 200 daily tons) requires only a 55 per cent addition to the labour force. For non-integrated paper mills, however (see table 9), a 100 per cent increase in production involves a 59 per cent increase in the number of workers. This is related to the fact stated above, that here it is the number rather than the size of the machines that has to be increased.

Turning to administration costs (see table 10), a comparison between a 50- and a 200-ton sulphite mill shows that the 300 per cent increase in production is attended by only a 68 per cent increase in the cost of administration. Even more striking is the fact that a doubling of capacity in a non-integrated paper mill (from 50 to 100 daily tons) leads to only a 22 per cent rise in administration costs, a very small figure compared with the 59 per cent increase in labour requirements.

Tables 13 and 14 compare the building volumes required for different types and sizes of mills. It will be seen that a paper mill requires a bigger increase in building volume for a given increase in capacity than does a pulp mill.

All these factors have a great influence on final production cost. Whereas the cost of wood, chemicals, pulp, fuel, power, etc., per unit of output is constant through all sizes of mill (see tables 5 and 6), wages for servicing and processing per ton of manufactured pulp decrease from 63:40 to 24:50 Swedish kronor, cost of administration from 23:10 to 9:70, and depreciation from 117:00 to 52:80.

A study of table 13 shows a remarkable decrease in cost of production between the 50- and 100-ton-a-day mills as compared with the difference between the 200- and 300-ton-a-day mills.

The reduction in cost of production as size increases is much smaller for non-integrated paper mills than for integrated mills. In the former case the 50- and 100-ton paper mills must reckon on the same cost of pulp, making a difference of no less than 114 Swedish kronor per ton of paper as compared with integrated mills.

The general conclusion is that under Swedish conditions it is not profitable to build pulp or paper mills with a daily capacity of 50 tons or less; to be profitable capacity should be at least 100 tons a day.

Table 1

PRELIMINARY ESTIMATED COST OF NON-INTEGRATED SULPHATE KRAFT PULP MILLS WITH PRODUCTIONS OF 50, 100, 200 AND 300 TONS AIR-DRY PULP PER TWENTY-FOUR HOURS

(*in thousands of Swedish Kronor*)[a]

	50 tons		100 tons		200 tons		300 tons	
	Unbl.	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*
Log yard	530	530	590	590	650	650	1,200	1,200
Wood prep. dept. and chip silos	1,600	1,600	2,265	2,265	2,800	2,800	3,800	3,800
Digester and diffuser depts.	1,960	1,960	2,270	2,270	3,590	3,590	5,000	5,000
First screening dept.	1,070	1,070	1,845	1,845	2,639	2,639	3,402	3,402
Bleaching dept.		1,290		1,860		2,430		3,000
Electrolytic plant and bleach liq. prep.		2,700		3,300		3,800		4,300
Salt store		20		25		30		35
Second screening dept.		400		620		830		1,100
Pulp-drying mach. dept.	1,415	1,415	2,330	2,330	4,270	4,270	6,184	6,184
Pulp store	60	60	75	75	90	90	100	100
Evaporation plant and soda recovery	4,100	4,100	5,200	5,200	6,300	6,300	9,500	9,500
Sulphate store	60	60	75	75	90	90	100	100
Causticizing dept.	1,100	1,100	2,086	2,086	2,968	2,968	3,930	3,930
Steam and power station	2,600	2,700	3,100	3,250	3,500	3,700	3,800	4,050
Electrical motors and cables	600	750	1,000	1,200	1,700	1,950	2,300	2,600
Piping between the different buildings	300	350	400	475	550	625	650	725
Water purification plant and pump station	500	500	725	725	1,320	1,320	1,750	1,750
Laboratory equipment	75	75	100	100	100	100	100	100
Machinery in repair shop	800	800	900	900	1,000	1,000	1,100	1,100
Office equipment	100	100	120	120	150	150	200	200
Insulation material and woodwork	900	1,100	120	135	155	175	185	110
Machinery in fire station	120	120	120	120	120	120	120	120
Cost of erection	1,020	1,300	1,390	1,860	1,900	1,900	2,900	3,600
Cost of freight	1,380	1,450	1,825	1,900	2,450	2,550	3,550	3,700
Cost of bldgs., chests, etc.	7,360	9,210	8,300	10,300	11,200	13,700	15,000	18,000
Admin. during erection	320	320	520	520	720	720	820	820
Excavation and planning of the site	650	675	875	925	1,225	1,300	1,600	1,700
Houses for staff and workers	1,500	1,500	2,000	2,000	2,500	2,500	3,000	3,000
Railway lines	600	600	800	800	1,000	1,000	1,200	1,200
Port	1,000	1,000	1,500	1,500	2,000	2,000	2,500	2,500
Unforeseen expenses	390	445	469	629	1,013	1,103	1,009	1,074
TOTAL COST	31,300	38,300	41,000	50,000	56,000	67,000	75,000	88,000

[a] $1.00 = 5.18 Sw.kr.

Table 2

PRELIMINARY COST ESTIMATE OF INTEGRATED SULPHATE KRAFT PULP AND PAPER MILLS WITH PRODUCTIONS OF 50 AND 100 TONS UNBLEACHED AND BLEACHED PAPER PER TWENTY-FOUR HOURS

(thousands of Swedish Kronor)[a]

	50 tons		*100 tons*	
	Unbl.	*Bl.*	*Unbl.*	*Bl.*
Pulp-mill machinery	10,420	14,830	14,331	20,136
Paper-mill machinery	9,600	9,600	14,600	14,600
Boiler house and steam turbine dept.	3,100	3,250	3,500	3,700
Electrical motors and cables	1,250	1,400	2,000	2,200
Piping between the different buildings	450	500	600	675
Water purification plant and pump station	725	725	1,320	1,320
Laboratory equipment	100	100	100	100
Machinery in repair shop	900	900	1,000	1,000
Office equipment	120	120	150	150
Insulation material and woodwork	170	180	220	235
Machinery in fire station	120	120	120	120
Cost of erection	1,500	1,800	2,000	2,500
Cost of freight	1,900	2,000	2,400	2,500
Cost of buildings, chests, etc.	8,850	11,000	12,000	14,000
Administration during erection	550	550	925	925
Excavation and planning of site	825	850	1,150	1,200
Houses for staff and labourers	2,000	2,000	2,500	2,500
Railway lines	800	800	1,000	1,000
Port	1,500	1,500	2,000	2,000
Unforeseen expenses	520	475	404	539
TOTAL COST	45,400	52,700	62,400	71,400

[a] $1.00 = 5.18 Sw.kr.

Table 3

PRELIMINARY COST ESTIMATE OF NON-INTEGRATED SULPHATE KRAFT PAPER MILLS WITH PRODUCTIONS OF 50 AND 100 TONS PAPER PER TWENTY-FOUR HOURS

(thousands of Swedish Kronor)[a]

	50 tons	*100 tons*
Paper-mill machinery	10,000	15,000
Boiler house and steam turbine dept.	2,300	2,700
Electrical motors and cables	750	1,200
Piping between the different buildings	150	200
Water purification plant and pump station	400	500
Laboratory equipment	75	75
Machinery in repair shop	800	900
Office equipment	100	120
Insulation material and woodwork	90	120
Machinery in fire station	120	120
Cost of erection	600	800
Cost of freight	600	800
Cost of buildings, chests, etc.	5,000	7,000
Administration during erection	280	480
Excavation and planning of the site	300	500
Houses for staff and labourers	1,500	2,000
Railway lines	500	800
Port	1,000	1,500
Unforeseen expenses	435	185
TOTAL COST	25,000	35,000

[a] $1.00 = 5.18 Sw.kr.

Table 4

ESTIMATED MANUFACTURING COST AT NON-INTEGRATED SULPHATE KRAFT PULP MILLS PER TON OF AIR-DRY PULP WITH PRODUCTIONS OF 50, 100, 200 AND 300 TONS OF UNBLEACHED AND BLEACHED PULP PER TWENTY-FOUR HOURS, BASED ON SWEDISH CONDITIONS

(*in Swedish Kronor*)[a]

	50 tons		*100 tons*		*200 tons*		*300 tons*	
	Unbl.	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*
Pulp wood: 6.7 resp. 7.4 m3 1.m at Kr.40	268	296	268	296	268	296	268	296
Process steam from extra fuel: 1.0 resp. 2.0 ton at Kr.12	12	24	12	24	12	24	12	24
Power: 350 kWh at Kr.0.03	—	10.50	—	10.50	—	10.50	—	10.50
Wages for service depts.	16	17.30	9.70	10.30	6.20	6.50	4.70	5
Coal for lime kiln: 104 resp. 116 kg at Kr.0.077	—	—	8	9	8	9	8	9
Sulphur: 25 resp. 27 kg at Kr.0.24	—	6.50	—	6.50	—	6.50	—	6.50
Saltcake: 100 kg at Kr.0.10	10	—	10	—	10	—	10	—
Limestone: 47 resp. 100 kg at Kr.0.024	—	—	1.10	2.40	1.10	2.40	1.10	2.40
Lime: 260 resp. 290 kg at Kr.0.08	20.80	23.20	—	—	—	—	—	—
Sodium chloride: 145 kg at Kr.0.045	—	6.50	—	6.50	—	6.50	—	6.50
Wages for processing	47.40	60.70	29	37.70	18.30	23.80	16.90	20.90
Furnishings	6	7	5	6	4	4.50	4	4.50
Lubrication oil	3	3	3	3	3	3	3	3
Material for repairs	8	9	7	8	6	7	6	7
Packing material	2	2	2	2	2	2	2	2
Administration	23.10	23.10	13.80	13.80	9.70	9.70	7.70	7.70
Overhead	12.20	15	10.50	11.90	7.30	7.90	5.40	6.10
Depreciation	117	145	78.30	96.60	52.80	65	48.30	57
Interest on capital (5%)	57.50	70.20	37.60	45.80	25.60	30.70	22.90	26.90
Interest on stores of wood, chemicals and finished products (6%)	7	8	7	8	7	8	7	8
SUMMARY	610	727	502	598	441	523	427	503
Recovery from turpentine: 12 kg resp. 13.2 kg at Kr.0.75 and tall-oil: 40 resp. 44 kg at Kr.0.30	21	23	21	23	21	23	21	23
Manufacturing cost at the non-integrated pulp mills	589	704	481	575	420	500	406	480

[a] $1.00 = 5.18 Sw.kr.

Table 5

ESTIMATED MANUFACTURING COST AT NON-INTEGRATED SULPHATE KRAFT PAPER MILLS PER TON OF PAPER WITH PRODUCTIONS OF 50 AND 100 TONS UNBLEACHED AND BLEACHED PAPER PER TWENTY-FOUR HOURS, BASED ON SWEDISH CONDITIONS

(*in Swedish Kronor*)[a]

	50 tons		*100 tons*	
	Unbl.	*Bl.*	*Unbl.*	*Bl.*
Air-dry pulp: 1.06 ton delivered net at pulp mill	624	745	510	609
Freight of pulp: 1.06 ton at Kr.30	32	32	32	32
Process-steam from fuel: 3.0 tons at Kr.12	36	36	36	36
Power: 250 and 300 kWh respectively at Kr.0.03	7.50	9	7.50	9
Wages for service departments	16	16	9.70	9.70
Wages for processing	51	51	44	44
Furnishings and chemicals	25	25	24	24
Lubrication oil	1	1	1	1
Material for repairs	8	8	7	7
Packing material	12	12	12	12
Administration	21.50	21.50	13.30	13.30
Overhead	12	12	7.50	7.50
Depreciation	95	95	66	66
Interest on capital (5%)	46	46	32	32
Interest on stores of chemicals and finished products (6%)	4	5	4	5
Manufacturing cost at the non-integrated paper mills	991	1,114.50	806	907.50

[a] $1.00 = 5.18 Sw.kr.

Table 6

ESTIMATED MANUFACTURING COST AT INTEGRATED SULPHATE KRAFT PULP AND PAPER MILLS PER TON OF PAPER WITH PRODUCTIONS OF 50 AND 100 TONS UNBLEACHED AND BLEACHED PAPER PER TWENTY-FOUR HOURS, BASED ON SWEDISH CONDITIONS

(in Swedish Kronor)[a]

	50 tons		*100 tons*	
	Unbl.	*Bl.*	*Unbl.*	*Bl.*
Wood and chemicals for pulp mill	329	377	316	364
Process steam from extra fuel: 2.5 resp. 3.5 tons at Kr.12	30	42	30	42
Power: 320 resp. 670 kWh at Kr.0.03	9.60	20.10	9.60	20.10
Wages for service depts.	22.70	24	13	13.70
Wages for processing	80	93.40	59.70	73.40
Furnishings and chemicals for paper mill	28	29	27	28
Lubrication oil	4.50	4.50	4.50	4.50
Material for repairs	14	15	12	13
Packing material	12	12	12	12
Administration	34.30	34.30	21	21
Overhead	19.81	21.51	15.76	16.66
Depreciation	178.94	206.54	118.24	136.64
Interest on capital (5%)	83.65	96.65	54.70	63.00
Interest on stores of wood, chemicals and finished products (6%)	9.50	11	9.50	11
Manufacturing cost at the integrated pulp and paper mills	856	987	703	819

[a] $1.00 = 5.18 Sw.kr.

Table 7

ESTIMATED NUMBER OF WORKMEN FOR NON-INTEGRATED SULPHATE KRAFT PULP MILLS WITH PRODUCTIONS OF 50, 100, 200 AND 300 TONS OF UNBLEACHED AND BLEACHED PULP PER TWENTY-FOUR HOURS

	Per 8 hours								*Per day*							
	50 tons		*100 tons*		*200 tons*		*300 tons*		*50 tons*		*100 tons*		*200 tons*		*300 tons*	
	Unbl.	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*
Log yard	5	5	5	5	6	6	8	8	10	10	10	10	12	12	16	16
Wood prep. department	2	3	2	4	3	7	4	8	4	6	4	8	6	14	8	16
Digester department	2	2	2	2	2	2	3	3	6	6	6	6	6	6	9	9
Diffuser department	1	1	1	1	2	2	3	3	3	3	3	3	6	6	9	9
First screening department	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
Bleaching department		1		1		1		1	1	3		3		3		3
Electrolytic plant and bleach liquor prep. dept.		3		4		5		6	9	12		12		15		18
Second screening department		1		1		1		1		3		3		3		3
Pulp drying machine	3	3	4	4	6	6	10	10	9	9	12	12	18	18	30	30
Pulp store	1	1	2	2	3	3	3	3	3	3	6	6	9	9	9	9
Causticizing department	1	1	2	2	2	2	3	3	3	3	6	6	6	6	9	9
Evaporation plant	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
Soda recovery	3	3	3	3	3	3	5	5	9	9	9	9	9	9	15	15
Chemical stores									1	2	1	2	1	2	1	2
Water purification plant and pump station	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
General workers:																
Transport workers									8	8	12	12	16	16	20	20
Repair shop									15	17	20	22	25	27	30	33
Boiler house	2	2	2	2	3	3	3	3	6	6	6	6	9	9	9	9
Power house	1	1	1	1	1	1	1	1	3	3	3	3	3	3	3	3
SUMMARY									95	117	116	144	147	182	194	233

Table 8

ESTIMATED NUMBER OF WORKMEN FOR NON-INTEGRATED SULPHATE KRAFT PAPER MILLS WITH PRODUCTION OF 50 AND 100 TONS PAPER PER TWENTY-FOUR HOURS

	Per 8 hours		*Per day*	
	50 tons	*100 tons*	*50 tons*	*100 tons*
Pulp store	1	2	3	4
Dissolving department	1	2	3	6
Beater room	1	2	3	6
Size prep. department	1	2	3	6
Paper-making machines	6	9	18	27
Rereelers	2	6	6	18
Duplex cutler	2	4	4	8
Balings			3	4
Reel packers			3	6
Rereelers for small reels			1	2
Sorters			20	30
Transport workers			8	12
Water purification plant and pump station	1	1	3	3
Oilmen	1	2	3	6
General workers			6	9
Boiler house	2	2	6	6
Power station	1	1	3	3
Repair shop			15	20
SUMMARY			111	176

Table 9

ESTIMATED NUMBER OF WORKMEN FOR INTEGRATED SULPHATE KRAFT AND PAPER MILLS WITH PRODUCTIONS OF 50 AND 100 TONS UNBLEACHED AND BLEACHED PAPER PER TWENTY-FOUR HOURS

	Per 8 hours				*Per day*			
	50 tons		*100 tons*		*50 tons*		*100 tons*	
	Unbl.	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*	*Unbl.*	*Bl.*
Log yard	5	5	5	5	10	10	10	10
Wood-prep. dept.	2	3	2	4	4	6	4	8
Digester dept.	2	2	2	2	6	6	6	6
Diffuser dept.	1	1	1	1	3	3	3	3
First screening dept.	1	1	1	1	3	3	3	3
Bleaching dept.		1		1		3		3
Electrolytic plant and bleach liq. prep.		3		4		9		12
Second screening dept.		1		1		3		3
Causticizing dept. and lime-kiln evaporation plant	1	1	2	2	3	3	6	6
Soda recovery	3	3	3	3	9	9	9	9
Chemical stores					1	2	1	2
Beater room	1	1	2	2	3	3	6	6
Size prep. dept.	1	1	2	2	3	3	6	6
Paper-making machines	6	6	9	9	18	18	27	27
Rereelers	2	2	6	6	6	6	18	18
Duplex cutter	2	2	4	4	4	4	8	8
Balings					3	3	4	4
Reel packers					3	3	6	6
Rereelers for small reels					1	1	2	2
Sorters					20	20	30	30
Transport workers					14	14	21	21
Water purification plant and pump station	1	1	1	1	3	3	3	3
Oilmen	1	1	2	2	3	3	6	6
General workers	2	2	2	2	6	6	6	6
Power station	1	1	1	1	3	3	3	3
Repair shop					25	27	30	32
SUMMARY					164	186	233	276

Table 10

COST OF ADMINISTRATION—SULPHATE PULP MILLS

(annual salaries in Swedish Kronor)[a]

Description	*No.*	*50 tons/ 24 hours*	*No.*	*100 tons/ 24 hours*	*No.*	*200 tons/ 24 hours*	*No.*	*300 tons/ 24 hours*
General manager	1	35,000	1	40,000	1	50,000	1	60,000
Factory manager		—		—	1	35,000	1	45,000
Pulp maker	1	20,000	1	25,000	1	25,000	1	25,000
Assistant pulp maker		—		—	1	18,000	1	20,000
Chief chemist	1	15,000	1	18,000	1	20,000	1	24,000
Mechanical engineer }	1	15,000	1	18,000	1	20,000	1	24,000
Electrical engineer }					1	20,000	1	24,000
Process shift foremen	3	36,000	3	36,000	3	36,000	6	72,000
Foremen for mechanical shop	1	12,000	1	13,500	1	13,500	2	27,000
Foremen for electrical shop	1	12,000	1	13,500	1	13,500	1	13,500
Foremen steam and power station		—		—	1	13,500	1	13,500
Foremen for wood yard	1	12,000	1	13,500	1	13,500	1	13,500
Foremen for transports	1	12,000	1	13,500	1	13,500	1	13,500
Shift chemists	3	24,000	3	27,000	3	27,000	3	27,000
Assistants in laboratory	2	10,000	2	10,000	3	15,000	4	18,000
Draftsmen	1	10,000	2	20,000	3	36,000	4	46,000
Secretary	1	18,000	1	20,000	1	24,000	1	24,000
Chief accountant	1	15,000	1	16,500	1	18,000	1	18,000
Office clerks and typists	5	42,000	8	70,000	12	100,000	12	100,000
Storekeeper	1	12,000	1	12,000	1	14,000	1	14,000
Assistant storekeeper and clerks	2	17,000	2	17,000	3	25,000	4	34,000
Porters	3	24,000	3	24,000	3	24,000	3	24,000
Messengers	2	6,000	2	6,000	3	9,000	4	12,000
	32	347,000	36	413,500	48	583,500	56	692,000

[a] $1.00 = 5.18 Sw.kr.

Table 11

COST OF ADMINISTRATION—PAPER MILLS

(annual salaries in Swedish Kronor)[a]

Designation	*No.*	*50 tons/24 hours*	*No.*	*100 tons/24 hours*
General manager	1	35,000	1	40,000
Factory manager		—		—
Paper maker	1	20,000	1	25,000
Assistant paper maker		—		—
Chief chemist	1	15,000	1	18,000
Mechanical engineer }	1	15,000	1	15,000
Electrical engineer }			1	15,000
Process shift foremen	3	36,000	3	36,000
Finishing house foremen	1	12,000	1	12,000
Foremen for mechanical shop	1	12,000	1	13,500
Foremen for electrical shop	1	12,000	1	13,500
Foremen for steam and power station		—		—
Foremen for transports	1	12,000	1	12,000
Assistants in laboratory	2	10,000	2	10,000
Draftsmen	1	10,000	2	20,000
Secretary	1	18,000	1	20,000
Chief accountant	1	15,000	1	16,500
Office clerks and typists	5	42,000	8	70,000
Storekeeper	1	12,000	1	12,000
Assistant storekeeper and clerks	2	17,000	2	17,000
Porters	3	24,000	3	24,000
Messengers	2	6,000	2	6,000
	29	323,000	34	395,500

[a] $1.00 = 5.18 Sw.kr.

Table 12 COST OF ADMINISTRATION—INTEGRATED PULP AND PAPER MILLS (*annual salaries in Swedish Kronor*)[a]

Designation	*No.*	*50 tons/24 hours*	*No.*	*100 tons/24 hours*
General manager	1	45,000	1	55,000
Factory manager		—	1	35,000
Pulp and paper maker	1	30,000		—
Pulp maker		—	1	25,000
Paper maker		—	1	25,000
Assistant pulp maker	1	18,000		—
Assistant paper maker	1	18,000		—
Chief chemist	1	20,000	1	24,000
Mechanical engineer	1	20,000	1	20,000
Electrical engineer	1	20,000	1	20,000
Process shift foremen	6	72,000	6	72,000
Finishing house foremen	1	12,000	1	12,000
Foremen for mechanical shop	1	13,500	1	13,500
Foremen for electrical shop	1	13,500	1	13,500
Foremen for power station		—	1	13,500
Foremen for wood yard	1	13,500	1	13,500
Foremen for transports	1	13,500	1	13,500
Shift chemists	3	27,000	3	27,000
Assistants in laboratory	2	10,000	3	15,000
Draftsmen	2	20,000	3	36,000
Secretary	1	20,000	1	24,000
Chief accountant	1	16,500	1	18,000
Office clerks and typists	6	51,000	10	85,000
Storekeeper	1	12,000	1	14,000
Assistant storekeeper and clerks	2	17,000	3	25,000
Porters	3	24,000	3	24,000
Messengers	3	9,000	3	9,000
	42	515,500	49	633,500

[a] $1.00 = 5.18 Sw.kr.

Table 13

BUILDING VOLUMES FOR DIFFERENT SECTIONS OF NON-INTEGRATED SULPHATE KRAFT PULP MILLS WITH PRODUCTIONS OF 50, 100, 200 AND 300 TONS PULP PER TWENTY-FOUR HOURS (*in cubic metres*)

	50 tons		*100 tons*		*200 tons*		*300 tons*	
	Unb. p/24h	*Bl. p/24h*	*Unb. p/24h*	*Bl. p/24h*	*Unb. p/24h*	*Bl. p/24h*	*Unb. p/24h*	*Bl. p/24h*
Wood prep. dept. and chip silos	9,700	9,700	11,600	11,600	15,600	15,600	21,000	21,000
Digester and diffuser dept.	15,000	15,000	23,000	23,000	40,000	40,000	55,000	55,000
First screening dept.	9,200	9,200	12,100	12,100	16,600	16,600	20,500	20,500
Bleaching dept.		11,200		13,500		15,200		17,500
Electrolytic plant and bleach liq. prep. dept.		8,900		9,500		11,100		13,200
Salt store		900		1,000		1,100		1,200
Second screening dept.		6,900		8,000		10,800		14,500
Pulp-drying machine	7,900	7,900	10,000	10,000	12,500	12,500	20,100	20,100
Pulp store	6,000	6,000	8,000	8,000	13,000	13,000	18,000	18,000
Evaporation and soda recovery	19,500	19,500	21,100	21,100	28,500	28,500	38,500	38,500
Sulphate store	1,100	1,100	1,300	1,300	1,500	1,500	1,700	1,700
Causticizing dept.	6,800	6,800	12,600	12,600	16,500	16,500	25,300	25,300
Water purification plant and pump station	10,400	10,400	11,000	11,000	14,800	14,800	20,000	20,000
Laboratory	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
Steam and power house	12,600	12,600	12,900	12,900	17,400	17,400	28,500	28,500
Repair shop	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800
Office	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
Fire station	300	300	300	300	300	300	300	300
TOTAL BUILDING VOLUME	121,300	151,900	146,700	176,700	199,500	238,700	271,700	318,100

Table 14

BUILDING VOLUMES FOR DIFFERENT SECTIONS AT NON-INTEGRATED SULPHATE KRAFT PAPER MILLS WITH PRODUCTIONS OF 50 AND 100 TONS PAPER PER TWENTY-FOUR HOURS

(*in cubic metres*)

	50 tons	100 tons
Pulp store	6,000	8,000
Dissolving department	2,000	3,000
Beater room and size prep. department	3,600	6,700
Paper-making machine room	25,000	49,000
Sorting and finishing department	14,000	25,000
Paper store	3,800	5,000
Water purification plant and pump station	10,400	11,000
Laboratory	2,000	2,000
Steam and power house	12,600	12,900
Office	4,000	4,000
Repair shop	16,800	16,800
Fire station	300	300
TOTAL BUILDING VOLUME	100,500	143,700

Table 15

BUILDING VOLUMES FOR DIFFERENT SECTIONS OF INTEGRATED SULPHATE KRAFT PULP AND PAPER MILL WITH PRODUCTIONS OF 50 AND 100 TONS UNBLEACHED AND BLEACHED PAPER PER TWENTY-FOUR HOURS

(*in cubic metres*)

	50 tons		100 tons	
	Unbl.	Bl.	Unbl.	Bl.
Wood prep. dept. and chip silos	9,700	9,700	11,600	11,600
Digester and diffuser dept	15,000	15,000	23,000	23,000
First screening dept	9,200	9,200	12,100	12,100
Bleaching dept		11,200		13,500
Electrolytic plant and bleach liq. prep. dept		8,900		9,500
Salt store		900		1,000
Second screening dept		6,900		8,000
Evaporation dept. and soda recovery	19,500	19,500	21,100	21,100
Sulphate store	1,100	1,100	1,300	1,300
Causticizing dept	6,800	6,800	12,600	12,600
Beater room and size prep. dept	3,600	3,600	6,700	6,700
Paper-making machine room	25,000	25,000	49,000	49,000
Sorting and finishing dept	14,000	14,000	25,000	25,000
Paper store	3,800	3,800	5,000	5,000
Water purification plant and pump station	10,400	10,400	11,000	11,000
Laboratory	2,000	2,000	2,000	2,000
Steam and power house	12,600	12,600	12,900	12,900
Office	4,000	4,000	4,000	4,000
Repair shop	16,800	16,800	16,800	16,800
Fire station	300	300	300	300
TOTAL BUILDING VOLUME	153,800	181,700	214,400	246,400

SURVEYING LOCATIONAL FACTORS FOR THE INSTALLATION OF PULP AND PAPER INDUSTRIES IN TROPICAL REGIONS[1]

CENTRE DE RECHERCHES ET D'ÉTUDES POUR L'INDUSTRIE DE LA CELLULOSE ET DU PAPIER

Tropical regions inevitably evoke the idea of areas where industrial development is still backward and the climate hard to support. Not long ago the idea of establishing a pulp and paper industry in such regions would only have met with scepticism or irony. Today there is rather the tendency to consider these regions as new countries with boundless possibilities where such industries can, as has been proved by the extremely encouraging results obtained by other industries in the same regions, be established under conditions enabling them to make a useful contribution to the general economic development of the country concerned.

The justification for such a project lies mainly in the abundant reserve of cheap raw materials for the pulp and paper industry to be found in these regions. Many experts have recognized that, in the long run, the use of tropical raw materials will be necessary if the world pulp industry is to continue to develop at its present rhythm.

Owing to the lack of an industrial infrastructure, factories in these regions will usually have to be self-

[1] A shortened version of the original paper, ST/ECLA/CONF.3/L.3.2.

sufficient in all operational requirements; they will have to produce all the power and steam they need and most of the chemicals required for the manufacture of pulp. Certain items of operational expenditure will seem inflated compared with those in industrial regions of temperate countries. The capacity of the plant, moreover, is likely to be lower than that of foreign competitors, causing a large rise in production cost. Against these unfavourable factors, however, there are certain important offsets that can ensure a competitive cost price. These are: (1) the cost price of wood is exceptionally low; (2) there is usually plenty of cheap labour available, and it is adaptable to most of the tasks needed in the operation of this kind of plant; and (3) sources of cheap fuel and power can sometimes be found, such as petroleum products (in Colombia and Venezuela) or waterfalls as a source of electricity.

It is thus evident that the balance sheet of the projected plant will be largely influenced by the way in which advantage is taken of local conditions. Hence the importance of a careful survey of locational factors in the preliminary studies.

Chronologically, four successive phases may be distinguished in these studies:

(1) A rapid survey of the region, leading to the delineation of certain areas where the establishment of a mill seems possible;

(2) An examination of these areas, leading to the selection of several alternative prospective sites;

(3) A detailed study of local conditions at each site, leading to a final decision regarding site;

(4) A general economic assessment of a proposed plant at the site selected.

The regional survey

This phase of the study aims at acquiring rapidly the maximum information possible on the country where the industry is to be established.

A knowledge of existing industrial development is required, and research should be concentrated on industries of recent establishment in order to ascertain (*a*) what difficulties they encountered during both construction and initial operations, and how those difficulties were surmounted; and (*b*) what maintenance and supply facilities might be provided during both the constructional and operational phases of the pulp mill.

Four groups of industry should be specially studied: (i) civil engineering enterprises; (ii) building and equipment maintenance enterprises; (iii) other enterprises able to participate in installing the plant; and (iv) industries able to supply building materials, chemicals, maintenance equipment, stores, etc.

It will be necessary to inquire into local reserves of specialized personnel and skilled labour, and into facilities for training locally recruited staff.

The legislation in force should be surveyed, especially as affecting standards for construction and installation, accident prevention and safety devices, wages, working conditions and social insurance.

A survey of economic conditions should aim at assessing the general economic climate and at acquiring detailed information on the market for paper. The former will encompass knowledge of foreign trade, its composition and direction, balance of payments; budgetary resources, availability of foreign exchange; expected development of different sectors of the economy. The latter will require an appraisal of import and domestic production figures, prices and price margins, and a knowledge of the principal consumers and their requirements.

Next comes an examination of the industrial infrastructure, of all those services that bear on the possibilities of constructing a plant, i.e., of importing, transporting and storing material before installation, and of ensuring that vital needs for operating a plant are fulfilled. This inquiry will cover port facilities, shipping services, road and rail networks, power and water supplies.

In this phase, too, primary information must be assembled concerning raw material supplies. Existing forest maps must be supplemented by data from every available source, including existing forest exploitation, so that a general idea is obtained of the density of the stands and of the characteristics of the species encountered in different areas.

This survey will have made it possible to select a number of areas as worthy of closer investigation with a view to determining potential sites.

Designating prospective sites

In the next phase of the inquiry, each piece of information obtained should guide and restrict the inquiry within the areas delineated, taking into account the ultimate objectives of the plant.

First, it is necessary to decide upon the plant's capacity and its production programme. Generally speaking, the plant will be directed at satisfying the domestic market; though a regional market may be contemplated also, rarely will it be possible to think in terms of a mill producing exclusively or primarily for the export market.

More detailed information will now be required about the mill's raw material supply area, its accessibility, transport means, fuel, power and so forth. No one site is likely to fulfil all requirements and a compromise must be sought. The numerous restrictions imposed on the selection of a really suitable site will, in this phase of the investigations, narrow the choice down to a very limited number of alternative sites.

Detailed study of local conditions

Providing the information collected hitherto has been sufficiently checked to ensure its validity, it is doubtful whether the intensive studies undertaken during this third phase will bring to light new elements conducive to rejecting one of the alternative solutions—save perhaps on the grounds of raw material supply, which has not yet been intensively investigated in the selected alternative sites. With this proviso, therefore, it is natural that during this third phase of the investigations attention will be concentrated on the prima facie most satisfactory solution, though the simultaneous study of one alternative solution, which could be put into effect should the first become impracticable, will be the most prudent course.

Study of the raw material supply will require, in the first instance, forest survey and inventory in the normal supply area of the proposed plant. It will require qualified personnel and a well-trained labour force and will normally take up to six months; clearly, then, it will be undertaken only if it is certain that other technical and economic conditions favour the establishment of a factory in that particular area. Soon after the inventory begins, a fairly precise idea can be obtained of the nature and occurrence of the prevailing species. Studies of their pulping characteristics, separately and in varying mixtures, can be undertaken. This, of course, is a crucial stage in the whole study. If a satisfactory pulp mixture cannot be obtained, or if the percentage of woods which must be rejected is excessive, the project must be abandoned and another solution found. Experience suggests that this danger is small, but it is a risk which has to be run. It is perhaps the strongest argument for the simultaneous study of two alternative solutions.

The other information assembled during this phase of the investigations will relate particularly to those aspects of local conditions on which more precise data is required for planning the plant. For example, if existing data on daily temperatures, humidity, average daily and annual rainfall, wind directions and velocities, are insufficient, local observations may have to be instituted. The nature of the terrain and the character of the subsoil must be established in detail; the preliminary study of water for the manufacturing process must be followed up by systematic sampling and analysis, and so forth.

Planning the plant

It is now possible to start drawing up plans for the plant itself, to specify the kinds and sizes of equipment necessary, and the nature and extent of auxiliary services required. Specifications will take into account local, especially climatic, conditions. It should be possible to estimate total investment costs to within 10 to 15 per cent, a degree of accuracy sufficient to afford an adequate indication of the burden of capital costs on the eventual product. Data concerning raw material yield, chemicals consumption, power needs, labour and maintenance costs, etc., will enable a fair estimate to be made of the probable cost of paper manufacture. These estimates, adjusted for transport costs, may be compared with current selling values in the consumption centres, making it possible to arrive at a balance sheet for the mill when in normal production and an estimate of the likely return on invested capital. These calculations will make it possible to turn to the study of means of financing the project.

FOREST INVENTORIES IN TROPICAL REGIONS[1]

Dammis Heinsdijk, assisted by K. P. MacGrath

The FAO publication *Planning a National Forest Inventory*[2] indicates the general acceptance among foresters both of the basic need for better inventories in modern forest management and of the exceptional role that modern aerial survey techniques can now play in this field.

The problem of assessment is first and foremost a problem of sampling; and with the increasing importance of statistical analyses over the last twenty years forest management has demanded even more precision in sample estimates. The old techniques of pre-arranged ground survey and sampling have consequently been subjected to critical scrutiny and a considerable amount of research in assessment methods has recently been devoted to meeting the demand for greater precision. Two important conclusions have emerged: (1) sampling must be randomized if it is to be capable of undergoing orthodox statistical check. (2) if sampling is to be kept within practical and economic limits and at the same time yield satisfactory results, the general population must be stratified into its component populations and sampling referred to the latter so that the significance of total variation may be reduced.

In the pure, or comparatively pure, forests of temperate regions the need has arisen for better assessment. More intensive forest management has called for estimates of increasing precision. In the tropics, the need is almost certainly as great, but attempts to attain any real precision are still in their infancy. Under tropical conditions, investment and the risks involved in pioneer development are high. Though a wider margin of error may perhaps be acceptable in the tropics the possibilities of inaccuracy in raw material estimates should be as clearly recognized as in temperate zones.

Aerial survey is now generally acknowledged as a standard approach in temperate forest inventories; but it is in the tropical forest that this technique will undoubtedly play its most important role for here, indeed, there is no technical alternative. The extreme variability of the tropical forest, and the comparative difficulty of penetrating it, mean that only the stereoscopic over-all view obtainable by air photographs can provide the key to economic and adequate sampling. As a means of enabling the surveyor to arrive at an early appreciation of the degree of precision that is economically practicable (assuming of course that the forest manager is realistic about the intensity of sampling) aerial survey has so far no satisfactory alternative in tropical forestry.

The topographical map is of course the first essential; the fundamental techniques of photogrammetry are the same in temperate and tropical zones. But the generally unbroken canopy of the tropical forest gives rise to difficulty in distinguishing topographical detail. Here becomes apparent the first big difference between temperate and tropical techniques. The usefulness of aerial pictures depends to a much greater extent on the personal skill of the observer. The topographical detail required, for interpretation in the first instance and subsequently for management purposes, is often obtained less from configuration of the stereoscopic model itself than from the topographical hints the interpreter picks up as a result of photo-examination of the vegetation. In general, with extensive areas available, mountainous terrain holds little interest, while in flat country the significant elevations are generally obscured by differences in the

[1] Originally issued as ST/ECLA/CONF.3/L.3.3.
[2] FAO Forestry and Forest Products Studies, No. 1, Washington, September 1950.

height of the vegetation. For example, a low mesa or plateau, becomes of soil differences, frequently shows up not as high ground but as a basin in the forest canopy and thus might easily be misinterpreted as part of a closed water-system rather than as a part of a more significant watershed.

However, continued photo-examination along with field verification reduces the likelihood of errors in photo-reading, since interpretative skill is always cumulative. For example, in Surinam, where the writer was engaged in this work continuously over a period of five years, it was possible finally to obtain much of the necessary information directly from the photographs. The results of this work have been detailed in a series of papers (pamphlets 7, 12 and 13) published by the Central Bureau of Aerial Survey in Surinam. Naturally, in a task of this kind—which was on a fairly extensive scale for the tropics—important results were obtained in the field of ecology, etc.; however, the main findings of interest in the present context were as follows:

(1) From the 1:40,000-scale photographs taken, it was possible to draw up topographical maps suitable for all kinds of management purposes. Photographs on a 1:20,000 scale were also available for some parts of the forest and if these revealed additional detail (e.g., the existence of a particular kind of vegetation) that detail was added to the general map.

(2) It was possible to map the major formations (swamp, dry-land forest, etc.) with great accuracy. The same was true for the pure or nearly pure stands occurring in comparatively small plots among the extensive areas of highly mixed woodland.

(3) As a result of extensive sampling it was possible to delineate with sufficient accuracy, within the major forest formations, the boundaries of different forest types. At the same time, within the mapped types, it was possible to point out high and low spots, and to indicate concentrations of certain upperstory species. This is obviously of great importance for valuable species, and it proved possible to do this for *Virola surinamensis, Goupia glabra, Ocotea rubra* and *Dicorynia paraensis*—all valuable tree species in Surinam.

(4) Some individual trees from the upperstory of the forest proved recognizable in the photographs only if the personnel were thoroughly familiar with the forest type in which they occurred.

(5) In the course of extensive sampling in which 17,868 upperstory trees were measured over an area of approximately 900,000 hectares, close relationship was found between crown width, diameter and height of marketable bole. There is evidently a close relationship between the volume of the upperstory of the forest shown in the pictures and the total volume of the forest, but as yet the data are insufficient to determine the mathematical correlation. However, from the stereoscopic view of the forest it was possible to make a satisfactory estimate of the total volume.

(6) Taking as a criterion the results of the detailed inventories carried out independently by the Forest Service, the random sampling (approximately 440 hectare samples on a 900,000 hectare forest) gave good data on the total volume of the forest types and on the order of magnitude in which the dominant and co-dominant species occur.

The result was that, in addition to providing an accurate topographical map indicating the physical features important for planned extraction, it was possible to draw attention to the most significant parts of the forest and to give a statistically confirmed indication of the volumes likely to be found. In some instances the species data were adequate, especially in those cases where it proved possible to produce a map which indicated the concentrations of the species of special interest. On the other hand, when data about a species occurring only as a chance component of one or more forest types was required, only a topographical map to lighten the task of ground survey could be provided. In all cases like these, finding and assessing particularly valuable but scattered species, there is probably no substitute for the "100 per cent estimate" so commonly practised in the tropics.

The general problem confronting all tropical exploitation is the one which at present confronts the writer in the Amazon Valley. In this extensive area several regions suggest themselves as suitable for exploitation, but for none of them are as yet available the data necessary to justify capital investment or permit planned exploitation. Here, the surveyor and the forest manager can but approach the question of sampling intensity from their individual, if complementary, technical viewpoints. The surveyor must indicate the degree of intensity necessary to obtain reliable estimates, and the forest manager must forsake the ideal of high precision for a more practical and realistic outlook.

Fortunately, the greater part of the Amazon of immediate interest has been covered by trimetrogon aerial survey. The central strip of vertical photographs of the trimetrogon set is as easily utilized for topographical mapping as were similar ones in the writer's experience, taken in Surinam. However, the obliques to either side of the verticals can yield only part of the data required—and that somewhat sketchily. Nevertheless, they can delineate the limits of the major forest formations as far as the middle distance and give an indication of topographical details for interpolation between adjacent flightstrips of verticals. In this way, useful maps have been drawn. But the accuracy of the whole depends on two things: the number of reference points for control, and the possibility of connecting the flightruns by means of their obliques. The extent to which these conditions are satisfied in the Amazon, while it does not allow of good mapping, does make possible the constitution of reconnaissance maps adequate to begin the tasks of interpretation and assessment. How far their accuracy will improve as field work progresses remains to be seen. But there is no doubt that they will yield infinitely better data for management purposes than could ever be obtained without photography.

Field work has just started. Some of the data already available on the first batch of sample plots are given in the following table. It affords a preliminary verification of the photographic evidence and gives an indication of variability in the forest type under study and of the intensity of sampling necessary for a stipulated degree of precision for management purposes. (See table 1.)

The data contained in the table are of particular interest in that they tend to confirm much of the experience in Surinam, although they concern an area 2,000 kilometres to the south. The following are the most significant conclusions drawn from that experience:

(1) It is clear that the greater the number of dominant and co-dominant species which can be grouped together the more chance there is of obtaining good statistical results.

Table 1

DATA FROM TWENTY-EIGHT SAMPLE PLOTS IN THE AMAZON VALLEY SURVEY

Sample number	*Tree species*									*Total species 1 to 9*	*Total species 2, 4, 8 and 9*	*Species x*
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*			
1	10.10	7.00	14.51	7.90	0.78	4.90	—	16.22	8.60	70.10	39.72	—
2	23.90	1.42	12.12	10.50	13.20	7.02	—	6.15	5.45	79.76	23.52	—
3	27.99	2.86	11.55	10.31	4.38	8.47	—	20.51	0.59	86.66	34.27	—
4	22.45	1.38	21.49	13.96	0.40	20.56	—	16.92	3.28	100.44	35.54	—
5	9.29	—	—	—	4.38	15.40	—	12.60	1.10	42.68	13.70	—
6	6.50	3.07	19.16	19.94	2.73	3.93	13.94	19.31	5.34	93.94	47.66	—
7	1.43	4.53	22.09	20.13	13.93	6.24	17.20	31.40	7.86	124.81	63.92	—
8	11.08	9.28	20.30	22.42	6.37	0.74	13.66	14.96	8.66	107.47	55.32	8.08
9	15.89	1.87	2.16	11.33	5.60	52.21	—	16.63	3.35	109.04	33.18	—
10	6.14	1.42	3.17	35.66	1.47	8.02	47.05	13.97	1.88	118.78	52.93	—
11	9.58	2.44	4.59	20.59	6.09	2.75	30.10	12.88	3.72	92.74	39.63	0.53
12	6.18	3.84	1.98	16.84	15.98	20.15	—	16.16	5.97	87.10	42.81	—
13	3.66	0.94	6.99	3.03	7.22	4.82	—	14.07	1.19	41.92	19.23	—
14	0.70	0.30	19.10	—	8.90	0.53	1.23	20.10	1.20	52.06	21.60	—
15	2.25	0.98	2.00	9.56	5.02	2.80	3.01	21.50	18.20	65.23	50.24	—
16	3.98	5.61	39.10	6.08	5.69	1.62	28.36	34.08	11.04	135.65	56.81	0.97
17	4.03	5.37	5.56	10.86	4.97	4.20	40.60	4.73	2.50	82.82	23.46	4.35
18	7.63	5.28	5.99	15.78	6.69	8.33	24.03	28.16	9.81	111.70	59.03	8.08
19	21.35	2.06	2.39	2.34	22.45	32.99	—	23.21	1.43	108.22	29.04	—
20	25.75	12.91	5.08	5.62	—	8.14	21.86	42.14	1.68	123.18	62.35	—
21	21.33	4.53	22.67	14.59	4.57	5.01	25.99	20.68	3.13	122.50	42.93	—
22	10.48	9.21	40.35	18.40	14.42	0.99	65.61	30.23	13.31	203.00	71.15	—
23	66.20	4.70	8.36	18.57	10.48	32.76	39.28	18.06	—	198.41	41.33	—
24	24.35	11.49	14.99	22.03	18.65	3.26	83.82	19.44	—	198.03	52.96	4.45
25	12.36	5.91	27.11	2.06	15.06	3.25	2.47	19.39	6.14	93.75	33.50	2.75
26	4.58	3.05	37.47	8.71	3.48	4.94	2.19	34.09	2.34	100.85	48.19	—
27	15.06	9.54	26.93	3.96	7.29	—	4.85	25.07	5.21	97.91	43.69	7.27
28	2.56	1.43	9.36	3.06	2.71	—	—	38.73	10.80	69.55	54.92	—
Average volume over 28, plots (m^3)	13	4	15	12	8	9	17	21	5	104	43	—
Coefficient of variation (per cent)	102	108	78	70	74	132	133	43	90	40	34	—

(2) A statistically acceptable figure for a single species is only likely to be obtained in those exceptional cases where the species occurs under almost every condition of the total sampling (as, for example No. 8 in table 1).

(3) The present selective exploitation of log-timber in the tropics—i.e., harvesting only one or two species out of the hundreds available—means that a general interpretation, not deliberately aimed at the "valuable" species, is unlikely to provide data of any value.

The data confirmed—what had appeared evident in the vertical photographs—that plots 5, 13 and 14 are typical of the low patches, and plots 22, 23 and 24 of the high (clumps of big trees with large crowns). It is hoped to use their photographic appearance as criteria for a preliminary stratification to rationalize future plot randomization and reduce the variability of the data.

Nevertheless, the data give some valuable indications of the advantages that can flow from an integrated interpretation of the photographic and the field evidence. For example:

(*a*) Species No. 6 has a variation coefficient of 132 per cent. On the plots, however, it shows either a high volume or a low volume (even zero); no readings occur round the mean. The explanation is simple. This species is concentrated on the descending slopes of "igarapés" (creeks). It is an understory tree which cannot be seen in the photograph, but the sampling has revealed its ecological characteristics. Had it been a "valuable" wood, it would at least have been possible to indicate on the topographical map the regions where it should be sought. If it proved of sufficient interest, then further sampling data could be scrutinized to delimit its occurrence, within its chosen habitat, to certain associations discernible in the aerial photographs and to narrow still further on the topographical map the areas where it is likely to occur.

(*b*) Species No. 7, on the other hand, is recognizable, both from the statistics and in the field, as a massive upperstory tree occurring in groups. This immediately suggests the need to be able to recognize these groups in the photographs. Appropriate stratification will then enable us to sample to the point of statistical reliability.

(*c*) Species X is a "valuable" wood which is rare in this region. Only if the special characteristics of the species were to make possible identification in the photographs (if, for example, photographing coincided with an unmistakable flowering) could it be hoped to evaluate its occurrence from any practicable general interpretation.

(*d*) Finally, though all the species met with may not be acceptable to a pulp and paper project, it is already evident from this initial sampling that the greater the number of the more widely occurring species that can be accepted, the sooner will it be possible to obtain by sampling a volume estimate of sufficient precision to throw light on a particular project. If in the above instance, for example, attention could be focused, and if necessary research undertaken on, species 2, 4, 8 and 9, good data would be obtained much more quickly than if the limitations imposed by exploitation techniques enforced the rejection of some of these species.

CONCLUSION

Generally speaking, aerial survey can yield immeasurably more and better data than can any ground survey—and at a fraction of the cost. But it is equally true that while tropical exploitation continues to concentrate on a very limited number of species having exceptional market value, small-scale photography certainly cannot as yet achieve anything like the reliability in assessment of marketable species which is obtainable for temperate forests. At best it can delimit the associations in which species will be found and give the order of magnitude of the volume of its occurrence from association to association. At worst it can almost certainly indicate the areas in which the species does not occur and so reduce the expense of a 100 per cent ground assessment, commonly practised in tropical forests.

But skilled interpretation of aerial photographs, making use of the data accumulated in widespread sampling, can quickly give reliable type-maps; it can indicate, with a precision adequate for extensive tropical management, the volume of the type as a whole, and can give rough data for its dominant components. If the technique of the pulp chemist can extend the range of material acceptable for pulping, thus making it possible to think less in terms of individual tree characteristics and more in terms of broader fibre categories, then it becomes at once more practicable to quickly obtain data sufficiently precise to be of real value from the industrial point of view.

Perhaps the most important conclusion to be drawn from experience of tropical aerial survey assessment is that the work has an inherently personal character. For example, it has been shown above that an assessment of species 6 will be obtained much more quickly if the surveyor is capable of observing the species' ecological characteristics and if the photograph examiner is able to map the descending slopes of the creeks. Otherwise, to get any information of value about this species, there is no alternative but to take more and more time-consuming samples; even so the practical difficulties involved are so great that it is doubtful whether good results will be achieved.

Tropical forest development does not in general follow the even tenor which is consistent with patient long-term assessment. It is marked by bursts of industrial inquiry that, by its very nature, is impatient for results. Since the occasions when industrial proposals have been under consideration have provided the major opportunities for tropical-forest development, the tropical forester is obliged at these times to take a realistic view of normal technical procedures in his attempts to meet the industrialists' demands for forest data. Since information is needed quickly time is invariably the most important factor. But the requirements of good interpretation are exacting, and the right kind of personnel for this type of work is not easy to find.

PRELIMINARY PROJECTS FOR PULP MILLS AND THEIR SERVICE FACILITIES IN TROPICAL REGIONS[1]

Centre de recherches et d'etudes pour l'industrie de la cellulose et du papier

If a decision has been taken to establish a plant, it may be assumed that the preliminary study will not only have specified: the capacity of the plant, and the production programme; the process to be employed; and the nature and extent of service facilities for operating the plant—but also the source and rhythm of the raw material supply, restrictions imposed by local conditions on the weight and size of pieces of equipment, the scope and capacities of the local construction industry which can be called upon to furnish certain materials.

The first phase of execution is to draw up a complete preliminary plan on the usual lines for industries of this kind. The principal components of this plan will be:

(A) The conception of the plant itself, e.g., the establishment of a manufacturing scheme for the different sections, the distribution of the equipment in the different buildings, the specification of all equipment, the determination of the essential characteristics of all the buildings; and

(B) The work schedule for the final construction operations, especially for work to be carried out on the site.

This paper does not list the various steps to be taken in formulating these two elements of the preliminary plan, since the general approach will be similar to that employed in installing any factory in a tropical region; it merely draws attention to certain modifications which may be found necessary, as a result of the restrictions imposed by local conditions, to both the plant scheme and the work schedule.

The plant scheme

Specifying the equipment

So far as possible the equipment specified should conform to standards adopted in other pulp and paper mills. Modifications to meet local requirements will usually arise from transport considerations, e.g., weight limits (paper machine presses, calender rolls; certain equipment, such as turbo-generators, may have to be sent unassembled) or size limits (digestors, evaporators). In either case a compromise must be reached between the needs of the manufacturing process and the facilities for transporting the equipment or assembling it on the spot. A study should be made, before a decision is reached, of the possibility of effecting a temporary or permanent improvement in the existing means of transport.

Buildings

Careful consideration must be given to choice of materials. Transport problems will usually make it difficult to dispatch assembled girders to the site, in which case provision must be made for an assembly yard in the perimeter of the plant and the design of the metal framework modified accordingly. Alternatively, the decision may be in favour of reinforced concrete.

The limitations of local construction contractors must not be overlooked. The inexperience of the labour employed, as well as limited equipment, may prevent work being carried out within the usual limits of tolerance.

[1] A shortened version of the original paper, ST/ECLA/CONF.3/L.3.4.

The design and disposition of the buildings must take into account climatic factors as well as matters like water disposal, local traffic, and links to rail, road and water communications. Maximum protection against the sun must be afforded, it will generally be necessary to rely on strong natural ventilation to combat heat and humidity, whilst protection against rain and the considerable drainage required pose special problems.

Provisional installation

The absence of external aid will usually mean that certain construction services will have to be temporarily installed. Careful provision for these must be made if they are not to endanger the rhythm of work on the site.

WORK SCHEDULE

Levelling of the site; buildings

When establishing the engineering works schedule, account must be taken of the long periods when work cannot be carried out, in particular during the rainy seasons. The first two stages: (1) levelling off foundations of industrial buildings and construction of dwellings; and (2) erection of a mechanical workshop and power station, arrangements for storing equipment, need to be carried out as continuous, uninterrupted, operations and planned accordingly; the third stage (3) erection of other industrial buildings, can be subdivided if necessary.

In general, slower working rhythm and long interruptions make it necessary to allow eighteen months or two years for these operations which could in normal circumstances be completed in less than a year.

Delivery of equipment

Arrangements will have to be made for the unloading, despatch and storage of very large tonnages of equipment. A detailed storage plan must be worked out in advance, and while every effort must be made to maintain the delivery and reception schedule, prompt revisions of the construction schedule must be made when it falters so that serious losses of time and money can be averted.

Building schedule

This will be difficult to work out since a compromise must be reached between the need for rapid execution and the need to limit calls on the local labour force and on foreign supervisors.

DRAWING UP THE WORKING PLAN

Though a working programme must be established well in advance, it should contain ample allowance for delays in construction arising from local limitations. Progress should be continually checked, and the programme amended to take account of any restrictions which arise.

The following stages in drawing up a working plan are recommended:

1. Establishment of a general lay-out for the plant, complete with specification of the main equipment required for each section of the mill; approximate placing of this equipment in the buildings.

2. Definition of the type of buildings and constructions required.

3. Preparation of a timetable for the whole project allowing for any restrictions which may be imposed by local conditions.

4. Preparations of preliminary plans for each section of the mill, in order of priority.

5. Detailed schedule showing delivery arrangements for all the supplies needed (ex works, shipment, arrival at port, customs formalities, despatch to and storage on site).

6. The storage plan should decide whether provision must be made for temporary buildings for housing equipment.

7. The preliminary plan could be complemented by a study of temporary installations on the construction site, including the buildings for storing equipment.

WOOD EXTRACTION AND TRANSPORTATION IN TROPICAL REGIONS[1]

PIERRE ALLOUARD

INTRODUCTION

In Mexico, Brazil, Colombia, and Argentina, a study was made of wood supply for pulp mills with annual production capacities of 15,000, 30,000, 60,000 and 100,000 tons. The following points were considered: general organization and exploitation; cost of wood delivered to mill; labour force, equipment, investment and working capital required.

Cost and yield estimates were calculated on the ton of green wood; it was conservatively assumed that four tons of green wood are necessary to obtain one ton of pulp. All estimates and calculations are made on the basis of unbarked wood, it being assumed that barking could be carried out at the mill under better conditions than in the forest. As a working hypothesis, it has been assumed that 50 per cent of the standing timber could be used as pulpwood, the remaining 50 per cent being used as fuelwood if profitable.

The estimated cost prices of wood include social welfare expenditure, reafforestation costs, salaries of administrative personnel and a margin for unforeseen expenses.

Though it has been assumed, in order to arrive at normal rather than initial costs, that working methods have become well established, ample margins have been included to allow for the study and trial of exploitation methods and for personnel training.

[1] The original paper (ST/ECLA/CONF.3/L.3.5) of which this is a shortened version, gives details of the estimates, e.g., labour requirements, wage rates, equipment specified etc., and arrives at estimates, for each project, and for all four mill sizes, of capital requirements and pulpwood costs. It also includes a commentary on the differences found between the different cost elements in the various projects.

Expenditure on permanent investment (purchase of land, permanent roads, preliminary studies, etc.) is amortized over fifty years, forestry equipment over four years. The costs of secondary, temporary roads, however, are included in annual exploitation costs.

Equipment cost estimates are based on prices and exchange rates operative on March 1, 1954.

For each project a methodical forest survey, with mensuration by the quadrillage method, has been envisaged.

It is assumed that the exploitation and management of the forests from which pulpwood, and perhaps also fuelwood, are to be extracted will be organized on a sustained yield basis. The method of exploitation provided for is clear felling, in relatively narrow strips.

Preliminary work

No tropical forest exploitation at present exists on a scale required for a normal-sized pulp mill. Experience gained in the exploitation of tropical lumber and the extraction of pulpwood in temperate countries can be applied only with certain modifications. Hence, though the present study may give an adequate idea of the methods to be adopted and of approximate costs, before the mill is installed, practical trials will need to be undertaken and yields controlled.

The exploitations have been divided into pulpwood production units of 60,000 tons (plus, in certain cases, a similar quantity of fuelwood). Each unit would have a large measure of autonomy, with its own part of the forest, its own workshop and its own store.

For mills of more than 15,000 tons, and particularly of 60,000 tons and over, a general administration would have to be created to manage and co-ordinate the exploitation units.

Preliminary survey

Aerial photographs are essential for defining the wooded areas and contour, for giving a general idea of volume per hectare, and for establishing a road network plan, etc. This information should be complemented by methodical ground surveys. Small-scale studies should be undertaken on the functioning of equipment under local conditions, so that working methods can be adjusted if necessary. Parallel studies should determine the possibilities of storing the various species to be used for pulping.

The road network

The primary road network will consist of permanent roads, at five- to ten-kilometre intervals, practicable for wood transportation even in the rainy season. Short sections, where heavy traffic will be concentrated, may have to be surfaced. Preferably, this network should be completed in the first few years, rather than constructed in stages during the entire rotation period.

Secondary roads, normally at half-kilometre intervals, would be temporary. Their cost would be chargeable to the annual felling account. Should road construction prove expensive, wider spacing may be adopted and the secondary roads supplemented by forest trails.

Forestry operations

Quadrillage, mensuration and marking. Since marking will be necessary, it is desirable that quadrillage and mensuration be also undertaken. This will facilitate both exploitation and mill operations, enabling cut to be controlled. The main element of cost, brushwood clearing, must be incurred in any case.

Felling will be carried out in two stages, small-diameter wood being felled and hauled first. ***Bucking*** will be by hand, into certain specified lengths. For the felling and bucking operations, it is estimated that two men can deal with ten tons a day.

Haulage. For small- and large-diameter woods respectively, D4 and D6 tractors equipped with winches and bulldozers are envisaged for the haulage operations. Given flat terrain and no excessive distances, these tractors should have daily capacities of sixty and ninety tons respectively. For *loading and transport,* 5- to 7-ton trucks would be used, equipped with trailers and mechanical loading devices.

Though most overheads are included in the over-all expenses for the whole project, certain items clearly rank as exploitation costs and have been included in the most price of pulpwood, e.g., supervisory personnel in the exploitation unit (unit manager, five yard foremen, and subordinate staff for each 60,000-ton unit), general management personnel, if more than one exploitation unit is involved, sundry vehicles, and allowances for unforeseen expenditure.

Special conditions in each country

Mexico

The area to be exploited is situated in the vast limestone plain of Yucatán, near the sea. The exploitation centre would probably be placed in Colonia, Yucatán, where the Maderera del Trópico enterprise is already installed. The area envisaged is covered with rather poor but fairly unbroken woodlands and is estimated to contain 100 tons of wood per hectare, of which forty tons per hectare may be reckoned as usable pulpwood. On the basis of a forty-year rotation period, and adding a 25 per cent margin to allow for possible reserved lands within the area, a 15,000-ton mill (i.e., an annual pulpwood supply of 60,000 tons) would require a supply area of 75,000 hectares. Because the afore-mentioned enterprise has solved the problems of settling industrial labour, it is generally easy to recruit suitably skilled workers, chiefly tractor or truck drivers and yard workmen. Supervisory personnel can be engaged without difficulty, and wages are not very high.

Expenditure on social welfare (excluding housing) may be reckoned at 25 per cent of the wages bill.

There is a five-month rainy season, but water drains easily through the limestone soil.

Owing to the rockiness of the terrain, primary roads will be costly to construct. They will be asphalted, and serve also as public highways; ten-km spacing will suffice.

Secondary roads, at kilometre intervals, will also be expensive. Haulage will be difficult because the nature of the terrain lowers tractor capacity.

Two alternative sites which were briefly examined in Mexico might, on closer investigation, prove superior to the Yucatán site studied.

Brazil

The contemplated mill would be installed at Porto Platon on the river Araguari in the Federal Territory of Amapá about 100 kms north of the Amazon. The forest is fairly rich, containing an average of 200 tons per hectare, of which about 100 tons is usable for pulpwood; 24,000 hectares would suffice for the supply area of a 15,000-ton mill. The exploitable area is sufficient to provide pulpwood without difficulty for a pulp mill with an annual capacity of up to 60,000 tons (240,000 tons of wood).

The territory of Amapá is very sparsely populated and the area chosen for the mill site uninhabited. Labour would have to be imported from other areas and trained. Social insurance may be reckoned at about 50 per cent of the wages bill.

In spite of labour difficulties, the forest wealth and the favourable terrain would make exploitation profitable. Fuelwood could be extracted to advantage, and would form the cheapest source of fuel—even for power.

Roads, unless surfaced, would not be costly or difficult to construct. A denser road network—say a 5 to 7 kilometre mesh—would, however, avoid unduly heavy traffic concentration, thus dispensing with the need for surfacing. The richness of the forest will keep transport distances and costs low.

Colombia

It is assumed that the mill would be installed at Puerto Berrio in the Magdalena river valley; an alternative site considered, Puerto Boyaca, though possessing richer forests, has certain economic disadvantages. The forest at Puerto Berrio contains a large proportion of fast-growing, low-density woods—a favourable factor since the mill's main production would be mechanical pulp and the rotation period could therefore be reduced from forty to thirty years.

The terrain is fairly sandy and the presence of gravel would facilitate the construction of all-weather roads. Broken ground, however, would add to road building costs.

Since the forests are poor, long transport distances would be involved and transport costs high.

Though labour will be readily obtainable—some drawn from nearby settlements—wages are high.

Pulpwood could be extracted at the rate of thirty-five tons per hectare. Only pulpwood would be extracted, as an oil pipeline passes through the site and petroleum would certainly be the cheapest form of fuel.

Argentina

The contemplated mill would be installed at Puerto Piray, in the Misiones Territory. It would be an extension, producing sulphate pulp from mixed tropical wood, to an existing sulphite mill project which aims to use, at the outset, certain natural stands of Paraná pine and later plantations of the same species. The sulphite mill will use annually about 150,000 tons of fuelwood; the sulphate mill will be based on the tropical wood resources remaining after the needs of the sulphite mill have been met.

The forest is not very rich; a safe estimate of the yield is 100 tons per hectare, i.e., 50 tons of pulpwood. Moreover, one-fourth of the area is too broken for exploitation, and another quarter must be reserved for agriculture. Nevertheless, an area of 75 km radius would more than supply the needs of a 100,000-ton mill, even after making allowance for the needs of the sulphite mill.

A 7 x 7 km network of primary roads would be necessary. Roads will be costly to construct—certain sections will need surfacing—and part of the capital cost should be borne by agricultural developments. Transport costs would be high, because of the long distances. Though labour is readily available, it is relatively expensive.

Pulpwood cost estimates

The following table gives estimates of the cost per ton of green wood delivered to the pulp mill for each of the four projects examined. In each case the estimates relate to a 30,000-ton mill, i.e., to an annual 120,000-ton pulpwood operation. All the figures are converted to U.S. dollars, and fourteen cost elements are distinguished.

Pulpwood cost estimates

Operation	*Mexico*	*Brazil*	*Colombia*	*Argentina*
1. Quadrillage, inventory, marking	0.21	0.07	0.38	0.18
2. Secondary road construction	0.36	0.02	0.17	0.29
3. Amortization of preparatory works (chiefly primary roads)	0.17	0.03	0.16	0.12
4. Primary road maintenance	0.29	0.14	0.50	0.49
5. Felling, bucking	0.25	0.24	0.48	0.38
6. Haulage	1.24	0.90	0.90	0.86
7. Loading and preparation	0.06	0.00	0.10	0.04
8. Transport	0.59	0.36	1.22	2.21
9. Sylviculture	0.53	0.27	0.85	0.68
10. Technical staff	0.52	0.57	1.14	0.78
11. General administration	0.12	0.27	0.40	0.24
12. Splitting	0.03	0.07	0.05	0.07
13. Sundry vehicles	0.19	0.10	0.24	0.44
Total	4.56	3.04	6.59	6.78
14. Unforeseen expenses [a]	0.46	0.36	0.65	0.67
Total cost per ton	5.02	3.40	7.24	7.45

[a] Ten per cent for Mexico, Colombia and Argentina; 12 per cent for Bra

ECONOMIC AVAILABILITY OF PULPWOOD FROM LATIN AMERICAN SUB-TROPICAL FORESTS[1]

ORLANDO D'ADAMO

The rain forests of Latin America constitute one of the largest reserves of timber in the world. So far the utilization of these forests has encountered great difficulties: the stands are very heterogeneous, they contain very few commercial species (sometimes as little as 1 or 2 m^3 per hectare), and technical studies have been few. A serious obstacle has been the difficulty of transporting products to the consuming centres, which, because industry and population in Latin American countries are highly localized, may be 1,000 to 2,000 km away.

The emergence of plywood, pulp and paper industries has opened up new prospects, which may lead to a profound change in the conditions for exploiting these forests, with repercussions on the regional and national economies.

In the past, *entrepreneurs* have tended all too often to lay their plans on a short-term basis, and in due course the forests have become incapable of supplying the amounts of raw material needed. While lack of foresight regarding raw material supplies may have consequences not too serious for those industries in which initial investment is low, it is fatal where such complex and costly undertakings as pulp and paper are concerned.

It is essential when planning a pulp and paper industry to make a careful appraisal of the conditions under which an ample, steady and cheap supply of raw material can be assured. Both the cost of the raw materials and the extent of the resources must be taken into account in the management plan.

Four separate preliminary stages, consisting of legal, natural, forestry and economic appraisals of the forest unit or stands, lead up to the final management plan, the essence of which is the policy decided upon for the exploitation of the forest. The plan must look on the forest as a source of raw material which is renewable and can therefore be permanent. If it fails to do so, not merely will the fate of the undertaking be jeopardized; indiscriminate exploitation of the forest will bring in its train serious consequences for the soil, water régime, etc., and hence for the whole economy, of the region in which the forests are located.

The most serious problem is to reconcile conservative management with economic exploitation. In the past it was thought that the costs of a commercial undertaking in tropical forests would be prohibitive because exploitation, to be profitable, had to be based on the extraction of only a fraction of the raw material—of those species with a commercial value.

Nature herself, however, provides the means of bringing about changes in the composition of the forest without prejudicing the possibility of exploiting the forest economically. Certain trees have a great capacity for regeneration and are capable of becoming the dominant species in a given stand. This biological fitness can be turned to account within the framework of a forest management plan in order to work towards a desired "standard composition" giving the possibility of economic exploitation. An appraisal of the natural, forestry and economic aspects of the forest stands enables the species capable of fulfilling this role to be determined. Once it has been decided which species shall eventually become the dominant ones, the elimination of the species no longer desired can be carried out ruthlessly.

The sustained yield, which is an expression of the orderly management of any forest or stand of timber, is a measure of the potential capacity of the industry and the limit of its natural expansion, assuming that supplementary sources of supply are not available.

If the species destined to dominate the ultimate pattern of the forest are the only ones capable of being used industrially, a transitional period of rotation of species will be necessary, when yields will be low and extraction costs high. Fortunately, however, there are always to be found in these stands species which, though no part of the long-range plan, have acceptable pulping properties.

By way of example, a management plan which has been adopted in a rain forest in the National Territory of Missiones may be cited. The forest unit concerned covers 4,400 hectares.

The plan aims at obtaining a forest which may be described as "mixed wood dominated by black laurel" (*Nectandra saligna*); studies show that this object can be achieved. The transformation would consist of facilitating the domination over the remaining complex of that species economically desirable and most apt biologically. This species will be exploited by clear cutting in high forest sectors and thinnings in the sectors undergoing regeneration. The method of clear cutting selected is that of the "single mobile sector" on an eighty-year cycle of rotations, which is the best technologically and at the same time gives the greatest wood yield. The rotations will average twenty years.

Repopulation with the selected species will, if it proves necessary, be carried out by direct sowing and perhaps by seedings.

This management plan will assure a progressively increasing annual yield of black laurel—the species which forms the basis of the plan. Other species will be exploited so as to fit in with the plan for regenerating certain sectors and transforming others. Some will be utilized for pulp and paper; others will be exploited for other commercial purposes. The volume extracted will be carefully co-ordinated with the plan so as to build up the basic species, thus gradually leading to a normalized forest as the species not desired are steadily eliminated.

[1] A shortened version of the original paper, ST/ECLA/CONF.3/L.3.6.

PULPWOOD FROM PERUVIAN CETICO (CECROPIA)[1]

BANCO DE FOMENTO AGROPECUARIO DEL PERÚ

INTRODUCTION

The forest area of Peru, extending eastwards from the Andes, covers some 60 million hectares. It has a great variety of tree species, as many as 250 different types being met with in the Amazon valley. These include rare woods of considerable commercial value and many others which, though abundant, have at the present time little or no commercial value. The utilization of the latter as raw materials for the production of pulp is technically feasible and could greatly benefit the country's economy.

Of these one of the most abundant is the *Cecropia*, belonging to the Moraceae family. It grows along the banks of the Amazon and its tributaries and is known locally as "cetico". It is found in forest clearings, and it is frequently the dominant species in second-growth forests.

The cetico is a small tree of medium bulk with a smooth, greyish-greenish bark. Its slender trunk narrows at the base, but as support it throws out numerous roots that curve towards the ground from a height of about one to one and a half metres. These trees have a short life, grow extremely rapidly, have hollow trunks and are customarily infested with small ants that can cause severe bites when the tree is molested. The cetico has the peculiarity of sprouting again once the tree has been felled. It has very large leaves, up to 90 centimetres in diameter and bunches of small green and whitish flowers. Currently, the wood is used locally only as fuel, though the bark is employed for cord manufacture.

The Banco de Fomento Agropecuario initiated studies into the industrial use of the cetico in 1949 and subsequently two missions[2] have carried out researches and on-the-spot surveys aimed at ascertaining the possibilities of using this wood for pulp production.

The first mission investigated raw materials, fuels and sources of power, means of communication, market possibilities, etc. To estimate the available cetico resources, reconnaissance trips were made by air, river and land along the banks of the Amazon and many of its tributaries. Samples of cetico wood were sent to Europe for mechanical pulping. To the mechanical pulp produced was added a small proportion of Swedish sulphite pulp, and several tons of newsprint were manufactured and used successfuly for printing several editions of newspapers in Italy and in Lima.

These studies lasted over a year and led to the following conclusions:

(1) The Peruvian Amazon region contains sufficient quantities of cetico wood, easily accessible and easy to transport, to guarantee, indefinitely, sufficient supplies for the production of newsprint to meet both present and future domestic consumption.

(2) Iquitos, which is one of the most densely populated centres of the Peruvian Amazon region, was considered to be perhaps the most appropriate place for installing a mill capable of producing some 6,000 tons of mechanical pulp annually.

(3) It was estimated that the establishment in some coastal area of a newsprint mill with an annual production of some 12,000 tons would be feasible. This mill would operate on the basis of 6,000 tons of mechanical cetico pulp produced in Iquitos and 6,000 tons of chemical pulp, possibly manufactured from sugar-cane bagasse.

The second mission, which arrived in Peru in 1952, continued the studies already begun. A survey of the region suggested that the Ucayali river area in the region of Pucallpa perhaps offered greater advantages than Iquitos. The river port of Pucallpa, 842 km distant from Lima, is connected with the capital by road and by a combination of road and railway.

Air survey of the Ucayali river area made it possible to fix the natural cetico stands. To date thirty-nine stands, distributed over 160 kilometres of the Ucayali and Pachitea rivers and their tributaries, in a belt averaging 300 metres wide on each bank, have been inventoried with 10 per cent sampling. The results show 105 cubic metres of usable clean wood per hectare. Simultaneous studies were concerned with the propagation of cetico, and with the cost of extraction. From all these studies it may be concluded that:

(1) Adding to the volume of cetico in pure stands that represented by dispersed trees, there is an average volume of 1,800 cubic metres of usable wood per lineal kilometre of river in the 160 kilometres of river surveyed.

(2) Growth is so rapid that a five-year rotation can be reckoned on for pulping purposes.

(3) Cetico grows naturally in new soils formed by the meanders of rivers. Thus the oldest trees—those of greatest volume—are found in those parts of the belts most distant from the river.

(4) Artificial plantations are practicable, and probably give a higher yield than natural stands. Different methods of direct sowing and transplanting were equally successful. Moreover, cetico sprouts freely from the stumps after felling; the growth rates of these sprouts are still under study.

(5) The cost of cetico wood delivered mill is estimated at $8.81 per cubic metre. Since the main expense in extraction is conveyance of the logs from the stands to the river's edge, this could be substantially reduced by mechanization.

In addition to these field studies, industrial tests on cetico wood sent to France showed that satisfactory newsprint could be manufactured from it.

CONCLUSIONS

As a result of all these studies, including a later detailed study of the economic aspects, it was concluded

[1] A shortened version of the original paper, ST/ECLA/CONF.3/L.3.7.

[2] The first, Cellulose Development Corporation, of England; the second, the French enterprise, Batineyret.

that the installation of a mill in the neighbourhood of Pucallpa for the production of 18,000 tons annually of newsprint entirely manufactured from cetico wood was feasible.

Cost estimates indicate that the paper produced, marketed in Lima, could compete with similar imported paper. All Peruvian newsprint, amounting to 12,000 tons annually, is at present imported, at a cost of over $3,000,000; thus the Pucallpa mill would mean a considerable saving in foreign exchange.

PULPING OF LATIN AMERICAN WOODS[1]

G. H. Chidester and E. R. Schafer

Introduction

On various occasions the Forest Products Laboratory has been requested to undertake pulp and paper investigations on woods growing outside the United States. One of the earliest projects of this kind consisted of pulping tests on several Chilean woods in 1913, only a few years after the laboratory was established. Since that time pulping experiments have been made on woods from many foreign countries. Those from the Latin American countries number thirty-nine individual species and ten mixtures of species, ranging from two woods to thirty-two woods in the mixture. In all, a total of 109 woods have been tested individually and/or in mixtures. This report presents essential data and brief descriptions of the results of these experiments.

Since the regular appropriations of the laboratory as a unit of the United States Forest Service do not cover work of this kind on foreign woods, the cost of this work has been covered by contributions of business organizations and other groups interested in the various projects. Acknowledgements of most of these contributions have been made in other publications and are too numerous to repeat here.

Insignis pine *(Pinus radiata)*

Extensive plantations of insignis pine in Chile have had a rapid growth, attaining pulpwood size in eight to ten years and a timber size of ten to fourteen inches in base diameter at an age of twenty-five to thirty years. The Forest Products Laboratory has evaluated this wood for making paper-grade and viscose-grade pulps. The average age of the logs tested was thirty-nine years, the average rings per inch, 3.5, and the density, based on oven-dry weight and green volume, was about 28 pounds per cubic foot.

For the production of unbleached kraft pulp, the wood was satisfactorily digested with 15.6 per cent of active alkali (based on moisture-free wood) expressed as Na_2O and sulphidity based on active alkali of 30 per cent. These, as well as the time and temperature conditions used, are similar to those used for southern pine. The yield of screened pulp was about 47 per cent by weight, or 13.15 pounds of moisture-free pulp per cubic foot of the green wood. Though a little lower in tearing strength, this pulp had higher folding strength and similar bursting and tensile strengths to commercial unbleached southern pine kraft pulp. The pulp therefore appeared to have sufficient strength for use in wrapping, bag, specialty papers, and paperboard of good quality.

A bleachable sulphate pulp with well-balanced strength properties was also produced under normal cooking procedures. To make this pulp, 21.5 pounds of chemical (total Na_2O) per 100 pounds of moisture-free wood was used to give a yield of about 45 per cent of screened pulp, or 12.6 pounds of pulp per cubic foot of green wood. This pulp was semi-bleached with 6 per cent total chlorine by either a one-stage hypochlorite or a two-stage chlorination-hypochlorite treatment to a yield of 44 per cent (based on wood) of pulp with brightness of 70 per cent. A little loss in strength resulted in the one-stage process, but the two-stage semi-bleached sulphate pulp was superior in strength to typical commercial semi-bleached sulphate pulp. The pulp was fully bleached to a brightness of 82 per cent with a total of 6 per cent of chlorine in a four-stage chlorination-hypochlorite treatment. The yield of bleached pulp was 43 per cent of the wood. The over-all average strength retention was about 95 per cent; therefore, the bleached pulp could be used in strong papers.

A viscose-grade of pulp was made from the insignis pine by pre-hydrolysis-sulphate pulping and a multi-stage chlorination-hypochlorite purification treatment. The yield of purified pulp was about 40 per cent of the wood. The chemical composition, solution viscosity, and reactivity were essentially the same as those of typical sulphite pulps used for continuous-thread viscose rayon.

Groundwood pulping tests were made on insignis pine grown in New Zealand. Compared to spruce grown under the same conditions, the pulp strengths and freeness were about the same. The energy consumption per ton of pulp was considerably more for the pine than the spruce, though it could not be considered excessively high. The pine groundwood had a distinct orange hue and was about 8 per cent points lower in whiteness than the spruce groundwood.

Eucalyptus species

(E. tereticornis, E. saligna, E. alba, E. kertoniana, E. gigantea)

The large plantations of eucalypt in Brazil, Argentina, and other South American countries are becoming important sources of wood for a number of uses. It is used a little for making pulp and paper, and considerably greater quantities are available for such use. As is well known, eucalypt is used extensively for paper making in Australia.

The Forest Products Laboratory has tested several species of Brazilian-grown eucalypt. Some years ago sulphite pulping tests on *E. tereticornis* and *E. saligna* resulted in pulps satisfactory for the chemical pulp component of newsprint and similar printing paper. Sulphate pulps made from these woods were a little stronger, but for use in newsprint paper they would have to be bleached.

[1] Originally issued as ST/ECLA/CONF.3/L.3.8.

A sample of *E. saligna* was tested more recently for sulphate pulping. A bleachable pulp was made in a yield of 48 per cent with 15.6 per cent active alkali (as Na_2O) based on the wood, which is normal for many hardwoods. The strength of the pulp compared favourably with good-quality hardwood sulphate pulp made from other species. The pulp was semi-bleached to a brightness of 75 per cent in a one-stage treatment with about 5 per cent available chlorine as calcium hypochlorite. A newsprint-type paper was made from the pulp with an addition of 20 per cent of clay (based on pulp). This sheet was slightly stronger than commercial newsprint but more absorbent and porous and somewhat less opaque. This type of pulp undoubtedly could be used in a number of paper furnishes. Bleachable sulphate pulp similar in quality was obtained from *E. kertoniana.*

Cold soda pulping experiments were made on a mixture containing 25 per cent each (by weight) of *E. saligna, E. tereticornis, E. alba,* and *E. kerkoniana.* In this process the chips were steeped in a caustic soda solution for about two hours at atmospheric temperature, washed, and fiberized. In this experiment the caustic soda solution concentration was 75 grammes per litre, and the ratio of caustic to wood was 35 per cent. The yield of pulp obtained was about 90 per cent. The pulp was semi-bleached with 15 per cent of chlorine as calcium hypochlorite in a single stage to a brightness of about 70 per cent. News-type paper of standard 37-pound weight (25 x 40-500) basis was made from a furnish consisting entirely of this pulp. The over-all quality of the paper was comparable to standard newsprint paper, though it was low in opacity and low in oil penetration. The details of this study are reported in another publication.[2]

Neutral sulphite semi-chemical pulping and paper making tests were made on *E. gigantea* from Tasmania. This pulp was obtained in a yield of 70 per cent and was readily bleached. The pulp was moderately strong, indicating it could be used in book paper. Satisfactory quality liner-board was made from the unbleached pulp.

Nothofagus species

Coigue (*N. dombeyi*), Roble pellin (*N. obliqua*), Nire (*N. antarctica*), Lenga (*N. pumilio*), Guindo (*N. betuloides*)

The *Nothofagus* species are important woods of the south temperate zone and resemble the North American beech (*Fagus grandifolia*) in some of their properties. Pulping tests were made on five of the species: coigue and roble pellin from Chile, and nire, lenga, and guindo from Tierra del Fuego, Argentina.

Incomplete pulping and a high amount of screenings were obtained when coigue was cooked by the calcium-base sulphite process. More satisfactory pulp was obtained with a good yield of 47 per cent of screened pulp when a sodium base was substituted for the usual calcium base. An ammonia-base sulphite pulp was purified and found to have a quality satisfactory for the manufacture of viscose rayon.

Cooking coigue by the sulphate process to a yield of 48 per cent (screened) resulted in a bleachable pulp that could be used to impart bulk and opacity in blends with longer-fibred and stronger pulps in the manufacture of high-quality paper. By a modified (pre-hydrolysis) sulphate pulping process, a pulp was obtained that, after purification, was found to be suitable for making into an acceptable quality of viscose yarn.[3]

Neutral sulphite semi-chemical pulp made from coigue was judged by its strength to be suitable for making into corrugating board. A satisfactory-quality viscose yarn was made from a purified pulp prepared by a modified neutral sulphite semi-chemical process.[3]

Coigue was readily reduced by the soda process to a fairly easily bleachable pulp, similar in quality to aspen soda pulp.

Roble pellin was easily pulped by the soda process, but the pulp was low in yield and very difficult to bleach.

Nire sulphate pulp produced in a yield of 48 per cent had good strength for a short-fibred pulp. It could possibly be used in papers not requiring much strength and in blends with longer- and stronger-fibred pulps. Nire neutral sulphite semi-chemical pulp produced in a yield of 78 per cent was relatively low in strength; but it was comparable to that obtained from the related species, coigue, and was similar to that from the North American beech.

Groundwood pulps made from nire, lenga, and guindo were very fine fibred and dark coloured, and had low strength. These pulps could be used as fillers and in products where strength is unimportant. If unbleached, their use would be limited further to papers or boards of low brightness.

Laurelia species

Tepa (*L. serrata*), Laurel (*L. aromatica*)

Pulping experiments were made on tepa and laurel obtained from Chile.

Tepa was pulped fairly completely by the calcium-base sulphite process when a large ratio of bisulphite to wood (equivalent to 6.6 per cent calcium oxide), and consequently a large volume of liquor in relation to wood, was used. The pulp was bleached to about 82 per cent brightness with about 4 per cent chlorine in a three-stage process. The alpha-cellulose content of this pulp was about 90 per cent, which is in the range of hardwood pulps used for xanthation. When tepa was pulped by the ammonia-base sulphite process, to a yield of 41 per cent and purified by a three-stage treatment, the alpha-cellulose content of the purified pulp was about 93 per cent.[4]

Bleachable sulphate pulp was made from tepa in yield of about 49 per cent. This soft, bulky pulp could be used in white printing paper in mixtures with longer-fibred softwood pulp. The pre-hydrolysis sulphate pulping of tepa, followed by three-stage purification, resulted in a pulp suitable for the manufacture of viscose rayon.[4]

Tepa was readily pulped by the neutral sulphite semi-chemical process to a yield of 81 per cent and converted into nine-point corrugating board comparable to those made from groundwood, chestnut chip, and straw. Tepa was also cooked to a yield of about 54 per cent by the

[2] *"The use, in Newsprint, of Bleached Cold Soda Pulps from Latin American Hardwoods"*, by G. H. Chidester and Kenton Brown.

[3] "Viscose Rayon Pulps from Chilean Coigue, Tepa, and Ulmo", by Simmonds, F. A. and Kingsbury, R. M. TAPPI *35*, (No. 4), 166-174, April 1952.

[4] Simmonds, F. A. and Kingsbury, R. M., *op. cit.*

neutral sulphite semi-chemical proces, both with and without pre-hydrolysis. These pulps, after purification by a three-stage chlorine-hypochlorite treatment were indicated by chemical analysis to be satisfactory for viscose rayon manufacture. The yield of purified pulp was about 43 per cent of the wood.[4]

The laurel was pulped only by the soda process. The yield obtained was 40 per cent of the wood. The wood was a little more resistant to pulping by this process than most North American hardwoods. The pulp was similar in quality to soda pulp made from aspen and could be used in book papers.

Ulmo (*Eucryphia cordifolia*)

A sample of ulmo from Chile was satisfactorily pulped by the usual (calcium-base) sulphite process. The yield of pulp was about 47 per cent. The pulp had a relatively high alpha-cellulose content, low pentosan content, and low solubility in organic solvents. The low strength of the pulp indicated its best use would be as a filler stock. Sulphite pulp produced in yield of about 44 per cent and purified in a three-stage treatment had an alpha-cellulose content of about 93 per cent; and by this and other tests it was indicated as suitable for the making of viscose rayon.[5]

Ulmo was also readily pulp by the sulphate process to a yield of 47 per cent with somewhat less chemical than is required for most hardwoods. The pulp was considerably lower in strength than some other hardwood pulps. It possibly could be used in mixtures with long-fibred softwood pulps in paperboard and specialty papers of moderate strength. Ulmo was converted into a commercially acceptable quality of viscose yarn by digestion with a pre-hydrolysis sulphate pulping procedure, followed by the customary purification and viscose manufacturing process.[5]

Sulphate semi-chemical pulp was made from ulmo in 64 to 71 per cent yield with strength that indicated its best use would be in corrugating board.

Ulmo was pulped by the neutral sulphite semi-chemical process with and without the pre-hydrolysis step for purification and evaluation for viscose rayon. Satisfactory pulps were obtained by both procedures.[5]

Gambombo (*Schizolobium parahybum*)

Gambombo from Colombia was made into sulphate pulp with strength that excelled some of the best hardwood pulps, especially in tearing resistance and folding endurance. Table 1 shows the relative strength of gambombo sulphate pulp, together with strengths of pulps from several other Colombian woods. The yield of bleachable pulp of about 52 per cent is high and in the range of yields obtained from North American hardwoods such as aspen and paper birch.

Groundwood pulp made from gambombo had good brightness and colour, and strength about 20 per cent less than that of aspen groundwood pulp. Gambombo chemi-groundwood pulp (a process in which the logs are treated mildly with chemicals before grinding) was much higher in strength than the groundwood. Mixtures of gambombo groundwood and chemi-groundwood pulps could undoubtedly be used in newsprint and paper of similar quality.

The pulping of gambombo in a mixture with other woods will be discussed in a later section.

Jobo (*Spondias mombin*)

Samples of jobo from Santo Domingo, Colombia, and Yucatán have been tested at the Forest Products Laboratory.

One sample was steam cooked, fiberized in a disk mill, and made into an acceptable quality of sheathing-grade insulating board.

Groundwood pulp made from jobo was not so strong as that made from gambombo, mentioned above. It compared closely in strength and brightness to that made from paper birch. Jobo chemi-groundwood pulp was about equal in strength and brightness to the gambombo chemi-groundwood. Like gambomba, mixtures of jobo groundwood and chemi-groundwood, could be used with appropriate amounts of long-fibre pulp in newsprint and other papers of similar strength requirements.

Jobo is readily pulped by the sulphate process. Table 1 shows that the pulp ranked third in strength among four Colombian hardwood sulphate pulps. The jobo sulphate pulp was in the strength range of the better quality hardwood sulphate pulps. The yield of bleachable pulp was about 52 per cent by weight, which is quite high.

Jobo was included in mixtures of woods and pulped by the sulphate process. These will be discussed later.

Ceiba

Ceiba bruja (*Ceiba pentandra*), Ceiba amarilla (*Hura* sp. probably *crepitans*)

Ceiba bruja is a very lightweight wood. Though its fibres are relatively long, they are thin walled. A comparison of the fibre length of ceiba bruja with several Colombian woods is shown in table 1. Samples from Colombia had densities of about 12 and 17 pounds per cubic foot (moisture-free weight and green volume), and a sample from Yucatán had a density of about 17 pounds. A sample of ceiba amarilla from Colombia had a density comparable to that of North American white spruce (24 pounds per cubic foot).

Ceiba bruja groundwood pulp was about equal in strength to gambombo groundwood but was darker in colour. Ceiba bruja chemi-groundwood pulp was a little stronger than gambombo chemi-groundwood but considerably darker; therefore it would require bleaching if used in printing-paper furnishes.

Ceiba bruja sulphate pulp was stronger than some of the best produced from North American species, especially in tearing and folding. It ranked first among the pulps obtained from the four Colombian woods shown in table 1. This greater strength is partially explained by the long fibres found in this wood. However, because of the high amount of parenchyma tissue in this wood, a great deal of which is dissolved in the pulping, the yield of about 39 per cent of bleachable pulp was low. It was necessary to use 30 per cent total chemical to obtain satisfactory pulping. In the bleaching tests it was found

[4] Simmonds, F. A. and Kingsbury, R. M., *op. cit.*
[5] Simmonds, F. A. and Kingsbury, R. M., *op. cit.*

that the pulp contained an appreciable amount of calcium carbonate. Ceiba bruja was pulped in mixtures with other woods by the sulphate process. These will be discussed later.

Ceiba amarilla groundwood pulp was comparable to that obtained from jobo. Unlike jobo, however, the strength was not improved in this instance by pre-treatment for the production of chemi-groundwood.

Caracoli (*Anacardium excelsum*)

The density and fibre length of a sample of caracoli from Colombia were comparable to those of the North American *populus* species. Caracoli sulphate pulp was made with a yield of 45 per cent that had fair-to-good strength properties in comparison with the best quality of sulphate pulp made from hardwoods. The pulp ranked fourth in strength properties in comparison with sulphate pulps made from three other Colombian woods (table 1). In the bleaching tests it was observed that the pulp contained an appreciable amount of calcium carbonate, indicating that the bleached sulphate pulp would have use in many bleached-paper products such as printing and absorbent papers, but not in products requiring highest strength.

Caracoli was steam cooked to a yield of 92 per cent, processed in a disk refiner, and made into satisfactory-quality, sheathing-grade insulating board.

The results of pulping a mixture of caracoli, jobo, gambombo, and ceiba bruja will be described later.

Orey (*Orie*) (*Campnosperma panamensis*)

Kraft (sulphate) and soda pulping tests were made on orey wood. In both cases the yield of bleachable pulp was about 48 per cent of the moisture-free wood, which is comparable to that obtained from common hardwoods used for pulping. The pulps were also of average strength in comparison with those from other hardwoods. Like many other tropical woods, orey could also probably be readily pulped by the neutral sulphite semi-chemical process.

Congona (*Chaunochita* sp.)

A sample of congona wood from Peru had a relatively high density (37 pounds per cubic foot, moisture-free weight, green volume) and grey colour. It was made into bleachable sulphate pulp with a yield of about 46 per cent for a total chemical consumption of about 14 per cent calculated as Na_2O based on moisture-free wood. The strength of the unbleached pulp compared favourably with hardwood sulphate pulps, being a little lower in bursting and tensile strengths and higher in tearing resistance and folding endurance.

Sulphate semi-chemical pulp made with a yield of about 59 per cent and total chemical consumption of about 9 per cent as Na_2O, met the strength requirements for corrugating board.

The yield of soda pulp obtained by the consumption of about 13 per cent of caustic soda (as Na_2O) was about 43 per cent. This pulp was about 20 per cent lower in bursting and tensile strengths, and 75 per cent lower in folding endurance than the sulphate pulp.

Pehuen, Araucaria pine (*Araucaria araucana*)

The density of a sample of pehuen from Argentina was 33 pounds per cubic foot.

The yield of sulphite pulp obtained was about 50 per cent. The unbleached pulp had fair strength and was light coloured. It probably could be used in moderate-strength wrapping papers.

Somewhat better strength was obtained in pulp produced by the sulphate process with a yield of about 48 per cent. Though only about half as strong as pine sulphate pulp, in general, pehuen sulphate pulp undoubtedly could be used in wrapping and paperboard to a limited extent and possibly in newsprint.

A yield of 43 per cent of pulp was obtained by the soda process. The strength of the pulp was about equal to that of the sulphate pulp.

Pehuen is closely related to Paraná pine (*Araucaria angustifolia*) now used in Brazil for the manufacture of sulphite and groundwood pulps and newsprint.

Olivillo (*Aextoxican punctatum*)

Olivillo has a very open structure, with about one-quarter of its volume having fibres of moderate wall thickness, the rest being thin-walled parenchyma or vascular tissue. The average length of the fibres is about two millimetres.

Olivillo from Chile was pulped by the soda process to a yield of about 39 per cent. The pulp was more difficult to bleach than most soda pulps. The pulp was longer-fibred than most North American hardwood pulps, and its strength was good in comparison. Olivillo pulp could undoubtedly be used in printing paper and paperboard, though its low yield would be disadvantageous.

Lingue (*Persea lingue*)

Lingue, from Chile, was readily digested by the soda process to give a yield of pulp of about 41 per cent.

Almacigo (*Bursera simaruba*)

Almacigo from Santo Domingo was made into sulphate pulp with properties indicating that the unbleached pulp might be used in container board; and perhaps in lower-grade wrapping paper if mixed with stronger fibres such as standard kraft. The bleached pulp appeared to be suitable for use in white-printing-paper formulas.

Wallaba (*Eperua falcata*)

Wallaba, from British Guiana, was made into sulphate pulp with good bursting strength but comparatively low tearing strength and folding endurance. The pulp could be used unbleached in papers where high strength is not required or dark colour not objectionable. Though a bleached sulphate pulp was produced from this wood, the pulp was found to bleach with difficulty.

In a single experiment wallaba was incompletely pulped by the sulphite process.

Mangrove (*Rhizophora mangle*)

This very dense (55 pounds per cubic foot) and dark-coloured wood was tested by the sulphate and groundwood pulping processes. The yield of bleachable sulphate pulp was about 43 per cent. The bleaching chemical requirement was relatively high. Though the short fibre of the pulp limits its use, the wood is worthy of consideration because of the high yield per unit of volume.

Mangrove is not a promising wood for groundwood pulping. The strength of the groundwood was fair in comparison with other hardwood groundwood pulps, but the energy consumption was high and the pulp very dark coloured. Much better strength was obtained in the chemi-groundwood pulp, but there was no improvement in colour by pre-treatment. Additional experiments are required to determine whether the chemi-groundwood pulp can be satisfactorily bleached.

Mixtures of woods

Large areas of broadleaved forests, especially those in the tropics, contain a wide variety of species providing timbers whose properties range from soft and light in weight to hard and dense. Some are light coloured, others dark. Most of them have short fibres, though there is considerable variation among species. Often there is an insufficient amount of one species or selected groups to make a pulping operation feasible. The whole forest, or at least a mixture of a number of species, must be considered if the utilization is to be successful.

Pulp manufacture has traditionally been conducted by processing different species separately; or, if in mixtures, with only two or three species having similar characteristics. Techniques for pulping larger numbers of woods, with varying properties, are not well established. Recent research on the pulping of mixtures has indicated some interesting possibilities for the utilization of these heterogeneous forest stands.

Colombian woods

A bleachable sulphate pulp using about 18 per cent of total chemical (NaOH plus Na_2S) was obtained from a mixture consisting, by weight, of 40 per cent jobo, 30 per cent caracoli, 15 per cent gambombo, and 15 per cent ceiba bruja. The yield of pulp was about 50 per cent. The strength of the pulp is shown in table 1. Semi-bleaching by use of a single-stage hypochlorite treatment was not successful because of the presence of small, dark, opaque particles which were found by qualitive tests to consist largely of calcium carbonate. This material, as noted above, was traced to the caracoli and ceiba bruja portions of the pulp. The particles were satisfactorily dissolved in the chlorination stage of a two-stage bleaching treatment, however. The pulp was semi-bleached by the two-stage treatment to a brightness of about 72 per cent with a total of 5 per cent chlorine. The bleaching treatment had very little effect on the strength of the pulp.

A news-type paper made entirely from the semi-bleached pulp was very strong and bright, had good texture, and showed evidence of a desirable open structure (i.e., low air resistance and high oil absorption), but it lacked seriously in opacity as compared to standard newsprint paper. The addition of 20 per cent of clay increased the opacity to 85 per cent, which is 5 per cent less than average standard newsprint. The loss in strength, caused by addition of clay, was excessive when higher amounts of clay were used. It is possible that groundwood or chemi-groundwood pulps made from one or more of these woods (described above) would furnish some of the properties lacking in this all-chemical-pulp paper.

Wrapping papers were made from the unbleached pulp that were well formed and had about 90 per cent of the bursting strength of the highest quality softwood kraft wrapping paper, 80 per cent of the tearing resistance, and 60 per cent of the folding endurance. Their strength was equivalent to that of many commercial wrapping papers. The use of a mixture of these hardwoods in a wide range of papers therefore appeared to be promising.

Mexican hardwoods

Fourteen hardwoods from Yucatán (table 2) were tested individually and in mixtures for the production of sulphate pulp. When the conditions used for all were the same, and in accordance with general requirements for producing bleachable pulp from most of the North Temperate Zone hardwoods used for papermaking, considerable variation between these species was noted. For example, tatsi and huano had low chemical requirements, and kitanche, ceiba, and kanchunup had high chemical requirements. The highest pulp yields were obtained from kochle and tatsi, and the lowest from ekulu and kanchunup. The range and average of yields of bleachable pulp obtained from the fourteen woods were about 10 per cent lower than those from North Temperate Zone hardwoods. The woods were pulped with and without the bark being removed. No appreciable difference in the pulping or the yield was obtained, but the pulps made from unpeeled wood were lower in strength and test-sheet density than those made from peeled wood.

The strength of the pulps obtained from ramon, kochle, and huano compared favourably with the better sulphate pulps made from northern hardwoods (table 3). Most of the other pulps were comparatively low in strength. The bleached pulps had high brightnesses and were satisfactorily clean.

Various mixtures of these fourteen woods and forty-eight Yucatán woods were pulped similarly. The data for several of the mixtures are given in tables 2 and 3. Judged by pulp-quality tests, any mixture of eight or more woods gave about the same results.

A bleached sulphate pulp made from a mixture of eight of the woods (mixture B, tables 2 and 3) was made into white printing, bond, writing, tissue, and towel grades of paper. The papers were clean, bright, and well formed. Though not so high in strength as is common for these grades of paper, they appeared to have acceptable quality.

A corrugating board made from sulphate semi-chemical pulp (yield 69 per cent) prepared from mixture A (without removing the bark), met commercial requirements for this product.

Another mixture of eight Yucatán hardwoods (ramon, jujub, ceiba, tatsi, chaca, kochle, pixoy, and huano) was pulped satisfactorily by the cold soda process. The pulp was of moderate strength compared to the strongest of this type made from northern hardwoods, but much darker in colour. The pulp was bleached to about 60 per cent brightness in one stage with calcium hypochlorite (12 per cent available chlorine). Newsprint-type paper was made entirely from the bleached cold soda pulp. Although the strength was adequate, the paper was more transparent and porous than the conventional product. Opacity was improved by adding about 40 per cent of a mixture of spruce and aspen groundwood pulps or by the addition of clay. This investigation is reported in detail in another document.[6]

Nicaraguan woods

Samples of Nicaraguan woods representing twenty-eight species were tested for producing bleachable sulphate pulp in four selected mixtures of two, eleven, fifteen and twenty-six species, respectively. The woods in each of these mixtures are listed in table 4. Although the individual woods varied widely in specific gravity, the averages of the mixtures ranged between 0.356 and 0.463 (i.e., from about 23 to 29 pounds per cubic foot) on the moisture-free weight, green-volume basis. This range is about the same as that of the medium density pulpwoods in North America.

[6] G. H. Chidester and Kenton Brown, *op. cit.*

The yields of unbleached pulp obtained from the mixtures ranging from 45 to 48 per cent were good for this grade. The unbleached pulp obtained from mixture D (table 5), which comprised all the woods in mixtures B and C, was a little stronger than the others, possibly because the wood was digested to a little higher yield and permanganate number. The quality of these pulps was equal to the best North American hardwood sulphate pulps (table 1). There was a little loss of strength on bleaching the pulp from mixture C.

It was found that washing the unbleached pulps over an inclined screen removed about 16 per cent of dark-coloured fine material (essentially parenchyma cells and vessel segments). The bleached pulps made from the remaining portion were improved in strength and might be used as a substitute for softwood sulphite pulp in many papers.

Table 1

THE DENSITY OF FOUR COLOMBIAN HARDWOODS AND THE STRENGTH AND FIBRE LENGTH OF SULPHATE PULP MADE FROM THEM

Wood	Density[a] (lb. per cu. ft.)	Average fibre length[b] (mm)	Strength of pulp[c]: Bursting strength (pts. per lb per rm.)[d]	Tearing resistance (gm. per lb. per rm.)[d]	Tensile strength (breaking length) (m.)	Folding endurance (Double folds)	Relative strength of pulp[c]: Bursting (per cent)	Tearing (per cent)	Tensile (per cent)	Folding (per cent)
Ceiba bruja	11.8	1.94	1.11	1.14	8,900	730	100	100	100	100
Gambombo	21.2	1.01	1.03	0.92	9,300	580	93	81	104	79
Jobo	22.7	1.35	0.84	0.90	7,930	380	76	79	89	52
Caracoli	23.7	1.26	0.68	1.06	6,600	125	61	93	74	17
Fixture[e]	19.7[f]	1.24	0.96	1.05	8,750	420	85	92	98	58
U. S. hardwoods	30[g]	1.26[h]	1.01[i]	1.01[i]	8,500[i]	420[i]	...	...	...	...

[a] Moisture-free weight and green volume.
[b] Measurements of whole fibres in the sulphate pulps, except as otherwise noted.
[c] At 350 millilitres freeness (Canadian Standard).
[d] Ream of 500 sheets, 25 by 40 inches.
[e] The mixture of wood contained by weight 40 per cent jobo, 30 per cent caracoli, 15 per cent gambombo, and 15 per cent ceiba bruja.
[f] Calculated average density weighted by the volume of each wood present.
[g] Average of eighteen pulpwoods ranging from 22 to 41 pounds per cubic foot.
[h] Average of means for nine hardwoods, ranging in mean fibre length from 0.74 to 1.82 millimetres.
[i] Average of comparable data for paper birch, sugar maple, American beech, red alder, sweetgum, and aspen.

Table 2

AVERAGE FIBRE LENGTH, SPECIFIC GRAVITY, AND YIELD OF BLEACHABLE SULPHATE PULP FOR CERTAIN YUCATAN HARDWOODS

Common name	*Botanical name*	*Average fibre length*[a] *Mn*	*Specific gravity*[b]	*Yield sulphate pulp*[c] *per cent*
	WOODS PULPED INDIVIDUALLY AND IN MIXTURES A AND B			
Ramon*	Borsimum alicastrum	0.98	0.747	45
Citinche (Kitanche)	Poincianella guameri	1.09	0.860	44
Jobo* (Jujub)	Spondias mombin	0.92	0.308	46
Ekulu*	Drypetes lateriflora	1.52	0.768	38
Alamo (Zacamua)	Ficus lapathifolia	1.24	0.398	41
Ceiba bruja*	Ceiba pentandra	1.67	0.279	40
Beeb* (Tatsi)	Pisonia aculeata	0.93	0.478	48
Chacabe* (Chaca)	Bursera simaruba	0.89	0.350	47
Koochle* (Kochle)	Cecropia obtusifolia	1.27	0.245	48
Chachi (Cacni)	Calyptranthes millspaughii	1.22	0.657	43
Pixoy*	Guazuma tomentosa	1.18	0.451	44
Palo de caja (Kanchunup)	Allophylus psilospermus	0.69	0.716	38
Ulva (Boo)	Coccoloba uvifera	1.01	0.712	39
Huano	Sabal japa	1.48	0.501	39
MIXTURE A[d]		...	0.456	41
MIXTURE B[e]		...	0.292	44
	WOODS PULPED IN MIXTURE C			
Yaxnic	Vitex guameri	...	0.667	..
Sabacche	Exostema mexicanum	...	0.646	..
Checnem	Metopium brownei	...	0.500	..
Jaboncello (Huaya)	Sapindus saponaria	...	0.706	..
Tzitzilche	Gymnopodium antigonides	...	0.662	..
Ciceh (Chike)	Chrysophyllum mexicanum	...	0.770	..
Elemuy	Malmea depressa	...	0.710	..
Tamay	Zuelania roussoviae	...	0.551	..
Balche	Spondias mombin	...	0.652	..
Taztab	Guettarola combsii	...	0.575	..
Caracolillo	Mastichodendron guarmeri	...	0.682	..
Kulinche	Astronium gravelene	...	0.727	..
Kilim	Spondias mombin	...	0.390	..
Zapotillo	Bumelia persimilis	...	0.816	..
Bec (Roble)	Ehretia tinifolia	...	0.614	..
Katalox	Swartzia cubensis	...	0.716	..
MIXTURE C[d]		...	0.630	43
	WOODS PULPED IN MIXTURE D			
Kazcat	Luehea candida	...	0.540	..
Habin (Jabin)	Piscidia grandifolia	...	0.635	..
Chululdzu	Exothea diphylla	...	0.634	..
Zacitsa (Cohiu)	Neomillspaughia emarginata	...	0.667	..
Chobenche	Trichilia sp.	...	0.480	..
Soc-yab	Gliricida sepium	...	0.833	..
Mora	Chlorophora tinctoria	...	0.754	..
Yuy	Casimiroa edulis	...	0.557	..
Pich	Enterolobium cyclocarpum	...	0.377	..
Xuul	Lonchocarpus sp.	...	0.744	..
Pasa-ak (Xpasak)	Simaruba glauca	...	0.374	..
Guayabillo	Eugenia petenensis	...	0.758	..
Pom	Protium copal	...	0.449	..
Kax	Randia armata	...	0.762	..
Sacboo	Hemiangium excelsum	...	0.535	..
Kiimche	Casearia dolichopylla	...	0.631	..
Pox	Annona purpurea	...	0.488	..
Chauche	Laetia thamnia	...	0.771	..
Zilil	Diospyros albens	...	0.662	..
Zihum (Zijum)	Crataeva tapia	...	0.408	..
Akitz	Thevetia guameri	...	0.606	..
Pálo de gas	Nectandra sanguiana	...	0.770	..
Majagua	Hibiscus tiliaceus	...	0.493	..
Kes	Godmania aesculifolia	...	0.413	..
Hyayancox	Exothea paniculata	...	0.607	..
Soc-chaca	Gilibertia arborea	...	0.423	..
Pata de xaca	Bauhinia spathacea	...	0.590	..
Chuyuchojum	Xylosma sp.	...	0.611	..
Catzin	Acacia guameri	...	0.671	..
Dzalam	Lysiloma bahamense	...	0.535	..
Granadillo	Platymiscium dimorphandrum	...	0.747	..
Huayate	Randia sp.	...	0.666	..
MIXTURE D[d]		...	0.629	44

[a] Measurements made on whole sulphate pulp fibers, see TAPPI *35* (5) 238–240 (May 1952) for details of the study.
[b] Moisture-free weight and green volume.The average specific gravity of the mixtures is weighted by the volume of each species present.
[c] Moisture-free basis.
[d] Equal parts by weight (moisture-free basis) of all species in the group.
[e] Equal parts by weight (moisture-free basis) of above species indicated by asterisk (*).

Table 3

STRENGTH PROPERTIES OF UNBLEACHED SULPHATE PULP[a]—MADE FROM CERTAIN INDIVIDUAL AND MIXTURES OF YUCATAN WOODS

Species or mixture[b]	Condition	Bursting strength, Freeness[c] 450 millilitres (pts. per lb. per rm.)[d]	Bursting strength, Freeness[c] 250 millilitres (lbs. per lb. per rm.)[d]	Tearing resistance, Freeness[c] 450 millilitres (gm. per lb. per rm.)[d]	Tearing resistance, Freeness[c] 250 millilitres (gm. per lb. per rm.)[d]	Folding endurance, Freeness[c] 450 millilitres (double folds)	Folding endurance, Freeness[c] 250 millilitres (double folds)	Tensile strength (breaking len...), Freeness[c] 450 millilitres (m).	Tensile strength (breaking len...), Freeness[c] 250 millilitres (m.)
Species									
Ramon	Peeled	0.54	0.95	1.31	1.03	13	215	5,450	7,500
	Unpeeled	0.50	0.81	1.34	1.07	20	240	5,100	7,100
Kochle	Peeled	0.72	0.90	1.30	0.80	330	876	8,000	8,850
	Unpeeled	0.68	0.79	1.13	0.86	70	275	6,850	8,300
Huano	Peeled	0.79	0.97	1.71	1.51	170	450	7,500	8,700
Mixture									
A	Peeled	0.47	0.58	0.97	0.88	9	37	4,950	5,900
	Unpeeled	0.40	0.57	0.97	0.83	5	32	4,600	6,200
B	Peeled	0.48	0.69	1.35	1.07	25	120	5,600	6,500
C	Peeled	0.48	0.69	1.30	1.07	15	90	5,100	6,300
	Unpeeled	0.37	0.58	1.03	1.02	8	44	4,500	5,750
D	Peeled	0.47	0.70	1.07	1.00	17	130	5,500	7,200
	Unpeeled	0.44	0.68	1.02	1.01	14	70	5,250	6,500

[a] Bleachable grade.
[b] See table 2 for yield of pulp, species included in mixtures, and other data.
[c] Canadian Standard.
[d] Ream of 500 sheets, 25 by 40 inches.

Table 4

SPECIFIC GRAVITY OF CERTAIN NICARAGUAN WOODS USED FOR SULPHATE PULPING TESTS

Common name	Botanical name	Specific gravity[a]
PULPED IN MIXTURE A		
Sangre drago	Pterocarpus vernalis	0.377
	Laetia procera	0.600
Average for mixture A[b]		0.463
PULPED IN MIXTURE B		
Aceituno	Simaruba glauca	0.350
Mangalarga colorado (Palo de agua)	Vochysia hondurensis	0.329
Mangalarga blanco	Xylopia frutescens	0.489
Anona (Lancewood)	Rollinia jimenzii[c]	0.354
Gausimo colorado	Luehea speciosa	0.462
Cebo	Dialyanthera otoba	0.363
Ceiba	Ceiba pentandra	0.373
Guarumo	Cecropia sp.	0.392
Jobo	Spondias mombin	0.421
Majagua	Belotia campbellii	0.195
Algodon	Croton glabellus[c]	0.416
Average for mixture B[b]		0.356
PULPED IN MIXTURE C		
Guasimo blanco	Geothalsia meiantha	0.368
Cedro macho	Carapa guianensis	0.495
Guavo colorado	Inga sp.	0.494
Guavo blanco	Inga sp.	0.549
Gavilan	Schizolobium parahybum	0.300
Tabacan	Cespedezia macrophylla	0.590
Lagarto (prickly yellow)	Zanthoxylum kellermanii[c]	0.483
Laurel blanco (Muneco)	Cordia allidora	0.388
Paraiso	Brosium utile	0.277
Mancita colorado	Byrsonima crassifolia	0.556
Gangreo (Yalic)	Gilbertia arborea	0.410
Kerosene	Tetragastris panamensis	0.660
Guayabon	Terminalia amazonia	0.600
Alcamphor	Protium copal[c]	0.443
Chilamate	Ficus sp.	0.361
Average for mixture C[b]		0.437
Average for mixture D[b] [d]		0.399

[a] Moisture-free weight and green volume.
[b] Mixture consisted of equal parts by weight (moisture-free basis) of each wood; calculated average specific gravity weighted by the volume of each wood present.
[c] Likely the correct species but positive identification of the sample was not possible.
[d] Mixture D consisted of all the woods in mixtures B and C.

Table 5

SULPHATE PULPING TESTS OF MIXTURES OF CERTAIN NICARAGUAN WOODS

Characteristics of pulps		*Mixture*[a]			
		A	*B*	C[b]	*D*
Yield (unbleached pulp) (per cent)		47	48	45	48
Permanganate number		11.5	13.6	13.0	14.0
Pulp strength[c]					
Bursting:	unbleached (pts. per lb. per rm.)	1.00	1.15	1.10	1.23
	bleached (pts. per lb. per rm.)	...	...	1.05	...
Tearing:	unbleached (gm. per lb. per rm.)	1.70	1.29	1.40	1.42
	bleached (gm. per lb. per rm.)	...	...	1.13	...
Folding:	unbleached (double folds)	550	610	720	1,125
	bleached (double folds)	...	...	500	...
Tensile:	(breaking length)				
	unbleached (m.)	7,900	8,900	8,600	9,450
	bleached (m.)	...	...	7,950	...

[a] See table 4 for composition of the mixture.
[b] Pulp from mixture C was bleached in four stages; ½ of 1 per cent of sodium peroxide (based on pulp) was added to the sodium hydroxide in the alkaline extraction stage. The total chlorine used was about 5 per cent. The brightness of the bleached pulp was about 84 per cent.
[c] Average of strengths at 450 and 250 millilitres Canadian Standard freeness. Ream of 500 sheets, 25 by 40 inches.

THE TECHNIQUE OF PULPING MIXTURES OF TROPICAL WOODS[1]

RÉGIE INDUSTRIELLE DE LA CELLULOSE COLONIAL DU MINISTÈRE DE LA FRANCE D'OUTRE-MER

Formerly the use of tropical woods for pulp production was viewed with scepticism. The species considered suitable for paper-making represented only a small percentage of the standing timber in the highly heterogeneous tropical forest. Extraction for pulping thus posed problems similar to those involved in the extraction of noble timber. In other words, pulpwood costs would come close to the cost of lumber, ruling out tropical pulpwood exploitation as uneconomic.

Only by accepting the heterogeneity of these forests, and pulping mixtures of tropical woods, can economic exploitation become possible. Many recent studies have shown that tropical mixtures can be successfully pulped. Moreover, they have shown that pulping in mixtures is not merely an economic necessity, imposed by the conditions of extraction; it is a technical necessity, stemming from the fibre characteristics.

Because of climatic conditions, there is no distinction—as in resinous woods—between spring and autumn fibres. The thin-walled spring fibres of conifers give a paper its tensile and bursting strength, while the thick-walled small-diameter autumn fibres endow it with tearing strength. A single tropical species cannot possess all these characteristics at the same time, being composed of more homogeneous fibres. If a paper is to fulfil the requirements of its various uses, several species have to be mixed. With tropical woods, to achieve the required heterogeneity of fibre, it is necessary to mix species before pulping.

That paper can be successfully made from tropical mixtures has been amply confirmed by laboratory research, followed up by industrial tests carried out in several French mills and in a pilot mill which has been installed at Bimbresso on the Ivory Coast.

[1] A shortened version of the original paper (ST/ECLA/CONF.3/L.3.9), which contains the results of the various laboratory tests referred to herein.

One of the fears was that, since different species have different lignin and other extractive contents, they would require different amounts of chemicals; thus simultaneous cooking gave rise to the danger that some species would be overcooked while others would remain in an uncooked state. In practice, however, each species in a mixed cook consumes only the amount of chemicals necessary for dissolving its incrustants; moreover, the quantity of alkali consumed is smaller than would be required if each species were cooked separately. This was established in a series of controlled laboratory tests, and further tests confirmed that the paper-making characteristics of the mixture were superior to those of pulps from the separate component species.

The supply on an industrial scale to a tropical mill of a wood mixture of constant composition from the paper-making standpoint raises certain problems. To achieve the desired "homogenized heterogeneity", there must be selection at some point, either at the time of felling or at the woodyard, and there must be provision for separate storage. If the species are stacked separately in the woodyard, then either control must be exercised at admission to the chipper house, or the species must be chipped and stored separately, control being exercised by combining the chipped woods before digestion. Clearly, having regard to the large number of species contained in the forest, these procedures involve expensive labour requirements, storage installations and supervision.

Fortunately, however, the tropical forest is less heterogeneous from a paper-making standpoint than it is botanically. Sorting can therefore be carried out in groups, e.g.:

(*a*) Species whose strength characteristics are all satisfactory;

(*b*) Species giving satisfactory results for tensile and bursting strengths, but with average or mediocre tearing strength;

(*c*) Species with satisfactory tearing strength, but with inadequate tensile and bursting strengths;

(*d*) Those few species all of whose characteristics are unsatisfactory. These will generally be species with fibre lengths below 900 microns, suitable only for fuel-wood.

In other words, sorting may be carried out at the time of felling into a limited number of groups determined by the paper-making characteristics of the species. Mixing would take place at the exit from the silos and it would be possible to ensure that the digesters are supplied with a mixture which, though it varies botanically, remains constant from the point of view of paper-making characteristics.

If no sorting whatever is carried out, if an attempt is made to rely on the heterogeneity of the forest to ensure a suitable mixture at the mill, then difficulties will be encountered, since the composition of the forest, though everywhere mixed, varies considerably from sector to sector. Only a thorough knowledge of the varying composition, and a judicious selection of felling sites based on that knowledge, can avoid complications.

Various tests have been carried out to determine the limits of variations admissible in the composition treated in the mill if serious modifications in the paper-making results are to be avoided. These tests have to some extent been verified industrially. On the whole it can be said that the possibility of using broadleaved tropical species in the paper industry can now be viewed optimistically and that, though no universal solution can be adopted, certain principles can be regarded as established.

1. The utilization by the paper industry of the tropical forest in its present state can be considered only if the various species are pulped in mixtures.

2. For both sylvicultural and paper-making reasons, the regeneration of the forest, after its first exploitation, should tend towards "controlled heterogeneity".

3. The pulping of mixed species offers undeniable advantages over cooks of individual species, which could be justified only in the case of certain pure stands containing species with favourable paper-making characteristics.

4. The supplying of a paper mill with a mixture having constant paper-making qualities can only be guaranteed by exact knowledge of the composition of the forest concerned and the geographical distribution of dominant species.

5. The composition of the mixture can contain important botanical differences without prejudicing the constancy of results, since numerous species have similar paper-making characteristics.

6. In the present state of knowledge of pulping technique, alkaline processes—especially the sulphate or the soda-sulphur process—with slight modifications according to the mixture, should preferably be employed in the production of pulp from broadleaved tropical species.

Only by the application of these basic principles can a tropical mill supply the paper industry with a raw material which, despite its highly varied origins, preserves its constant qualities.

PRELIMINARY RESULT ON THE PULPING OF SOME BRAZILIAN TROPICAL AND SUB-TROPICAL HARDWOODS[1]

L. Rys, A. Boenisch, W. Overbeck and A. Schwarz

Introduction

Brazil's limited plantations of eucalyptus, black wattle (*Acacia decurrens*), Paraná pine (*Araucaria angustifolia*) and certain other species will not, at the present time, support large scale pulp and paper production. For any considerable expansion, therefore, it is necessary to turn to the virgin forests. The exploitation of the tropical and sub-tropical hardwood forests for pulp presents a number of problems. The object of the experiments carried out at the Klabin mills was simply to provide some preliminary information concerning the pulpability of the species found in these forests. The conclusions cannot be regarded as final because, in the absence of reliable forest surveys, it cannot be said that the woods tested correspond to the average composition of the forest in the territories they were drawn from.

Two wood mixtures were examined: the first consisted of twenty-one different species from the Amazon region; these were sent by plane by the Government of Amapá and were thus available in relatively small quantities; the second consisted of thirty different species drawn from the virgin forests in Paraná.

Since the study was intended to throw light on practical pulping problems, no attempt was made to pulp the single species separately. It is not considered that it will be practicable to exercise selection, either in the forest or at the mill, in exploiting mixed tropical hardwood forests, save perhaps to eliminate rare species of high commercial value or exceptionally hard woods difficult to cut.

The sulphate process was selected for the experimental cooks; experience shows that it is more generally applicable and has advantages from the standpoint of fuel and chemicals consumption.

Limited as was the scope of the experiments conducted, the results may be regarded as encouraging.

Wood from the Amazon region

Each wood was subjected to microscopical examination and chemical analysis, and its specific weight and shrinkage determined.

Because only limited quantities were available, the mixture was cooked in a perforated basket, suspended

[1] A summary of the original paper (ST/ECLA/CONF.3/L.3.10), which includes fifty-six pages of tables, charts and photomicrographs setting out the characteristics of the woods tested and detailed results of the tests carried out. Eighteen of the tables are here included.

in the digester and surrounded by eucalypt chips from the mill's own six-year-old plantation. The Amazon mixtures consisted of equal parts of each species, relative occurrence in the forest being unknown. The eucalypt chips were from *E. saligna,* though some hybrids may have been present as well.

Three sulphate cooks were carried out: a long cook, with some overcooking, a normal soft cooking, and a still shorter cook. From the last, the three Amazon woods of highest density were excluded. This last may correspond to a normal mill-cook if reasonable bleachability is to be obtained for Amazon wood. A normal three-stage bleaching process was used (chlorination, alkali extraction, and hypo-after-bleaching).

These cooking and bleaching tests indicated that the mixture (containing woods with specific gravities varying from 0.25 to 1.2) cooks fairly well, though not so well as eucalypt alone. Yield is about the same, it can be bleached to a good colour and has good mechanical strength. No doubt these results could be further improved by better adaptation of cooking and bleaching conditions. The inclusion of very high-density woods seems to have no detrimental effect.

Wood from the Paraná region

There are several hundred different species in the Paraná hardwood forests and their distribution is by no means uniform from sector to sector. This makes it impossible to select a sample which can be regarded as representative from the standpoint of exploitation. To make the test of some practical value, therefore, all trees were felled over an area of 1,250 m² in what was considered the worst part of the forest, consisting of trees which would normally be considered only as fuelwood. It was considered that if these gave acceptable results, no difficulties would be encountered with mixtures from other and better parts of the forest.

Thirty species were found, and these were examined microscopically, analysed chemically, and specific weights and shrinkage determined as before.

Six sulphate cooks were carried out. The first, a long cook, gave a relatively low yield, to be explained by the presence of high extractives of Cambuí wood *(Eugenia vellosiana).* From the next cook, carried out under exactly similar conditions, Cambuí wood was omitted; higher yield and better mechanical strength and colour for the unbleached pulp resulted. For the next cook, using weaker liquor and a higher temperature, the Cambuí wood was cooked simultaneously, but separated in a perforated basket. For the mixture strength was maintained and yield improved; the Cambuí wood, on the other hand, had low strength and a very low yield.

From each of the next three cooks were omitted four species of high-priced sawmill wood and five species of white wood which can be used for other purposes. In all these cooks the influence of Cambuí wood was more marked, since the sample now consisted of over 50 per cent by weight of that species.

Bleaching tests were then carried out on five of the cooks.

From these tests it may be concluded that, in sulphate pulping, the differences between Amazon wood and Paraná wood, of deliberately chosen inferior quality, are by no means great. If woods of high extractive content were eliminated from the Paraná mixture, yield, pulp quality and chemical consumption would all improve.

Even really hard woods, of specific gravity over 1.0, can be successfully cooked in a mixture by the sulphate process. The resulting pulps can be bleached to a good colour, and the mechanical strength of the pulp, bleached and unbleached, is satisfactory for paper making.

These results suggest that the majority of deciduous woods, growing anywhere in Brazil, can be cooked as a mixture by the sulphate process and give a pulp of quality equal or superior to that of eucalyptus.

Supplementary information

The tropical or sub-tropical woods may be divided—according to their sulphate pulping qualities when cooked singly—into three main groups:

The first group gives at 50 SR.	Breaking length	Over 8,000 m
	Fold	Over 700
	Mullen	Over 6 kg/cm²
The second group gives at 50 SR.	Breaking length	6,000 to 8,000 m
	Fold	300 to 700
	Mullen	4 to 6 kg/cm²
The third group gives at 50 SR.	Breaking length	Under 6,000 m
	Fold	Under 300
	Mullen	Under 4 kg/cm²

Tables 14 and 15 give details of the sulphate cooking of two very different Amazon woods. Imbaúba (No. 9, table 1) has a specific weight of 0.28 and thin-walled fibres 1.1 mm in length; Caripe (No. 12, table 1) has a specific weight of 1.1 (the heaviest wood examined) and thick-walled fibres 1.5 mm in length. The Imbaúba sulphate pulp proved very strong for short-fibred wood. Caripe, in spite of its high density, was pulped without difficulty, though the pulp was not strong. Certain high-density woods, however (e.g., Cambuí—No. 3, table 7) do give trouble when pulped alone; if possible, woods of this type should be eliminated from commercial pulping. Imbaúba and Caripe fall respectively into the first and third groups enumerated above. Table 16 sets out the strength properties of some thirteen single species of Paraná woods, which may be considered as falling into the first group, while tables 17 and 18, respectively, show the strength properties for single species in groups 2 and 3.

Clearly there can be no sharp division between the three groups enumerated. But a thorough knowledge of the pulping qualities of single species is clearly of value in considering problems of commercial cooking, and hence questions of selection and planting.

Table 1

AMAZON WOODS: SPECIES TESTED

No.[a]	Common name	Species	Family	Diameter in mm with bark	Diameter in mm without bark	Percentage volume of bark
1	Louro (Itauba)	Misolaurus	Lauraceae	[b]		
2	Caqueira (Envira)	Xilopia	Anonaceae	[b]		
3	Imbaúba de mata	Pourouma	Maraceae	80	76	9.8
4	Breu	Protium sp.	Burseraceae	110	104	10.6
5	Macucu	Licania	Rosaceae	85	79	13.6
6	Envira	Laertia	Flacourtiaceae	80	73	16.7
7	Amapá	[c]	Moraceae	100	82	32.7
8	Matá-matá	Eschweilera	Lecythidaceae	110	98	20.6
9	Imbaúba	Cecropia	Moraceae	55	53	7.2
10	Tamanqueira (Morototo)	Didymopanax morototoni	Araliaceae	55	52	10.6
11	Abiurana	Eclinusia	Sapotaceae	70	65	13.7
12	Caripe	Licania sp.	Rosaceae	90	86	8.7
13	Jarana	Eschweilera	Lecythidaceae	70	62	21.5
14	Arari	Siparuma	Monimialeae	65	57	23.0
15	Guajará	Chrysophyllum	Sapotaceae	115	107	13.4
16	Tanari	Couepia	Rosaceae	80	68	27.7
17	Pará-pará (Carauba)	Jacaranda copaia	Bignoniaceae	85	77	17.9
18	Breu branco	Protium sp.	Burseraceae	80	76	9.7
19	Ucuba	Virola surinamensis	Myristicaceae	110	186	38.8
20	Cajurana	Trichylia	Meliaceae	110	102	14.1
21	Jara	Lucuma (Poteria)	Sapotaceae	130	126	6.1

[a] Key to tables 2 and 3.
[b] Wood received without bark.
[c] Not identified.

Table 2

AMAZON WOODS: SPECIFIC WEIGHT AND CHEMICAL ANALYSIS

(*percentages*)

No.	Quantity received (kg)	True specific weight of bone dry wood	Ash	Extractives: Ether	Extractives: Alcohol	Extractives: Total	Furfurol (barbituric acid)	Pentosans	Lignin[a] with ash	Lignin[a] ash free	Methoxyl
1	3.7	0.6683	1.17	2.82	1.41	4.23	8.81	12.85	33.57	32.95	7.03
2	3.4	0.8316	0.85	0.83	2.19	3.02	7.62	11.76	31.67	31.41	6.54
3	2.0	0.3427	0.45	0.65	0.50	1.15	7.62	11.61	23.13	23.09	6.02
4	12.9	0.5683	1.43	0.35	1.28	1.63	9.23	14.20	23.75	22.97	7.20
5	10.0	0.8633	1.27	0.23	1.88	2.11	7.64	12.09	32.66	30.89	6.48
6	8.2	0.6333	0.93	0.70	1.59	2.29	10.10	14.65	28.05	27.87	6.73
7	5.5	0.5762	0.45	0.24	2.16	2.40	7.37	11.00	31.55	31.47	6.46
8	8.1	0.9805	0.91	0.43	5.00	5.43	9.30	13.69	33.24	32.98	6.76
9	4.0	0.2828	1.40	0.44	1.31	1.75	7.26	12.30	24.55	23.08	6.08
10	3.6	0.2575	0.99	0.45	2.13	2.58	12.33	17.32	22.79	22.22	6.38
11	8.6	1.0360	1.65	0.92	1.50	2.42	7.16	11.77	26.95	26.12	6.19
12	12.3	1.1040	0.68	0.07	0.35	0.42	8.19	13.61	27.43	26.29	5.39
13	4.7	0.8368	0.83	0.18	1.07	1.25	9.43	14.61	30.12	29.99	6.95
14	6.0	0.7007	0.93	0.21	3.65	3.86	8.91	13.29	31.57	31.24	6.75
15	8.9	0.7648	0.77	0.32	1.84	2.16	8.72	13.07	29.77	28.93	7.23
16	3.1	0.6427	0.42	0.24	1.65	1.89	5.03	7.49	33.98	33.51	6.46
17	6.4	0.4077	0.62	0.16	0.53	0.69	4.98	7.88	31.85	31.68	6.77
18	4.0	0.4683	2.15	0.37	1.23	1.60	9.37	13.88	27.14	25.80	6.62
19	6.5	0.5417	0.67	0.09	1.21	1.30	10.06	14.97	29.25	29.06	6.43
20	4.3	0.4951	0.82	0.33	1.43	1.76	11.47	16.80	25.35	25.26	5.95
21	2.9	0.8467	1.36	0.13	1.88	2.01	8.46	12.80	28.79	27.78	6.38

[a] Lignin determination before removing extractives.

Table 3

AMAZON WOODS: MEASUREMENT OF FIBRES

No.	Average fibre length: measured [a]	Average fibre length: calculated [b]	Average diameter (middle of fibres)	Average area: parenchym	Average area: vessels
1	1.736	1.827	0.030	0.11 x 0.050	0.80 x 0.25
2	1.069	1.108	0.020	0.10 x 0.025	0.60 x 0.20
3	1.144	1.180	0.040	0.07 x 0.025	0.65 x 0.22
4	0.890	0.914	0.028	0.05 x 0.020	0.32 x 0.13
5	1.387	1.429	0.030	0.05 x 0.035	1.10 x 0.35
6	1.792	1.859	0.037	0.05 x 0.040	0.60 x 0.20 1.30 x 0.15
7	1.397	1.441	0.025	0.15 x 0.040	0.40 x 0.20
8	1.492	1.549	0.016	0.08 x 0.030	0.55 x 0.18
9	1.114	1.155	0.050	0.07 x 0.030	0.45 x 0.32
10	0.914	0.942	0.040	0.15 x 0.030	0.70 x 0.17
11	1.433	1.474	0.025	0.08 x 0.025	0.90 x 0.18
12	1.467	1.494	0.030	0.05 x 0.025	0.90 x 0.28
13	1.487	1.526	0.018	0.10 x 0.025	0.35 x 0.30
14	1.023	1.042	0.020	0.11 x 0.025	0.60 x 0.18
15	1.092	1.131	0.015	0.06 x 0.015	0.40 x 0.10
16	1.915	1.986	0.028	0.10 x 0.040	0.80 x 0.30
17	1.108	1.158	0.035	0.12 x 0.040	0.50 x 0.28
18	0.885	0.911	0.024	0.07 x 0.030	0.30 x 0.15
19	1.422	1.452	0.022	0.05 x 0.040	1.00 x 0.22
20	0.796	0.826	0.015	0.08 x 0.020	0.40 x 0.15
21	1.468	1.513	0.020	0.10 x 0.030	0.50 x 0.15
22	0.957	0.995	0.015	0.05 x 0.020	0.25 x 0.25
23	6.333	7.036	0.075	1.10 x 0.020	[illegible]

[a] Total length of all fibres / Number of fibres

[b] Calculated according to formula given in *Handbuch der Mikroskopie in der Technik*, Band V, page 547, by Dr. Hugo Freund.

Table 4

COOKING DATA AND UNBLEACHED STRENGTH OF AMAZON AND EUCALYPT WOOD

	Wood used: Eucalypt, in digester	Amazon wood, in Perforated basket	Eucalypt, in digester	Amazon wood, in perforated basket	Eucalypt, in digester	Amazon wood, in perforated basket [c]
No. of cook	384 [b]	384 G	385 [b]	385 G	386 [b]	386 G
Chips						
Wet, kg	50.00	1.837	52.0	0.9072	50.0	1.800
Dry, kg	31.00	1.497	33.44	0.7575	31.58	1.506
Bone dry %	62.0	81.5	64.30	83.5	63.16	83.7
Cooking liquor						
Litres per 1 kg dry wood	4.67		4.32		4.8	
NaOH kg	5.35		5.62		5.44	
Na_2S kg	1.74		1.83		1.77	
Na_2O total kg	5.52		5.81		5.62	
Na_2O on b.d. wood %	17.0		17.00		17.0	
Na_2O as NaOH kg	4.14		4.36		4.22	
Na_2O as Na_2S kg	1.38		1.45		1.41	
Sulphidity % [a]	25		25		25	
Cooking time						
Until max. temperature	1.30		1.30		1.30	
At max. temperature	4		2		1.0	
Total hours	5.30		3.30		2.30	
Max. pressure kg/cm²	8.5		8.5		7.2	
Max. temperature °C	170		170		165	
Na_2S g/1. in black liquor	2.22		4.78		5.73	
Yield						
Total %	49.23	50.57	49.5	49.53	52.56	54.75
Screened %	49.23	50.57	49.5	49.05	52.50	53.77
% Screenings	0	0	0	1.0	0.11	1.8
Roe No	3.2	3.68	2.8	3.84	3.68	6.72
Colour (G.E.)	31	26	35.5	25.5	38.0	31.0
Strength 55° S.R.						
S.R. initial	15	15	16	15	16	15
Time minute	25	25	22	22	23	21
Tensile—m	9142	8131	9229	8775	8753	9654
Mullen kg/cm²	5.03	4.18	5.13	4.78	5.01	5.24
Stretch %	4.0	3.7	3.75	3.70	4.0	4.0
Fold	341	206	443	424	707	601
Elmendorf, gr	104.0	111.2	103.8	99	112	101

[a] Na_2S calculated as Na_2O in % of total Na_2O.

[b] Steamed before cooking.

[c] Eighteen species used only, the hardest (Nos. 8, 11 and 12) being eliminated.

Table 5

BLEACHING DATA AND BLEACHED PULP STRENGTH OF AMAZON AND EUCALYPT WOOD

	Wood used			
	Eucalypt, in digester	*Amazon wood in perforated basket*	*Eucalypt, in digester*	*Amazon wood in perforated basket*[a]
	Cook No.			
	384	*384 G*	*386*	*386 G*
	Roe No.			
	3.2	*3.68*	*3.68*	*6.72*
Chlorination stage				
Chlorine used, %	1.81	2.66	2.88	6.24
Consistency, %	2.0	2.0	2.0	2.0
Temperature, °C	20	20	20	20
Time, minutes	50	40	60	50
Alkali extraction				
NaOH used, %	2.0	2.0	2.0	2.0
Consistency, %	4.0	4.0	4.0	4.0
Temperature, °C	40	40	40	40
Time, hours	2	2	2	2
Hypochlorite stage ($CaOCl_2$)				
Chlorine used, %	1.6	1.47	0.9	1.96
NaOH, %	1.0	1.0	1.0	1.0
Consistency, %	4.0	4.0	4.0	4.0
Temperature, °C	40	40	40	40
Time, hours	8	8	8	8
Chlorine distribution				
Chlorination, %	53.0	64.3	76.2	76.0
Hypochlorite, %	47.0	35.7	23.8	24.0
Chlorine used, total %	3.41	4.13	3.78	8.20
NaOH total %	3.0	3.0	3.0	3.0
Yield bleached				
Calculated on unbleached, %	95.1	94.5	94.6	90.9
Calculated on bone-dry wood	46.9	47.8	49.7	48.4
Colour (G.E.)	79	79	82	82
Strength at 55° S.R.				
S.R. initial	15	14	16	15
Time, minutes	35	24	34	27
Tensile, metres	8074	8196	9903	9959
Mullen, kg/cm²	5.17	4.56	5.78	5.45
Stretch, %	3.75	3.25	4.8	4.2
Fold	399	531	580	504
Elmendorf, gr	99	106	106	99.1

[a] Only eighteen species used.

Table 6

AMAZON WOODS: DATA AND RESULTS OF SULPHITE COOKING

Cooking acid:	4.96% total SO_2	
	1.09% combined SO_2 0.95% CaO	
Cooking time:	Up to 105°	35 minutes
	At 105°	120 minutes
Up to temperature	135°	30 minutes
	At 135°	445 minutes
	Total cooking time	630 min. = 10.5 hours
Yield 52.2%		
Roe No. 8.6		
Colour 36 G.E.		
	S.R.°	55
	Tensile	7098
	Fold	151
	Stretch, per cent	3.664
	Elmendorf, gr.	65.9
Bleaching:	8% chlorine for chlorination	
	1.85% chlorine as Ca—hypochlorite	
	2% NaOH alkali extraction	
	88.4% yield on unbleach pulp	
	Colour G.E. 85	
	S.R.°	55
	Tensile	7508
	Fold	254
	Stretch, per cent	3.969
	Elmendorf, gr.	65.9

Table 7

PARANÁ WOODS: DECIDUOUS SPECIES TESTED

(from an area of 1,250 m²

No.[a]	Common name	Species	Family	Woodyard measurement solid m³	Gross weight kg
1	Canela-preta	Laurus atra	Lauraceae	1.125	1106.2
2	Caviuna	Dalbergia nigra	Leguminosae	1.483	1741.4
3	Cambuí	Eugenia vellosiana	Myrtaceae	3.120	3120.0
4	Cravo-bravo	b	Cordiaceae	0.540	579.2
5	Peroba-rosa	Aspidosperma	Apocynaceae	0.715	499.1
6	Bico de pato	Machaerium	Leguminosae	0.977	1117.0
7	Vassourinha	Allophylus edulis	Sapindaceae	0.248	233.7
8	Capixingui	Croton floribundus	Euphorbiaceae	2.670	1997.9
9	Pitangueira	b	Myrtaceae	0.144	132.6
10	Branquilho	Sebastiana klotzschiana	Euphorbiaceae	0.307	276.8
11	Peroba d'agua	Sessia brasiliensis	Compositae	0.406	391.4
12	Araticum	Rollinia	Anonaceae	0.048	41.2
13	Leiteiro-duro	Peschiera catharinensis	Apocynaceae	0.284	267.0
14	Pau de largato	b	b	0.090	93.0
15	Guasatonga	Casearia inaequilatera	Flacourtiaceae	0.060	79.2
16	Canela-sebo	Siparuna	Monimiaceae	0.023	24.4
17	Açoita-cavalo	Luehea	Tiliaceae	0.124	122.2
18	Mandioqueiro	Didymopanax morototoni	Araliaceae	0.313	286.4
19	Limoeiro-bravo	Siparuna brasiliensis	Monimiaceae	0.133	86.5
20	Vassourão	Piptocarpha	Compositae	0.233	211.0
21	Guamerim	b	Melostomataceae	0.043	41.2
22	Capororoca	Rapanea ferruginea	Myrsinaceae	0.126	129.8
23	Figueira-brava	Ficus doliaria	Moraceae	0.170	138.6
24	Canafistula	Cassia ferruginea	Leguminosae	0.157	210.2
25	Sete-capotes	Britoa sellowiana	Myrtaceae	0.122	99.0
26	Imbira de sapo	Xylopia	Anonaceae	0.108	132.1
27	Cedro	Cedrela	Meliaceae	0.013	14.3
28	Angico	Piptadenia rigida	Leguminosae	0.121	124.4
29	Canga-branca	b	b	0.050	59.4
30	Vermelhinho	b	b	0.049	54.2
				14.002	13409.4

[a] Key to tables 8, 9 and 10.
[b] Not identified.

Table 8

PARANÁ WOOD: COMPOSITION OF SAMPLE FROM AN AREA OF 1,250 M²

No.	Weight of delivered wood: not[a] suitable	barking loss	net	Percentage of: not[a] suitable	barking loss	Percentage of humidity	Bone dry wood kg	Percentage of each species
1	105.0	87.1	914.1	9.4	8.7	49.81	458.79	7.820
2	80.4	192.7	1468.3	4.6	11.6	33.66	974.07	16.602
3	468.0	398.0	2254.0	15.0	15.0	31.49	1544.21	26.320
4	579.2	—	—	100.0	—	39.13	—	—
5	125.1	56.1	317.9	25.0	15.0	35.14	206.20	3.515
6	110.0	194.2	812.8	10.0	19.2	38.23	502.07	8.558
7	46.5	15.6	171.6	19.8	8.3	41.41	100.54	1.714
8	199.0	332.3	1466.6	10.0	18.4	38.61	900.20	15.343
9	32.6	10.4	89.6	24.5	10.4	29.62	63.06	1.075
10	133.6	12.3	130.9	48.2	8.5	33.80	86.66	1.477
11	60.4	31.6	299.4	15.4	9.5	52.43	142.42	2.428
12	—	7.4	33.8	—	18.0	41.80	19.67	0.335
13	15.2	21.7	230.1	5.7	8.6	32.51	155.29	2.647
14	28.0	6.8	58.2	30.1	10.4	41.78	33.88	0.577
15	38.6	4.2	36.4	48.7	10.3	35.28	23.56	0.402
16	—	5.6	18.8	—	22.9	49.36	9.52	0.162
17	—	28.4	93.8	—	23.2	43.88	52.64	0.897
18	—	76.6	209.8	—	26.7	51.96	100.79	1.718
19	—	8.8	77.7	—	10.2	46.14	41.85	0.713
20	—	19.0	192.0	—	9.0	64.68	67.80	1.156
21	—	7.0	34.2	—	16.9	41.06	20.16	0.344
22	35.6	13.4	80.8	27.4	14.2	41.35	47.39	0.808
23	—	21.9	116.7	—	15.8	55.81	51.57	0.879
24	30.6	19.1	160.5	14.5	10.6	42.11	92.91	1.584
25	99.0	—	—	100.0	—	44.00	—	—
26	—	16.1	116.0	—	12.6	57.10	42.90	0.731
27	—	4.5	9.8	—	31.3	36.69	5.08	0.086
28	—	22.8	101.6	—	18.3	48.19	64.32	1.096
29	—	7.4	52.0	—	12.4	39.18	31.63	0.539
30	—	8.2	46.0	—	15.2	39.52	27.82	0.344
	2186.8	1629.2	9593.4	16.3	14.5	38.85	5867.00	100.000

[a] Impossible to bark because of the shape, or strongly deteriorated.

Table 9

PARANÁ WOODS: SPECIFIC WEIGHT AND CHEMICAL ANALYSIS
(*percentages*)

No.	True specific weight of bone-dry wood	Ash	Extractives			Furfurol (barbituric acid)	Pentosans	Lignin[a]		Methoxyl
			Ether	Alcohol	Total			with ash	ash free	
1	0.5975	0.50	0.78	2.61	3.39	10.08	14.50	22.87	22.75	6.37
2	0.7013	1.68	0.29	1.86	2.15	11.05	16.54	25.41	25.26	7.46
3	0.9947	0.66	3.73	9.58	13.31	7.77	11.91	33.78	33.23	7.18
4	0.9349	1.24	4.08	11.22	15.30	8.42	12.09	41.22	40.84	6.59
5	0.9058	0.75	0.05	3.68	3.73	10.33	15.26	26.47	26.13	7.34
6	0.6813	0.54	2.54	1.75	4.29	10.34	14.79	28.40	28.10	8.44
7	0.7166	1.53	0.54	3.72	4.26	9.06	12.94	34.16	33.54	6.60
8	0.5027	0.93	0.30	2.27	2.57	10.71	16.02	26.07	25.87	6.94
9	0.7437	1.35	4.93	11.62	16.55	10.07	17.08	33.47	32.35	6.89
10	0.6894	0.70	0.75	2.69	3.44	7.30	11.07	34.36	34.21	6.71
11	0.4927	2.09	0.28	2.35	2.63	10.86	16.28	30.45	29.45	6.80
12	0.5278	2.07	0.18	1.49	1.67	9.96	14.07	23.34	22.98	6.25
13	0.7000	1.08	0.65	5.20	5.85	11.13	16.33	24.99	24.12	6.89
14	0.6075	1.02	0.13	1.75	1.88	9.53	13.00	25.61	25.44	7.46
15	0.8498	0.85	0.21	2.92	3.13	10.36	13.63	27.18	26.07	6.35
16	0.4432	0.62	0.22	1.36	1.58	10.81	16.08	25.51	24.40	7.13
17	0.6778	2.39	0.30	1.11	1.41	9.80	13.77	26.33	25.41	7.06
18	0.4499	0.75	0.35	1.78	2.13	11.19	16.49	26.84	26.70	6.72
19	0.3763	0.83	0.58	2.34	2.92	8.41	11.86	22.61	22.02	6.74
20	0.4093	0.69	0.01	0.29	0.30	11.26	16.41	24.17	23.76	6.53
21	0.8342	0.90	3.37	6.69	10.06	7.14	10.55	45.57	44.68	5.89
22	0.7091	0.47	1.45	3.44	4.89	12.06	17.89	28.43	28.31	6.78
23	0.4300	1.42	0.37	2.10	2.47	11.92	18.02	35.68	35.01	6.23
24	0.6478	1.63	0.88	5.23	6.11	10.65	15.31	31.08	31.14	6.35
25	0.6142	0.31	0.98	1.16	2.14	9.72	13.32	33.43	33.28	6.57
26	0.4341	0.51	0.41	0.71	1.12	11.45	15.66	28.56	28.40	6.95
27	0.4989	0.24	0.61	1.73	2.34	8.87	12.99	29.43	29.12	5.79
28	0.5270	0.74	0.73	2.80	3.53	12.64	18.80	28.02	27.85	6.52
29	0.7332	0.96	0.40	1.10	1.50	10.67	15.68	25.81	25.76	7.48
30	0.8520	1.26	0.48	6.45	6.93	9.68	13.78	35.05	34.91	7.07

[a] Lignin determination before removing extractives.

Table 10

PARANÁ WOOD: MEASUREMENT OF FIBRES
(*millimetres*)

No.	Average fibre length		Average diameter (middle of fibres)	Average area	
	measured[a]	calculated[b]		parenchym	vessels
1	1.048	1.108	0.025	0.12 x 0.030	0.50 x 0.12
2	0.569	0.615	0.015	0.10 x 0.015	0.18 x 0.13
3	0.953	1.018	0.015	0.05 x 0.020	0.30 x 0.05
4	0.741	0.786	0.020	0.07 x 0.020	0.40 x 0.12
5	1.358	1.439	0.020	0.10 x 0.020	0.50 x 0.07
6	0.996	1.048	0.015	0.15 x 0.015	0.40 x 0.15
7	0.975	1.030	0.025	0.05 x 0.040	0.50 x 0.10
8	0.966	1.003	0.040	0.13 x 0.030	0.70 x 0.22
9	0.583	0.613	0.012	0.05 x 0.020	0.45 x 0.07
10	1.050	1.111	0.022	0.07 x 0.020	0.40 x 0.05
11	1.297	1.352	0.035	0.10 x 0.040	0.75 x 0.10
12	0.836	0.888	0.040	0.15 x 0.025	0.20 x 0.20
13	0.817	0.839	0.025	0.05 x 0.030	0.60 x 0.08
14	1.549	1.627	0.025	0.07 x 0.030	0.40 x 0.15
15	1.190	1.246	0.020	0.08 x 0.015	1.00 x 0.08
16	0.725	0.762	0.025	0.13 x 0.030	0.55 x 0.12
17	1.255	1.340	0.030	0.04 x 0.030	0.80 x 0.08
18	1.049	1.101	0.040	0.12 x 0.030	1.00 x 0.20
19	1.429	1.521	0.060	0.15 x 0.040	1.20 x 0.25
20	1.235	1.278	0.040	0.07 x 0.030	1.10 x 0.12
21	0.979	1.048	0.018	0.05 x 0.025	0.40 x 0.25
22	0.684	0.717	0.025	0.08 x 0.035	0.50 x 0.05
23	0.961	1.014	0.025	0.10 x 0.020	0.35 x 0.25
24	0.667	0.680	0.018	0.15 x 0.020	0.25 x 0.15
25	0.641	0.692	0.015	0.07 x 0.030	0.55 x 0.05
26	1.095	1.146	0.020	0.22 x 0.040	0.20 x 0.12
27	0.820	0.880	0.030	0.12 x 0.040	0.25 x 0.20
28	0.782	0.827	0.018	0.12 x 0.025	0.35 x 0.15
29	1.296	1.352	0.025	0.08 x 0.028	0.60 x 0.22
30	1.213	1.318	0.020	0.07 x 0.030	0.70 x 0.05

[a] $\frac{\text{Total length of all fibres}}{\text{Number of fibres}}$

[b] Calculated according to formula given in *Handbuch der Mikroskopie in der Technik*, Band V, page 547, by Dr. Hugo Freund.

Table 11

SULPHATE COOKING OF PARANÁ WOOD

	Wood used						
	With Cambui	*All woods excluding Cambui*	*Excluding Cambui*	*Cambui in perforated basket*	*Without saw mill and some white wood*		
	Cook No.						
	378	*379*	*380*	*380 G*	*381*[b]	*382*[b]	*383*[b]
Chips							
Wet kg	50.0	50.0	38.5	1.953	50.1	52.0	50.30
Bone dry kg	30.55	30.9	24.37	1.357	33.35	34.03	35.36
Bone dry %	61.1	61.8	63.3	69.5	66.5	65.5	70.72
Cooking liquor							
Wood liquor ratio	4.45	4.69	4.66		3.74	4.08	4.26
NaOH kg	5.16	5.22	4.23		5.48	5.60	5.94
Na_2S kg	2.16	2.18	1.38		1.78	1.82	1.94
Na_2O total kg	5.71	5.78	4.37		5.67	5.78	6.15
Na_2O on wood weight	18.7	18.7	17.0		17.0	17.0	17.37
Na_2O as NaOH	4.00	4.04	3.28		4.25	4.34	4.61
Na_2O as Na_2S kg	1.71	1.73	1.09		1.42	1.45	1.54
Sulphidity[a]	30.0	30.0	25.0		25.0	25.0	25.0
Cooking time							
Till max. temp.	3	3	3		3	1	1
At max. temp.	4	4	4		4	4	4
Total hours	7	7	7		7	5	5
Max. pressure kg/cm²	5.8	5.9	7.3		7.4	7.0	8.8
Temp. max. °C	160	160	165		165	165	170
Waste liquor: Na_2O g/1	4.34	4.70	4.80		3.10	2.86	4.13
Yield							
Total, %	45.6	47.64	49.8	43.3	44.3	47.0	44.27
Screened, %	45.0	47.55	48.4	41.4	43.8	45.7	44.02
Screening, %	1.37	0.20	2.85	4.40	1.16	2.8	0.56
Roe No.	6.60	4.17	3.70	13.20	8.24	10.0	7.12
Colour G.E.	26	30	29	24	19.5	22.0	25
Strength at 55° S.R.	—	—	—	—	—	—	—
S.R. initial	13	13	13	13	14	16	15
Beating time min	32	26	22	36	25	21	24
Tensile m	8333	8642	8314	6083	7527	7283	8847
Mullen kg/cm²	4.74	4.46	4.54	3.20	4.20	4.20	4.52
Stretch, %	3.6	4.0	4.0	3.1	3.0	4.0	3.5
Fold	368	396	370	56	366	258	402
Elmendorf, gr	90.4	81.8	80.6	81.9	81.8	78.1	83.0

[a] % Na_2S calculated as Na_2O on Na_2O total.
[b] Steaming before cooking.

Table 12

BLEACHING DATA AND BLEACHED PULP STRENGTH OF PARANÁ WOOD

	Wood used: All species	Without Cambui	Without Cambui	Without saw mill and some white wood	
Cook No.	378	379	380	381	383
Roe No.	6.60	4.17	3.70	8.24	7.12
Chlorination					
Chlorine used, %	4.45	2.80	2.6	6.08	5.73
Density, %	2.0	2.0	2.0	2.0	2.0
Temperature, °C	20	20	20	20	20
Time, min	55	20	60	60	50
Alkali extraction					
NaOH used, %	2.0	2.0	2.0	2.0	2.0
Density, %	4.0	4.0	4.0	4.0	4.0
Temperature, °C	40	40	40	40	40
Time, h	2	2	2	2	2
Hypochlorite bleaching ($CaOCl_2$)					
Chlorine used, %	2.92	2.39	1.75	3.05	2.2
NaOH, %	1.0	1.0	1.0	1.0	1.0
Density, %	4.5	4.5	4.0	4.0	4.0
Temperature, °C	38	40	40	40	40
Time, h	8	6	8	9	8
Chlorine distribution					
Chlorination, %	60.4	54.0	59.8	66.5	73.6
Hypochlorite, %	39.6	46.0	40.2	33.5	26.4
Total chlorine consumption, %	7.37	5.19	4.35	9.13	7.93
NaOH total, %	3.0	3.0	3.0	3.0	3.0
Yield of bleached pulp					
On screened unbleached pulp, %	93.06	95.4	95.0	90.3	90.0
On dry wood, %	41.9	45.36	46.0	39.5	39.6
Colour (G.E.)	81	82	81.5	81	81
Strength at (55° S.R.)					
S.R. initial	13	13	13	14	15
Time, min	30	31	26	25	21
Tensile, m	8109	7756	7527	9013	8279
Mullen, kg/cm²	4.49	4.58	4.62	5.02	4.25
Stretch, %	3.6	3.5	3.5	3.8	3.5
Fold	401	251	266	230	190
Elmendorf, gr	80.3	80.6	81.1	70.4	69.0

Table 13

ANALYSES OF EUCALYPT WOOD FROM PARANÁ

(E. saligna *6 years old*)

Wood sample	I	II	1P	2P	6P	7P	Value: Max.	Value: Min.
Spec. weight, bone dry	0.62	0.68	0.49	0.72	0.61	0.43	0.43	0.72
Pentosan (Tappi), %	16.61	11.94	14.43	16.77	12.52	14.33	11.94	16.77
Furfurol (Barbituric acid)	—	—	9.68	10.38	8.56	9.44	—	—
Lignin (Tappi), %	27.72	26.81	26.30	24.77	28.17	28.92	24.77	28.92
Ether extract (Tappi), %	0.82	0.19	0.24	1.60	0.13	0.98	0.13	1.60
Alcohol extract (Tappi), %	2.02	1.52	0.62	4.82	1.47	1.59	0.62	4.82
Ash, %	0.64	0.73	0.68	0.61	0.71	0.85	0.61	0.85

Table 14

INFORMATIVE SULPHATE COOKING: IMBAÚBA

Na_2O / b.d. wood	= 17%	Cooking liquor	= 19.26 g Na_2O / Litre
Sulphidity	= 25%	Waste liquor	= 5.4 g Na_2O / Litre
Humidity	= 12.81%	% Alkali consumed	= 71.96%
Wood: liquor	= 1 : 8.82	Alkali consumption / b.d. wood	= 12.24%

Yield 60.28%
Screening 4.82%
Roe No. 5.68
Colour .... 39 GE

SR°	Beginning 14	25	35	45	55
Tensile m	8,959	9,085	9,754	11,160	
Fold	874	1066	1588	1978	
Mullen kg/cm²	5.115	5.775	6.250	6.418	
Elmendorf	92.6	75.5	66.0	70.4	
Beating time, minutes	12	16	20	23	

Total cooking time: 2 hours, 1 hour at 165°C max. temp.

Table 15

INFORMATIVE SULPHATE COOKING: CARIPE

Na_2O / b.d. wood	= 17%	Cooking liquor	= 66.43 g Na_2O / Litre
Sulphidity	= 25%	Waste liquor	= 20.63 g Na_2O / Litre
Humidity	= 19.45%	% Alkali consumed	= 68.94%
Wood: liquor	= 1 : 2.55	Alkali consumption / b.d. wood	= 11.74%

Yield 57.04%
Screening 0%
Roe No. 3.52
Colour .... 38 GE

SR°	Beginning 13	25	35	45	55
Tensile m	3,927	4,416	4,909	5,400	
Fold	13	29	66	128	
Mullen kg/cm²	1.980	2.568	2.833	3.000	
Elmendorf	107.6	112.2	118.7	96.8	
Beating time, minutes	22	28	32	36	

Total cooking time: 3.5 hours, 2.5 hours at 165°C max. temp.

Table 16

INFORMATIVE SULPHATE COOKING OF PARANÁ WOODS

(Group 1)

No.	Common name	% Yield			Tensile			Fold			Mullen			Elmendorf		
		Roe	Total	Screened	SR 25	SR 45	SR 55	SR 25	SR 45	SR 55	SR 25	SR 45	SR 55	SR 25	SR 45	SR 55
6	Bico de pato...........	3.7	51.24	49.14	5,688	9,617	10,285	60	966	1,286	3.17	6.50	7.39	124.5	102.2	97.7
8	Capixingui............	7.4	51.49	48.80	6,897	8,666	9,773	86	380	595	3.55	4.52	5.03	75.8	74.8	69.8
9	Pitangueira............	6.9	44.35	41.95	4,352	8,527	10,286	27	1,026	1,034	2.16	5.16	6.64	56.4	82.4	75.1
10	Branquilho............	16.7	53.01	36.76	6,339	7,816	9,119	113	643	827	4.41	5.73	6.27	83.4	77.0	72.7
10	Branquilho [b]...........	8.0	42.51	42.34	6,250	8,602	8,518	100	814	1,063	3.98	6.25	6.65	119.9	112.5	107.6
12	Araticum.............	12.0	46.09	45.85	8,676	11,586	10,222	318	901	941	5.14	6.69	7.42	88.2	88.8	72.0
14	Pau de largato.........	4.3	52.08	49.62	8,239	10,129	10,542	1,067	1,643	1,703	5.93	7.38	7.50	141.5	109.5	102.2
16	Canela-sebo...........	8.8	53.88	52.26	7,584	8,397	9,087	438	838	1,100	4.68	5.37	6.60	104.2	99.0	84.2
17	Açoita cavallo.........	9.3	51.46	47.25	10,016	11,595	11,145	1,410	1,534	2,077	7.18	7.78	8.05	127.6	103.7	113.4
19	Limoeiro-brava........	8.9	46.90	43.48	6,107	7,586	8,842	142	410	788	3.13	4.28	4.54	91.3	74.4	65.1
20	Vassourão............	9.8	55.94	52.17	6,970	8,417	8,205	323	682	931	3.52	4.51	4.95	80.6	83.6	76.7
23	Figueira-branca........	7.4	40.11	38.93	7,410	9,805	9,902	992	1,456	1,624	4.71	6.14	6.34	96.9	75.5	71.5
26	Imbira de sapo.........	8.8	54.27	49.21	7,324	9,470	9,943	325	557	1,069	4.65	5.90	6.76	105.0	81.5	102.5
27	Cedro................	15.6	56.78	51.94	7,168	9,638	10,271	358	1,160	1,238	4.66	6.05	6.62	85.6	78.5	67.3
27	Cedro [b]...............	12.1	49.91	48.64	8,173	9,686	10,159	506	1,326	1,690	4.25	6.05	6.18	106.6	94.3	98.3
		9.3	50.00	46.56	7,146	9,302	9,753	418	955	1,198	4.34	5.89	6.46	99.2	89.2	85.1

[a] All cooked in 10-litre rotary digester, electrically heated; Temperature: 165°C for 1 hour; Total cooking time: 2 hours, 17% Na_2O/ bone dry wood, 25% sulphidity.
[b] Total cooking time: 2.5 hours.

Table 17

INFORMATIVE SULPHATE COOKING OF PARANÁ WOODS

(Group 2)

No.	Common name	% Yield			Tensile			Fold			Mullen			Elmendorf		
		Roe	Total	Screened	SR 25	SR 45	SR 55	SR 25	SR 45	SR 55	SR 25	SR 45	SR 55	SR 25	SR 45	SR 55
4	Cravo-bravo...........	6.6	45.10	42.18	4,418	7,525	7,875	10	211	391	1.95	3.99	4.72	60.5	85.2	84.9
5	Peroba-rosa...........	6.4	47.00	43.66	5,271	7,197	7,481	129	469	472	2.91	4.60	4.83	142.2	130.6	110.4
13	Leitero-duro...........	5.6	54.59	51.67	5,142	6,309	6,620	36	285	320	2.47	3.60	4.00	77.3	81.4	77.7
18	Mandioqueiro..........	8.4	53.11	50.89	6,337	7,474	8,300	72	180	408	3.17	3.67	3.96	80.0	86.8	82.5
21	Guamarim.............	13.4	52.32	49.31	5,836	6,956	8,579	51	223	574	2.95	4.13	5.45	106.6	102.2	91.1
29	Canga-branca..........	8.0	54.53	53.14	6,981 [a]	7,693	8,765	212 [a]	360	473	4.52 [a]	4.84	5.31	116.3 [a]	106.6	95.7
30	Vermilhinho...........	6.7	42.19	41.50	5,452	6,976	7,366	48	196	468	3.17	4.50	4.71	112.2	111.1	120.0
		7.9	49.83	47.48	5,409	7,161	7,855	53	275	444	2.77	4.19	4.71	96.5	100.6	94.6

[a] SR = 35.

Table 18

INFORMATIVE SULPHATE COOKING OF PARANÁ WOODS

(Group 3)

No.	Common name	% Yield			Tensile			Fold			Mullen			Elmendorf		
		Roe	*Total*	*Screened*	*SR 25*	*SR 45*	*SR 55*	*SR 25*	*SR 45*	*SR 55*	*SR 25*	*SR 45*	*SR 55*	*SR 25*	*SR 45*	*SR 55*
1	Canela-preta	5.2	53.42	52.62	4,040	5,730	6,617	10	116	262	2.01	3.20	4.29	68.2	89.6	85.3
2	Caviuna	10.4	52.04	49.97	4,023	6,488	7,810	10	77	192	1.95	3.84	4.96	86.7	80.2	73.8
3	Cambuí [a]	15.1	43.33	42.03	2,507	3,716	4,003	2	9	13	0.75	1.78	2.06	33.9	50.7	54.0
3	Cambuí [b]	17.6	53.72	—	3,799	4,651	5,339	8	29	32	1.71	2.36	2.74	60.0	68.8	68.8
3	Cambuí [c]	17.9	44.82	—	2,986	4,033	5,016	4	17	20	1.35	2.17	2.53	40.6	52.0	70.5
7	Vassourinho	12.8	53.80	45.84	4,855	6,018	6,471	19	85	106	2.60	3.42	3.72	66.0	67.4	69.2
11	Peroba d'agua	16.4	55.6	53.69	4,612	5,867	6,095	21	73	133	2.50	3.14	3.30	65.7	62.2	56.4
15	Guatasunga	10.0	53.88	52.87	4,560	5,889	6,396	20	49	85	2.09	3.00	3.08	80.2	78.4	73.8
22	Capororoca	5.0	49.29	48.43	2,708	3,874	5,071	2	5	10	0.88	1.29	1.90	26.6	35.2	44.2
24	Canafistula	5.6	51.83	49.36	4,260	6,289	6,877	19	131	209	2.17	3.86	4.48	86.1	80.6	83.8
25	Sete-capota	11.4	43.20	32.09	3,768	5,016	5,380	5	33	45	1.54	2.61	2.64	42.5	45.5	47.2
		11.6	50.44		3,829	5,234	5,916	11	57	106	1.78	2.79	3.25	59.7	64.6	66.0

[a] 25 per cent Na_2O/wood.
[b] 17 per cent Na_2O/wood.
[c] 21 per cent Na_2O/wood.

THE PULPING OF PERUVIAN CETICO FOR THE MANUFACTURE OF NEWSPRINT[1]

BATINEYRET (BATIGNOLLES-CHATILLON & ATELIERS NEYRET BEYLIER)

INTRODUCTION

Studies and experiments on a dominant species of the Amazon forest—the cetico or *Cecropia*—were recently undertaken by the French enterprise, Batineyret, with a view to assessing its value to the pulp industry. The essential advantages of the cetico area: (1) it grows mostly in homogeneous stands. This makes for easy felling operations and avoids the difficulties inherent in dealing with mixed woods; (2) these stands are found mainly on river-banks, greatly facilitating exploitation and transportation; and (3) the cetico is one of the few tropical woods which can be ground suitably for mechanical pulp.

Experiments were carried out on the industrial manufacture of newsprint—a daily paper being printed on the paper obtained—while studies were made on the practical installation of a mill and its expectations of profit. The conclusions drawn were entirely favourable.

I. CETICO MECHANICAL PULP: PAPER PRODUCED FROM CETICO MECHANICAL PULP AND CONIFEROUS CHEMICAL PULP

About fifty tons of cetico wood, felled in July, 1951, were sent to France from Peru, and transported to a mechanical pulp mill in Savines.

1. *Manufacture of cetico mechanical pulp*

At Savines cetico mechanical pulp was obtained by using, without adaptation, the equipment of the mill which daily pulps spruce wood for the manufacture of newsprint for various French periodicals. Batches of the pulp obtained were tested at the laboratory of the Ecole française de papeterie and at the Domeynon paper mills.

2. *Manufacture of newsprint and trials of papers*

At the Domeynon paper mills, four sample papers were manufactured under industrial conditions: No. 1—ordinary newsprint (20 per cent unbleached sulphite, 80 per cent spruce mechanical), Nos. 2, 3 and 4 containing unbleached sulphite and cetico mechanical in proportions 30 : 70; 25 : 75; and 20 : 80, respectively. No difficulties were experienced in making Nos. 2 and 3, though for No. 3 the speed of the reeler-cutter had to be slightly reduced. No. 4 proved difficult, and breakages were frequent even when machine speed was reduced to 120 metres per minute.

Standard tests were then carried out on these four papers, along with three other newsprint, two of French manufacture, one of United States origin. The tests successfully demonstrated that newsprint can be manufactured under industrial conditions from cetico mechanical pulp with the addition of 25 to 30 per cent coniferous chemical pulp. Subsequent commercial runs by the Societe générale de'impression, Grenoble, in the printing of *Dauphiné libéré,* established that papers 2 and 3 behaved well and gave satisfactory printing results.

II. CETICO CHEMICAL PULP AND 100 PER CENT CETICO PAPER

1. *Manufacture of cetico chemical pulp*

Although good newsprint could thus be manufactured from cetico mechanical pulp at the ratio of 70 to 75 per cent to 30 to 25 per cent sulphite pulp, thus offering the possibility of a great saving in imports for Latin American countries, nevertheless a fair proportion of the raw material (the 25 to 30 per cent sulphite pulp) would still have to be imported.

It was thought worth while, therefore, to study cetico as a possible suitable raw material for the chemical pulp needed for newsprint. The manufacture of chemical pulp was undertaken by the sulphate process and its characteristics ascertained. These showed that the pulps obtained very closely resembled those of pulps from European conifers and were only very slightly inferior to spruce pulp. Moreover, yields were particularly satisfactory—in every case exceeding 50 per cent—whereas with European conifers yields were scarcely over 40 per cent.

2. *Manufacture of 100 per cent cetico paper*

One hundred per cent cetico paper was next manufactured on a laboratory scale. The resultant paper was found to be at least equal to ordinary newsprint; however, this conclusion must be accepted with some reservations, since laboratory treatment tends to preserve pulp characteristics.

Semi-industrial trials were also undertaken, but as certain equipment was not available at the plant, the pulp obtained was rather inferior to the laboratory pulp. In spite of this the paper produced proved to be excellent.

Two standard papers prepared (45 : 55 and 35 : 65 cetico chemical and cetico mechanical) were found to compare very favourably with average French papers.

Conclusion

From these trials, the following conclusions can justifiably be drawn:

(a) By means of the Kraft process high-quality bleached chemical pulp can be made from the Peruvian cetico, bearing comparison with any but spruce pulp.

(b) By mixing cetico chemical and mechanical pulps, a newsprint can be produced which has characteristics similar to those of standard newsprint.

(c) The best proportion of chemical pulp to mechanical pulp in the mixture would be at the maximum one-third.

(d) By classic bleaching methods, papers can be obtained which are equal or superior in brightness to newsprint currently available on the world market.

(e) It may be assumed from the foregoing that it would be possible to print the paper obtained on high-speed printing-presses.

[1] A shortened version of the original paper (ST/ECLA/CONF.3/L.3.11), which contains nine tables giving the results of tests carried out on cetico pulps and papers, and estimates of production costs at the proposed Pucallpa mill.

III. Economic study

A thorough study was also made, from both the practical and economic points of view, of the possibilities of installing a pulp mill and of the likely profitability of such an enterprise.

1. *Organization*

It would seem practicable, in the case of Peru, especially, to unite in one mill the three manufacturing processes: mechanical pulping; chemical pulping; and paper making. Substantial savings would result from such a grouping as one central plant for power and steam production, one workshop for maintenance and repair, and one general administration would be required for the three units. Transportation of pulp to the paper mill—always a costly factor—would be avoided. Installations auxiliary to the three main units would of course be necessary.

2. *Site*

Pucallpa was selected as being in the heart of the cetico production area and close to a source of good quality fuel. Its link to Lima, the capital, was considered satisfactory after a careful study of traffic statistics for all seasons of the year.

3. *Investment, production costs, profits*

A careful study was made of investment costs and the impact of capital costs on production costs, allowing for the necessary working capital at the normal rate of interest. Total costs were carefully estimated, taking into account cost and transport of raw materials, labour, wood extraction, and transport of the finished goods to Lima. The studies led to the conclusion that, in spite of the burden of transport between Pucallpa and Lima, newsprint could be manufactured at Pucallpa and delivered to Lima for $103 per ton. Since the prices of imported newsprint in Lima at that time were $231 and $300 per ton, for Finnish and United States newsprint respectively, it may be reckoned that an 18,000-ton newsprint mill at Pucallpa, working to full capacity, would show an annual profit of over $2 million. Details of these estimates are given below.

Cost price in Lima per ton of newsprint manufactured at the Pucallpa mill

	Quantity	Unit cost	Value (in soles)	Total
Bone-dry wood	1.5 tons	44.00	66.00	66.00
Materials				
Lime	28.00 kg	0.10	2.80	
Sulphur	7.00 „	0.65	4.55	
Salt	44.00 „	0.08	3.52	
Size and aluminium			30.00	
Talc	25.00 „	0.65	16.25	57.12
Fuel (for power production)	0.86 tons	190.00	163.40	163.40
Water purification				100.00
Manual labour				283.33
Maintenance				
Sundries			100.00	
Machine			80.00	
Heavy			50.00	230.00
General expenses				50.00
				949.85
Factory cost price				
Capital costs: 993.00 soles per annum			55.10	
Cost of transport to Lima			600.00	655.10
Total				1,604.95[a]

[a] Calculated on the basis of 15.60 soles to the US dollar, equals $103.
Sales price in Lima per ton of imported United States' newsprint: $300.
Sales price in Lima per ton of imported Finnish newsprint: $231.
Profit, estimated per ton: $128 ($231–$103).
Profit, estimated per annum (18,000 tons): $2,306,000.

ECONOMICS OF NEWSPRINT PRODUCTION[1]

P. R. Sandwell

Introduction

In the major exporting countries prior to World War II, a newsprint paper mill of less than 300 tons of daily capacity would have been considered uneconomic. In less than fifteen years the minimum economic size of a new mill has risen to 500 tons. It is the purpose of this paper to discuss the reasons for this situation and to examine the extent to which they would apply under the somewhat different conditions which exist in Latin America.

Definitions

Newsprint paper is susceptible of two definitions: one based on the form in which it is usually manufactured, and the other based on the use to which it is put. A definition of the first kind is the following para-

[1] Originally issued as ST/ECLA/CONF.3/L.3.12.

phrased version of the specifications used by the United States Customs:

"A paper made from a mixture of mechanical pulp and chemical pulp conforming to specific limits as to weight, caliper, finish, ash content, degree of sizing, percentage of chemical pulp content, and the dimensions of the sheets or rolls in which form it is shipped".

A more fundamental definition of the second kind might be something like this:

"A paper capable of rapidly absorbing ink, strong enough to stand the strain of running through modern presses at high speed, and yet so cheap that it can be used in large quantities to produce newspapers which can be sold at a price no higher than that of a few cigarettes".

In regions where there is an abundance of both coniferous wood and cheap electrical energy the two definitions are consistent. In regions where this is not the case, the first definition might as well be ignored.

In this paper, for the sake of uniformity, weights and measures are expressed in metric units, currency in dollars of the United States of America.

Part I

North American conditions

Capital investment

General. Newsprint mills producing paper which conforms to the first stated definition contain four main components: (1) mechanical pulp mill; (2) chemical pulp mill; (3) paper mill and (4) general services.

The relationship between size and capital cost, which differs for each component, depends upon the matters now to be discussed.

Mechanical pulp mill. Although Keller's first pulpwood grinder has changed in size and capacity, the basic mechanical pulping unit is still a driven rotating abrasive cylinder against which pulpwood is pressed in the presence of water. In its present state of development, a pulpwood grinder driven by an electric motor will produce, from coniferous wood, some forty tons of pulp per day: sufficient to support the manufacture of fifty tons of newsprint paper. Since additional capacity is obtained by multiplying the number of basic units, and since such auxiliary units as the *screen* and *thickeners* are of matching capacity, a reasonable relationship exists between capital cost and capacity over a fairly wide range. To be specific, the total cost of a groundwood mill, from pulpwood bins to pulp storage chests, varies about as follows:

Daily newsprint tons per day	*Daily GW pulp tons per day*	*Total capital $*	*Unit capital per daily ton of newsprint $*
100	80	1,800,000	18,000
200	160	3,000,000	15,000
300	240	3,900,000	13,000
400	320	4,800,000	12,000
500	400	5,800,000	11,600

Chemical pulp mill. In the case of chemical pulp the position is rather different. If the pulpwood belongs to the narrow range of species to which the sulphite process is suited, and if the mill location is such that pollution by mill effluent is so unlikely that the concentration and burning of waste liquor is not required, the minimum mill-size is determined by the capacity of one digester. To be economic a mill digester should be proportioned to produce about fifty tons of sulphite pulp per day: sufficient to support the manufacture of at least 250 tons of newsprint paper. Consequently only two such digesters would be required to support a newsprint mill of 500 tons capacity: an uncommon situation because such a mill would be subject to rather large cyclic swings. Mills of more reasonable proportions suffer from higher unit capital costs, as the following table will show:

Daily newsprint tons per day	*Daily sulphite pulp tons per day*	*Total capital $*	*Unit capital per daily ton of newsprint $*
100	20	1,100,000	11,000
200	40	1,800,000	9,000
300	60	2,300,000	7,700
400	80	2,800,000	7,000
500	100	3,200,000	6,400

If the pulpwood available to the mill is not suitable for sulphite pulping, a semi-bleached sulphate is usually used. In this case the capital cost situation is less favourable because the elements which control capacity are the chemical recovery units, not the relatively smaller pulp digesters, washers, screens and thickeners. Consequently, a semi-bleached sulphate mill of reasonable size is far larger than would be required to support a newsprint mill. For this reason the use of sulphate pulp in the manufacture of newsprint paper makes necessary the disposal of surplus pulp by sale or by conversion to other products. While this situation will be ignored for the purposes of this paper, the following capacity/capital relationship should be recorded:

Daily newsprint tons per day	*Daily sulphate pulp tons per day*	*Total capital $*	*Unit capital per daily ton of newsprint*
500	100	6,600,000	13,000
1,000	200	9,200,000	9,200
1,500	300	12,000,000	8,000

This relationship rests on the economics of the chemical recovery process, a situation over which the relative merits of batch and continuous pulping methods have little influence.

There are, of course, two other possibilities: (1) the use of purchased chemical pulp and (2) the manufacture of semi-chemical pulp. The first is usually found to be but a means of deferring capital expense, not a means of assuring economy. The second may well provide a satisfactory solution: a matter which is discussed later in this paper.

Paper mill. It is the cost of the paper mill which has set the pattern of size in the newsprint exporting countries. Of the means of blending dilute pulps, making paper, and producing rolls ready for shipment, the paper machine itself determines daily capacity.

Apart from a few paper machines of greater than normal width constructed around 1930, whose initially disapppointing performance is still fixed in the minds of the more conservative, newsprint machine widths, speeds, and capacities have evolved more or less as follows:

Year	Wire width (mm)	Speed (metres per minute)	Output (tons per day)
1920	4,000	250	65
1930	6,000	300	120
1940	6,000	400	160
1950	7,200	450	210
1954	7,200	550	250

Paper mill economics are such that for over-all efficiency the paper machines should be installed in pairs. It is quite usual, as an initial step, to install the mating machine as soon thereafter as possible. The effect on capital cost of installing machines corresponding to a nominal range of newsprint capacities is as follows:

Daily newsprint tons per day	Paper machines (No./wire/speed)	Total capital $	Unit capital per daily ton of newsprint $
100	1/4000/400	3,800,000	38,000
200	2/4000/400	7,200,000	36,000
300	2/6000/400	10,000,000	33,300
400	2/7200/450	13,000,000	32,500
500	2/7200/550	15,000,000	30,000

General services. For the sake of clarity, the cost of the facilities for handling and storing raw materials and finished products, water supply, heat and power generation and distribution offices and laboratories, shops and stores, transportation and communication may be grouped together.

While the capital cost of these general services varies greatly from region to region, and from site to site, a typical new North American mill would probably have to bear costs of the following order:

Daily newsprint tons per day	Total capital $	Unit capital per daily ton of newsprint $
100	7,300,000	73,000
200	10,000,000	50,000
300	11,800,000	39,000
400	13,400,000	33,500
500	15,000,000	30,000

Total capital costs. In summary, the total capital cost of new mills of various capacities, based on the use of coniferous woods suitable for both the mechanical and sulphite processes, constructed on a site of a reasonable kind, and supplied with hydroelectric power from a public utility, would cost (in thousands of dollars) the following amounts:

Item	Daily capacity in tons of newsprint				
	100	200	300	400	500
	(Amounts given in thousands of dollars)				
Mechanical pulp mill	1,800	3,000	3,900	4,800	5,800
Chemical pulp mill	1,100	1,800	2,300	2,800	3,200
Paper mill	3,800	7,200	10,000	13,000	15,000
General services	7,300	10,000	11,800	13,400	15,000
TOTAL PLANT CAPITAL	14,000	22,000	28,000	34,000	39,000
Unit plant capital per daily ton of newsprint.	140	110	93	85	78

The relative significance of these plant capital costs is portrayed in Figure 1 on page 194.

The effect of the cost of the general services, particularly in the small plants, is quite apparent. It is also evident that a reduction of the cost of the general services resulting from sharing them with an existing operation, or from taking advantage of some special circumstance peculiar to a specific site, can have a marked effect on the cost of a new plant.

Capital charges. The total investment (in thousands of dollars) in plant and working capital for new mills of various capacities is as follows:

Item	Daily capacity in tons				
	100	200	300	400	500
	(Amounts given in thousands of dollars)				
Plant capital	14,000	22,000	28,000	34,000	39,000
Working capital	1,000	2,000	3,000	4,000	5,000
TOTAL INVESTMENT	15,000	24,000	31,000	38,000	44,000
Unit investments	150	120	103	95	88

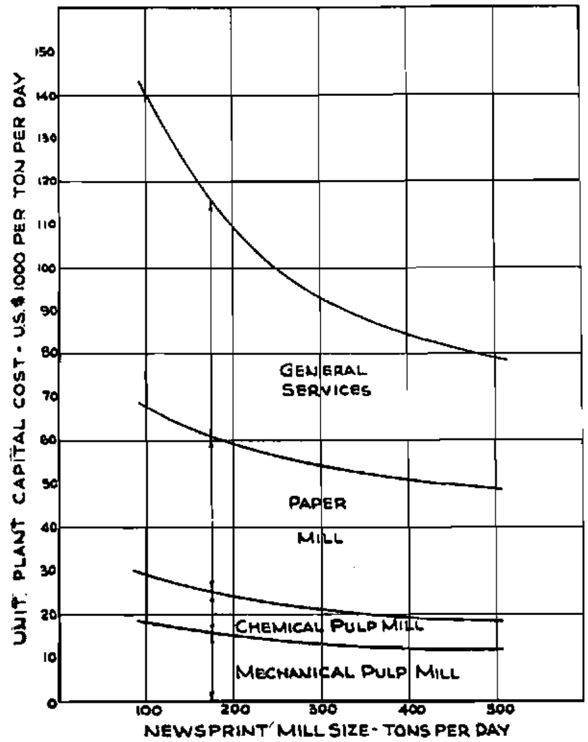
In order to cover interest charges on borrowed money, depreciation to the extent allowed by income tax laws, insurance, property taxes, recurring minor capital expenditures, and income taxes, and after these charges to provide the ordinary shareholders with dividends at current rates of about 6 per cent, a newsprint manufacturer in North America should receive a gross return of about 20 per cent upon the risk capital invested. On this basis, the corresponding total fixed charge against production for mills of various capacities is as follows:

Daily capacity tons per day	Capital charges per ton of newsprint $
100	71.00
200	56.00
300	49.00
400	44.00
500	41.00

In North America such total unit capital charges are somewhat less in the south than they are in the north-east or north-west. In northern Europe they tend to be

Figure 1

UNIT TOTAL AND COMPONENT PLANT CAPITAL COSTS FOR NEWSPRINT MILLS OF VARIOUS SIZES



lower than in North America as a whole, but the possibility of finding a situation where the larger mills can be supported is also more limited. In either region there are, of course, many possibilities for providing additional newsprint capacity in smaller increments at lower unit capital costs, such as by the modernization or expansion of existing mills. It is for this reason that far more new capacity has been brought into being since World War II by modernization than by the construction of new mills.

Manufacturing costs and profits

Variable direct manufacturing costs. Of the variable direct costs of newsprint manufacture, that of pulpwood may be more or less under the control of the newsprint manufacturer; that of electric power is sometimes under his control; whereas those of chemicals, operating supplies, and fuel are determined by the market for those items and by nothing else. In calculating the cost of pulpwood and electric power one must assume an "arm's-length" relationship between the forest owner or the power producer (on the one hand) and the newsprint manufacturer (on the other) even if actual ownership or control rests in a single entity. In this manner, and by using accepted market prices or rates in those areas of North America where most of the newsprint is made, or is likely to be made, the following direct costs may be assumed independently of mill capacity:

Item	*Unit*	*Cost unit* $	*Cost per ton of newsprint* $
Pulpwood..............	m^3	7.50	25.00
Materials and supplies...	—	—	10.00
Electric power..........	kWh	0.004	5.00
Fuel...................	million kcal	1.75	5.00
TOTAL VARIABLE DIRECT MANUFACTURING COSTS			45.00

In the above calculation the cost of fuel is expressed in terms of the amount of usable heat contained in steam generated by the fuel in a steam boiler of conventional design.

Relatively fixed direct costs. The cost of labour, its management and supervision, will vary according to the size of the enterprise. For typical North American conditions the following unit costs are fairly representative:

Daily newsprint tons per day	*Daily cost* $	*Cost per ton of newsprint* $
100	2,800	28.00
200	5,000	25.00
300	6,900	23.00
400	8,600	21.50
500	10,000	20.00

Total capital and manufacturing costs. In summary, the sum of the capital charges and the direct manufacturing costs in North America for new mills of various capacities is more or less as follows:

Daily newsprint tons per day	*Capital charges per ton* $	*Variable direct per ton* $	*Relatively fixed per ton* $	*Total per ton* $
100	71.00	45.00	28.00	144.00
200	56.00	45.00	25.00	126.00
300	49.00	45.00	23.00	117.00
400	44.00	45.00	21.50	110.50
500	41.00	45.00	20.00	106.00

In the actual case, a new mill in the north-east will experience somewhat higher costs than those shown above, whereas a new mill in the south or north-west will experience somewhat lower costs. New mills in northern Europe will not, on the average, experience total costs which differ greatly from those tabulated in the foregoing (under free market conditions and present circumstances) though the individual unit costs may vary widely.

Sales prices. For the purpose of this paper it may be assumed that variations in the price of newsprint during the last thirty years are of only historic interest and that, for the economic conditions of today, the price is stable. In North America, with few important exceptions, the price is based upon delivery at the port of New York with an adjustment for freight to establish the price at which newsprint leaves the mills. Provided that a new mill does not depend on very distant markets, it is probably safe to assume that, after allowing for freight and selling costs, the mill must sell its product for about $125 per ton.

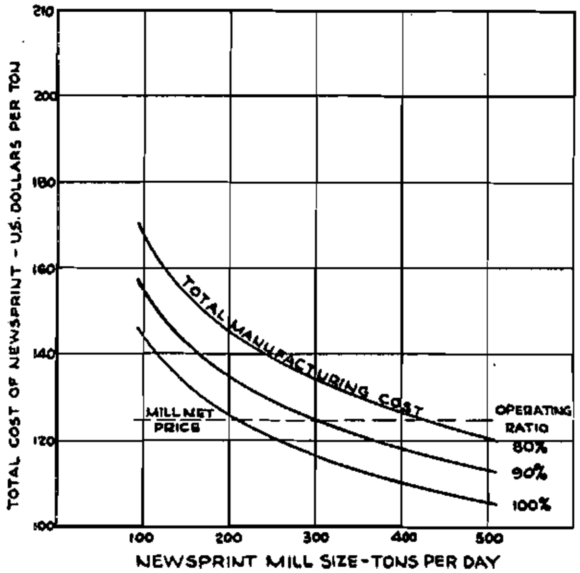
Margins of profit. From all the above it is possible to compare total costs (including the normal profit expected by investors) and net selling prices. Since some consideration must be given to operating ratios (as between actual output and full capacity) Figure 2 compares selling prices with total manufacturing costs at three operating ratios.

Summary of the situation in North America

On the basis outlined above it is evident that, in North America, and in the form in which it is usually made, newsprint can be produced economically only in mills of relatively large capacity. This situation is approximately the same in northern Europe, although

Figure 2

Newsprint selling prices with total manufacturing costs for newsprint mills of various sizes in North America



in both regions additional capacity can be provided more economically by the modernization or expansion of existing mills. Conditions which have fostered and allowed this situation include the following: (1) a large, stable, but competitive market; (2) abundant coniferous wood of high quality, in a paper-making sense; (3) low-cost hydroelectric power developed in advance of demand; (4) low-cost fuels from competitive sources; (5) educated and trained labour, physically fit; (6) sound industrial and technical management, acting under both stable economic and predictable political conditions; (7) an environment of advanced production, communication, and transportation methods.

Part II

Latin American conditions

General economic circumstances

Markets. Comparatively speaking, markets for newsprint in Latin America are not large. By 1960, under conditions of "free" supply (i.e., without restrictions due to foreign exchange control), the greatest consumption in any one country might reach 1,200 tons per day: for Latin America as a whole, 3,000 tons per day.

Market prices are relatively higher, since they are based in the main upon North American prices, to which are added transportation and related charges. In certain specific instances mill net sales prices of $160 per ton have been calculated. Though significant variations from this price may be justified, according to one's point of view, it would seem to be a reasonable figure to use for the purpose of this paper.

As to the necessary "quality" of newsprint for Latin America it is probably safe to say that the second and more fundamental definition (mentioned at the beginning of this paper) should apply, thus giving the possibility of a more liberal selection of raw materials and processes than would otherwise be the case.

Raw materials. Apart from the conifers of Chile and the Paraná "pines" of the south-central plateaux, the forests of Latin America do not contain species suitable for the economic manufacture of newsprint by methods which are conventional in North America and northern Europe. There are, however, important stands of species in various parts of the continent for which interesting technical possibilities exist. Although agricultural residues also present possibilities, these materials hardly meet current economic requirements even under the most favourable conditions. Consequently, the cost patterns which have been developed in North America might in most cases be modified in Latin America by process requirements, conceivably resulting in higher rather than lower costs, at least in the higher mill capacity ranges.

Energy. Throughout Latin America, with a few important exceptions, fuel and electric power are scarce and expensive, particularly in the areas where the most suitable raw materials are to be found. In one important region, heat and power costs are three times as high as those in North America. Furthermore, the desire to improve living standards in Latin America has created a demand which, for the time being, has outstripped the possibility of financing new fuel and electric-power developments to such an extent that reserve capacity can seldom be made available in the relatively large amounts required by the newsprint industry. Consequently, the processes which are so successfully used in North America lose their advantage, further upsetting the cost pattern as it is now understood.

Transportation. Two important general considerations in respect to transportation in Latin America are:

(1) While the important markets are within reach of ocean shipping—a fact which favours the importation of newsprint from the northern hemisphere—the continent's forests are not as favourably located with respect to the important markets or to ocean shipping, a fact which tends to lower the mill net sales prices to a greater extent than the prices in metropolitan areas would indicate.

(2) Established land and sea communications are not such as to favour the transportation of newsprint from one Latin American country to another.

Consequently mill sizes are apt to be limited by the markets which are near at hand.

Labour. In general, in most Latin American countries labour is abundant and wages are comparatively low. On the other hand, industrial skills are lacking, as one would expect in countries where, until recently, emphasis has been placed on agriculture and the sale of raw materials. Consequently, productivity is low and certain limits are placed on the use of highly technical plant. Some of the practices in current use in North America cannot, therefore, be fully counted upon at present. This is a situation which has a greater bearing on the timing of industrial development than upon the ultimate extent of industrial development, because labour can always be trained.

Capital. In Latin America, in general, domestic capital is scarce and foreign private capital is not readily forthcoming. Therefore higher dividend rates are required. In some instances dividends of less than 15 per cent fail to attract private investors. On the other hand, corporate income-tax rates are relatively low, particularly for new industries of public importance.

Newsprint costs and profits

Assumptions. For the sake of simplicity the analysis which follows will be based on the assumption that a hypothetical Latin American newsprint mill would have available to it supplies of raw materials suitable for pulping by more or less conventional methods and that the mill would be located so as to serve the larger metropolitan markets.

Sales prices. Under these circumstances it will be assumed that the mill will be able to sell its output at a mill net price of $160 per ton.

Capital charges. Under the conditions which have been assumed, it will be found that the capital cost of construction in Latin America will not differ materially, for a newsprint mill as a whole, from current experience in North America. A greater use of less expensive European equipment would be offset by higher transportation costs on that equipment. Lower construction labour rates would be offset by slower construction and the need for housing, roads, and similar facilities which are not necessarily required in North America at present.

As to capital charges, it may be assumed that the same gross return on risk capital as is expected in North America will apply in Latin America, lower taxes balancing higher dividends, with the result that the fixed charge against production for mills of various sizes will remain as follows:

Daily capacity tons per day	*Capital charges per ton $*
100	71.00
200	56.50
300	49.00
400	44.00
500	41.00

Manufacturing costs. While the cost of pulpwood will vary from place to place, and the price may appear to be very low in isolated cases, *particularly where there is as yet no substantial market for it,* it is not true to say that average Latin American pulpwood costs will be lower than those in the northern hemisphere. A typical *estimated* cost for one particular region in Latin America is $7.50 per solid m^3.

On this basis, and in the light of other cost relationships, the variable direct manufacturing costs for a hypothetical Latin American mill may be expressed as follows:

Item	*Unit*	*Cost unit $*	*Cost per ton of newsprint $*
Pulpwood..........	m^3	7.50	25.00
Materials and supplies	—	—	15.00
Electric power.......	kWh	0.0125	15.00
Fuel................	million kcal	5.30	15.00
TOTAL VARIABLE DIRECT COSTS			70.00

For the relatively fixed direct cost of labour, its management and supervision, lower rates of pay in Latin America are somewhat offset by lower productivity and higher social security charges. On balance the cost would be lower than in North America with the relatively fixed direct manufacturing costs being about as follows:

Daily newsprint tons per day	*Daily cost $*	*Cost per ton of newsprint $*
100	2,500	25.00
200	4,400	22.00
300	6,100	20.50
400	7,600	19.00
500	9,000	18.00

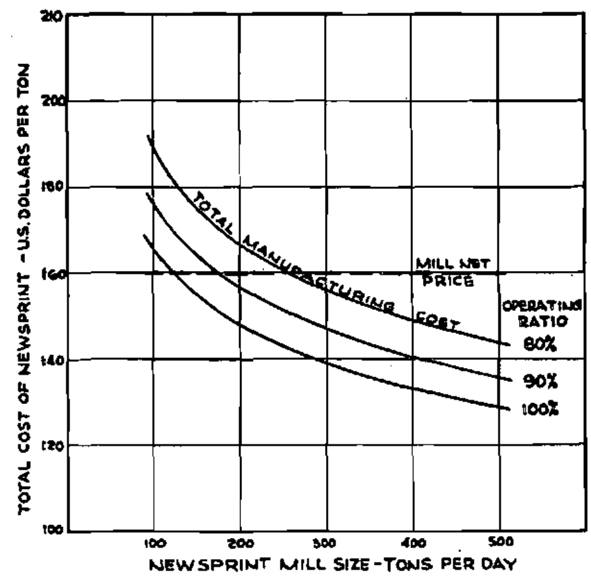
In summary, the combined capital charges and direct manufacturing costs, for a hypothetical newsprint mill in an arbitrarily assumed location in Latin America should be more or less as follows:

Daily newsprint tons per day	*Capital charges per ton $*	*Variable direct per ton $*	*Relatively fixed per ton $*	*Total per ton $*
100	71.00	70.00	25.00	166.00
200	56.00	70.00	22.00	148.00
300	49.00	70.00	20.50	139.50
400	44.00	70.00	19.00	133.00
500	41.00	70.00	18.00	129.00

Mill capacities. From all the above it is possible to compare total costs and net selling prices for a hypothetical Latin American mill, at various operating ratios, as shown in figure 3.

Figure 3

NEWSPRINT SELLING PRICES WITH TOTAL MANUFACTURING COSTS FOR NEWSPRINT MILLS OF VARIOUS SIZES IN LATIN AMERICA



It will be seen that while the economics of mill size favour the larger mills in Latin America just as they do anywhere else, higher selling prices allow the contemplation of smaller mills. Even so, it would not seem prudent to consider a mill of much less than 300 tons per day capacity, unless it is part of an integrated operation, or unless some specific location has an outstanding advantage (such as a nearby source of cheap power and fuel).

Newsprint possibilities

Mill sizes. It may be concluded that, for newsprint manufacture by conventional methods in Latin America, the following will be true:

(1) Where sufficient pulpwood can be developed, and where the output can be sold, an independent two-machine mill of something less than 300 tons per day capacity can be justified.

(2) Where smaller mills are indicated, to suit market or pulpwood conditions, an independent mill must be justified by some definite local advantage.

(3) Where smaller mills are indicated to suit market conditions, but not by pulpwood limitations, integration with other pulp, paper, or forest products will be found to be necessary.

In spite of these conclusions it is evident that conditions in Latin America are sufficiently different from those in North America to justify departures from conventional techniques which may well change the economic pattern altogether. Some of these possibilities will now be discussed.

Processes. Much research has been carried out in respect to pulping processes whose avowed objects are: (1) to reduce unit capital costs, particularly for mills of small capacity; (2) to allow the wider use of deciduous woods, particularly in those areas lacking conifers.

Such processes include, in the main, the chemical groundwoods and the semi-chemicals. While it is true that their successful development would be of tremendous value in north-eastern North America and northern Europe, where many possibilities exist for the exploitation of hardwood forests by mills of modest capacity, they seem to be of even greater interest for Latin America particularly because: (1) they offer relief from high fuel and power costs; (2) they would not be limited by the rather rigid paper specifications to which the mills in the exporting countries must conform.

Heat and power. The high cost and scarcity of fuel and power in most Latin American locations compels more attention than it usually does in North America, or even in Europe. The unlikelihood of public or private utility power systems being able to meet the growing demand, or of being able to supply newsprint mills in the places where forests and markets require them to be built, may require self-containment in respect to power. Consequently, Latin American newsprint manufacture may well require a combination of process and service plants so balanced that the objects of high efficiency and self-containment are attained. Conventional newsprint mills offer the least attractive possibilities in this respect.

Equipment. The cost patterns which have been described in this paper have resulted from certain trends in the development of pulp and papermaking equipment, most of which has followed the "economy through size" formula. In the case of the newsprint paper machine, we have discussed the development from narrow slow machines to wide fast machines. If mills must be small for reasons of raw materials or markets, retrogression to narrow slow machines should not be the only means open to the industry. In other respects most modern equipment has been developed to meet the needs of larger mills, and small ones must either use equipment not suited to them or revert to equipment of older design. In either case the economy of the small mill suffers. Consequently, if small mills are to be required for Latin American conditions, new equipment designs to suit such mills are going to be necessary. Their nature is not the concern of this paper.

Mill design. In a conventional newsprint mill the process equipment represents little more than half of the total capital investment. Consequently, there is more to the design of a mill than the careful selection of currently available equipment and the placing of it in a group of buildings. In Latin America, opportunities for radical new *mill* design are relatively great, and should lead to the same refreshing new trends that are so apparent in the contemporary architecture of the continent. If attention is concentrated upon the needs of smaller mills the adverse cost patterns described in this paper should be susceptible of some improvement, particularly if the full exploitation of new processes and a balancing of heat and power requirements are inherent in such designs.

Summary of situation in Latin America

1. On the basis of conventional techniques, and under the conditions assumed for the purposes of this paper, it appears that newsprint can be produced in Latin America in mills of more modest size than are needed in the northern hemisphere. Nevertheless, very small mills, sized to match raw material or market conditions, require either some special local advantage or integration with other plants in order to make them economic.

2. On the other hand, more liberal paper quality requirements, and the current development of new processes well suited to Latin American raw materials, suggest the possibility of new mill designs, equipment better suited to small capacities, and a balance between heat and power, the combination of which may well overcome the disabilities of the cost patterns inherent in conventional newsprint manufacturing techniques.

Conclusion

Information contained in this paper is intended to explain current North American newsprint manufacturing practices and to establish a basis for assessing proposed developments in Latin America. The data contained herein are reasonably accurate for an average hypothetical situation, to which no specific situation will necessarily conform. It is concluded that newsprint mills in Latin America need not be as large as those in the exporting countries, particularly if new techniques are employed and new designs are developed.

THE USE, IN NEWSPRINT, OF BLEACHED COLD SODA PULPS FROM CERTAIN MIXTURES OF LATIN AMERICAN HARDWOODS[1]

G. H. Chidester and K. J. Brown

Introduction

Newsprint, conventionally made from softwoods by blending about 80 per cent groundwood pulp with 20 per cent chemical pulp, cannot be made from most hardwoods in the same way. Although some low-density hardwoods like the poplars produce groundwood pulp having sufficient sheet strength to enable their use in a considerable portion of the blend, groundwood pulp from most hardwoods is too low in strength to permit its use in this manner.

[1] Originally issued as ST/ECLA/CONF.3/L.3.13.

In addition to the possibility of using hardwood sulphate or soda pulps for papers of the magazine type that might be used as newsprint, other alternatives for producing pulps of adequate strength are based on the use of high-yield pulps prepared by a mild chemical treatment followed by a separation of fibres by mechanical means. Three such alternative possibilities are: (*a*) the neutral sulphite semi-chemical process, (*b*) the chemi-groundwood process, and (*c*) the more recently developed cold soda process.

In the neutral sulphite semi-chemical process, wood chips are digested at high temperatures and pressures to yields of 75 to 85 per cent. The softened chips are reduced to pulp, usually in a disk mill. In the chemi-groundwood process wood blocks are digested in a similar manner before grinding in the conventional way. The cold soda process developed at the Forest Products Laboratory[1] consists of treating chips with caustic soda at low temperatures and atmospheric pressures, and reducing the softened chips to pulp in a disk mill. The pulp yield is usually 85 to 90 per cent. Under favourable conditions the use of steam and pressure vessels is avoided. Limited experiments at the Forest Products Laboratory[2] consists of treating chips with caustic soda process may be adaptable to a quick, continuous procedure. For example, chips and caustic soda were passed through a mill with a rotating roll inside a revolving cylinder, and the partially reduced chips were then fiberized in a disk mill.

The semi-chemical process has had extensive commercial development in the United States. This kind of pulp has been used to a limited extent in newsprint. Chemi-groundwood pulp is used in one large mill in the United States as a component of newsprint. Though not as far advanced commercially, the cold soda process merits consideration as a process for making newsprint from hardwoods because of its potentialities for low cost and small investment. The process is used in one mill in Italy for a component of a newsprint furnish.

A recent investigation[3] at the Forest Products Laboratory showed that pulps prepared from cottonwood (*Populus deltoides*) by the semi-chemical, chemi-groundwood, or cold soda processes could be substituted for the long-fibre chemical pulp component and to a considerable extent for groundwood pulp to produce a good-quality newsprint. Small-scale newsprint trials with cold soda pulps alone have produced papers having adequate strength but lower opacity than the standard.

The work of the Forest Products Laboratory on the cold soda process has shown encouraging results with some species, including poplars, red alder, birch, and sweetgum. Certain species, such as the oaks, on the other hand, have not responded so well to this treatment. Higher concentrations of caustic soda or forced penetration were required and the pulp strength was lower. Also, in the few trials made up to the present time, softwoods have not produced results so good as hardwoods.

Along with considerations of the quality of newsprint made from short-fibre pulps, it is important to recognize the factor of the behaviour of such stocks on the paper machine, especially at high speeds. Although the dry strength and rate of drainage of water from the stock may be adequate, the strength of the wet sheet tends to be low. Low wet strength may lead to greater difficulty with breaks at the wet end of the machine and is usually more evident as the machine speed is increased. Provision for transfer rolls to help carry the sheet and other means to prevent breaks are undoubtedly desirable to permit the reduction of the long-fibre component to a minimum.

In view of the interesting possibilities indicated for the use of cold soda pulp for newsprint, the Economic Commission for Latin America requested the Forest Products Laboratory to conduct trials with a mixture of eight Yucatán hardwoods. Similar trials were also made with a mixture of four species of eucalypts from Brazil in co-operation with the United States Machinery Co., Inc. The cost of the work was covered by financial contributions of these two organizations.

Description of wood used in tests

The eight Yucatán hardwood species were received in the unpeeled condition. The average diameters of the logs varied from six to thirteen inches (see table 1). The densities of these woods varied over a wide range of eighteen to forty pounds per cubic foot, with the average of their equi-mixture being twenty-eight. These woods were selected because of their abundance, chemical composition, and sulphate pulping characteristics.

The Brazilian eucalypt logs were also received unpeeled. They had average diameters of four to five inches. The densities of the four species of eucalypts varied from thirty-two to thirty-six pounds per cubic foot, and were similar to that of paper birch (*Betula papyrifera*).

The bark was removed from all of the logs before they were converted into standard ⅝-inch chips. The chips were screened before pulping to remove undersized and oversized material.

Cold soda pulping

All of the cold soda pulping experiments were made on mixtures containing equal weights (moisture-free basis) of each of the Yucatán and Brazilian species. Preliminary treatments were made in autoclaves of 0.5-cubic-foot capacity by using four pounds of moisture-free chips. Treatments to provide enough pulp for bleaching and paper-making were then made in a tumbling digester of 14-cubic-foot capacity and holding 100 pounds of chips.

The chips were steeped at temperatures of 24° to 47° C for periods of one-half to two hours. The static pressure in the treating vessel was varied from one to eleven atmospheres. One trial was made with the air removed from the chips prior to the steeping operation.

After the caustic soda treatment the softened chips were washed with water and removed from the treating vessel. The chips from the small-scale tests were fiberized in an 8-inch single-rotating disk attrition mill, and those from the larger-scale treatments were fiberized in a 36-inch, double-rotating disk attrition mill.

The pulps produced were washed, sampled for yield, and tested for physical properties according to standard TAPPI methods.

[2] Brown, K. J., and McGovern, J. N. *Paper Industry*, 35, No. 1 :66-69 (April 1953).

[3] Second progress report on "Newsprint Production from Hardwoods", by the Department of Commerce to Subcommittee No. 5 of the Committee on the Judiciary, House of Representatives, pp. 55-66.

Effect of sodium hydroxide concentration

Atmospheric steeping treatments of two-hour duration were made on the Yucatán mixture in which the chemical concentration was varied from 25 to 75 g/l. This resulted in a decrease of pulp yield from 89.5 to 84.6 per cent and an increase in caustic soda consumption from 5.5 to 8.0 per cent (see table 2). The amount of chemical used was in the same range as found previously for the cold soda pulping of North American hardwoods, but the pulp yields were lower. The relatively low yields obtained were probably due to a mechanical loss of small material, such as ray cells, parenchyma, and vessel segments, that were so prevalent in some of the Yucatán woods, especially huano (*Sabal japa*).

The strength properties of the Yucatán cold soda pulps were increased by raising the concentration of the treating liquor (see table 3). These strength values were lower than those of aspen and cottonwood cold soda pulps tested previously.

Increasing the concentration of caustic soda from 50 to 100 g/l in a series of two-hour atmospheric steeps on the eucalypt mixture decreased the pulp yield from 90.0 to 88.8 per cent (table 2). The amount of caustic soda consumed ranged from 6 to 8 per cent (based on the moisture-free wood). These results were similar to those found previously for the cold soda pulping of the United States hardwood sweetgum (*Liquidambar styraciflua*).

The densities of the eucalypt cold soda pulps increased with increasing chemical concentration, those made from 100 g/l being the most dense. Since bulk is an important characteristic of groundwood-type papers like newsprint, the larger-scale treatments were made by using an intermediate concentration of 75 g/l.

The energy used to fiberize the softened eucalypt chips in the 36-inch mill was 25.5-horsepower days per ton of moisture-free pulp (see table 4).

Effect of pressure and vacuum

A hydrostatic pressure of eleven atmospheres applied to the treating solution surrounding the chips from the Yucatán mixture produced better liquor penetration in a half-hour than was obtained during the two hours of natural penetration at atmospheric pressure. Removing the air from the chips before the hydrostatic impregnation resulted in further acceleration of liquid movement. To illustrate this, the percentage of chips that remained submerged in water after the treatment was used as a measurement of liquor absorption. None of the chips that had been pre-evacuated (No. 3014, table 2) floated after treating as compared with only 34 per cent sinkage of the chips from the atmospheric treatment (No. 3009, table 2).

The strengths of the pulps from the half-hour forced-penetration treatments were as high but not higher than those of the two-hour natural-soak pulp (table 3). This indicated that even though the chemical had reached the centre of the chips in thirty minutes when pressure was used, this time was not enough for the desired chemical reaction to take place. For this reason, and because of the lack of opportunity to explore the possibilities for atmospheric-pressure treatment, the larger-scale treatments were of two-hour duration with eleven atmospheres of pressure being applied to the liquor during the first half-hour to ensure complete penetration. Since the pulps were very bulky, the concentration of the treating liquor used to obtained maximum pulp strengths was 75 g/l.

Fiberizing the softened Yucatán cold soda chips in one pass through the 36-inch attrition mill required moderate amounts of energy (table 4). Two of the pulps produced were recycled through the mill to increase their densities and strengths. The second pass through the mill required larger amounts of energies because of low operating efficiencies. This difficulty would be overcome in commercial practice by refining at higher consistency than was possible during these trials.

Effect of temperature

Increasing the temperature of the caustic soda solution from room temperature to 47° C increased the rate of liquor penetration and produced softer chips from the Yucatán mixture (No. 3074, table 2). The pulp was darker in colour, however, and probably would have been more difficult to bleach.

Bleaching experiments

All of the unbleached Latin American cold soda pulps were light brown in colour and had brightnesses of 32 to 37 per cent, much too low for use in newsprint.

The cold soda pulps were bleached in a single-stage process with calcium hypochlorite. Previous experiments in brightening cold soda pulps made from temperate-zone hardwood had shown calcium hypochlorite to be more effective than other bleaching agents commonly used for groundwood pulps. The amount of bleaching chemical used varied from 10 to 15 per cent and was reported as available chlorine based on the moisture-free weight of the pulp. Other bleaching conditions are given in table 5. The bleached pulps had brightnesses ranging from 56.6 to 69.2 per cent.

The loss in pulp yield in bleaching averaged about 2 per cent based on the original moisture-free wood. Bleaching caused very little change in the strength, density, and freeness of the pulps. There was no change in the opacity of the bleached Yucatán cold soda pulp as the freeness was lowered from 430 to 250 millilitres in a test beater.

Pulp screen classification

The distribution of fibre sizes in the bleached cold soda pulps was determined by screen fractioning tests, using an Appleton Classifier. In comparison with a commercial softwood groundwood pulp (see table 6), the cold soda pulps were found to have less coarse material, higher intermediate fractions and fewer fines. Lowering the freeness of the Yucatán cold soda pulp from 430 to 250 millilitres decreased the fibre-length index from 0.131 to 0.100.

The cold soda pulps made from short-fibred woods had fibre-length indexes similar to those of the groundwood pulp made from a long-fibred wood. This showed that the cold soda treatment had helped preserve the fibre length during the mechanical fiberizing. The chemical treatment also resulted in the cold soda pulps having stronger bonds between the fibres, as was shown by the higher strengths of the cold soda pulps compared to those of the softwood groundwood pulp (see table 6).

The fibre-length index of the Latin American pulp was lower than that of bleached cold soda pulp made from aspen (table 6) in the same freeness range. This fact, coupled with strength data, indicated that the fibre separation during the fiberizing operation was not so satisfactory for the woods tested in this study.

Paper-making experiments

Newsprint papers of a standard 37-pound weight (500 sheets 25 by 40 inches) were made on a 12-inch experimental Fourdrinier paper machine from the bleached Latin American cold soda pulps. Eight paper-machine runs were made. The pulp furnish, freeness at the headbox, and properties of the sheets are given in table 7.

The cold soda pulps were beaten lightly before papermaking for periods of five to ten minutes. The pH value was adjusted to about 6.0 with sulphuric acid and further to 5.0 with alum. These conditions were constant for all runs. In two runs, 15 per cent clay was added to the beater stock. Two trials were made with 30 and 40 per cent of a commercial groundwood pulp made from a spruce-aspen mixture added to the Yucatán cold soda pulps. Another run was made with 20 per cent semi-bleached southern pine sulphate pulp present. The sulphate pulp was beaten for thirty-five minutes to a freeness of 515 millilitres.

No serious difficulties were evident during the runs on the paper machine. The strength of the wet web was from fair to good for the runs made from 100 per cent Yucatán cold soda pulp. There was a tendency for the sheet to stick on the first press roll. The furnishes containing clay and groundwood pulp had poor wet strengths, while the furnish with the sulphate pulp present had very good wet strength and did not stick on the press rolls.

The eucalypt cold soda pulp had poor wet strength, so that a pickup felt was needed to lift the sheet from the wire. There was also some sticking at the first press.

The formation in all the papers was uniform. The papers made from the Yucatán cold soda pulp that was fiberized to a freeness of 430 millilitres had a number of small shives present (Nos. 4305, 4306, 4307, and 4308). Papers made from the Yucatán pulp that was refined to a lower freeness of 250 millilitres (Nos. 4351, 4352, and 4353) had very good appearance and contained very few shives. The presence of shives in the pulp was believed to have been partially caused by the incomplete fiberizing of the chips from the species ramon (*Brosium alicastrum*) that remained hard after the caustic soda treatment. A sample of each of the experimental sheets is attached to this report.

The strengths of all the experimental papers containing 100 per cent cold soda pulps were about equal or above those of a commercial newsprint paper used for comparison (table 7). The opacities of these sheets were in a low range of 78.4 to 81.1 per cent. Adding clay or groundwood pulp to the Yucatán pulp furnish increased the opacity to a value as high as 87.6 per cent, just below the 88 per cent considered as a permissible minimum for the United States market.[4]

All of the experimental papers were more bulky and porous than commercial newsprint, even though a maximum pressure was applied at the wet-press section in an attempt to densify the sheet. The best-quality paper, from a newsprint standpoint, was made by using 40 per cent groundwood pulp and 60 per cent bleached Yucatán cold soda pulp. The sheet containing 20 per cent southern pine sulphate pulp had very good strength properties but had a low opacity of 77.3 per cent.

The brightnesses of the experimental papers, which were 59.8 to 65.7 per cent for the runs made with the Yucatán pulp and 69.8 per cent for the eucalypt run, were all higher than the value of about 58 per cent usually obtained in commercial newsprint.

Conclusions

Although there was no opportunity in this work for thorough exploration of the applicability of the cold soda process to the woods used, the following general conclusions may be drawn:

1. The mixtures of eucalypts from Brazil and the mixture of tropical hardwoods from Yucatán tried in this investigation can be successfully pulped by the cold soda process.

2. Within the limits of these experiments the strengths of the cold soda pulps from these species mixtures increase as the concentration of the chemical in the treating liquor increases. The pulp strength also increases as the pulp is processed to a lower freeness.

3. The cold soda pulps made from the species mixtures are not so strong at the same freeness as the best cold soda pulps made from populars.

4. The cold soda pulps from these mixtures can be bleached with economical amounts of calcium hypochlorite to brightnesses of 56 to 70 per cent.

5. Papers made entirely from the bleached cold soda pulps had adequate strength and brightness for newsprint but were more transparent and porous than the conventional product.

6. A good-quality newsprint paper can be made from a mixture of the Yucatán cold soda pulp and groundwood pulp, although printing tests would be needed for complete evaluation.

[4] "Study of Newsprint Expansion". A progress report of the U.S. Department of Commerce to Subcommittee No. 5 of the Committee on the Judiciary, House of Representatives, October 1952.

Table 1 Physical properties of several Latin American hardwoods

Wood			Properties		
Country	*Common name*	*Botanical name*	*Specific gravity*[a]	*Density*[a] *(lb. per cu. ft.)*	*Average diameter of log (in.)*
Yucatán, Mexico	Ramon	*Brosium alicastrum*	0.700	43.7	10.8
	Jujub	*Spondias mombin*	0.320	20.0	8.4
	Ceiba	*Ceiba pentandra*	0.289	18.0	13.0
	Tatsi	*Pisonia aculutea*	0.496	30.9	7.0
	Chaca	*Bursera simaruba*	0.365	22.8	10.3
	Kochle	*Cecropia obtusifolia*	0.341	21.3	7.8
	Pixoy	*Guazuma tomentosa*	0.493	30.8	8.1
	Huano	*Sabal japa*	0.533	33.3	6.5
Brazil, South America	Eucalypt	*E. saligna*	0.585	36.5	3.9
		E. tereticornis	0.575	35.9	4.6
		E. kirtoniana	0.513	32.0	4.5
		E. alba	0.560	34.9	5.0

[a] Oven-dry weight and green volume.

Table 2

CONDITIONS AND RESULTS OF COLD SODA PULPING OF LATIN AMERICAN HARDWOOD MIXTURES

Treatment No.	Wood	Treating pressure (atmospheres)	Total time (Hr.)	Temperature (°C)	Sodium hydroxide charged: Solution concentration (gm. per l)	Sodium hydroxide charged: Original moisture-free-wood basis (per cent)	Sodium hydroxide consumed (original moisture-free-wood basis) (per cent)	Pulp yield (per cent)
				Latin American mixtures				
2018	Yucatán mixture[a]	1	2.0	24	25	12.5	5.5	89.5
3017	"	1	2.0	26	50	25.0	6.8	86.7
3009	"	1	2.0	26	75	37.5	8.0	84.6
4122, 4123, 4125, and 4127	"	11[b]	2.0	30	75	54.8	8.2	85.9
3011	"	11	0.5	23	50	45.4	5.5	85.6
3014	"	11[c]	0.5	26	50	45.4	5.3	84.0
3074	"	11	0.5	47	50	43.7	8.1	85.5
2530	Eucalypt mixture[d]	1	2.0	21	50	23.8	6.8	90.9
2531, 4062, and 4063	"	1	2.0	28	75	34.9	6.7	89.5
2532	"	1	2.0	24	100	45.8	8.3	88.8
				United States hardwoods				
2968, 2969, and 2970	Aspen	1	2.0	25	50	35.5	7.5	90.0
4118	Cottonwood	1	2.0	30	45	24.0	5.5	91.3

[a] Mixture contained equal parts by weight (moisture-free basis) of: ramon, jujub, ceiba, tatsi, chaca, kochle, pixoy and huano.
[b] ½ hour at 11 atmospheres, plus 1½ hours with pressure gradually reduced to 7 atmospheres.
[c] Preceded by evacuation of chips under a 26.5-inch vacuum.
[d] Mixture contained equal parts by weight (moisture-free basis) of: *E. saligna*, *E. kirtoniana*, *E. tereticornis*, and *E. alba*.

Table 3

STRENGTH PROPERTIES[a] OF UNBLEACHED LATIN AMERICAN COLD SODA PULPS

(*Pulp freeness = 250 millilitres Canadian standard*)

Treatment No.	Wood	Pulp yield (per cent)	Burst strength (pts. per lb. per rm.)[b]	Tear resistance (gm. per lb. per rm.)[b]	Tensile strength (breaking length) (M.)	Folding endurance (Double folds)	Density (gm. per cc)
			Latin American mixture				
3018	Yucatán mixture	89.5	0.25	0.68	2,800	2	0.43
3017	"	86.7	.35	.75	3,600	6	.50
3009	"	84.6	.42	.81	4,200	7	.52
4122/4123	"	85.2	.50	.80	5,000	15	.54
4127[c]	"	86.9	.31	.71	3,260	3	.50
3014	"	84.0	.32	.75	3,550	5	.49
			United States hardwoods				
2968, 2969, and 2970	Aspen	90.0	.72	.76	6,750	165	.67
4118	Cottonwood	91.3	.54	.95	5,150	34	.63

[a] The pulps were processed in a 1.5-pound test beater unless otherwise noted.
[b] Ream of 500 sheets, 25 by 40 inches.
[c] Refined to a 250-millilitre freeness in a 36-inch disk mill.

Table 4

CONDITIONS AND RESULTS OF FIBERIZING LATIN AMERICAN COLD SODA PULPS

Mill run No.	Treatment No.	Material	Fiberizing energy: First pass (Hp.-days per ton)	Second pass (Hp.-days per ton)	Total (Hp.-days per ton)	Pulp freeness (Canadian standard) (ml)
1008	4122, 4123	Yucatán mixture	30.9	...	30.9	400
1009	4125	"	6.8	45.7	52.5	270
1012	4127	"	21.2	25.2	46.4	250
944	4062, 4063	Eucalypt mixture	....	....	25.5[a]	500

[a] Energy consumed in 2 passes.

Table 5

BLEACHING OF COLD SODA PULPS IN ONE STAGE WITH CALCIUM HYPOCHLORITE

Bleach No.	Treatment No.	Species	Available chlorine[a] as calcium hypochlorite (per cent)	Consistence (per cent)	Temperature (°C.)	Duration (min.)	pH[b]: Beginning	pH[b]: End	Brightness (G.E. equivalent): Original (per cent)	Brightness: Final (per cent)
				Latin American mixtures						
3062	4127	Yucatán mixture	10.0	10.0	37	60	11.6	10.1	37.1	56.6
3065	4127	"	12.0	8.9	37	80	11.1	10.0	37.1	61.4
3063	4127	"	12.5	10.0	38	85	11.6	9.5	37.1	62.1
2968	4122, 4123	"	15.0	9.3	38	60	11.3	9.3	32.3	64.4
3064	4127	"	15.0	10.0	37	120	11.7	9.3	37.1	67.0
2374	4062, 4063	Eucalypt mixture	15.0	8.6	37	120	11.5	9.2	34.2	69.2
				United States hardwood						
2250	4035	Aspen	10.0	7.0	35	90	11.1	9.1	48.6	69.8

[a] Percentages are based on weight of unbleached moisture-free pulp.
[b] Sodium hydroxide added as required to maintain pH within the range shown.

Table 6

SCREEN CLASSIFICATION AND STRENGTH PROPERTIES OF BLEACHED COLD SODA PULPS

Bleach No.	Freeness (Canadian Standard) (ml)	Screen analysis[a]—Fraction: On 24-mesh (per cent)	On 42-mesh (per cent)	On 80-mesh (per cent)	On 150-mesh (per cent)	Passing 150-mesh (per cent)	Fibre-length index	Test-sheet properties[a]: Burst strength (pts. per lb. per rm.)[a]	Tear resistance (gm. per lb. per rm.)[b]	Density (gm. per cc)
				Yucatán cold soda pulps						
2968	430	1.1	15.6	48.4	9.1	25.8	0.131	0.28	0.91	0.44
3065	250	.1	3.5	47.8	10.5	38.1	0.100	0.30	0.75	0.56
				Eucalypt cold soda pulps						
2374	500	1.7	24.7	29.7	10.4	33.5	0.113	0.15	0.41	0.38
				Aspen cold soda pulp						
...	285	6.0	37.8	18.9	9.2	28.1	0.132	0.49	0.97	0.60
				Commercial spruce groundwood pulp (shipment No. 3097)						
...	165	15.4	18.2	16.4	15.2	34.8	0.112	0.25	0.63	0.43

[a] Tests made on lapped pulp.
[b] Ream of 500 sheets, 25 by 40 inches.

Table 7

NEWSPRINT PAPERS MADE FROM BLEACHED COLD SODA PULPS FROM LATIN AMERICAN HARDWOOD MIXTURES

Machine pulp furnish run No.		Clay added (per cent)	Headbox freeness (Canadian Standard) (ml)	Sheet weight (lb. per rm.)[a]	Thickness (mils)	Density (gm. per cc)	Burst strength: Mullen (pts.)	Burst strength: Unit (pts. per lb. per rm.)[a]	Tear resistance (gm. per lb. per rm.)[a]	Folding endurance (double folds)	Tensile strength (lb. per in. width)	Oil penetration (sec.)	Porosity (sec.)	Opacity (per cent)	Brightness (G.E. equivalent) (per cent)	Ash content (per cent)
	Experimental newsprint from Yucatán hardwood mixture															
4305	100 per cent bleached cold soda (bleach No. 2968)	0	310	36.9	4.0	0.51	7.6	0.21	0.72	3	8.3	17	3	78.4	60.2	1.0
4351	100 per cent bleached cold soda (bleach No. 3065)	0	170	35.7	3.9	0.51	10.2	0.29	0.60	3	8.2	26	8	81.1	60.2	...
4306	100 per cent bleached cold soda (bleach No. 2968)	15	365	38.6	4.0	0.53	6.2	0.16	0.66	0	6.4	18	4	85.2	64.2	8.0
4352	100 per cent bleached cold soda (bleach No. 3065)	15	160	36.6	3.9	0.52	7.6	0.21	0.53	1	5.7	21	8	87.1	65.7	...
4307	70 per cent bleached cold soda (bleach No. 2968), 30 per cent spruce-aspen groundwood mixture (shipment No. 4018)	0	230	37.0	4.1	0.50	6.7	0.18	0.59	1	5.4	30	9	85.6	60.8	...
4353	60 per cent bleached cold soda (bleach No. 3065), 40 per cent spruce-aspen groundwood mixture (shipment No. 4018)	0	155	36.8	4.2	0.48	8.1	0.22	0.53	1	6.9	29		87.6	59.8	...
4304	80 per cent bleached cold soda (bleach No. 2968), 20 per cent semi-bleached southern pine sulphate	0	380	36.5	3.9	0.52	10.6	0.29	1.16	11	9.1	21	4	77.3	61.1	...
	Experimental newsprint from eucalypt mixture															
3672	100 per cent bleached cold soda (bleach No. 2374)	0	300	36.1	4.6	0.43	6.6	0.18	0.50	...	7.7	10		80.9	69.8	...
	Commercial newsprint paper															
	80 per cent commercial spruce groundwood, 20 per cent commercial spruce sulphite	...	...	36.0	3.0	0.69	8.2	0.22	0.66	2	7.5	43	20	90.3	61.6	...

[a] Ream of 500 sheets, 25 by 40 inches.

ECONOMIC ASPECTS OF INTEGRATING PULP AND PAPER INDUSTRIES WITH OTHER FOREST INDUSTRIES[1]

J. A. Hall

The history of the forest products industries in highly industrialized countries has too often been one of reckless exploitation followed inevitably by regret. The forests are first thought of as "mines" to be exploited for their most valuable products without thought of replacement or regard for the results of their disappearance. As a nation develops, it is forced by scarcity of wood to look on forests from a different point of view. With industrial maturity comes the realization that forests can produce maximum values only if the forest products industries are integrated to make the best possible use of the crop and if the forests are operated on a sustained-yield basis.

The industrially less-developed countries of the world can learn much from the mistakes of their industrially more mature neighbours. The Latin American countries, for example, knowing the mistakes made during the exploitation period in the United States, can better plan the orderly development of their forest resources.

Wood played a major role in the industrialization of North America. It served as fuel, as building material for ships, homes, and factories, as mine timbers in the coal mines, and as railroad ties to support the growing transportation system. With industrialization came high-speed machine tools and assembly-line production methods that ate even faster into the dwindling forests.

The prodigal use of the forests that characterized life in the United States during the past century is without parallel in the world's history. Not only did we become terribly efficient in harvesting and manufacturing wood without regard for the forest, we also became terribly efficient in clearing land for agricultural use at the expense of the forest, and too often at the expense of the land resource itself.

Gradually we began to realize that our "unlimited" forests were indeed limited. We began to see that one-product forestry is wasteful and that our remaining forests would have to be operated on a sustained-yield basis to produce the wood we need to maintain our standard of living. We learned to recognize the meaning of the term "integrated utilization", which means simply that the crop is harvested and used as grown, with utilization enterprises in balance with the quantity and quality of wood produced.

At some time in the process of industrialization of the Latin American countries, requirements for wood will begin to put a heavy demand on the forests. For this reason, in the long-range planning of forest industries it is well to envisage integrated operations such as now exist quite widely in the northern hemisphere. This foresight is important whether or not a high degree of integration is possible in the near future. Without it, exploitation methods might leave the forest in no condition for effective integration in the future.

Forest crops are distinguished from most other products of the soil in that the methods used in harvesting go far toward determining the yield and quality of succeeding crops. Single-product industries removing only high-quality material gradually degrade an originally good forest to a type in which the trees are not suitable for conventional uses. This unproductive forest can be made productive only by reversing this process: low-quality wood must be harvested in order to encourage reproduction and growth of good trees.

If a permanent industry is to be established, a fundamental question is: "What will the yield be like during the next cutting or even the next rotation?" With the kind of balanced utilization envisaged under integration, it should be possible to exert sylvicultural control over the future crop in a way not possible with a single-product industry. Yet the nature of the raw material is going to shift, and since markets are continually changing according to economic and technological variations, it follows that a completely integrated utilization development cannot be a static affair. It should, as far as possible, be adaptable to conditions that may change rather rapidly.

Under an ideal integrated plan all high-grade material would go into lumber, veneer, and other high-quality products; all low-grade and chippable material into pulp, paper, building board, and the like; and all non-chippable material into chemically converted products. The residue from one stage in processing would be picked up and used at a lower stage. For example, wood of mixed grades could be put through a sawmill or veneer mill that would take out only the high-grade materials; the chippable residue could then be processed by a pulp mill. Chemical industries could use sawdust, shavings, and the wood substance in spent pulping liquors. In practice, of course, local factors will determine what plants will suffice for utilizing the available forest crop. These plants need not be located all in one place, but may be dispersed to make the best use of transportation facilities and raw materials.

Industries based on mechanical conversion, such as sawmills and plywood plants, have the advantage of being simple. Installation and operation costs are relatively low and only a few specialists are required. However, these industries are exacting in the quality of raw material they require.

The chemical and pulp and paper industries are much more complex. Capital investments are high and many specialists are required. These industries, however, can make fuller use of the forest crop. Chemical industries can, in fact, act as scavengers, converting great quantities of "waste" material into valuable products.

Each component of an integrated operation has a minimum economic size. It is necessary, therefore, that the forest be sufficient to supply each component with enough raw material to operate at least a minimum-size plant. It is also necessary that the potential market for each product be large enough to absorb the production of at least a minimum-size plant.

A prerequisite for the establishment of an integrated industry, therefore, is an adequate forest inventory and adequate marketing research. The forest inventory should include volume, species, growth, and yield data,

[1] Originally issued as ST/ECLA/CONF.3/L.3.13.

and a forecast of the composition of the future forest. Without these it will be difficult to attract the large capital investments that forest industries, particularly the pulp and paper industries, require.

At present, practically any forest material can be converted into pulp. The techniques are fairly well known, although further research is needed to find the most suitable processes and conditions for species and combinations thereof. The crucial problems that remain are largely problems of economics. Often the integration of pulp and paper industries with other forest products industries can create a favourable balance in an otherwise unfavourable economic formula.

There are several reasons why costs can be reduced by growing timber for many uses rather than for one use. The tools of harvesting have changed, but the essentials remain the same: we must cut a tree, allow it to fall, cut it to pieces, and collect and transport those pieces by some means. The more value we can get out of these operations, the lower our raw material costs will be. In a completely integrated operation, each piece can be assigned to the end product that will yield its highest value.

In a multiple-use operation, part of the cost of growing mature trees of high value can be defrayed by the earlier harvest of younger, low-cost material. A good job of harvesting, which would include thinning and removing cull trees, can increase the value of the forest by speeding up the rotation and the production of a new crop. It can also reduce the danger of fire and thus lower fire-protection costs.

A less tangible, but no less important, value of integrated operations lies in the ecological effects of management practices. A completely integrated operation is able and can afford to take or leave any part of the forest crop; in this way it promotes the lowest-cost and most efficient sylviculture.

The degree and form of integration that is best for any given situation depends upon many factors, including:

1. The size and character of forest ownership;
2. The history of forest exploitation and development;
3. The nature of the industrial setup;
4. Various economic conditions, such as density of population, size of the potential market, distance from markets, transportation facilities, sources of power, and so forth.

The size of individual ownership alone does not limit the development of satisfactory integration. There are a great many examples in the United States of good integration that has developed on a basis of many small forest ownerships and many small industrial enterprises. There are also several examples of very large, well-integrated operations that have developed under completely unified ownership of forest resources and industrial plants.

Because capital investments are high, completely integrated operations usually demand a sustained supply of raw material from a large area. In many cases such a supply is dependent upon the general state of industrial and cultural development in a given area. Integration, therefore, will usually proceed with the general industrial development of the country. If it moves too fast, it may bog down in raw material shortages or a lack of markets for its products.

For the Latin American countries the immediate problem is to provide the pulp and paper requirements of the countries so as to reduce their needs for costly imports. Fortunately, the pulp and paper industry can use a wide variety of species and qualities of material. For this reason it is an ideal starting point for an integrated operation: the pulp and paper mill can improve the forest and its yield by selectively cutting low-grade and cull material while it is contributing to the industrial and cultural development of the area. Industrialization, in turn, will eventually increase supplies of chemicals and equipment for making pulp and paper. As a result, paper will cost less and the whole movement will be given further impetus.

A pulp factory is merely a first process; in a fully integrated operation its product could be used in a variety of ways. Paper products, for example, include not only newsprint, wrapping paper, and container board, but hundreds of specialty products, such as tissues, building papers, artificial leathers, filters, wet-strength papers, and towelling. Pulp can be used to manufacture building board or hardboard, and the chemical grades can be the basis of entire industries manufacturing cellophane, rayon, or cellulose derivatives. There is always the opportunity to shift from one specialization to another as economic conditions and markets dictate.

In recent years a new type of integration has developed; there is now a fair amount of integration of pulp and paper products with other kinds of wood products in the manufacture of a whole range of new kinds of goods. The forest products industries are not only drawing out of the same wood barrel, their products are more and more appearing in the form of composite products.

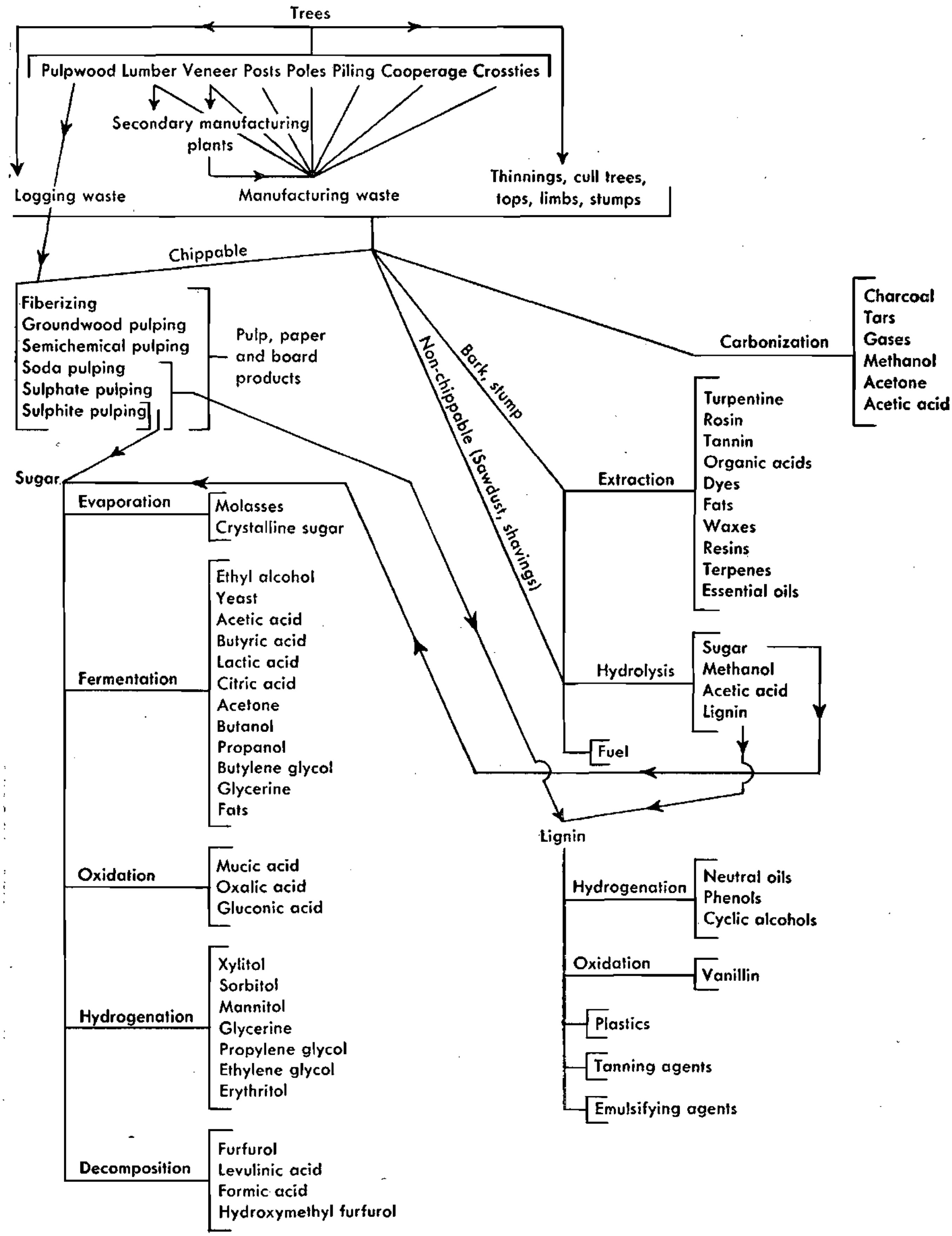
The paper honeycomb structural panel is a good example of a composite product. Paper, in the form of a paper honeycomb core, is combined with strong and stiff facings of wood or hardboard to form a permanent exterior structural building material. The paper is resin impregnated and bonded to the facings by waterproof adhesives. The panels produced in this way combine the functions of the studs, joists, nails, and insulation. They can be used for house panels, movable partitions, truck bodies, aircraft and boat parts, furniture, and many other applications.

Strong papers treated with phenolic resin can perform structurally much as wood does. They are strong and stiff when dry and not much weaker when wet. When such papers are bonded to veneer, they reduce the expansion of veneer and produce a stiff sheet material that is especially useful for boxes. When they are bonded to certain kinds of plywood, they obscure minor defects, patches, and checks, and provide a better base for painting. When these papers are bonded to low-grade lumber, they reduce the swelling of the lumber by about 40 per cent, cover sizable knots and defects, and produce a uniform-textured surface for painting.

Paper overlays can play a dual role in integrated operations. First, they can be made from thinnings, cull trees, or sawmill and veneer mill residues, and second, they can upgrade low-grade lumber, veneer and plywood to produce quality products. They can, therefore, contribute much to good forestry by making cull trees and little-used species worth the cost of getting them out of the way so that better trees can grow to maturity.

Figure 1

CHEMICAL UTILIZATION OF WOOD



Although pulping processes can use a wide variety of species and qualities of wood, there will aways be a residue that cannot be used in this way. Through chemical conversion, however, this residue can be used to produce charcoal, sugar, alcohol, yeast, acetone, glycerine, vanillin, tanning agents, plastics, and many other organic chemicals (figure 1).

Three primary chemical industries that might fit into an integrated utilization programme are wood distillation, wood extraction, and wood hydrolysis.

The production of charcoal for fuel is an important industry in some of the Latin American countries. Chile, for example, with no domestic supply of oil and a limited supply of coal, consumes an enormous quantity of charcoal annually for industrial and domestic fuel. National consumption is estimated at not less than 150,000 tons annually and may well be considerably more.

Only a small amount of the charcoal produced in Latin America comes from wood distillation plants. Most of it is produced in primitive pits or beehive ovens without recovery of the by-products. The principal by-products, methanol and acetic acid, are two of the three common commercial solvents essential to the development of large-scale chemical industries. The third is ethyl alcohol, which can also be produced from wood by hydrolysis.

Wood distillation can be a good tool of forest management, because the industry can use tops and limbs as well as low-grade cull wood. There is no question that, if the economic situation is satisfactory, wood distillation is an attractive component of integrated forest utilization. It can also be a destructive process of over-exploitation.

Extractives from wood include a variety of products that differ widely, depending upon the species and the part of the tree from which they are obtained. They include water-soluble products, such as carbohydrates, organic acids, tannins, and dyes, as well as fats, oils, waxes, resins, terpenes, and essential oils. Extraction industries are generally based on a high-value product from one or two species. Often only the bark is processed. Because these industries are closely tied to local species and local economic conditions, it is difficult to generalize about them. However, they can add value to the products of an integrated operation and should not be overlooked, especially in the tropics.

The wood hydrolysis reaction is unique among the processes that have been proposed for the chemical utilization of wood in that there is no limit to the potential market for its various products. Further, the process is adaptable to all species and all forms of waste.

Wood contains about two-thirds carbohydrate in the forms of cellulose and hemi-cellulose and nearly one-third lignin. By treating wood with acids and heat, the carbohydrates can be converted to sugars, leaving lignin as a residue.

In acid processes for the pulping of wood, notably the sulphite process, and in the pre-hydrolysis sulphate process considerable amounts of sugars are liberated and are present in the waste liquors. In some countries these sugars are thoroughly utilized, usually by fermentation. In Sweden, for example, the fermentation of these sugars to alcohol or other products is required. Large quantities of yeast for human or animal food are prepared from the same raw material.

Theoretically, complete hydrolysis should produce about 1,300 pounds of sugar and 500 pounds of lignin per ton of dry wood. Since some sugar is destroyed by the hydrolyzing chemicals, the theoretical yield is never obtained. However, a percolation process now being used in Europe and studied and improved by the U. S. Forest Products Laboratory and the Tennessee Valley Authority yields about one thousand pounds of fermentable and non-fermentable sugar per ton of dry wood.

Wood-sugar molasses with a sugar concentration of 45 per cent can be used for animal feeding. Feeding tests have shown that the sugar in wood molasses is equal in feed value to the sugar in blackstrap molasses. The Germans have also experimented with the production of human food from this process. About half the sugars may be crystallized for edible glucose; the rest may be fermented to produce alcohol or used to grow yeast for human food or livestock feed.

A number of different yeasts can be grown on wood sugar. Depending on the type and growing conditions, they may be high in fats or high in B vitamins and as much as half protein. Yields of 40 per cent of the weight of the wood sugar are readily obtained by operating commercial plants.

In addition to alcohol and yeast, a number of other fermentation products can be obtained from wood sugar under properly controlled conditions. These include acetic, butryic, lactic and citric acids, and acetone, butylene glycol and glycerine (figure 1).

Furfurol is the final decomposition product of the pentose sugars during hydrolysis. The final decomposition product for the hexose sugars is levulinic acid. Both are valuable intermediate organic chemicals. Levulinic acid is used in the pharmaceutical industry and has promise as an industrial chemical, while furfurol is much in demand for the manufacture of nylon.

The lignin residue from the hydrolysis reaction can be converted into vanillin and such products as oil-well drilling compounds, tanning materials, plastics, and linoleum adhesives.

Although the possibilities of wood hydrolysis are exciting, economic factors have restricted its development in most parts of the world. The process requires large quantities of low-cost material, such as sawdust and other wood waste. But sawdust and wood waste are bulky and difficult to concentrate. As a result, the process is economically feasible only under the most favourable conditions, such as under war pressures and shortages or in areas where derived products are lacking or expensive, or where waste is particularly easy to obtain and handle in quantity.

There are many serious considerations, however, that should affect our thoughts on the use of wood as a source of carbohydrate. One of the accompanying features of the rise of industrialization has been a tremendous increase in the population of the world. In a little over a century the world's population has increased by approximately two and one-half times. Fairfield Osborn in his striking book, *Our Plundered Planet,* estimates that there are not more than 4 billion acres of arable land left to fill the needs of 2 billion people, or less than two acres per capita. According to a generally accepted computation, the products from 2.5 acres of land of average quality are required to provide even a minimum adequate diet for each person. These figures indicate the heavy impact of population on the agricultural resources of the earth when those resources are measured in terms of traditional methods of producing food. Further industrialization of agriculture and the possible exploitation of new lands can only delay a little the application of the rule of Dr. Malthus.

There can be no political stability in the world if the basic needs of the people for subsistence are not satisfied. For this reason it would be well to look for new ways to satisfy the world's needs for food. Wood offers one way.

If we consider the unused wood crop in the United States alone, it amounts to something like 150 million tons a year. This is a very conservative figure and has little relationship to the amount of wood that could be grown on the 630 million acres of forest land in the United States if this land were intensively managed. There are no really reliable figures on the amount of wood that could be produced in the world under even simple forms of forest management, but there is no doubt it would be enormous.

The problem is to turn this vast quantity of carbohydrate material, at least in part, to the task of feeding the world's population. It has already been stated that methods for converting the carbohydrate content of wood to simple sugars or protein are available. Roughly, a ton of wood can be converted into a half-ton of sugar or a quarter-ton of yeast with a protein content of approximately 50 per cent. We have here the possibility not only of producing vast quantities of edible carbohydrate material from wood, but of transforming it into nutritive protein, which is perhaps the greatest single lack in the diet of most of the world's teeming population.

William Vogt, who is Chief of the Conservation Section, Division of Agricultural Cooperation, Pan American Union, claims that Latin America is faced with the problem, within its own borders, of at least 20 million and probably 40 million displaced persons. Writing in *Unasylva*, he said, "These tens of millions are displaced not in a political sense, but in an ecological sense. They are concentrated on sloping lands, the cultivation of which, under our present economic system, can result only in rapid, and in many cases permanent, destruction of the means of subsistence.

"In terms of slope, climate, favourable temperatures, soils, etc., only about 5 per cent of South America's land can, in terms of modern western civilization, be considered arable", Mr. Vogt continues. "A very high proportion of this 5 per cent is adjacent to rivers. In few parts of the world is agriculture, the basis of existence of the vast majority of Latin American people, so immediately associated with the hydrologic régime, and in no part of the world is the hydrologic régime balanced on so delicate an equilibrium, so vulnerable to disturbance".

Mr. Vogt continues, "Latin America, from Mexico to southern Chile, has been gravely wounded by disturbance of the hydrologic régime, primarily as a result of deforestation. Poverty has been extended, living standards lowered, and some countries brought to the brink of starvation, through lack of proper use of forests".

The fact that so small a proportion of the land of Latin America is arable should certainly be borne in mind when planning the economic development of these countries. With increasing populations, these countries may be forced to turn to wood as a source of carbohydrate and protein food or feed.

Mr. Vogt's article suggests still another type of integration—the integration of forest uses. We must think of forests not only in terms of forest products, but in terms of watershed protection, wild life habitat, soil stabilization, and recreation. These uses must be integrated if maximum values are to be obtained from the forests.

Integration, then, begins with an appraisal of the forest in terms of its use. How can it best be used? Is it needed for watershed protection? Can it be logged without causing destructive erosion? Would greater values accrue from leaving it as a wild life refuge?

Next comes an appraisal of the forest as a source of raw material. What products can it economically produce on a sustained-yield basis? The plan for integrated utilization of a forest must be a long-range plan, based not only on the present forest, but the future forest.

Finally there is the integration of the products of the forest to produce new kinds of materials.

The pulp and paper industry can well be the heart of an integrated operation. By using thinnings, cull trees, and low-grade wood, it can improve the forest and pave the way for other forest products industries. By using the residues from sawmill and veneer plants, it can place these industries on sounder economic footings. Its products can contribute to both the cultural and the industrial development of a country.

Planning for the integrated utilization of a forest in an industrially underdeveloped country takes vision. It takes study. It takes careful consideration of interrelated economic factors. But the results of such planning can reward a country with sound industries, firmly rooted in a perpetually renewable resource. As long as the sun shines and the rains fall there need be no shortage of wood in the world if we manage the forests well and learn to use the tools of industry for the more complete employment of wood in meeting human needs.

THE AMAZON REGION AND THE PAPER INDUSTRY

A. DE MIRANDA BASTOS

The Amazon basin covers a vast area of some 7 million square kilometres, about half of which lies within the territory of Brazil. Because of its extent and the variations in its climate, it contains a large variety of trees, which have been the object of research for many years. It is only recently, however, that a systematic study has been made of the density of the stands in some areas and of their economic value in terms of area covered, means of transport, composition of the stands and frequency of the various species.

[1] A shortened version of the original paper (ST/ECLA/CONF.3/L.3.15).

The Amazon basin is destined to become a world centre of pulp and paper production. Nevertheless, many of the projects and plans put forward over the last fifty years with a view to industrializing local economic resources, have been doomed to failure. There have been many reasons for such disappointments, including shortage of capital and labour, unhealthy conditions, poor transport and insufficient agricultural production to meet local demand.

These difficulties are in course of being overcome. Towards the end of 1951, the Food and Agriculture Organization of the United Nations appointed a mission which is making field studies. Its findings will be particularly interesting, in view of the information and recommendations contained therein.

In addition, the Superintendencia do Plano de Valorizacão Economica da Amazonia (SPVEA) set up in 1953 to foster the development of agricultural, industrial and mining production in the region, is undertaking development work of a positive nature, for which it has large and ever-increasing economic resources at its disposal. The Federal Territory of Amapá, created in 1943, contains, apart from its fibre resources, rich manganese deposits and a considerable hydro-electric potential, and has helped to develop the Brazilian Amazon region. Studies of forest species have been made in the Territory with a view to exploitation. Experts from FAO and ECLA have concentrated their efforts on the area close to the Paredao waterfalls on the Araguavi river; a hydro-electric plant is planned at these falls, with an initial capacity of 25,000 kilowatts and possibilities of expansion to 100,000 kilowatts. All the conditions are present for converting this zone into a large paper-producing centre. Light-coloured species, with a low density, predominate in the area. It has been estimated that economic exploitation could be based on a minimum of 250 cubic metres per hectare. Again, surveys made in the vicinity of the Vila-Nova river proved that, on the basis only of trees with diameters of more than 30 centimetres, over 240 cubic metres of usable wood per hectare would result; this wood conversely, is dark-coloured and has a high density. This proves that there is an immense variety of species to be found in the region and that, as regards the paper industry, the important thing is to know how to select the area which will meet technical and economic requirements.

POTENTIAL USE OF WOOD FROM THE UPPER PARANA (PARAGUAY) FOR MAKING PULP AND PAPER

E. B. Hamill

The dense sub-tropical forest of the Upper Paraná, in Paraguay, has excellent potentialities for the establishment of a pulp and paper industry. The soil is fertile and the climate is good; large coniferous plantations can be developed; there is a navigable river system; plenty of water is available for pulping operations and as a potential source of hydro-electric power. The Servicio Téchnico Interamericano de Cooperación Agrícola, at the request of the Paraguayan Government, undertook a study which established that the installation of a pulp and paper industry in this area would be a key factor in an integrated forest-utilization programme and in the colonization of the region. The problems to be solved are of an economic rather than of a technical nature.

The upper Paraná forest is some 350 km in length and from 50 to 75 km wide. A section of this area extending some 100 km along the Paraná river and about 30 km wide offers the best prospects. It is crossed by navigable rivers and contains the three most important hydro-electric potentials. There are on an average some thirty different tree species per hectare; *Leguminosae* predominate, over twenty-seven of that family having been identified. Enough varieties of bamboo are found to provide roughly 10 per cent of the fibrous raw material available in the Alto Paraná for paper making. It is estimated that, including all species, this region could supply about 100 cubic metres of usable wood per hectare.

The Régie industrielle de la cellulose coloniale, France, carried out the biometric study of these woods. Biometric study is the mensuration of the fibre lengths and widths, cavity diameters and thickness of walls; and its purpose is to permit a first classification of the woods likely to be used in the manufacture of pulp and paper. Tests were made on eighty-one samples of broad-leaved tropical species and three samples of bamboo. The results obtained are summarized below.

1. *Fibre lengths.* These are short-fibred species. Among those tested, about 60 per cent had fibres less than 1 mm in length and only four exceeded 1.7 mm. Although fibre length is not a decisive factor, it does constitute a drawback when fibres are shorter than 1 mm, that being considered the critical value. It appears, therefore, that twenty-four species out of the eighty-four studied should be eliminated from the standpoint of fibre length alone.

2. *Width of the fibres.* This varies considerably, but is unusually large for tropical species. This results in low felting power and is the principal reason for the low tearing resistance of numerous species.

3. *Cavity diameters.* These are usually low; of the species studied, 71 per cent had fibres with a cavity below 20 microns, and in 25 per cent the value did not even attain 6 microns.

4. *Thickness of walls.* The spread of this characteristic is particularly poor; for 57 per cent of the species the wall thickness is between 8 and 11.9 mm, and for about 90 per cent this value is calculated as between 6 and 15.9 microns.

5. *Coefficient of flexibility.* The figures are quite favourable; about half of the species have good flexibility coefficients, and about a third show particularly satisfactory figures, above 70.

[1] A shortened version of the original paper (ST/ECLA/CONF.3/L.3.16).

6. *Felting quality.* Because of the relatively poor length and relatively good width, felting qualities on the whole have low values. Only 10 per cent of the species studied show favourable results, and the three species of bamboo were among these. The proportion of favourable wood species is thus limited to only 7 per cent. Because of their very weak felting properties, some 62 per cent of the species tested were eliminated as potential paper-making material.

Briefly, then, the species studied may be characterized by their short fibre length, excessive width and slight wall thickness. Paper made from the remaining samples would have reasonably satisfactory tensile and bursting resistance, but insufficient tearing resistance.

Of the eighty-one broad-leaved tropical woods investigated, twenty had properties which would make them satisfactory raw material for making pulp and paper. Of these, the following seventeen were selected, which are found in the Alto Paraná forest in a volume exceeding 1.15 per cent:

Species	*Percentage within the stands*
1. Laurel negro (*Ocotea suaveolens*)	20.75
2. Rabo (*Lonchocarpus leucanthus*)	14.00
3. Laurel ajuy (*Nectandra sanguinea*)	8.92
4. Caabuzu (*Lonchocarpus muhlbergianus*)	5.18
5. Laurel amarillo (*Nectandra falcifolia*)	4.48
6. Grapia (*Apuleia praecox*)	4.40
7. Aguai (*Chrysophyllum maytenoides*)	4.13
8. Loro blanco (*Bastardiopsis densiflora*)	4.07
9. Guayavi (*Patagolula americana*)	3.90
10. María preta (*Diatenopteryx sorbifolia*)	3.86
11. Isapy'y blanco (*Machaerium stipitatum*)	3.09
12. Anchico colorado (*Piptadenia rigida*)	2.45
13. Ivaporoity (*Muyceugenia baporeti*)	1.88
14. Alecrin (*Holocalyx balanse*)	1.68
15. Kancharana (*Gabralea cangerana*)	1.26
16. Koku (*Allophylus edulis*)	1.20
17. Persiguero (*Symplocus pubescens*)	1.18
	86.43

In other words, the seventeen species selected represent over 86 per cent of wood volume in the forest.

Cooking and bleaching tests were made by the laboratories of the Régie industrielle de la cellulose coloniale. The wood was chipped and the chips screened to eliminate pieces below 1 cm x 1 cm. The cooking liquor contained from 2.5 to 3.5 per cent sulphur and from 16 to 21 per cent caustic soda, based on the dry wood weight. A miniature retort of 45-litre capacity was used, having all the features of commercial pulp retorts. The cooks were based on mixtures of woods ranging from those corresponding to the average composition of the forest to the exact opposite. The same method was used with the three bamboo samples. After cooking, the pulp was washed with hot water to prevent reprecipitation of lignin.

When the wood mixture was used in the proportion found in the forest, the results of the bursting, tearing, tensile and folding tests were only slightly better than those obtained when the woods were mixed in the reverse proportion. Operation on an industrial scale would give the same results, even if the mills used only one of the species. The inclusion of bamboo wood in the mixture led to no cooking problems: it did not increase tearing resistance, but bursting and folding resistances improved.

The standard chlorination method of bleaching was followed. In general, the pulps were easy to bleach to 80 per cent G.E. brightness. Bleaching yields were high and the cellulose resisted the treatment well. Bleached pulps present a bursting resistance superior to that of natural pulps, but on the other hand the tensile, tearing and folding resistances undergo a slight decrease.

Conclusions

Despite their heterogeneous nature, the species of the Upper Paraná forest region, mixed in the same proportion as found, will make a homogeneous paper pulp under normal working conditions. No special methods are required. The use of chemicals is relatively low in both cooking liquor and bleaching. The pulp is not suitable for making high-resistance packing paper, since its properties are only average, but by mixing it with 40 to 60 per cent coniferous pulp or pulp made from certain tropical plants, first-quality wrapping papers can be obtained. The pulp is easy to bleach and can be used to make various types of writing paper. Mixed with 20 to 40 per cent of coniferous pulp, it can be used for fine printing papers. It can be blended with mechanical pulp or other low-grade materials to make ordinary writing or printing papers; there seems little likelihood, however, that the pulp could be used alone for making newsprint, in view of its poor resistance characteristics. Tests of the suitability of Upper Paraná species for making purified pulp for chemical use do not entirely rule out this possibility, though they lead to no definite conclusion.

IV. Aspects of pulp and paper manufacture based on other Latin American forest resources

OTHER LATIN AMERICAN FOREST RESOURCES AS SOURCES OF RAW MATERIALS FOR PULP AND PAPER[1]

THE SECRETARIAT

INTRODUCTION

The immensity of Latin America's tropical and subtropical forest resources—some 800 million hectares—tends to overshadow the fact that the region possesses substantial reserves of other forest types: coniferous stands amounting to around 30 million hectares and about 90 million hectares of temperate broadleaved forests. These latter figures are indeed substantial in relation to the region's population. For example, the area of coniferous forest per inhabitant in Latin America is very close to that in Europe; while the area of temperate broadleaved forest per head is several times that in Europe.

This paper gives a short survey of these other resources: natural stands of conifers, natural temperate hardwood forests, and plantations of conifers, tropical and sub-tropical hardwoods, and poplars and willows.

Thereafter some of the more important of these resources are discussed in turn in rather more detail. Here the treatment is uneven, since the amount—and kind—of information available concerning each of these resources differs very much from country to country. Hence the space accorded to any particular topic in this paper is in no way an index of the importance of that particular resource in the region as a whole.

There follows a short discussion of some of the problems involved in exploiting these various resources for pulp and paper, and the paper concludes with one or two general conclusions which may be drawn.

It is regrettable but true that most of the literature on plantations is descriptive, and mainly concerned with the silvicultural aspects of plantations. It has not, for example, been possible to present data which would establish a comparison between the gross costs of making available pulpwood supplies from plantations of various species with the corresponding costs for extracting pulpwood from natural stands. Some information regarding the cost of establishing plantations—notably of insignis pine, parana pine and eucalyptus—has been presented in background papers submitted to this meeting, however, and the salient facts have been set out in appendices attached to this paper.

A SHORT SURVEY

Coniferous forests

Most coniferous species grow naturally in regions enjoying a cool temperate climate. Thus in the northern hemisphere the majority of coniferous forests are found in a broad belt to the south of the treeless tundra region. This also explains the limited occurrence of conifers in Latin America, where the land mass tapers towards the south, scarcely reaching into the temperate zone. Indeed, out of over 925 million hectares of forest in this region, less than 30 million hectares, or some 3 per cent, are composed of coniferous stands; of these not more than 11 million hectares are today being exploited. This does not mean that these forests are of no value to the pulp industry. What can be achieved, even with slender forest resources, has been shown in Japan, where about 8 million hectares of coniferous forests produce, apart from other wood categories, some 5 million m^3 of pulpwood, yielding about 1.2 million tons of pulp—roughly the amount needed to supply current paper and board requirements in Latin America.

The two important families of conifers found in Latin America are araucaria and pine. Neuquén pine (*Araucaria araucana*) is found only in Chile and in the Patagonia region of Argentina, far away from the important paper-consuming centres; though possessing excellent pulping qualities, its use today is confined to local plywood and sawmill industries. Another species of this genus, however, the Paraná or Misiones pine (*Araucaria angustifolia*) is reported to cover some 9 to 10 million hectares in the Brazilian States of Paraná, Santa Catarina and Rio Grande do Sul, the Misiones territory in Argentina and, to a very small extent, the southern mountainous regions of Paraguay.

The other important natural stands of conifers belong to the pine family, and comprise a large variety of species, each adapted to particular soil and climate conditions. A recent investigation, for example, on the pine resources of Guatemala has shown that in that country alone nine different species of pine occur between sea level and an altitude of 4,000 metres, the upper limit of the forest zone. For Latin America as a whole it is estimated that existing pine forests cover some 16.5 million hectares, of which about 7 million hectares are today being utilized. Large stands of natural pine forests are found only in Mexico and in Central America, South America having none of any considerable size.

Temperate broadleaved forests

It is estimated that Latin America has some 90 million hectares of temperate evergreen and deciduous hardwood stands, including high altitude forests in the tropical and sub-tropical zones; this corresponds to about 10 per cent of the region's forested area. This type of forest appears first in the foothills, at 1,500 to 1,800 metres, and continues to the timber line, between 3,000 and 3,700 metres above sea level. Most of these hill forests are situated in

[1] Originally issued as ST/ECLA/CONF.3/L.4.0.

remote regions, along the Andes chain and in Central America, and are not yet accessible; in many cases they are regarded purely as protective crops. Only about 10 million hectares, mainly in Chile and Argentina, are today being utilized, yielding some valuable hardwoods; so far felling has been carried out mostly for local use, and exploitation on an industrial scale is rare.

Plantations

Apart from natural pine and araucaria stands, plantations of *conifers* represent an important prospective source of pulpwood in Latin America. Theoretically, enough pulpwood (about 160 to 180 million cubic metres) to produce all the world's pulp could be obtained in perpetuity from 15-20 million hectares of fast-growing coniferous species; and to give this pulpwood yield as part of a balanced supply of fuelwood, sawlogs, pulpwood and other industrial wood, 100 million hectares would suffice.

Systematic research and experimental selection have shown that there are many quick-growing species capable of producing pulpwood in a very short time. Rotations of fifteen to thirty years can be achieved, with thinnings profitably available for pulpwood after six to ten years. Sometimes the growth of individual species in plantations shows a spectacular increase compared with that achieved in their normal habitat. Plantations provide, quickly and in a concentrated area, large quantities of homogeneous material. Costs may be lower than for roundwood drawn from natural stands, while the standardized material leads to economies in handling and processing.

Insignis pine (*Pinus radiata*), which has been planted on a large scale in Chile since 1935, now covers 200,000 hectares, mainly concentrated in the Concepción region. A conservative estimate of average annual growth is 20 cubic metres per hectare, though growth up to 30 cubic metres and more is not uncommon. In ten years' time, it is reckoned, the volume of wood available annually will have reached 4 million cubic metres.

Paraná pine has been planted since 1944 in the five most southerly States of Brazil. In spite of many difficulties some 2,500 hectares have been established and valuable experience gained. This work was carried out by the Instituto Nacional do Pinho. Apart from this, several enterprising private firms have also been planting this species; though set-backs have been experienced, it is reported that these firms have succeeded in establishing some 11,500 hectares.

As well as plantations of coniferous species, there are quick-growing sub-tropical *broadleaved species* also capable of quickly providing abundant material for the pulp industry. In Brazil, for example, some 144 species of eucalypts have been tried, of which six have been planted on a large scale. Special success has attended *E. saligna* and *E. grandis*, both of which are suitable for pulp and paper. In the State of São Paulo alone, by 1941, a total of 1,000 million trees—some 400,000 hectares—had been planted. Eucalypts have also been established in other Latin American countries; in Argentina, where a million trees were planted in 1953 alone; in Cuba, in Uruguay and other countries.

Poplars and willows are also an important potential source of pulping material. The most extensive plantings in Latin America are in the Paraná delta area of Argentina, where, of a total area of a million hectares, 100,000 have already been afforested. The best stands can show an average annual growth of 20-30 cubic metres per hectare during the first ten to twelve years.

This rapid survey has mentioned some of the more important forest resources in Latin America, apart from the tropical and sub-tropical hardwoods, which are capable of contributing towards the future expansion of the region's pulp and paper industry. In the sections which follow certain of these will be discussed in somewhat greater detail.

Chile's insignis pine

Insignis pine is native to a very small area—about 30 square miles, in the Monterey country of California. In its native habitat it was never of any economic importance. Today there are well over half a million hectares of densely stocked plantations of this species in the southern hemisphere. Over half these are in New Zealand, and some 250,000 are in Chile, in roughly the same latitude as the New Zealand plantations.

Large scale planting of this species has gone on in Chile since 1935, mainly in the seven provinces round the city of Concepción and its adjoining seaport of Talcahuano, close to the steel centre of Huachipato, some 550 km south of Santiago.

The percentage age composition of some 173,000 hectares of these plantations is as follows:[2]

Age in years	*Percentage of total area*
1-3	20
4-6	27
7-9	23
10-12	16
13-15	9
16-18	3
19 up	2

(in 1953)

Thus only 14 per cent of the area consisted of trees over twelve years old, while trees of six years and under accounted for almost half the total area.

Some 85 per cent of the plantations are privately owned. Indeed the role and achievement of private investment, especially by numerous people of moderate means, are a very striking feature of this pine planting in Chile. Without foreign loans or investment the Chilean public has provided funds with which to plant some 180,000 hectares. Various enterprising private companies have played a great part in this campaign, and the Forest Department of the Government of Chile has helped greatly by providing land owners with good supplies of transplant seedlings at a reasonable price. Finally, the basic law of no taxation up to the age of thirty years for planted forest land has been a very great asset.

Growth is extremely rapid, figures of 30 and more cubic metres per hectare being by no means uncommon. Average growth over the plantations as a whole may be put conservatively at 20 cubic metres per hectare.

The total annual production forthcoming from these plantations is estimated by the Corporación de Fomento de la Producción as follows:

[2] These and subsequent data in this section are taken from paper 4.1: *Pulpwood from coniferous plantations*, by the Compañía Manufacturera de Papeles y Cartones, S.A. (Chile). The paper also draws on the text of a lecture on *Pino Insigne* given at the University of Concepción in July 1954 by C. W. Scott, Professor of Timber Utilization, University of Chile, Santiago.

Year	Total volume of wood available (thousand cubic metres)
1957	400
1958	658
1959	917
1960	1,175
1961	2,068
1962	2,961
1963	3,854
1964	3,993
1965	4,132
1966	4,271

These are indeed striking figures. Clearly there will be an ample supply for both pulping and sawmilling, and the desirability of developing integrated utilization needs no underlining. Moreover, this production can be maintained on a sustained yield basis, since the species is very easy to plant and tend in this zone, and can in fact be naturally regenerated with ease. One large pioneer planting company is already renewing all its stands naturally, without artificial planting. Where necessary to improve soil fertility, leguminous soil improvers can be grown.

There are other factors too, which make these stands of insignis pine exceptionally promising for pulp and paper. The region is actually or potentially fairly accessible by road and rail to the seaport of Talcahuano. Ample hydroelectric power is available (at Chilean pesos 1.7 per kWh in 1954).[3] Water supplies can be organized, and effluents can be disposed of in the sea. The basic chemicals are available in Chile's northern provinces (around Antofagasta) or in the south.

Distances, as the crow flies, from the plantations to the seaport range from 15 km to 160 km for the outlying plantations near Constitución, averaging about 80 km. In many cases, however, these distances would have to be doubled to allow for the actual routes the truck roads would have to take. The terrain is undulating and not especially difficult. Local rock and gravel is lacking in some areas, while the rather wide rivers are in flood at certain seasons and dry at others; hence they are not good perennial floating streams.

At present the road system is very limited and poor; owners of smaller plantations tend to rely on the State to provide roads, and the value of land for planting is said to rise ten-fold if a new forest road is made in the vicinity. Nevertheless, compared with the Andean hardwood forests, and with many other forests in Latin America, these plantations may be said to be readily accessible.

As a matter of fact, the size of the crop in sight from these plantations presents some problems. As long ago as 1946, for example, it was estimated[4] that the future supply of insignis pine from the Chilean plantations would exceed foreseeable markets by about one-third. True, many changes have taken place since that date, and in some respects those estimates were pessimistic. For example, it was assumed that Chile would supply only her own needs of paper (estimated to treble) and that there would be no exports of pulp and paper. Already plans have been approved for two mills and construction has already begun. They will produce 50,000 tons of sulphate pulp, 44,000 tons of newsprint, 6,000 tons of kraft paper and 4,500 tons of board—a production programme more than adequate to meet Chile's current needs in some respects, though of course requirements will have risen by the time the mills are established and in full production. It is clear that the possibility of a pulp and paper export industry based on these plantations is by no means ruled out; indeed negotiations for the establishment of a dissolving pulp industry, primarily for export, are said to be already proceeding. Though geographically badly situated for competing in many of the world's pulp and paper markets, markets within the region are rapidly expanding, often more rapidly than the rate at which indigenous production is rising; many countries will be glad to secure their import needs from a source which does not require hard currency expenditure. There should be a considerable area over which Chilean products can successfully compete. It must be borne in mind that the amount of pulpwood becoming available is likely to lower its price relative to other forms in which the pine can be used, e.g., lumber; this effect will be aggravated if owners clear fell stands at an early age, say fifteen years, as they are inclined to do.

To sum up: Chile's resources of insignis pine are capable of satisfying national needs of pulp and paper for many years to come. They represent one of the region's most important and valuable resources, and may be able to make a useful contribution towards satisfying growing needs elsewhere in the region.

Paraná pine

Paraná pine *(Araucaria angustifolia)* is the most important conifer in Latin America at present, and indeed its chief export timber. The main stands are in Brazil, particularly in the State of Paraná, with smaller but substantial amounts in Santa Catarina and Rio Grande do Sul, and in Argentina in the territory of Misiones.[5]

The Paraná pine grows to considerable heights, very often above 40 metres, and has an average trunk diameter of one metre. Classified as a white softwood, it has a specific gravity of 0.50 to 0.55; long-fibred (fibre length averages 3.5 mm), it has very good pulping characteristics and is one of the most important species pulped in both Brazil and Argentina.

Except for the more accessible stands of this species, as that in Misiones, Argentina, and some of the lesser stands in Brazil, a large proportion of the Paraná pine is handicapped at present by its distance from the sea and from consuming centres, by the consequent cost of transportation from the areas where it grows, and, in the northern part of its range, by a lack of natural regeneration on which sustained yield might be based. This lack of regeneration may be due to the relatively dry winter, which the seedlings do not easily survive, to the attractiveness of the edible seeds to domestic and wild animals, to fire and other such factors. Further south, with a wetter winter, natural regeneration is much better. If the natural stands on non-agricultural land in the south could be conserved until rising population, improving communications and increasing consumption of paper modify the economic conditions of exploitation, there is no doubt that these forests would be most valuable both as a source of lumber and plywood and of long-fibred material for pulp, paper and fibreboard, and thus

[3] About US$0.006 as of October 1954.

[4] Haig report of 1946, *Forest Resources of Chile as a Basis for Industrial Expansion* (Forest Service, U.S. Department of Agriculture, in co-operation with the Corporación de Fomento de la Producción).

[5] See paper 4.6, *Forestry Measures undertaken by the Argentine Government to increase Pulp and Paper Production*, by the Administración Nacional de Bosques, Ministerio de Agricultura y Ganadería de la Nación (Argentina).

suitable for integrated development. It should be mentioned that the life of these stands has been estimated at no more than forty years if the present felling, mainly or solely for lumber, continues without adequate regeneration of the forests.

In addition to the natural stands of this species, artificial stands are steadily being created. In Brazil both the Instituto Nacional do Pinho and a number of enterprising private firms have been planting this species, and to date, in spite of difficulties encountered, some 14,000 hectares have been successfully established. In Argentina, too, planting is proceeding, government-assisted, in the Misiones territory where the species is native; the aim is to exploit the existing natural stands, primarily for pulp, while reafforesting with the same species at a rate appropriate to ensure continuous yield.

The difficulties in establishing plantations are largely those which hinder natural regeneration. Moreover, as a seedling, the Paraná pine has a long tap root which makes handling in the nursery difficult. However, similar difficulties were encountered in Australia with the related *Araucaria cunninghamii*, or "hoop pine", and successfully overcome; the Australian experience will no doubt be of value in Latin America.

A valuable report to the Government of Brazil on Paraná pine[6] recommended practical steps for accelerating and cheapening the planting of this tree. The report dealt also with the question of planting on the treeless prairie areas, or *campo limpo,* of Brazil as against in the existing habitat, after natural stands have been cut down. Though planting on the *campo limpo* was easier, growth was variable and poor, so that it proved more expensive in the end. It does not seem likely that this species can be successfully established outside the area to which it is native.

The eucalypts

The eucalypts[7] are native to Australia, where over 400 species are known. Experiments to ascertain their suitability for pulp and paper manufacture began there as early as 1920, but it was not until 1938 that the first commercial production of eucalypt pulp began. Today seventeen species are used for pulping in different parts of the Commonwealth; others are suitable for pulping, but economic factors—inaccessibility, scattered occurrence, distance from pulp mills or from markets—preclude their use.

The introduction of the eucalypts on a large scale into Brazil is credited to the pioneer work of the late Sr. Edmundo Navarro de Andrade, one-time Chief of the Forestry Service of the Paulista Railway. Early in this century, various specimens of eucalypts were to be found in Brazil, mainly in parks and gardens. As a result of experiments carried out by Sr. Andrade on many indigenous and foreign forest species, the Company's directors decided, on the basis of the excellent results achieved with eucalypts, to go ahead with these species as the basis for their forest culture; 144 species have been tried, and six planted on a large scale. To date the Paulista railway records having planted 40 million trees.

[6] Report by Mr. L. J. Rogers, of Australia, FAO expert who visited Brazil at the request of the Brazilian Government in 1953.

[7] See papers 4.4, *The cultivation of eucalypts in the State of São Paulo,* by Armando Navarro Sampaio, and 4.9, *Pulp and paper making from Eucalypts in Australia,* by R. B. Jeffreys.

The example of the Paulista railway was soon followed by many private planters in this wood-hungry area, and today it is estimated that there are 1,000 million eucalypts in the State of São Paulo alone—representing, at 2 m x 2 m, about 400,000 hectares. The wood is mainly sold on the open market for fuel and for constructional and other purposes. Several species, including *E. saligna* and *E. grandis,* both of which have met with particular success, are suitable for pulping. Today three mills in the State are pulping eucalypts and three others are contemplating doing so. Though not suitable for all types of paper, its very rapid rate of growth assures it an important part in the future development of the pulp industry; in general it requires to be mixed with long-fibred pulps.

Eucalypts have also been introduced into many other Latin American countries, notably Argentina and Mexico. The versatility of the eucalypt family means that there are species with very diverse qualities, adapted to a large variety of soils and climates. It is conceivable that, in the future, quite a number of countries in the region will find that plantations of selected eucalypt species may be able to make a significant contribution towards the manufacture of short-fibred pulp.

Central American pines

Another major asset of Latin America in natural conifers is the great area of various species of *Pinus* in Mexico and Central America, particularly Honduras and Nicaragua. Much of this pine is similar to the slash pine *(P. elliottii,* formerly *caribaea)* of the south-east of the United States, i.e., one of the four species sold as "southern yellow pine" in that country and as "pitch pine" in Great Britain; but there are also lighter and more easily worked and nailed pines, such as the *P. patula* which is so successful and valuable as a planted exotic in South Africa. All these pines are suitable for pulp, in addition to their value as lumber.

However, rather as in the case of much of the Paraná pine *(Araucaria angustifolia)* of Brazil, the true pines (*Pinus* spp.) of Mexico and Central America are handicapped at present by the mountainous or undeveloped terrain on which many of them grow. In Mexico the main stands are from 1,200 to 3,300 metres (3,900 to 10,700 ft.) above sea level; and the more accessible are already under the pressure of fellings for lumber. Some of the Central American pines are at a lower altitude but in areas still very undeveloped; and they are ravaged by fire, shifting cultivation and uncontrolled felling for lumber and fuel. On the other hand, they require only protection from fire, grazing and uncontrolled felling, to enable them to regenerate naturally and profusely, in many areas. If this protection could be given to them they would be undoubtedly at some future date, perhaps sooner than expected, a great asset to the countries concerned for integrated use as a source of lumber, pulp and paper and fibreboard. Similarly remote stands of conifers in other parts of the northern hemisphere have become or are becoming economic sources of pulp.[8]

In due course this should be economically possible in Mexico and Central America, if in the interval the pine stands are not destroyed.

[8] An example of this is the recent pulp development in such central States of the United States as Arizona and Idaho, remote from the sea and the main markets; see the article on this subject in the *Journal of Forestry,* U.S.A., for August 1954.

Experience in Mexico and elsewhere suggests that many of these pines could be planted with great advantage in the countries to which they are native, on accessible land unsuitable for agriculture.

Poplar and poplar-willow

Latin America's largest consumer of paper—and second largest producer—is Argentina. Yet Argentina is one of the countries in the region least well endowed with fibrous resources for pulp and paper manufacture. The Paraná pine of the Misiones territory has already been mentioned; her other main resource lies in the extensive plantations of willow and hybrid poplar-willow in the Paraná Delta.[9]

In this area some 700,000 hectares are available for planting; the area is close to the federal capital, one of the main consuming centres, and there are excellent river facilities for transporting pulpwood, other raw materials and finished products. Already some 30,000 tons of pulp are being made from this willow, and output is to be doubled. Indeed Argentina will look entirely to plantations in this area for her future supplies of mechanical pulp. Though the poplar-willow *(Salix alba var. coerulea)* is of particular significance, a number of other species are currently being pulped. Moreover, extensive trials are proceeding with a view to determining which species and varieties offer the best prospects for further reafforestation. For example, the behaviour of 500 strains of salicaceae from all parts of the world is being studied in experimental plots. Of the *Populus* spp., experience suggests that attention should be concentrated on EuroAmericana poplars 1-154 and 1-214.

Only afforestation on a large scale can solve the pulp industry's raw material problem in Argentina. The Government encourages and facilitates private planting in a variety of ways. Though the case of the willows and poplar-willows in the Paraná Delta is perhaps unique in Latin America, they are clearly destined to become the basis of one of the most important pulp and paper centres in the region.

Temperate hardwoods

The largest and best natural stands of temperate hardwoods in Latin America are in the Chilean Andes, with some outliers of much smaller extent in the coastal *cordillera.* Two species, an Antarctic beech, coigüe, and a wood of moderate weight, tepa *(Laurelia serrata),* make up about half of the crop. There are virtually no plantations of any of these hardwoods. The best and most accessible of the forests are being heavily overcut for lumber alone, and often only that of the most valuable species. It is extremely desirable to find an outlet for the less valuable species and the waste wood cut in the present lumbering. The best hope lies in integrated use, including pulping if that is economically possible. These temperate hardwood stands are on much steeper and more remote ground than the Chilean plantations of *pino insigne,* and their wood is shorter-fibred than that of the conifers. As raw material for pulping the hardwoods will find it difficult to compete with the *pino insigne* in Chile.

The temperate hardwood stands of Mexico and Central America, of oak *(Quercus)* and other species, suffer even more than the hardwoods of Chile from the disadvantages just described; they are as remote as the pines of those areas, or more so, and less attractive for pulp.

For these reasons Latin America's temperate hardwood stands cannot be considered a promising source of supply for pulp and paper.

Plantation problems

If we leave out of account the tropical and sub-tropical hardwoods, it is evident that some of the more promising of Latin America's forest resources are plantation forests rather than natural stands. This is partly because some of the natural stands are remote and difficult to exploit, partly because wood scarcity in particular areas in the past has encouraged large-scale planting which is today bearing fruit. Thus in a number of countries existing plantations offer a better prospect for pulp and paper development than do the natural forests; in others, only plantations can solve the problem of stringent fibrous material supply. There is often a tendency to look upon plantations as a better solution to the problem of ensuring continuous, uniform, high yield than overcoming the complexities of exploiting natural forests. The reasons are not far to seek. Plantations can provide, in a concentrated area, large amounts of material on a sustained yield basis, homogeneous in its pulping qualities and uniform in size, thus facilitating handling, preparation and processing.

These are real advantages; but at the same time there are dangers attached to a policy of large-scale planting. Clearly, plantations should not compete with agriculture. This is especially important in densely populated areas, where plantations should be limited to soil unsuitable for agricultural crops or livestock. Many of the existing artificial forests are composed of only one species and it is noted that pure stands are more susceptible to disease than mixed forests, pure even-aged stands being the most susceptible of all. In the long run monoculture can produce adverse soil conditions. Moreover exotic species are often more liable to disease in plantations than they are in their natural habitat. With suitable precautions, however, it is believed the risks can be spread and reduced to an acceptable level. After all, natural forests are often pure and are often devastated by disease; a notable example is the chestnut *(Castanea)* blight in the United States. Agriculture does not shrink from monoculture but takes suitable steps to practise it safely.

A new article by Professor Boyce[10] gives a good up-to-date account of the damage caused in the past by fungal and insect disease in forests; it mentions the relative freedom from disease, up to the present, of pure crops of *Pinus radiata (pino insigne)* in New Zealand, Chile, Australia and South Africa, but cautions against complacency. The relatively short rotation or life necessary with the fast-growing trees, to get a crop of pulp or saw timber, reduces the financial risk; but South Africa has shown very well how the risk can be much reduced, by growing a number of species of pine, in pure blocks limited as to size and total percentage of the crop.

[9] See papers 4.3, *Pulpwood from salicaceous species of the Paraná Delta,* by Enrique G. Valente, and 4.8, *Production of chemical pulp and groundwood from willow, poplar and poplar-willow,* by Celulosa Argentina, S.A. Planting in the Delta is not limited to salicaceous species; see paper 4.5, *Pulpwood from plantations of exotic conifers in the Paraná Delta,* by Celulosa Argentina, S.A.

[10] Of Yale University. See *Unasylva,* Vol. 8, No. 1, March 1954.

Thus she has planted some eight species of pine but no one species is more than 26 per cent of the total, whilst insignis pine is only 10 per cent. Yet a very high growth rate is retained, from *Pinus pinaster (maritima)* (of selected race), *caribaea, longifolia, patula, taeda,* etc., in addition to *radiata (insignis).*

Fire protection has been especially well studied and organized in North America, Australia and New Zealand. Their experience, and that of other countries, is available in the abundant literature on the subject. In many parts of Latin America effective fire protection of plantations, especially the inflammable conifers, is well understood and practised.

Soil exhaustion may be specially important with eucalypts and the use of nitrogen-fixing *Leguminosae* in mixture may be necessary. Germany has classic experience of the penalties of monoculture of spruce *(Picea abies* syn. *excelsa),* clear felled on short rotations, especially or perhaps mainly in soils or sites unsuitable for the species, for climatic or other reasons. Clearly, species should not be planted where they do not thrive well naturally; and their effect on the soil, if grown pure on a short rotation, should be studied, as in agriculture.

Careful analysis of the selected species and considerable research should precede any large-scale planting programme, which should also provide for the detection and control of disease and insect epidemics.

Finally, it may be mentioned that there is so much waste land available for afforestation in Latin America that there is no need to use agricultural land for that purpose, or to fell hardwoods of any value in order to plant conifers. Indeed there are vast areas in the region in dire need of afforestation for protective reasons only, without reference to its potential value or the former crop.

According to FAO's 1953 World Forest Inventory, about 200,000 hectares were afforested in Latin America during the quinquennium 1947-1952. Most of these plantings took place in Argentina, Brazil, Chile and Uruguay. The same source indicates that present afforestation plans for the period 1953-1957 in the region amount, in aggregate, to over 300,000 hectares.

Conclusions

None of the Latin American countries is today self-sufficient in pulp and paper. Each is conscious of the fact that undue dependence on imports must inevitably carry with it the danger of frustrated consumption. Where domestic markets are so small that there is no possibility of establishing an indigenous industry this situation must be accepted—for the time being. But in all those countries where the domestic market is large enough to support a native industry of economic size, a pulp and paper problem may be said to exist, and a compulsion to solve that problem is strongly felt. In seeking a solution, each country will look first and foremost to the fibrous resources it at present possesses; if it is deficient in suitable fibres, it will contemplate the creation of appropriate resources. This urge is by no means an expression of far-reaching autarchic policies; it reflects a natural desire to achieve some measure of security in the supply of a vital raw material.

It follows therefore that the solution adopted will differ from country to country. It follows, too, that any attempt to range the several resources of the region in any order of preference, be it on the basis of extent, suitability or economic prospects, would be an idle exercise—even were any such ranking possible.

Each of the forest resources discussed in this paper will have its part to play in the development of the region's pulp and paper production. Some may well come to have a more than local significance. If they do, it will be because their products have successfully measured themselves against their rivals, in quality and price, on neighbouring markets; it will not be because they have been singled out for special development in some regional plan. While every country will endeavour to build up an indigenous industry on a scale sufficient to ensure against future paper famine, no country will pursue the aim of complete self-sufficiency regardless of the price it has to pay. Thus the test of the market will, in the last analysis, determine whether, when and where specialization within the region will develop.

For these reasons, no attempt has been made in this paper to measure Chilean insignis pine against the poplar-willows of the Paraná Delta, eucalypts in Brazil against Central American pine, conifers in natural stands against plantations. The paper has simply sought to establish that the Latin American region possesses, apart from its immense reserves of tropical and sub-tropical broadleaved forests, a very considerable wealth of other forest resources, in great variety, all of which are capable of making a substantial contribution to the satisfaction of the region's future needs of pulp and paper.

Appendix I

Some examples of plantation costs

The following notes exemplify planting costs in selected plantation schemes currently under way in certain Latin American countries. They are not comparable, not merely because they are compiled in different ways, but also because they do not include the same items. The São Paulo eucalypts example, for instance, includes land rent; the others do not, although a footnote gives some information about land values in the case of Chilean insignis pine. The Chile example covers only establishment costs in the first two years; the others cover costs over the rotation period. Moreover, the others include interest charges, the Chile example does not; interest charges would probably have to be reckoned over a twelve to fifteen year period, i.e., a longer rotation than for either São Paulo eucalypts or Paraná Delta poplar and poplar-willow.

INSIGNIS PINE IN CHILE

(*Chilean pesos*[a] *per hectare*)

Species: Pinus insignis Syn P. radiata
2,500 trees per ha.; spacing 2 x 2 metres.

Operation	Lower estimate[b]	Higher estimate[b]
1. Clearing ground in preparation for planting	1,260	7,000 [c]
2. Marking out tree positions	200	
3. Holing for seedlings	500	
4. Planting	400	3,264 (items 2–6)
5. Holing and planting for 30 per cent replacements	255	
6. Seedlings (2-year transplants)	975	
7. Weeding	500	2,000
8. Fencing	1,800	1,800
9. Taxation	1,360	3,000 (items 9–10)
10. Indirect charges including overheads	1,360	
TOTAL	8,610	19,564

Average: Approximately Chilean pesos 14,000 per ha.

[a] At the time these calculations were made (September 1954) the parity rate or equivalent purchasing power could be reckoned at the basis of Chilean pesos 276 = US$1.00.

[b] As reported to the FAO Forestry Mission in Chile. The estimates shown include costs to the end of the second year but exclude the cost of the land. In the Concepción zone this cost averaged about Ch.$7,000 per ha. in 1954, for reasonably good non-agricultural land suitable for pine, and ranged from some Ch.$3,000 for poor and remote land to some Ch.$15,000 per ha. for good and very accessible land, near roads or railways.

[c] Includes ploughing.

EUCALYPTUS IN THE STATE OF SÃO PAULO (BRAZIL)

(*Brazilian cruzeiros*[a] *per hectare*)

Species: Eucalyptus var. Growing period: 7 years.
2,500 trees per ha.; spacing 2 x 2 metres.

Operation	Case I [b]	Case II [c]	Case III [d]
1. Clearing and cleaning	1,395	2,500	2,500
2. Pest extermination (mainly sauva ant)	30	30	30
3. Ploughing	460	612	—
4. Harrowing	50	170	—
5. Squaring and holing	90	110	2,750
6. Seedlings[e] (nurseries)	1,125	1,125	1,125
7. Planting	270	270	270
8. Cultivation and cleaning[f]	1,680	2,520	6,000
9. Inspection and pest control	2,500	2,500	2,500
Total operating expenses	7,600	9,837	15,175
Rent of land[g]	1,120	1,120	1,120
Interest on capital investment[h]	4,460	5,753	8,906
TOTAL PLANTATION COST/HECTARE AT THE END OF 7 YEARS	13,180	16,710	25,201

[a] At the time these calculations were made (May 1954) the parity rate or equivalent purchasing power could be reached on the basis of Brazilian cruzeiros 32 = US$1.00.

[b] Case I: with mechanized equipment on flat land.

[c] Case II: without mechanized equipment on flat land.

[d] Case III: without mechanized equipment on inclined land where ploughing is not possible.

[e] Includes seed cost, sowing, transploughing, tending and transportation of seedlings to plantation site.

[f] Six cleanings per year during first two years.

[g] 8 per cent per annum on a value of Cr.$2000/ha. over 7 years.

[h] 8 per cent per annum over a period of 6 years.

PARANÁ PINE AND POPLAR-WILLOW IN ARGENTINA

(*Argentine pesos*[a] *per hectare*)

(1) *Misiones*

Species: Paraná pine (*Araucaria angustifolia*). Growing period: 15 years.
1,600 trees per ha.; spacing 2 x 3 metres.

First year:	
Clearing and soil preparation	820.—
Marking	45.—
Extermination of ants	360.—
Seeds, 55 kg/ha. at 12 Argentine pesos per kg.	660.—
Holes and sowing	260.—
4 harrowings	900.—
Miscellaneous expenses, care and supervision of the work	140.—
TOTAL	3,185.—
Second year:	
Replacement about 30 per cent, 500 plants at 0.40 Argentine cents each	200.—
Holes	150.—
Planting about 500 plants at 0.40 Argentine cents each	200.—
3 harrowings	480.—
Extermination of ants	300.—
Miscellaneous expenses, care and supervision of the work	100.—
TOTAL	1,430.—
Third year:	
Replacement about 10 per cent, about 166 plants	66.40
Holes	49.80
Planting of about 166 plants at 0.40 Argentine cents each	66.40
3 harrowings	420.—
Extermination of ants	250.—
Miscellaneous expenses, care and supervision of the work	80.—
TOTAL	932.60
Fourth year:	
Miscellaneous work	760.—
From the fifth to the fifteenth year:	
Clearing of firebreak roads, fire insurance, about 400 Argentine pesos per hectare per annum	4,400.—
TOTAL 1st to 15th year	10,707.60
With adequare capital and on the basis of 5 per cent interest and a 15-year growing season, the cost of planting per hectare will be	18,500.—
Return per hectare, estimated on the basis of 300 cubic metres per hectare and a value of 150 Argentine pesos per cubic metre of unfelled wood	45,000.—
Net profit per hectare	26,500.—

(2) *Paraná Delta*

Species: Poplar-willow (*Salix alba var. coerulea*). Growing period: 8 years.
1,600 trees per ha.; spacing 2 x 3 metres.

First year:	
Drainage	1,000.—
Clearing, tilling of the soil	500.—
Cuttings	250.—
Planting	200.—
3 weedings using a scythe between the trees and a tractor between rows	500.—
Rodent control	100.—
Miscellaneous expenses, supervision	50.—
TOTAL	2,600.—
Second year:	
Replacement	100.—
Weeding	500.—
Ditch cleaning	100.—
Miscellaneous expenses, supervision	50.—
TOTAL	750.—
Third year:	
Weeding	400.—
Ditch cleaning	100.—
Miscellaneous expenses, supervision	100.—
TOTAL	600.—

From the fourth to the eighth year:	
Miscellaneous expenses, about 100 Argentine pesos per hectare	500.—
TOTAL, 1st–8th year	4,450.—
With adequate capital and on the basis of 5 per cent interest and a growing season of eight years, the cost of plantation per hectare after eight years	6,228.—
Total return per hectare, on the basis of 7,000 linear metres of saw timber and 4,000 metres of small dimension stock—about 170 cubic metres in total [b]	16,000.—
Profit per hectare, approximately	9,772.—

Species: Poplar. Growing period: 8 years.

First year:	
Drainage	800.—
Clearing, tilling of the soil	500.—
Cuttings	250.—
Planting	100.—
3 weedings, using a scythe between trees and a tractor between rows	500.—
Rodent control	100.—
Miscellaneous expenses	50.—
TOTAL	2,300.—
Second year:	
Replacement	100.—
Weeding	500.—
Ditch cleaning	100.—
Miscellaneous expenses	50.—
TOTAL	750.—
Third year:	
Weeding	400.—
Ditch cleaning	100.—
Miscellaneous expenses	100.—
TOTAL	600.—
From the fourth to the eighth year:	
Miscellaneous expenses, estimate (yearly)	100.—
Total fourth to eighth year	500.—
TOTAL, 1st–8th year	4,150.—
With adequate capital and on the basis of 5 per cent interest and an eight-year growing season, plantation expenses after eight years, per hectare, amount to	6,142.—
Total return per hectare, on the basis of 8,000 linear metres of saw timber wood and 4,000 metres of small dimension stock [c]	35,000.—
Less	6,142.—
	28,858.—
Exploitation and transport expenses	6,000.—
Profit per hectare, estimate	22,858.—

[a] At the time these calculations were made (May 1954) the parity rate or equivalent purchasing power could be reckoned on the basis of Argentine pesos 11 = US$1.00.

[b] One linear metre of unfelled willow saw timber (over 3½ in.) is worth up to two Argentine pesos and one metre of small dimension stock, up to 0.40 Argentine cents (May 1954); 400 Argentine pesos need to be added for posts, stakes and fuelwood.

[c] The poplar is marked in logs two metres long, and fetches 8.25 pesos on the average market (May 1954) on the basis of 10.50 pesos per linear metre of roundwood.

MEXICAN EXPERIENCE WITH CONIFEROUS PLANTATIONS FOR PULP AND PAPER[1]

HANS LENZ

A primitive kind of paper was manufactured by the natives of some regions of Mexico even before the Spanish Conquest. It was used in their religious ceremonies, as garments, and for the manufacture of books and manuscripts.

The pre-Cortez manufacturing process is still found in isolated regions, but the kind of paper produced is used only for certain rites. It is made from the American agave and other species.

After the Spanish Conquest only imported paper was used for printing, as local manufacture was banned in order to give Spain the monopoly of all supplies to her overseas provinces, and it was only after the achievement of independence that the first paper mill was set up. Towards the end of the 19th century a start was made with the manufacturing of sulphite pulp, while the establishment of the first groundwood mills made it possible to use locally produced mechanical pulp for the first time. Since paper output was low, for many years no difficulty was experienced in obtaining raw material supplies. Then, as now, oyamel wood *(Abies religiosa)* was used for the manufacture of sulphite and mechanical pulp.

As consumption rose, material supplies became scarce. The problem became more acute during the First World War when pulp imports had to be restricted. There was a tendency to overestimate the stands of oyamel so that at first the paper industry showed little or no concern in the conservation or artificial reafforestation of this conifer. Systematic reafforestation practices are very recent in Mexico, and achievements to date are merely on a local scale.

It was the paper makers who were the originators of industrial plantations. One of the best known is the privately-owned property of La Venta located 24 km from Mexico City, covering an area of 400 hectares at an altitude of 2,700 metres, with an average rainfall of 1,200 mm.

The soil at La Venta is a clayey mould. Reafforestation began in 1917, and has continued ever since. La Venta has been exploited continuously for more than thirty years. During that period, thanks to sound management, its output capacity has increased five-fold, stocks are normal and a steady future increase may be expected.

Originally there was no tree nursery, so reafforestation began with the planting of seedlings which had appeared spontaneously near the place to be reafforested. When the nursery was first established in 1920 the trees were planted in metal containers; later waxed paper cylinders were used, and finally tarred brown paper cylinders. These methods proved satisfactory, but when the need arose to increase the plantations and extend them to other areas, it was found that this process was slow and costly; reafforestation with root stock was therefore attempted. Very satisfactory results were obtained with pine, but not with oyamel and other species, which yielded higher percentage failures. However, even-

[1] A shortened version of the original paper, ST/ECLA/CONF.3/L.4.2.

tually this practice replaced all others. Eighty per cent of the pine trees survive, but the percentage of survival of oyamels is not so satisfactory, and the problem of losses of this species has still to be solved. Bare root stock planting is performed by hand; manual labour is cheap, and local conditions prohibit the use of machinery successfully employed elsewhere.

Of the 400 hectares at La Venta, 220 are being exploited; the rest consists of buffer areas or reafforestation areas not yet ready for exploitation. Of the 220 hectares being worked, about 70 per cent is made up of artificial plantations and the rest is composed of an almost pure natural oyamel stand which was conserved from the outset.

Although the species are mixed in the artificially reafforested woodland, for forest management purposes it is reckoned that pine covers 170 hectares and oyamel 50 hectares.

A minimum felling diameter of 35 cm was established on the basis of a 40-year rotation. In fact, many trees reach this diameter in thirty years; annual average increases of more than 1 cm in diameter have been obtained and in some years maximum increases of 2 cm.

Because the forest is in process of formation, a very conservative exploitation policy is practised. Fellings are limited to 35 per cent of growth in the case of pine and 56 per cent in the case of oyamel; the higher figure for oyamel is a consequence of the many mature large-diameter specimens contained in the original forest.

The case of La Venta is not unique. There is another private forest, called Zacayucan, situated near the now inactive volcano, El Xitle, which corroborates the experience gained at La Venta. It is a tract of about 400 hectares located in the neighbourhood of the urban area of Mexico City with an average altitude of 2,350 metres; the utilizable area is limited to about 150 hectares.

The topsoil is composed of a deep layer of volcanic earth. The first attempts to plant trees on this inhospitable soil were made in 1937. Since then innumerable difficulties have been encountered, but extremely valuable experience has been gained. The objectives pursued at Zacayucan are essentially experimental rather than commercial; for the industrial concern which has undertaken the work the volume of wood which can be extracted is negligible.

An important part of the work done at La Venta and Zacayucan is in connexion with seed. Modern equipment was recently installed at La Venta for the extraction, cleaning and treatment of seed. There are machines to dry the cones, to remove, clean and separate the seeds, which afterwards undergo a disinfection process. Necessary supplies will thus be available in future, even in periods of shortage, since crops from abundant years will be kept in a specially installed refrigeration chamber.

The pulp and paper industry in Mexico has never absorbed more than 6 to 8 per cent of the wood extracted from domestic forests. Nevertheless the supply of wood products is an acute problem and one which it is hoped will be solved through the development of sound forest management and extensive reafforestation.

PULPWOOD FROM SALICACEOUS SPECIES OF THE PARANÁ DELTA[1]

Enrique G. Valente

Sources of raw material for mechanical pulp are of great concern to Latin American countries intent on expanding their domestic production of paper; it is especially important for newsprint production since mechanical pulp constitutes approximately 80 per cent of the furnish of this type of paper.

In Argentina, the Paraná Delta produces types of wood that are very suitable for the making of mechanical pulp; industries already installed there have been utilizing this raw material for approximately forty years.

Description of the region

This region is situated at the mouth of the Paraná and Uruguay rivers, and it is in the lower delta, an area that covers approximately 400,000 hectares, that the most advanced stage has been reached in the cultivation of salicaceous species. Here a number of islands have been formed by the deposit of silt carried down by the Paraná river. These islands are subject at intervals of approximately eleven years to floods of short duration which offer a free means of irrigation and, at the same time, a natural form of fertilization on account of the silt deposited when the waters recede.

[1] A shortened version of the original paper (ST/ECLA/CONF.3/L.4.3) which includes details of investment and production costs for salicaceous species in the Delta.

Forest species

The salicaceous species cultivated in the Delta region belong to the *Populus L.* and *Salix L.* genera, commonly known as poplars and willows, among which are species whose physical characteristics are very suitable for the production of mechanical pulp.

Among the poplars may be mentioned the native poplar (*Populus nigra* var. *italica* Munch Kochne), Carolina poplar (*P. angulata* Aiton), a name employed for a method of cultivating *P. deltoides* Marsh. These species are greatly affected by rust, and have been replaced by hybrids reared in Italy that have proved both adaptable and resistant, e.g., A. M. poplar (ex *Populus euramericana* F.I. 154) and similar hybrids. The willow most suitable for the production of mechanical pulp is the willow poplar (*Salix alba* L. var. *calva* Meyer); several other willows are more adaptable and are therefore cultivated, but their wood is not rated so high.

Reproduction

The salicaceous species are reproduced by cuttings; these are readily obtainable either from official nurseries in the area or from private properties.

Preparation of the land and planting

The first step is to carry out operations which will permit rapid draining of the land after floods, keeping the water in motion so that the plants do not suffer from a lack of air and from variations in temperature to which they are exposed when the water becomes stagnant.

The islands should first be interlaced with canals over 8 metres wide which connect rivers and streams. This permits the utilization of the total surface of the islands for cultivation, making it possible to drain the central lowlands and giving access to these areas for planting and extraction. The next step—ditch-digging—has hitherto been done by hand. The use of excavators and mechanical diggers would reduce the cost and permit a rapid expansion of the area planted.

The greater part of the surface of the islands is covered with large expanses of *Scirpus giganteus* and other marshy grasses, while in the escarpments the "monte blanco", consisting of ceibos, pindoes, ingá, lapachillo *(Lanchocarpus nitidus)*, mata ojo, laureles canelones, blanquillos, curupies with twining plants, epífitas and ferns, is found. The task of eliminating the "monte blanco" is compensated by the sale of the products extracted. Burning the grasses woud destroy organic matter needed to enrich these young soils.

The preparation of the land is carried out between May and July, although this period may be prolonged until September. The cuttings are planted in the prepared land between July and September. The most favoured spacing is 3 x 1.5 metres or 3 x 1 metres.

Care of the plants

Clearing operations, to keep down competing vegetation, are necessary in the first three years, while ditches must be maintained continuously. Precautions need to be taken against fire and rodents.

Production costs

Pulpwood is harvested after nine years. Capitalized costs plus amortization (at 6 per cent) work out at 7,339 Argentine pesos per hectare.

One hectare of salicaceous species yields raw material for 76 tons of mechanical pulp, so that the cost of standing timber per ton of pulp is 96.50 Argentine pesos. According to present charges, the cost of felling, transport to the river, loading, freight and unloading at the mill wharf amounts to 85 Argentine pesos per ton of mechanical pulp.

Thus the raw material required to produce one ton of mechanical pulp from salicaceous species grown in the Paraná Delta costs 181.50 Argentine pesos delivered mill site.

THE CULTIVATION OF EUCALYPTS IN THE STATE OF SÃO PAULO[1]

Armando Navarro Sampaio

I. Brief history

The Companhia Paulista de Estradas de Ferro was responsible for introducing the economic planting of the eucalypt in the State of São Paulo and elsewhere in Brazil. Specimens of this Australian forest genus had originally been introduced to Brazil by the Jesuits in about 1800.

In 1904, Edmundo Navarro de Andrade was commissioned by the Cia. Paulista de Estradas de Ferro to study the problem of providing wood required as quickly as possible for a variety of purposes, and began to experiment with the seeds of all the forest species he could find, both indigenous, e.g., peroba, araribá, Paraná pine, and foreign, including casuarinas, eucalypts, cypress and pine.

During five years of observation, Navarro found that the genus *Eucalyptus* far surpassed the other species in development and adaptability, and on his advice the Company chose it as the basis for their forest cultivation. Since 1909 the progress has been so remarkable that the Forestry Service now has 40 million eucalypts on its register. Later Navarro inspired the State of São Paulo to increase Government-owned forests by eucalyptus planting. Thus by 1941 there were enough eucalypt plantations in the State of São Paulo to enable it to survive the acute shortage of imported liquid fuels during the Second World War.

[1] A short version of the original paper, ST/ECLA/CONF.3/L.4.4.

In nearly all the other countries of Latin America, plantations of various species of the eucalypt exist on a small scale.

In countries on the west coast of South America, in Chile for example, the eucalypt that develops best is *E. globulus.* This is, in fact, one of the species that grows in many parts of the world; it is of high economic value, producing a variety of wood, ranging from that used for rayon in Southern Europe, to some of the best timber for durability. It also thrives along with other eucalypts in Argentina and in Uruguay. In Bolivia, in the neighbourhood of La Paz, some of the roads are bordered by *E. resinifera* and *E. camaldulensis,* which grow well at an altitude of 3,400 metres.

II. The suitability of eucalypts to soils and to climatic conditions

The eucalypt is exigent about the physical conditions of the soil, and less so about chemical conditions. Because of its tap-roots it needs a highly permeable soil, and therefore should preferably be planted in a poor, permeable soil rather than in a rich and less permeable one. Clayey soil should be avoided as far as possible. However, the adaptability to different soils varies with the species (see table 1).

Although the eucalypt is found mainly in sub-tropical areas, it will also thrive in cold and tropical climates (see table 2).

Table 1

SUITABILITY OF EUCALYPTS TO SOILS

Species	*Soil*: *Rich*	*Poor*	*Dry*	*Moist*	*Subject to flooding*	*Sandy*	*Dry and sandy*	*Calcareous*	*Granitic*	*Ferruginous*	*Basaltic*	*Salty*	*Coastal*	*Clayey*	*Stony*
affinis			x												
alba		x		x		x								x	
albens							x								
algeriensis				x											
amplifolia					x										
angulosa			x				x								
baileyana		x	x												
bakeri		x													
bicolar			x												
bosistoana								x							x
botryoides				x		x						x			
calophylla	x		x												
camaldulensis	x			x											
cambageana										x				x	
camphora					x										
capitellata		x				x									
cinerea															x
consideniana		x	x												
cornuta				x									x		
corymbosa		x	x												
corynocalix			x												
crebra															x
dealbata															x
deanei									x						
diversicolor	x			x											
dives		x													
dumosa			x												x
eximia															x
fasciculosa			x												
ficifolia									x						
foecunda								x							
globulus				x								x	x		
gomphocephala								x					x		
goniocalyx	x									x				x	
grandis [a]			x				x								
haemastoma			x												
hemiphloia			x												
incrassata			x												
kirtoniana [a]					x										
laevopinea	x										x				
leucoxylon									x						x
lindleyana	x			x											
loxophleba	x														
macrorrhyncha												x			
maculata		x		x											
maculosa			x												
maideni		x													x
marginata													x		
melanophloia			x												
microcorys	x														
microtheca		x			x										
morrisii															x
obliqua			x												
occidentalis										x				x	
ochrophloia				x											
odorata			x					x							
ovata					x										
paniculata		x										x			
patens	x			x											
pilularis	x											x	x		
planchoniana								x	x						
piperita		x													x
polyanthemos			x												
populifolia	x														
propinqua		x	x												
punctata			x												
redunca		x													
resinifera							x						x		
robusta					x							x	x		
rudis					x							x			
saligna							x								
salubris		x	x												
scabra		x													
siderophloia	x		x									x			
sideroxylon			x												
sieberiana			x												
squamosa		x	x												
stellulata	x			x											

Table 1 (continued)

Species	Soil: Rich	Poor	Dry	Moist	Subject to flooding	Sandy	Dry and sandy	Calcareous	Granitic	Ferruginous	Basaltic	Salty	Coastal	Clayey	Stony
stricta			x												
stuartiana			x			x							x		
tereticornis				x		x									
triantha		x													
umbra		x													x
uncinata			x							x					
viminalis	x			x		x									
woolsiana	x														

[a] According to recent investigations, the Australian *E. grandis* is the species introduced into Brazil as *E. kirtoniana.*

Table 2

SUITABILITY OF EUCALYPTS TO CLIMATIC CONDITIONS

Species	Suitability: Suitable for tropical climates	Suitable for temperate climates	Suitable for cold climates	Sensitive to drought	Resistant to drought	Highly sensitive to cold and frost	Slightly sensitive to cold and frost	Resistant to cold and frost
affinis		x						
alba	x							
albens		x			x			
amygdalina			x					x
andrewsi			x					
angulosa					x			
bicolor		x						
bosistoana						x		
botryoides	x							
calophylla	x							
camaldulensis	x	x			x		x	
cambageana	x							
capitellata		x						
cinerea			x					
citriodora	x	x		x		x		
coccifera			x					
corymbosa	x	x						
corynocalyx					x			
crebra	x	x	x					
dealbata		x						
erythronema						x		
eximia		x						
exserta	x	x					x	
gigantea			x					x
globulus		x		x				
goniocalyx		x						
grandifolia	x							
grandis		x						
gunnii			x					x
linearis			x					
longifolia			x			x		x
loxophleba	x							
macarthuri			x					
macrorrhyncha		x						x
maculata	x	x				x		
malanophloia	x	x						
melliodora			x					x
obliqua			x	x				x
ovata			x					
planchoniana	x							
piperita						x		
polyanthemos			x			x		
populifolia		x						x
propinqua		x						
pulverulenta			x					
punctata		x						
regnans			x					x
resinifera	x	x			x			
robusta		x					x	
rubida		x	x					
saligna		x		x				
scabra		x						
sieberiana			x					
smithii			x					
stuartiana								x
tereticornis	x	x					x	
triantha		x						
umbra		x						
urnigera			x					
viminalis			x					x

III. Cultivation methods

1. *Seeds*

Up to the present time it has been possible to plant eucalypts on a large scale by intensive cultivation with improved methods and by rigorous selection of seeds and seedlings. As the species vary greatly it is important that the seeds should not be mixed, as this would result in heterogeneous stands and lower profits. Though fertile seeds in batches offered for sale represent only 10 to 15 per cent of the total weight, one kg of seeds usually provides an average of 25,000 fertile seedlings.

2. *Seed-beds*

Sowing is carried out in seed-beds with dimensions varying according to the nursery plot, the ideal size being 1 metre wide by 3 metres long. No more than 50 grammes of seed must be sown per square metre, as a larger quantity produces excessive germination, which weakens the development and vigour of the seedlings.

Before sowing the seed-bed must be disinfected against weeds. After the seeds have been scattered as uniformly as possible, the seed-bed should be covered with a mat, resting on the raised edges and made of bamboo grass, or any other available material. The best months for sowing in São Paulo are between July and October, i.e., before the rainy season begins.

3. *Transplantation*

The seedlings are ready for transplanting forty to sixty days after sowing. After the seed-beds have been well watered, only the well-developed seedlings are removed and placed provisionally in containers with water or well-moistened soil. They are subsequently transplanted to hexagonal earth-block vases, which are made in the nursery itself by compressing a well-sieved, moist mixture of earth and manure. A special press known as *torrao paulista* is used.

After many years of experiment it has been found that vases made in this way are an improvement over boxes, not only because they prevent damage to the roots of the plants but also because transplanting to the final destination is facilitated. This is done directly, without removing the seedlings from the vases; these eventually disintegrate and blend with the soil. After planting, the earth-blocks or vases are covered by bamboo mats supported by pitchforks fixed every 2 metres.

4. *Vase-beds*

With this method two or three seeds are sown in each vase, a selection of the strongest to be retained being made later. Plants grown in such vases show the best development; a few days after being placed in its final hole the vase will disintegrate of its own accord, and the plant will begin its normal growth.

5. *Soil preparation*

As in any plantation, the soil must be well worked to obtain economic results. After eradication of weeds, which at all costs should not be burnt, ants should be exterminated, as these insects are the greatest enemy of the eucalypt; where possible the ground should then be ploughed, for the intercalary growing of cereals.

6. *Planting distances*

Controlled experiments in São Paulo, with cuts at seven, twelve and nineteen years, gave maximum volume per unit area for 2 x 2 metres planting. All the wider spacings, up to 6 x 6 metres, gave results far inferior, and for the time being 2 x 2 metres may be regarded as the most productive spacing. Experiments currently being conducted with less spacing will in due course show whether the ideal spacing is less than the recommended 2 x 2 metres.

7. *Permanent planting*

Planting in a permanent site is carried out during the rainy months which, in Brazil, are generally from October to March. Rainy days and the cloudy ones which follow, when the soil is sufficiently humid, are chosen for this operation.

8. *Cultivation operations*

During the first two years, the successful growth of the eucalypt greatly depends on the cultivation methods employed. While it is young, it must have no competition from other vegetation; if good results are to be achieved the soil must be kept free of weeds, either by ploughing or flat hoe weeding.

(a) *Insect control.* In Brazil, during the first two years of growth it is necessary to make frequent inspections of the plantations for signs of a sauva ant attack, for at this time the greatest damage is done. Formicides with a methyl bromate base are an efficient method of extermination.

(b) *Fire prevention.* Fire is a problem during the dry season and rigorous measures are necessary to ward off this danger.

(c) *Disease control.* No serious damage by fungi or bacteria has been noted so far; the eucalypt appears to be very resistant.

IV. Improvement and selection of the principal economic species

The general plan for improving the economic species of the eucalypt aims at more uniformity and homogeneity of future stands by reducing the percentage of flaws and weak trees, and by improving the charactertistics of the species to be planted. In this way it is hoped to increase the production per hectare of good quality wood for various purposes, and to achieve the basic object of the plan—greater profits with less expenditure.

A. Basic studies

It was first necessary to observe and classify the species already in existence in the various plantations and a new herbarium was initiated with selected species. Samples from Australia, Tasmania and of the Forestry Service's own material were mounted and comparative studies on economic species carried out.

Measurement of over 20,000 diameters of fifty-nine different species showed that, of the species generally cultivated by the Forestry Service, *E. grandis* has the most notable development, followed by *E. saligna,* while *E. citriodora* is the most homogeneous and *E. saligna* the most variable.

B. Selection of principal species and creation of new economic types

Since in Brazil eucalypts are chiefly used for fuelwood, railroad ties, poles, stakes and lumber in general, selection and hybridization should be orientated towards the species economically suitable for these purposes.

The types used for fuelwood must be fast growing and have thin bark, wood of greater density, and a structure which facilitates quick drying. For poles or ties, the trees must have thick bark and temperature-resisting wood, and must grow straight. Species of higher specific gravity, thin bark and greater yield should be chosen for charcoal. Higher grade wood of lesser density and less subject to splitting and twisting is used in joinery.

1. *Isolation of improved strains*

As most of the species of the genus *Eucalyptus* show many variations, the isolation of improved strains is of considerable importance. Hundreds of trees of the most economic species were selected and comparative studies made with trees of their lineage.

A comparative study of the effects of soil and climate on trees derived from those selected was then made, so that the best types could be chosen in accordance with specific aims. Samples were planted in Aimorés for regional study of the progeny of different species. The behaviour of the trees was observed from germination to felling age—fuelwood being felled at eight years and wood for poles at fifteen.

2. *Hybridization*

By the study of progeny and isolation of strains, it is hoped to separate the best material without new varieties being created, unless natural hybrids occur with a combination of favourable characteristics.

3. *Plots for seeding*

The Forestry Service needs a great quantity of seeds, both for its own plantations and for eucalypt growers all over the country. The seed crop up to December 1953 was 15,944 kg, of which 2,361 were used by the Service, 13,329 were sold and 256 were sent free on request. The need for greater care in seed selection has led to the creation of seed plots.

4. *Tests of the behaviour of the species*

In order to suit the species to the soil in Aimorés, the Service has tested nineteen species to be exploited for fuelwood and twenty species intended for pole manufacture. Similar tests have been carried out in other plantations.

C. SEED SELECTION FOR NEW PLANTATIONS

For the creation of new plantations, the harvest from the selected seed-bearing trees was carefully controlled to avoid mixing. Subsequent controls at the seedling stage aim at ensuring a uniform development of the stand.

D. APPLIED ENTOMOLOGY

The entomological section of the Forestry Service collects insects from the various plantations and undertakes inspections of the eucalypt stands. To defend the eucalypt against insect attack, insect habits are systematically studied, since the intensive cultivation adopted is liable to encourage the adaptation of one or more varieties of insect.

1. *Nurseries*

The nurseries are attacked by various groups of insects, among which are crickets, termites and ants. The insect which has caused most of the damage is known locally as "lava-pés". Studies to find the most effective insecticide are being made.

2. *Plantations*

In the Aurora plantation the problem is a small ant of the genus *Acromyrmex* which attacks the aerial system directly after planting, killing many of the stocks. This pest has not yet been successfully combated.

In the Guarani and Bebdouro plantations, termites, which injured the roots of the seedlings directly after planting, caused a great deal of concern, as the percentage of survivors among the stocks was very low. The insecticide giving the best results was white arsenic. An experiment covering 120 hectares showed four species well adapted to the soil conditions and also resistant to termite attack. *E. alba* was chosen as the most desirable since it was also fast growing.

E. THE STATISTICAL SECTION

The Forestry Service has more than 40 million eucalypts planted over an area of 15,716 hectares. The plantations are divided into 750 stands of different area. The statistical section has the following tasks:

(i) To study the conditions of economic development.

(ii) To study any change that might be made in spacing and to abandon any plantation rendered uneconomic by the number of missing trees.

(iii) To select the plots assigned for the production of poles, logs and ties.

(iv) To estimate fuelwood output, and various eucalypt products used by the Cia. Paulista de Estradas de Ferro and other consumers.

F. THE TECHNOLOGICAL SECTION

Some technological work must be undertaken to assist studies on the improvement of eucalypt wood. For example, work on the manufacture of eucalypt pulp was begun in 1946 at Rio Claro. The species *E. alba* and *E. saligna* produce fibres about 1 mm in length and give a pulp of excellent quality with good bleaching properties; tests proved that it is possible to manufacture fine paper from eucalypt pulp alone. Parallel investigations have been concerned with overcoming the tendency of eucalyptus to split, of some importance in the manufacture of railroad ties.

V. Exploitation methods

The eucalyptus forest can be grown from seed or by the coppice system. The latter method has advantages in that the life of the tree is prolonged without a great deal of expense and the shoots develop very much faster than do plants grown from seedlings; they do not, however, have the longevity of those trees left to grow undisturbed.

As in all trees, the life of the eucalypt has three distinct phases; progressive youthful growth, maturity and decay. During the first phase, the tree grows chiefly in height; during the second phase it increases mainly in diameter, while the roots and shoots are weak. The first phase does not usually extend beyond fifteen to twenty years. After this period the growth is practically entirely diametral. The most active period appears to be the first five years, average annual growth ranging from 2.5 to 3 metres.

With the coppice system of exploitation, trees must be felled level with the ground, leaving the stumps with a smooth, inclined surface to prevent them from collecting rain-water and rotting. The forests must be divided into as many plots or sections as there are years in a rotation period. One plot is felled each year; in this way, when the last plot has been felled, the first will be ready for felling the following year.

VI. Average costs of plantations

Average actual costs (May 1954) of planting and cultivating a one-hectare eucalypt plantation (2,500 trees spaced 2 x 2 metres apart) in the State of São Paulo, until its exploitation at the end of seven years, were as follows:

1. With mechanized equipment on flat land: Crs. 16,723.
2. Without mechanized equipment on flat land: Crs. 13,143.
3. Without mechanized equipment on inclined land where ploughing is not possible: Crs. 25,191.

In fact, manual labour, though more expensive, is preferred, partly because of the difficulty of obtaining machinery and parts, partly because manual operations result in purer stands and fewer failures.

VII. Uses of eucalypt wood

1. *Fuelwood*

Tests on both goods and passenger trains fuelled with five to ten year old eucalypt wood have shown results 20 per cent better than when other wood was used. The eucalypt has the same calorific value as the best native trees. Its superiority lies in the fact that, since a cubic metre of eucalypt wood gives a large quantity of uniform fragments, it saves space.

2. *Charcoal*

As charcoal is one of the chief needs of Brazil's metallurgical industry, experiments were carried out in the use of eucalypt wood in charcoal production. Successful results were obtained and several large metallurgical concerns now have eucalypt plantations.

3. *Posts*

Eucalypt posts have been used increasingly since the first tests were carried out successfully in 1920 by the Cia. Paulista de Estradas de Ferro. Preservative treatment (with Wolman salts and subsequently with mineral creosote) trebles the service life to thirty years. *E. tereticornis* gives the best results.

4. *Stakes*

During the past twenty years eucalypt wood has been widely used in São Paulo for stakes in house construction. For this purpose the species used must be at least fifteen years old and of sufficient density. Eucalypt stakes are especially suitable for harbour embankments. Fence stakes treated with Wolman salts are in demand throughout Brazil, and are largely used by both State and national highways departments.

5. *Sleepers*

One of the principal preoccupations of the Forestry Service has been to study the possibility of using eucalypt wood for railway sleepers. The supply of sleepers is one of the crucial problems of the Brazilian railways, especially in the State of São Paulo, where the few remaining forests which can be exploited for suitable wood are situated far away. Tests on eucalypts have been carried out on an increasing scale during the last fifty years.

In 1925 and 1926, twenty-year old eucalyptus trees were felled on some of the Paulista Forestry Service estates for tests of sleeper durability. The results were the best possible: the average durability was twelve years, which compares with the best of Brazil's native trees recommended for this purpose.

The chief difficulty in constructing eucalypt sleepers is the pronounced tendency of all eucalypt species to split at the extremities, from the centre to the periphery; this must be due to different radial and tangential tensions.

It appears that the best method is, whenever possible, to cut two sleepers from the same section of the trunk, as whenever the medulla is on one of the faces of the sleeper and not in the centre the wood will not split. The tree must therefore have a large enough diameter to permit the cutting of two sleepers from each section; this means that age and diameter are important factors.

Two and a half years ago 20,000 narrow-gauge sleepers, cut according to the above method, were supplied to the Paulista railway. Only about 2 per cent had to be discarded because of splitting.

6. *Civil construction*

Eucalypt timber is much in demand, in the São Paulo market, for the making of beams, rafters and laths.

The Forestry Service's saw-mill at Rio Claro now produces eucalypt timber on a large scale, supplying the Paulista railway company for the repair of cars and wagons, and providing a surplus for sale on the market.

7. *Joinery*

E. citriodora has been very successfully used for making finely-carved furniture, as well as cart-wheels, wheel naves, cart poles, etc. Other eucalypts have proved satisfactory for writing cabinets, chairs, tables, shelves, etc.

8. *Essential oils*

Eucalypt oil, which is extracted from the leaf, has an active principle known as eucalyptol, which, due to its balsamic properties, is widely used medicinally. Economic extraction, however, has proved possible only with two species: *E. citriodora* and *E. globulus*. The former also produces an oil with an active principle known as citronelal, which is widely used in the manufacture of soaps and perfumes.

9. *Tannin*

Though the bark of some eucalypts contains up to 19 per cent tannin, in Brazil its extraction has not proved economical.

A recapitulation of the applications of a great number of eucalypts to several end uses is given in table 3.

Table 3

UTILIZATION OF EUCALYPT WOOD

Species	Use: Paper	Charcoal	Fuelwood	Railway wagons	Sleepers	Naval construction	Piling	Bridging	Bridge decking	Oars	Civil construction	Paving blocks	Joists	Ceilings	Flooring	Window frames	Laths	Furniture	For carving	For curving	Farm carts	Fittings for agricultural implements	Tool handles	Fence posts	Wheel hubs	Wheel spokes	Clutches and wheel teeth	Mallets	Cart beams	Cooperage
alba	x		x																											
baileyana																							x							
bosistoana								x													x			x						
botryoides		x			x	x												x	x	x	x									
camaldulensis		x	x		x		x	x	x		x	x	x	x		x		x			x			x		x				
citriodora		x											x					x	x	x	x			x	x	x	x		x	
corymbosa					x		x					x								x				x						
corynocalyx					x		x						x								x			x						
eximia*			x																											
exserta			x															x						x						
globulus		x				x	x	x				x						x		x				x		x			x	
gomphocephala						x															x									
goniocalyx			x		x																					x				
grandis	x		x																											
gunnii*		x																												
lindleyana	x																													
longifolia		x			x															x		x		x		x			x	
macrorrhyncha		x	x																					x						
maculata						x		x	x			x				x		x			x		x		x	x			x	x
maideni																										x				
microcorys					x				x			x	x		x	x				x	x				x	x				
paniculata		x	x	x	x		x	x			x													x	x	x	x	x	x	
pilularis	x				x	x					x	x			x	x		x								x				
polyanthemos			x																	x							x			
propinqua					x		x									x	x			x										
punctata					x	x					x						x			x				x						
regnans	x			x																										
resinifera							x		x			x	x			x	x	x												
robusta		x				x					x					x					x									
saligna	x		x								x	x		x	x			x												
stuartiana*																								x						
tereticornis		x	x		x			x	x		x	x	x			x		x	x		x			x						
trabuti																		x												
triantha					x		x		x		x	x			x	x	x							x						
viminalis	x	x	x							x				x									x							x

*Produce weak, low-grade timber. Also included in this group are *cinerea, dives, haemastoma, maculosa, melanophloia, obliqua, piperita, rubida, sieberiana* and *stellulata.*

VIII. THE EUCALYPT AS RAW MATERIAL FOR PULP AND PAPER

Studies carried out in the State of São Paulo

Until recently the only domestic source of supply of paper made principally from eucalypt pulp was a small paper mill at Jundiai, with a daily output of 9 tons. The pulp is produced with the soda process and is mixed with 25 per cent imported chemical pulp or local mechanical pulp obtained from Paraná pine. Only *E. saligna* is used in this mill.

There are at present other industrial concerns utilizing eucalypt for paper making, among them the Cia. Melhoramentos de São Paulo, at Caieiras using *E. saligna* in a proportion of 75 per cent to 25 per cent conifer pulp. The mill has an average daily production of 30 tons of writing, printing and toilet paper.

The Forestry Service considers that the eucalypts which give the best pulp yield in Brazil are *E. saligna* and *E. grandis.* Their woods are of medium density and of a sufficiently light colour to make bleaching easy. Moreover they can supply as good a pulp as the best employed in Australia. It is estimated that felling at eight years gives the best results for pulping.

It is believed that Latin America has no other source so abundant and valuable as eucalypt for meeting the needs of a pulp and paper industry. It is recognized, however, that the eucalypt alone will not be able to solve the entire problem of raw material supplies for pulp and paper production; it can, however, be used in substantial amounts blended with pulp from long-fibred, slower-growing species.

PULPWOOD FROM PLANTATIONS OF EXOTIC CONIFERS IN THE PARANÁ DELTA[1]

LAMBERTO GOLFARI

INTRODUCTION

The Paraná Delta, a triangle of almost one million hectares of low flooded lands, is composed of innumerable islands formed by the ramifications of the Paraná river before it converges with the Uruguay river and flows into the River Plate estuary.

This area offers excellent conditions for afforestation due to: its position, protected as it is from the salt water of the Atlantic by a fresh water barrier almost 200 km in length formed by the River Plate estuary; its semi-humid, temperate to warm climate; its soil, rich in organic matter and of a high moisture content; its location, near the city of Buenos Aires, a large wood-consuming centre; and, lastly, the relatively cheap river transport facilities.

Up to the present, salicaceous species, willows *(Salix)* and poplars *(Populus)* have been employed almost exclusively in the afforestation of this area. Recently interest has been awakened in certain conifers, particularly *Pinus elliottii* Engelm. and *Pinus taeda* L., both of which are notable for their remarkable adaptation to these surroundings and their highly satisfactory development, These two species surpass the salicaceous types in the excellent wood they produce for mechanical and chemical pulping and for working. They also offer the possibility of resin production.

I. ECOLOGY OF THE DELTA

1. *Climate*

The climate of the Paraná Delta is sub-tropical-temperate of the semi-humid type. The average annual temperature oscillates around 17°C., with only slight differences during the coldest and warmest months. Frosts are very rare and of short duration.

The average rainfall is a little less than 1,000 mm annually; soil humidity, in fact, depends more on the water table than on rainfall. Relative humidity averages 77 per cent annually, from a minimum of 69 per cent in December to a maximum of 84 per cent in June.

2. *Contours and natural vegetation*

All the islands are low, their elevation varying approximately between 0 and 3 metres above sea level. Nevertheless, three different characteristic formations may be noted: (a) *The "bañados" or flooded lands:* these occupy more than three-quarters of the total surface and are generally situated in the interior of the islands. They are the lowest lands and are subject to periodical inundations. (b) *The lands of medium level* are frequently found bordering on the flooded lands or on the banks of the large rivers and some streams. (c) *"albardones" or escarpments:* these are the highest levels formed by narrow strips of land varying between approximately 20 and 100 metres wide, situated on the banks of oxbows, streams and rivers.

3. *Soils*

An examination of the conformation of the various types of soil discloses three distinct horizontal layers: the first organic, the second silty limous and the third sandy. The very porous sandy layer is almost always saturated with water. The silt layer, almost always quite porous, may vary from 10 cm toover a metre in thickness. The upper organic layer varies similarly in thickness, and also in compactness and degree of decomposition. In the great majority of cases, the soils of the Delta are acid.

4. *Hydrographic system*

As the lands of the Delta are low, they are subject to periodic inundations of diverse origin and varying intensity: (a) *Repuntes* (ebbs)—these are the most frequent, occurring almost daily in the lower Delta. They are partly connected with the sea tides and partly influenced by the south-southeasterly winds which slow down the outflow towards the estuary. (b) *Mareas* (high tides)—are of the same origin as the *repuntes.* They occur only a few times during the year when the winds are stronger and more lasting; when very high they cover the escarpments. (c) *Crecientes* (floods)—these occur when the rivers rise because of abundant rainfall in the upper reaches of the Paraná river or in the Uruguay river basin. They occur usually every ten or twelve years. All these inundations raise the land level by depositing silt and sand on receding.

The first and most important condition for the cultivation of any area of the Paraná Delta, either of low or medium level, is to provide an outlet for the water by means of ditches or canals which, depending on their importance, may be made either by hand or by machine.

These ditches assist the drainage system; they also lower the underground water level, thus increasing the effective area where tree roots can develop; they facilitate the ebb and flow of the *repuntes,* thus promoting the elevation of the land by sedimentation.

II. CONIFERS TESTED IN THE DELTA

1. *Pinus elliottii* Engelm[2]

The outstanding qualities of this species are its ability to develop perfectly on poorly drained lowlands where the cultivation of other conifers is impossible; its resistance to stagnant water or to inundations of a certain intensity and its tolerance to acid soils. It also has a fairly rapid rate of growth and is a good producer of resin. In the Delta it grows almost as well as the willows and better than the poplars.

2. *Pinus taeda* L.

This species shares the good qualities of the former, even though it may not tolerate stagnant water as well. Though there are more difficulties at the transplanting stage, it grows faster and supplies a slightly lighter wood. It is a moderate resin producer.

Taxodium distichum Rich. does not develop as well as the above species; *Pinus radiata Don., P. palustris Mill., P. pinaster Sol* and *P. pinea* L. have not proved successful in the Delta.

[1] The original paper (ST/ECLA/CONF.3/L.4.5) of which this is a shortened version, includes charts of rainfall and growth, and a series of photographs illustrating pine planting in the Delta.

[2] This species originated in the south-eastern United States. It had been incorrectly named *P. caribaea,* thus confusing it with the species found in the West Indies and Central America.

III. Biological review of *Pinus Elliottii* and *P. Taeda* in the Paraná Delta

1. *Rate of growth*

Having survived the critical period following the actual planting of trees, which generally takes place during the winter, the pines usually regain their normal rate of development in a few months. The average growth in height of both species, in good and even moderate soil, exceeds one metre annually during the first twelve years. During the same period the diametrical growth, measured at chest level, 1.30 metres, is more than 1.5 cm annually.

The period of greatest development, both in diameter and height, generally takes place between the third and sixth years. The first thinning-out of dense plantations should take place not later than the tenth year of growth.

2. *Soil conditions*

The adaptation of both species to the diverse types and formations of soil is noteworthy, they appear to prosper in any type of soil found on the islands. The most favourable seems to be the sandy ground where the ceiba grows, frequently on the banks of watercourses, the least propitious being some of the clayey escarpments of the higher Delta. Even in the latter case, however, growth of these two pines is more satisfactory than that of willows and poplars.

3. *Extension of roots and resistance to humidity*

As the lands of the Delta area have a fairly shallow water level the root extensions of pines are almost always superficial. Both the pines have a really remarkable endurance to the humidity of the soil, which helps them to survive conditions caused by stagnant water or floods.

4. *Seed production and regeneration*

As the plantations are still young, the oldest pine forest in the entire Delta being twelve years old, the production of seed up to the present has been insignificant. It is therefore still too early to forecast possibilities of natural regeneration, but certain indications give grounds for optimism.

IV. Cultivation of *Pinus Elliottii* and *P. Taeda*

1. *Young plants and nurseries*

The sowing of seed is carried out in autumn (March-April), or preferably at the end of winter (August-September), in plots of ground 1 metre in width and of lengths varying in accordance with requirements; the rows are spaced 10 to 20 cm apart.

Protection from certain kinds of birds is needed, but a more dangerous and common enemy of the young plants is a fungus disease called "damping off", which may attack them in the first few weeks of life. This can be prevented by watering the plots with a solution of 3 per cent commercial sulphuric acid or with Ferbam as soon as germination begins and the first small shoots appear.

2. *Planting and distances*

Planting takes place, preferably in ploughed land, between April and August, advantage being taken of the greater water availability in the humus layer, reduced evaporation and high relative humidity.

The bare root method is the most rational and economical, and is carried out with species between eight and twelve months old if planted at the end of winter, or between twelve and sixteen months old in the autumn. Planting in rough clay pots, though more costly, involves fewer losses and can be carried out under conditions unsuitable for bare root planting.

Although complete data is not yet available on the yields of *Pinus elliottii* and *P. taeda* plantations at varying distances, it is considered that an appropriate spacing for *P. elliottii* is 2 x 2 metres, and for *P. taeda* 2 x 2.5 metres. Slightly wider spacing facilitates land clearance by caterpillar tractors.

3. *Clearing and felling*

It is suggested that in a plantation with a spacing of 2 x 2.5 metres appropriate for either species, and an estimated 80 per cent survival, clearing might be: 1st thinning—in the 8th year, felling 600 trees; 2nd thinning—in the 12th year felling 400 trees; and 3rd thinning—in the 16th year, felling 200 trees. Approximately 400 trees would then be left for the final felling, between the 20th and 25th year of growth, the wood being used to make pulp or in the sawmills.

4. *Yields*

In a small twelve-year old forest, the average height and diameter of pines was measured and the yield estimated: Of 1,650 *P. elliottii* and *P. taeda*, 76 per cent of the former and 80 per cent of the latter were still standing after eleven years.

The estimated volume of barked wood per hectare for mechanical or chemical pulp at the 12th year of growth was 255 m^3 for *P. elliottii* and 280 m^3 for *P. taeda.* These figures correspond to average annual increments per hectare (with bark) of 30 and 33 cubic metres.

V. Prospects

It is probable that the *Pinus elliottii* and *P. taeda* will increase steadily in the Paraná Delta in the near future, and will supply the country with wood for the manufacture of pulp and paper, wood for sawmills and posts, and resin for various industries.

In addition to the favourable ecological conditions the geographical position of the Delta is advantageous. Its furthest points are some 100 km away from Buenos Aires and from these points, using the relatively cheap river facilities, the wood can be sent to the larger paper plants and sawmills, almost all of which are situated on the banks of the Paraná river.

Not only do these pines compare favourably with the salicaceous species, by virtue of their vigorous growth, their freedom from disease, and their adaptation to different soils; they will also benefit soils now exhausted by successive planting of salicaceous trees during a great number of years.

FORESTRY MEASURES UNDERTAKEN BY THE ARGENTINE GOVERNMENT TO INCREASE PULP AND PAPER PRODUCTION[1]

ADMINISTRACIÓN NACIONAL DE BOSQUES, MINISTERIO DE AGRICULTURA Y GANADERÍA DE LA NACIÓN (ARGENTINA)

GENERAL BACKGROUND

Argentina's consumption of paper is high and is steadily expanding. Prices of paper, board, and of products manufactured therefrom have been rising; many of these have to be imported at considerable expense. Official organizations have therefore sought a solution to this problem by encouraging the domestic manufacture of some products, replacing imports and thus contributing to an improvement of Argentina's trade balance.

Surveys and studies may by the National Postwar Council—established in 1945—provided the general economic framework for consideration of the pulp and paper problem, which, the Argentine Government maintained, required urgent solution.

The starting point was a quantitative and qualitative study of the country's pulp resources, especially as regards raw materials available and their rational exploitation.

Many raw materials can be used for pulping—cereal straws, flax and hemp fibres, sugar-cane bagasse, vegetable fibre by-products, wastepaper, rags, etc. But special emphasis was laid on wood since forests, if soundly managed, can provide a permanent supply of raw materials for pulp. Attention was first concentrated on those indigenous and exotic species, especially conifers, which grow well in Argentina. Studies were concerned with the suitability and silvicultural characteristics of native species and with the possibility of acclimatizing exotic varieties, having regard to soil and climatic requirements and general economic importance. These studies have led to a series of measures carried out in accordance with the goals of the First Five-Year Plan (1947-52); this programme will be further developed under the Second Five-Year Plan. The following pages describe the activities carried out, especially those in the field of forestry, to promote pulp and paper manufacture.

THE FIRST FIVE-YEAR PLAN

Decree No. 8,594/49 of the First Five-Year Plan stressed the need for finding stable and permanent solutions to the problem of newsprint shortage and requested the different specialized government organizations to report on the best physical, geographic and economic conditions available in Argentina for the development of newsprint mills.

Subsequently, national and foreign manufacturers were invited to install one or more plants for this purpose. It was agreed to give them the following facilities:

(1) Exchange permits for machinery, equipment and accessories;

(2) Exemption from customs duties for same;

(3) Priorities for fuel and power quotas;

(4) Wood raw material supplies at the lowest possible price;

(5) Facilities for the immigration of technical personnel and skilled workers;

(6) Status as an industry of national interest.

A later decree authorized the Ministry of Industry and Commerce to sign reciprocal agreements with concerns that fulfilled the conditions laid down in the earlier decree. As a first result, the installation of an industrial plant for the manufacture of chemical pulp, at Puerto Piray, Misiones, is now practically complete. Its output capacity is 30,000 tons yearly, requiring an annual supply of 130,000 to 140,000 cubic metres of raw material.

At the same time, on the basis of the commitments contracted by the Government, the National Forest Administration—the organization in charge of forest resources—has adopted the necessary measures to ensure a supply of raw material to this industrial plant.

The wood from artificial plantations of Paraná pine will be utilized for the manufacture of chemical pulp. This species can be used for the manufacture of pulp after a growth period of ten to fifteen years, at the end of which the trees have a diameter of 18 to 22 centimetres and yield about 250 cubic metres per hectare.

In the interval, until these plantations can be used, most of the raw material will come from government-owned natural forests in the San Pedro area. Wood stocks have been estimated at an aggregate 1,500,000 m^3, of which only one million m^3 will be used for chemical pulp, since part of the total volume is needed for other purposes, in accordance with the policy of rational utilization of forest resources.

Wood from private forests, estimated at about 400,000 m^3, will also be used to supply the needs of the paper industry; this raw material, added to that from the government-owned forests, is expected to yield 340,000 tons of chemical pulp.

Mechanical pulp will be made entirely from wood extracted from artificial plantations. Of especial interest are the quick-growing *Salicaceae*, for which the country has a really advantageous cultivation area—both from the ecological and locational point of view—in the Delta of Paraná.

These two existing sources—natural forests for the manufacture of chemical pulp and plantations for mechanical pulp—should ensure satisfactory supplies for the paper industry. The Reafforestation Plan of the Republic, prepared by the National Forest Administration, will then make possible extraction of the necessary volume of raw material while ensuring stable and permanent supplies.

Under the policy inaugurated in 1947 for the development of domestic raw material production, the principal areas chosen for raw material production were Misiones and the Paraná Delta. The former was chosen because of its physiographic characteristics, about 80 per cent of the area being suitable for afforestation. Among other species very valuable to the domestic economy, Paraná pine *(Araucaria angustifolia)* is found there. The Paraná

[1] A shortened version of the original paper, ST/ECLA/CONF.3/L.4.6.

Delta area is especially suitable for forestry, and particularly for the cultivation of *Salicaceae* and certain *Coniferae,* eminently suitable as pulpwood.

Misiones area

Paraná pine, which grows naturally in the northeastern sector of Misiones is very suitable for the manufacture of chemical pulp. Furthermore, some rather small artificial plantations have proved that with adequate techniques new pine stands can be planted in the area. They grow remarkably well, for studies made show that, during a period of ten to fifteen years, one hectare of this species can yield 250 m^3 of wood (including thinnings). In this environment *Eucalyptus saligna* and *E. alba* also grow rapidly, and could, within ten years, produce 500 m^3 of raw material very suitable for mechanical pulp. Moreover, though plantations of *Pinus caribaea* were initiated only a few years ago, tests made with this species have shown that it also is perfectly adaptable to the area. For these reasons, therefore, priority was given to the Misiones area.

The Paraná pine woods consist of stands of various sizes, growing in association with other species peculiar to the Misiones sub-tropical forest. These "pine stands" extend over some 80,000 hectares, about 50,000 of which are government-owned. Present resources will supply the needs of the country for the next ten to fifteen years. This is sufficient time for artificial plantations to begin production; the policy adopted for the utilization of this species is based on artificial reafforestation.

Yields from the exploitation of the natural Paraná pine woods for the manufacture of paper are estimated at about 130,000 m^3 of wood annually, making possible the yearly manufacture of about 170,000 tons of newsprint, sufficient to cover normal domestic consumption. To maintain this yield, about 500-600 hectares should be reafforested each year; this activity should be supplemented by conservation measures and the development of the more valuable species which are found with Paraná pine, such as "cedro" *(Cedrella pissilis),* "incienso" *(Microcarpus frondosus),* "peteribí" *(Cordia trichotoma),* "guatambú" *(Balfourodendron riedelianum)* and "canela guaicá" *(Ocotea puberula).*

The activities of the Reafforestation Establishment, Pino Paraná General Manuel Belgrano, Misiones, and the measures adopted by the National Forest Administration, have directly contributed to the development of raw material production in the area. Through the intervention of the above-mentioned establishment, plantations of Paraná pine and eucalyptus have been effected. The National Forest Administration has approved work plans for the planting of 4,225 hectares with pine trees in Misiones. It is estimated that private individuals have to date planted 5,000 hectares with pine trees. Advice has been given and observations and studies made on various forestry problems affecting this area.

The National Forest Administration does its best to ensure Paraná pine planters an adequate seed supply—a basic problem which cannot be solved entirely by the use of seed-bearing trees in the region. Negotiations for the import of seeds from Brazil have not been as successful as expected and the problem of seed supply still urgently awaits solution.

The amount of seed needed is extraordinarily large because, of every 150 seeds to the kilogramme, only about 100 are considered to be fertile. About 8,000 to 10,000 seeds, weighing 60 to 70 kg, are needed per hectare; to sow an area of only 300 hectares a year, about 20 metric tons of seed would be needed. Therefore everything that refers to seed-bearing trees is important, as this is a diœcious species, which, in the case of well-developed trees, produces on an average about 10 kg of seed per tree in normal crop years.

Among the other species tested at Misiones, special mention should be made of *Pinus caribaea,* whose growth rate exceeds all expectations. In the future it will undoubtedly play a special role in supplying raw material for making pulp and paper.

The Reafforestation Establishment has planted 118 hectares with Paraná pine and has acquired useful experience in the cultivation of plantations both of this species and of *Eucalyptus sp.*

The Paraná Delta area

The Paraná Delta covers some one million hectares, of which about 700,000 hectares are suitable for woodlands. This and other factors—water-supply, means of communication, nearness to the Federal Capital, etc., combine to give excellent conditions in this area for the production of raw materials. The Estación Forestal Presidente Perón was therefore founded with the double mission of carrying out forestry research on the most suitable species to be grown in this area and of actually planting large stands.

This organization, on the Paraná Mini river of the Paraná Delta, covers an area of 2,700 hectares. Its main objectives are: to contribute, even though modestly, to the production of raw material; to undertake research related to production, especially with regard to drainage of marshland for plantations and techniques to be applied; to study forest species, their possible acclimatization, their climatic and soil requirements, and their silvicultural characteristics; to seek to control various adverse factors resulting from the natural environment and artificial man-made factors; to study the growth of the trees and their possible quantitative and qualitative improvement, as well as rotation periods, etc.

This organization, besides contributing to the future supply of raw material from experimental plantations and large-scale distribution of cuttings and seedlings of chosen species, of guaranteed quality, and free of charge or at particularly favourable prices, gives daily guidance to planters on the basis of the observations made at the station.

Among the forest species spread over the Delta area, the *Salicaceae* predominate; others which are becoming increasingly numerous are some *Coniferae* and in particular some *Pinus.* Of the *Salicaceae,* special importance is given to the genus *Populus;* of the *Salix,* the poplar-willow *(Salix alba var. ceorulea)* is of particular significance and there are also several hybrid or "half-breed" strains, especially in the lowlands. Furthermore, experimental lots, each of 210 hectares, have been established for a study on the behaviour of 500 strains of *Salicaceae* coming from all parts of the world, mainly Italy, the United States, England and Holland.

Special mention should be made of Euroamericana poplars I-154 and I-214 (Italy); the former was introduced into Argentina in 1939. These two strains developed by the Institute of Experimental Poplar Cultivation Casale Monferrato, in Italy, are those which offer the best cultivation possibilities.

Other species and strains are also under observation and thirteen main poplars are being tested.

The Estación Forestal maintains scientific contact with similar institutions elsewhere in the world, and, on request, furnishes information on forestry matters. As it has been planting forest trees since 1946, it has acquired some experience on various technical and economic problems. Some of these are referred to in the following paragraphs.

For economic plantations of *Salicaceae* in the Delta area, the system of using cuttings, suckers or shoots is almost exclusively employed. They are mainly planted on lands with very high tides. The following observations on cuttings may be of interest:

(*a*) For each size of cutting, the number of shoots decreases and the height of the plant increases with the shallowness of implantation.

(*b*) Plants from thick cuttings are superior in height and number of shoots to those from thin cuttings.

(*c*) The wood yield per hectare, studied on the basis of seven-year old plantations of I-154 poplar, decreases remarkably with the increase in distance between the plants:

Distance m.	Volume m³/hectare
2 x 3	172.0
3 x 3	137.4
5 x 5	90.3
6 x 7	70.2

This is why, in Argentina, a different planting technique from that recommended by European poplar growers is used.

Some of the experiments made on *Pinus caribaea* and *P. taeda* are of general interest because the wood of both species seems to have excellent pulping qualities. *P. caribaea* planted in 1948 in groups in earth-block vases gave very good results; after thinning, one plant was left in each group. At the end of 1949 this pine had grown to a height of 1.60 centimetres.

In 1950, after high, lasting tides and strong persistent winds, it was noted that some *P. caribaea* trees, planted in 1948 in low-lying areas, fell over and became bent. On higher ground—that is, in semi-hilly or hilly districts—there was no damage. On investigation, it was noted that the root system of the fallen trees was formed by superficial lateral rootlets and that the main root was either very underdeveloped, being very short and weak, or entirely missing. The branch system grew vigorously and increased so much in weight that the centre of gravity was displaced upwards. The plant did not therefore have the necessary support to remain upright in a softened soil.

Data on the growth rate of *Salicaceae* planted at different distances and also of other species which grow well in this area provide a basis for advising small and large-scale planters.

Forest plantations in the Delta area involve relatively high planting costs. Soil preparation and ditch digging are in general very expensive; control of weeds and rodents, as well as the maintenance of suitable planting distances, all require attention and expenditure is inevitable.

The Presidente Perón forestry station, on the basis of the experience acquired in its own plantations, is well-placed to give advice on the different aspects of plantation operations.

The different kinds of ditches affect the development of the plantations, as do the various numbers and sizes of the ditches and drainage canals used. It was proposed that a certain number of machines should be used for this work in the Delta, and several are already in operation.

The influence on growth of the lay of the land is interesting. The stands at the border of the plantation are better developed and more vigorous. The average border tree has a 50 per cent greater volume and a higher commercial value than the tree in the interior of the lot.

Besides ditch digging, weeding is essential for the satisfactory development of the plantation. Weeding, particularly of pajonal, is partly done by crushing with the tractor. The experience gained at this station has shown that the tractor is much more economical for such work than manual labuor. Today there are hardly any plantations of over 50 hectares without a tractor.

Observations on the effects of pruning the trees have shown that in most cases pruning leads to a reduction in growth.

Species	Age, years	Distance m	Average diameter of the plantation: cm without pruning	cm with pruning	Percentage reduction
Poplar 154	7	6 x 7	27.5	24.1	13
Poplar 154	7	3 x 3	16.6	15.8	5
Poplar 154	3	5 x 3	5.7	5.5	4
Poplar 214	4	2 x 3	12.2	11.1	9
Pino taeda	3	2 x 2.5	10.7	9.5	12
Pino caribaea	5	2 x 4	13.3	12.4	7

Plantation pulpwood costs

Tables 1 and 2 below give some data on the cost of pulpwood from plantations in Misiones and in the Paraná Delta.

Credit, development and assistance

During the period of the First Five-Year Plan, the Argentine Government passed the law of Protection of Forest Resources, which provides the legal means and expedients for the implementation of Argentine forest policy. Among other measures favourable for the development of the Argentine forest economy, article 59 of this law provides that:

> "The Banco de la Nación Argentina and the Banco de Crédito Industrial shall grant private individuals special credit for afforestation and reafforestation work, and industrialization and marketing of forest products, adjusting the terms and rates of interest to the respective requirements".[2]

In compliance with this article, the Banco de la Nación Argentina, under the guidance of and in collaboration with the National Forest Administration, has approved

[2] Throughout this paper, the translation of articles and regulations is unofficial.

Table 1

COST OF PULPWOOD FROM PLANTATIONS

(*Argentine pesos per hectare*)

Paraná pine: growing period 15 years

	First year	*Second year*	*Third year*	*Fourth year*	*Fifth to fifteenth year*	*Total*
MISIONES						
Clearing: soil preparation	820					
Marking	45					
Ant extermination	360	300	250			
Seeds	660					
Holes and sowing	260	150	50			
Harrowing	900	480	420			
Plant replacement		200	66			
Planting		200	67			
Firebreaks, fire insurance					4,400	
Miscellaneous including supervision	140	100	80	760		
TOTAL	3,185	1,430	933	760	4,400	10,708

Poplar-willow: growing season 8 years

	First year	*Second year*	*Third year*	*Fourth to eighth year*	*Total*
PARANÁ DELTA					
Draining	1,000				
Clearing, tilling	500				
Cuttings	250				
Planting	200				
Weeding	500	500	400		
Rodent control	100				
Replacement		100			
Ditch cleaning		100	100		
Miscellaneous, supervision	50	50	100	500	
TOTAL	2,600	750	600	500	4,450

Poplar: growing season 8 years

	First year	*Second year*	*Third year*	*Fourth to eighth year*	*Total*
PARANÁ DELTA					
Draining	800				
Clearing, tilling	500				
Cuttings	250				
Planting	100				
Weeding	500	500	400		
Rodent control	100				
Replacement		100			
Ditch cleaning		100	100		
Miscellaneous, supervision	50	50	100	500	
TOTAL	2,300	750	600	500	4,150

Table 2

PROFITABILITY OF PLANTATION PULPWOOD

(*Argentine pesos per hectare*)

	Misiones pine	*Delta poplar-willow*	*Delta poplar*
Total costs	10,708	4,450	4,150
Total costs (including interest at 5 per cent)	18,500	6,228	6,142
Return	45,000[a]	16,000[b]	29,000[c]
Net profit per hectare	26,500	9,772	22,858

[a] 300 m^3 per hectare, at 150 pesos per m^3 unfelled.

[b] 7,000 and 4,000 linear metres of saw timber and small dimension stock at 2 and 0.4 pesos respectively (unfelled) per linear metre, plus 400 pesos for posts, stakes and fuelwood.

[c] 8,000 and 4,000 linear metres of saw timber and small dimension stock at market prices, less 6,000 pesos for exploitation and transport.

the regulations and seek to encourage forestry production in general and the supply of raw materials for pulping in particular. Up to 1952, the National Forest Administration had approved afforestation and reafforestation projects covering 24,000 hectares to be carried out with the help of official loans totalling 75 million pesos.

Some extracts from these regulations may be of interest. The loans are defined as being intended for: "preparation of the soil, purchase of seedlings and plantation and maintenance costs— until the third year—of forest species suitable for the production of raw material for paper manufacture"; credit will be given "up to 90 per cent of investments to be made and within maximum amounts per hectare and per area listed". Other conditions established by these regulations include: 5 per cent interest; period of repayment up to ten years for raw materials for paper manufacture; obligation of presenting an afforestation project to the Bank signed by an authorized agronomist and approved by the corresponding forest authority.

Article 57 of the Law of Protection of Forest Resources (No. 13/273/48) states that: "Artificial forests and woods are declared tax-exempt". Article 60 states, "Profits invested in new forest plantations and in general forestry improvements shall be exempt from profit taxes". According to article 62, paragraph (e), the Government is authorized to "instigate forest fire insurance" and, according to point (g) of the same article, to "distribute seeds, cuttings and seedlings free of charge". Article 63 states that "all equipment, supplies, drugs, seeds, forest cuttings and other items necessary for the country's afforestation and reafforestation and for research, which have to be imported by the forest agencies, shall be exempt from customs duties".

The importance of technical guidance to forest producers, provided by the Government through its Agency, is clearly shown by the number of persons who almost daily visit the offices of the National Forest Administration and its subsidiaries, especially the Estación Forestal Presidente Perón in Paraná Miní; expert advice is sought not only by landowners interested in forest plantations but also by banking institutions and technicians.

A special aspect of this guidance work is the publication of information bulletins, prepared by the National Forest Administration and distributed to interested parties, dealing with the planting and care of the different forest species, with special emphasis on those suitable for pulping.

The Second Five-Year Plan

This plan, to be implemented during 1953-57, will give a significant impetus to forestry. The fundamental objective is stated in chapter XI, entitled "Forest action":

"In forestry matters, the Nation's fundamental objective must be to achieve self-sufficiency in its timber requirements, ensuring at the same time the stability and evolution of a sound forest economy." (XI.F)

As to general objectives, it is pointed out that: "A knowledge of forest resources is indispensable and for this purpose a forest inventory and the management of the country's forested area will have to be completed (XI.G.1), providing among other things, in XI.G.2, that the forest régime, that is forest utilization, should be adjusted to the norms established in Law 13,273, which are based on:

"(a) ensuring the perpetuity of the forests;

"(b) their integral utilization;

"(c) the rational use of wood raw materials;

"(d) conservation and growth of forest resources;

"(e) when convenient, recovery of degraded woodlands".

Consideration is also given to forest co-operatives and colonies, which "shall be assisted technically and financially by the State, so that they can work in economic forestry units or mixed units". (XI.G.3)

The State will sponsor the mechanization of forestry work and the domestic manufacture of forest machinery. (XI.G.6)

Bank credit will promote forest exploitation, afforestation and reafforestation, stimulating private investments according to the objectives of this plan.

The National Forest Administration will give technical advice to banking institutions. (XI.G.7)

Federal and provincial forestry agencies will undertake research on the adaptation of new forest species, thus ensuring the future supply of wood raw materials, especially of softwood (XI.E.20)

With regard to areas to be reafforested, the Second Five-Year Plan states that "on a long-term basis it will be necessary to afforest and reafforest a minimum area of 660,000 hectares over the whole country", of which "60,000 hectares will be used for the production of raw materials for pulp and paper manufacture". (XI.G.4)

A goal of 78,000 hectares has been set for afforestation and reafforestation during the five-year period. Of this figure, 20,000 hectares would be for future pulpwood supplies; this work will be done by:

Item	Annual tonnage required by 1957	Percentage increase over present output
Newsprint	50,000	108
Other types of paper	230,000	53[a]
Board and paperboard	125,000	47
Mechanical pulp	50,000	657
Chemical pulp	135,000	300

[a] Over 1951 output.

The Five-Year Plan also sets output objectives for the pulp and paper industry, which should achieve the following goals by 1957:

Though these figures fall short of expected requirements in 1957, it should be noted that during the first year of the Second Five-Year Plan practically 80 per cent of all the objectives have already been attained.

Technological characteristics of the most suitable species found in Argentina for the manufacture of pulp

Agentine forests are characterized by a scarcity of conifers. In a forest area of 48.6 million hectares, of which only 22.9 million are considered productive, there are only 100,000 hectares of accessible and 100 hectares of inaccessible conifers, against 22.7 million hectares of broad-leaved stands.

In Argentina, only two araucarias—*Araucaria angustifolia* and *A. araucana*—with fibre lengths of 3.4 to 4.5 millimetres, and *Podocarpus palatorei*, with fibre lengths of 2.0 to 2.5 millimetres, occur in sufficient quantity to merit study. Of these, *A. araucana* must be discounted, in spite of the good qualities of the wood, because it grows very slowly and extraction is difficult owing to the lack of roads.

The "hill pine" *(Podocarpus parlatorei)* is being used for groundwood in Tucumán, but transport difficulties are the principal impediment to greater utilization.

Thus, among the so-called long-fibred woods, Paraná pine *(Araucaria angustifolia)* is the most interesting and important species for the manufacture of chemical pulp in Argentina. This tree grows to considerable heights, very often above 40 metres, and has an average trunk diameter of one metre. These gigantic trees, with their horizontal tops and branches which bend upwards, tower over the average level reached by the forest vegetation. The trunk is pyramidal, straight and bare, as the branches fall off to about three-quarters of the height, ending in a crown-shaped top. The branches can grow to 10 metres in length, and where they meet the trunk the conical knots of the pine are formed, which are characteristic resin deposits. The bark is relatively smooth and dark coloured, with violet undertones in the saplings and a reddish grey colour in the older trees. The thickness of the bark depends on the diameter of the trunk, and can reach 6 centimetres. In adult trees bark accounts for 24 per cent of the total volume.

Paraná pine grows in mixed stands, along with yerba maté, black laurel, cedar, cancharana, guatambú, etc. It grows rapidly, and in ten years may reach a diameter of 22 centimetres. In twenty years the diameter may be up to 40 centimetres.

Paraná pine wood is yellowish-white when cut, but becomes a slightly pinkish yellow when it has been exposed to the air. It usually has pink or light grey veins. The texture is fine and uniform, with a straight grain. It is classified as a white softwood, with a specific gravity of 0.50 to 0.55. It is heavier than *Abies pectinata* wood, which it resembles in its lack of resin ducts. In density it is similar to *Pinus sylvestris* and *P. pinaster* but its compression resistance is lower. Knots appear in the higher part of the tree. These are hard and a light red in colour, with a length of up to 30 centimetres.

Chemical composition of the knots

	per cent
Resin	32
Lignin	18
Cellulose	30
Ash	0.67

Tests made for the manufacture of pulp from the knots have not been successful. The pulps are strongly coloured and difficult to bleach.

Table 3 shows the results of analysis of sapwood and heartwood.[8]

Table 3

	Sapwood (per cent)	*Heartwood (per cent)*
Ash	0.46	1.00
Pentosans	6.50	5.96
Lignin	31.10	29.40
Solubility in:		
Ether	1.89	2.64
Alcohol	—	—
Benzene	2.09	5.69
Cold water	0.50	3.41
Hot water	1.17	5.46
1% NaOH	12.85	16.23
Cross and Bevan cellulose	58.85	57.25

Bisulphite pulps manufactured from Paraná pine are strong, hard, and poor in pentosans and resins, of a light colour, with extraordinarily long fibres (sometimes reaching 6 millimetres). These are factors which produce bulky and hard paper. They are also a source of difficulty in screening.

Unbleached pulp yields are from 55 to 60 per cent, according to the degree of cooking, and bleached pulp yields from 43 to 45 per cent. Easily bleachable pulps are produced, especially when saplings are used.

[8] Data obtained at the laboratories of Cellulosa Argentina, S.A., in Juan Ortiz, Santa Fé

At 45 degrees S.R., the following characteristics were obtained:

Breaking length	8,000 to 11,000 metres
Resistance to folding	1,300 to 2,000
Burst factor	40
Weight	50 grammes/square metre
Active chlorine	1 to 1½ per cent

The solutions used for bisulphite cooking contained 5 to 6 per cent total SO_2, and 1 to 2 per cent of combined CaO. Cooking time was ten hours at a temperature of 135 to 140° C.

In recent years, the lack of long fibres for paper manufacture has led to an intensified study of broad-leaved or short-fibred woods.

The characteristics of the different broad-leaved species growing in the Misiones sub-tropical forest and as yet unexploited are being studied in the laboratory of the National Forest Administration for possible use in paper making.

The cellulose content of these sub-tropical hardwoods ranges from 40 to 50 per cent, rarely exceeding 50 per cent. The lignin content fluctuates between 21 and 27 per cent. Perhaps the most interesting characteristic is the high pentosan content—from 18 to 20 per cent. The so-called secondary constituents, which do not form part of the cell wall, are abundant but their amounts vary according to the species. They include tannins, colouring matters, and waxes, but very rarely resins. These extractives are very important: they often determine the use to which wood will be put.

The white timbó has given good results with sulphate cooking. Bleached pulp yields range from 43 to 45 per cent. Its fibres, although short, give quite a strong sheet after beating. Properties of paper manufactured from this wood are of the following order:

Breaking length	7,500 to 8,000 metres
Tear factor	50
Resistance to folding	150 to 500

Its low tear factor makes it unsuitable for wrapping paper, but adequate for printing.

It is also worth noting that the Borsari enterprise has planned the installation, at Ushuaia, of a kraft-type paper plant, using lenga wood, for which it has already requested the necessary credit from the Government. Tests of kraft paper manufactured at the pilot plant of the Universidad del Litoral have been successful, as compared with other papers of the same type sold on the local market. The average breaking length of above 5,000 metres for a paper without sizing or loading is very promising.

Mechanical pulp manufacture in Argentina began in 1913, at the El Fenix plant on the river coast. Since then, manufacture has been continuous, but always on a small scale. The most common species used in Argentina are poplars ("criollo", "Mussolini", "carolina") and the poplar-willow, besides the hill pine, which is used with good results in Tucumán.

These woods give a light pulp, composed of fibres with a maximum length of 1 to 1.5 millimetres and a minimum of 0.2 to 0.3 millimetres. The yield amounts to about 70 kg pulp from 100 kg of moisture-free wood. The rest is lost through barking, screenings, etc.

Conclusions

Under the First Five-Year Plan (1947-52) and the Second Five-Year Plan (1953-57), the Argentine Government has continued to foster the development of pulp and paper manufacture. The following achievements may be noted.

I. *New factories*

Decree No. 8594/49 has given rise to the possibility of installing new factories, on the basis of existing raw material stocks and future supplies; at some of these production is already under way.

II. *Production of wood raw material*

1. As Misiones is a very favourable natural habitat for Paraná pine *(Araucaria angustifolia)*—an excellent conifer for the manufacture of pulp and paper—priority has been given to this species in the area. Its regeneration has been helped artificially and more knowledge has been acquired on its biological and economic characteristics. The complete adaptation of *Eucalyptus saligna, E. alba* and *Pinus caribaea* to this area, has also been demonstrated. Special attention was given to these species in order to produce an abundant supply of raw materials in a relatively short time.

2. After the soil has been suitably prepared, the Paraná River Delta offers favourable conditions for the growth of *Salicaceae* and some *Pinus*. The proximity of this area to the Federal Capital emphasizes its importance. Priority has been given to drainage, forest species and techniques to be applied.

3. Special credit measures favour the creation of forest plantations by private enterprise. The credit operations of the Banco de la Nación Argentina and of the Banco de la Provincia de Buenos Aires are fully under way.

4. Permanent technical impetus and guidance, sale of seeds, cuttings and seedlings at special prices directly contribute to the production of raw material.

III. *Present studies*

The following studies relevant to the production of raw material for the manufacture of pulp and paper are being pursued:

1. Biological and economic characteristics of native and exotic species suitable for pulp and paper manufacture.

2. Implementation of adequate techniques for the planting of economically planned stands, with special regard to the use of machinery with the aim of reducing plantation costs.

3. Control of the different factors adverse to economic production.

SOUTH AFRICAN EXPERIENCE IN THE PLANTING OF EXOTIC SPECIES[1]

N. L. King

South Africa and its timber resources

The Union of South Africa covers an area of 122 million hectares. Since only 10 per cent of this area receives an average annual rainfall of 760 mm or more, immense areas are devoid of indigenous trees. Only 3.5 per cent of the area (4.3 million hectares) is wooded, and 95 per cent of the forests are of a dry type, consisting of scrub and mimosa (Acacia Karoo), of little economic value save as a source of poles and fuel.

The real timber forests—moist forests, in regions of relatively high rainfall, yielding large-size sawlogs—cover only 202,000 hectares, or less than 0.2 per cent of the Union's land area. They are composed of Podocarps (the only important indigenous softwoods, known locally as Yellowwoods) and a large number of broadleaved species. But all the more useful timber trees are too slow growing for commercial purposes, the Yellowwoods, for example, taking 150 to 200 years to reach 46 to 48 cm d.b.h.

The insignificance of South Africa's timber resources makes plain the need for artificial afforestation. This started during the eighties of last century, when some nineteen small plantations were started. From this humble beginning, however, an industry of national importance has arisen; in the State plantations alone it today provides employment for over 31,000 persons.

[1] A slightly shortened version of the original paper, ST/ECLA/CONF.3/L.4.7.

Species which have proved successful

The original plantings comprised various exotics and a number of the more desirable indigenous species. The latter proved a failure and attempts to grow them were discontinued. The early plantations included both *Pinus pinaster* and *P. pinea,* which had been introduced at the Cape in 1652 by Dutch settlers and had proved at home in their new environment. The use of the latter was discontinued, since it forks badly even when crowded. *P. pinaster,* however, proved quite successful, and has been used on a large scale. Though tolerant of poor soils, it grows slowly and its wood is hard and heavy. A strain recently introduced from Portugal gives better results.

By contrast *P. radiata,* or *P. insignis,* seeds of which were obtained from a tree growing in the Botanic Gardens at Cape Town, showed extremely rapid growth; its soil requirements, however, are more exacting.

P. canariensis, with about the same rate of growth as *P. pinaster,* though demanding a soil of the same type as *P. radiata,* yields a hard, strong and heavy wood; it is now mainly grown for electric transmission and telephone poles.

Outstanding among the hardwoods tried is *Eucalyptus diversicolor* (Karri gum); it grows rapidly in deep moist soil and yields a strong wood suitable for pick handles and certain building timbers. Climatically, it is suited only to limited areas in the Cape. *Eucalyptus globulus* (Blue gum) also proved successful in certain areas, but this species is no longer planted because of its susceptibility to damage by a snout beetle.

P. caribaea, P. taeda and *Acacia melanoxylon* (Blackwood) have been grown on a large scale in the region between George and Humansdorp and in the summer rainfall area; the last-named requires deep moist soil and yields an attractive wood used mainly for furniture.

P. rogburghii (longifolia) and *P. patula* are grown on an extensive scale on the mountains near King William's Town. The former thrives best in the warmer and richer soils on the lower slopes of mountains. Doubt has now arisen as to the utility of its wood on account of its spiral grain. *P. pataula,* introduced in 1914, thrives at altitudes of 900 to 1,500 metres; fast-growing, and yielding a light softwood of many uses, it has become of major importance in the summer rainfall area. In the same area *Eucalyptus saligna* and *Acacia mollissima* (Black Wattle) are grown for special purposes on eight- to ten-year rotations.

In the Transkei, an area set aside for the exclusive use of natives, a type of forestry has been evolved to meet the natives' specialized requirements. This fertile, well-watered tract covers 4 million hectares and has a population of 1.25 millions. Most of the natives live in wattle and daub huts roofed with thatch grass, each hut requiring a number of poles and about 1,000 laths (saplings). Each hut, of which there are about a quarter of a million, is rebuilt every ten years or so, giving rise to an annual requirement of about 25 million laths. Plantations of various eucalypts and black wattle on an average rotation of ten years met the natives' needs for fuel, poles and laths and stopped the gradual spoliation of the indigenous forests.

The native mode of building is now undergoing a change, the traditional huts giving way to more substantial buildings. To meet future needs for building timber and rough furniture, plantations of *P. patula, P. caribaea, P. taeda* and *P. roxburghii* were started some years ago.

Black wattle was privately introduced into Natal in 1864, from Australia, and has since spread rapidly. Twenty years later tests disclosed that the bark contains a high percentage of tannin. Today 162,000 hectares are devoted to wattle culture and the export of bark is valued at nearly two million pounds sterling annually. The bark is ready for stripping in eight to ten years. Wood is a sideline on these wattle plantations, but it is used in the mines, in a hardboard factory, is sold as poles and is in strong demand as fuel.

Eucalyptus saligna is in great demand for mine timber, because of its straightness and rapidity of growth and the lightness of the wood it yields. In addition it is used for box-making, paper and hardboard manufacture and may shortly be used for rayon. If thinned heavily while young, it yields excellent furniture timber providing the wood is properly kiln-dried.

More recently private planters in Natal have turned their attention to softwoods, in addition to wattles and eucalyptus, and considerable areas have been planted, mainly with *P. patula* and *P. caribaea.*

Afforestation started on the sandy soil in the hot, steamy coastal belt of Zululand with *P. caribaea, P. taeda, P. palustris, Eucalyptus saligna, E. paniculata* and *E. maculata.* Private individuals and concerns have followed the State's lead, concentrating on *E. saligna.*

In the Transvaal, where the climate is similar to that of Mexico, various pines have been tried. *P. patula* has been highly successful, while *P. pseudo-strobus* grows even more quickly and yields a better wood. It has proved a shy seed-bearer, but will rival *P. patula* once adequate supplies of seed become available.

Soil preparation

Originally the soil was merely pitted at the required spacing. This cheap method proved satisfactory for pines, but not for broad-leaved species, and thorough preparation proved necessary—either ploughing and harrowing or hand picking, the former being most satisfactory. However, because of rising costs, pitting is being reverted to where rodents are not troublesome and the vegetation not too rank.

Methods of establishment; spacing

Wattle seeds are always sown *in situ* after scalding with boiling water, but pines, generally speaking, are established with nursery-raised plants. A point of interest is that in many newly established nurseries pine seedlings turned yellow and died. This was found to be due to the absence of mycorrhiza, and was remedied by inoculating the soil with soil from a pine plantation where pines had been successfully grown.

Various spacings have been tried, but general practice today on first and second quality sites is 2.7 x 2.7 metres for pines and eucalypts, while wattles grown for tan bark are established from seed sown in lines 1.8 to 2.7 metres.

Tending

After wide spacing in the early days, the pioneers turned to dense initial stocking followed by light and frequent thinning. This, while resulting in early suppression of branches and tending to produce timber of high quality, lengthened the rotation and increased production costs. This policy had much to commend it so far as pines were concerned, but hardwoods, if overcrowded for a lengthy period, become more or less moribund and never regain full vigour despite thinning. Wattles should be reduced to their final spacing (1,100 to 1,250 trees per hectare) within two and a half to three years from sowing. Eucalypts grown on a rotation of eight to ten years for poles are generally planted 2.7 x 2.7 metres and left unthinned.

For pines present practice is to thin heavily in early youth to promote diameter growth. To counter heavy branch development, artificial pruning is necessary. This is carried out in three stages, i.e., to 2.4, 4.6 and 6.7 metres when the trees are 6, 9 and 12 metres tall respectively. About 50 per cent of the volume of pruned trees will consist of knot-free timber.

Rotation periods

These vary according to species, site quality and objects of management. In the case of pines, management aims at producing trees with an average diameter of 116 cm at the thick end. The rotations necessary to produce trees of the requisite size may be summarized as follows:

Kind of tree	Rotations (years)		
	1st quality sites	2nd quality sites	3rd quality sites
Fast growing pines, i.e., *P. radiata, P. patula* and *P. pseudo-strobus*	30	40	50
Medium fast, i.e., *P. caribaea* and *P. taeda*	35	45	55
Slow growing, i.e., *P. pinaster, P. canariensis, P. roxburghii* and *P. palustris*	40	50	60
E. saligna and *E. diversicolor* (for large sized timber)	30	40	
Acacia melanoxylon (for furniture wood)	50	60	

E. saligna for mine timber eight to ten years.

Acacia mollissima for bark and wood eight to ten years.

Yields per hectare

Yields per hectare for the several pines are estimated as follows:

Kinds	Estimated yield per hectare (cubic metres)		
	1st quality sites	2nd quality sites	3rd quality sites
Fast growing species	525	420	245
Medium fast	455	336	175
Slow growing	280	245	154

Thinnings represent 25 to 30 per cent of the final yield.

Of any large area, generally speaking 20 per cent can be regarded as first quality site, the balance being made up of about 50 per cent second and 30 per cent third quality.

For the State softwood plantations, average annual yield has been estimated at about 7 m³ per hectare. Information available suggests average annual yields per hectare of 17.5 m³ for *E. saligna* grown under eight to ten-year rotations, 10.5 m³ for wattle plantations and 7 m³ for other hardwoods.

Area of plantations : age classes

Timber plantations in South Africa today cover some 623,000 hectares. Of the 197,000 hectares of State plantations, 160,000 are under conifers, the most important being *P. patula*, with 41,000. Of the 425,000 hectares of private plantations, only 66,000 are under conifers; the hardwoods are principally tan wattles (232,000 hectares) and eucalypts (116,000).

Age class detail is available only for the State plantations. Age class 1920-40 accounts for 90,000, and age-class 1940-53 for 63,000, of the 160,000 hectares of coniferous State plantations. These figures reflect government action for afforestation following the timber famine of the First World War.

Disposals and utilization

Disposals from State forests and plantations in 1952/53 were as follows:

	Quantity in cubic metres		
	Indigenous forests	Plantations	Total
Softwood saw logs	2,850	577,900	580,750
Hardwood saw logs	3,830	67,000	70,830
Mine timber and poles	2,230	88,300	90,530
Pulpwood	—	24,100	24,100
Firewood	8,270	114,400	122,670
	17,180	871,700	888,881

Most of this was softwood, nearly all from thinnings, and hence too small for purposes other than box-making. In coming years the plantations will yield a growing volume and larger sizes.

Data for disposals from private forests are not available, but it is estimated that private plantations yielded 142,000 m³ of softwoods, 2,407,000 m³ of wattle wood and 2,095,000 m³ of eucalypt and other hardwood. Total disposals—State and private—thus amounted to about 5.5 million m³.

Sawmills based on indigenous forests in the last decades of last century and the first decades of this century were small-scale and short lived. Since 1933 the sawmill industry—mainly privately-owned but based on State pine plantations—has grown rapidly and will continue to expand. Large sizes are converted into building timbers, smaller ones into boxes. About 28,000 m³ (mainly short lengths, slabs and edgings) went from the State plantations for pulping in 1953. The main difficulty facing the pulpwood industry is the high transport cost to sites where an adequate supply of water is available.

Future yield and requirements

The potential yield from South Africa's plantations and indigenous forests may be reckoned at about 7.5 million m³ annually. Current requirements are estimated at 7 million m³ (including 3.1 structural and industrial timbers, 1.1 round and partly processed wood for the mines and 2.8 fuelwood). These requirements are likely to grow to 8.9 million m³ in the next decade, indicating a future gap between potential yield and requirements of about 1.4 million m³.

Areas available for afforestation

In the winter rainfall area, in south-western and southern Cape, about 1.4 million hectares receive a rainfall of 762 mm or more. However, only a narrow band along the foothills has a sufficient depth of soil for tree-planting, and when allowance is made for other uses only 20,000 hectares or so remains available for afforestation.

In the summer rainfall area, about 8.9 million hectares receive sufficient precipitation. But over 60 per cent of the area the soil is unsuitable, while further large areas must be written off since they are already occupied by forests and plantations, sugar and other crops, and native reserves where land is short. The area remaining, 0.9 to 1.2 million hectares, would be quite sufficient to satisfy the nation's timber requirements, but it has to be borne in mind that practically all this ground is given over to ranching and agriculture, and farmers may be loath to sacrifice such pursuits to tree planting.

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PRODUCTION OF CHEMICAL PULP AND GROUNDWOOD FROM WILLOW, POPLAR AND POPLAR-WILLOW[1]

CELULOSA ARGENTINA, S.A.

I. GENERAL CONSIDERATIONS

1. *Brief data on salicaceous species*

The Salicaceae, which are mostly found in temperate zones, belong to the plant family of the dictoyledons and to the order of the salicals, which includes the genera *Salix* and *Populus.*

The *Salix* genus—generally bushes and small trees —require a considerable amount of water and are frequently found in marsh-lands or on the margins of watercourses. These plants—commonly known as osiers and willows—are characterized by their thin, long, supple branches. They are not only ornamental; in some species they are suitable for the manufacture of baskets. The willows grow very well on low, very moist or flood lands, such as the Paraná Delta, where the willow-poplar accounts for 80 per cent of all willow plantations. Among other advantages, it is preferred for its white, almost ungrained wood, with more compact fibres and a low specific volume. It is easy to bark when green and, once cut, it can be stored in the open for some time without spoiling.

Hybrid willows rank second in importance in the Delta plantations. These are derived from crossing the "criollo" willow (red willow—*Salix humboldtiana*) principally with the weeping willow (*Salix babilónica*), and secondly with the willow-poplar.

The trees of the *Populus* genus grow to a considerable height and bloom before the leaves appear. They grow best on dry, high lands.

The Mussolini poplar (A.M.)—also known as Euro-americana 154—has given excellent results in the Delta plantations. Its growth is fairly rapid and the wood is white. It has the disadvantage of not keeping more than four months in storage, as the bark falls away and the wood loses all consistency as a fibrous material. Mechanical pulp from this wood and from the "criollo" poplar produce soft papers, that is, papers with considerable bulk and little weight.

2. *Mechanical pulp from short-fibred wood*

Poplar and willow woods in Argentina provide excellent mechanical pulps for the manufacture of many types of boards and certain grades of paper.

Experiments made with a species of poplar (quaking aspen—*Populus tremuloides*) at the Forest Products Laboratory, Madison, U.S.A., indicated that it is preferable to use a pulp stone with a smooth surface for the production of pulp for the manufacture of book paper. A high-strength pulp can be obtained with this smooth stone and, for a given quality, output is greater and power consumption less than with a sharp stone.

To produce pulps of the same degree of strength, more power is required for poplar than for spruce. When ground under similar conditions, the poplar was more finely ground, consumed less power per ton, yielded a fibre of lower strength and shorter average length, and had a higher Schopper Riegler degree.

With the object of improving the quality of mechanical pulps, a number of experiments have been carried out on the treatment of wood by steam, boiling water and chemicals before grinding. Although these treatments make the pulp yields drop slightly and sometimes call for a greater consumption of power during grinding, no great improvement in the resistance and characteristics of the fibres was expected to result. Nevertheless, as a result of steam and boiling water pre-treatments, mechanical pulps made from poplar wood did improve, although they were not as bright as mechanical conifer pulps obtained by the same process. Furthermore it was not necessary to increase power consumption to obtain this improvement.

The chemical treatment of wood before grinding was also studied; in general this pre-treatment is employed to obtain a brighter pulp than that produced by a simple steam or boiling water process.

Most of the tests were conducted with spruce, which was treated with sodium sulphite and sodium carbonate. As the pulp obtained was not sufficiently bright, in one of the tests it was necessary to grind the treated wood at low pressure using a slightly sharpened stone, which, in turn, caused a decline in output. In another case, production costs of this mechanical pulp were higher than those for pulp from untreated wood, but the pre-treatment permitted a reduction in the proportion of sulphite pulps required, with consequent saving, in newsprint

[1] A shortened version of the original paper (ST/ECLA/CONF.3/L.4.8), which includes fifteen tables setting out the results of the tests conducted.

manufacture. From the foregoing it may be deduced that chemical pre-treatment may be recommended when the cost of sulphite cellulose is high.

Bleaching extends the usefulness of mechanical pulps. Earlier bleaching experiments were not successful because of the high costs of reagents and because the white colour obtained had little stability.

There is now a renewed interest in mechanical pulps with a more permanent white colour for use in the manufacture of book paper. The high cost of bleaching is no longer of importance and interest is all the greater because oxidizing agents can be used which give more permanent results than the reducing agents formerly employed. Recently great importance has been attached to sodium and calcium hypochlorites and to sodium peroxide.

II. Laboratory tests

1. *Chemical pulp from common or red willow*

The density of the wood from common or red willow *(Salix humboldtiana)* ranges from 400 to 450 kg/m^3, which is low compared with that of other short-fibred and long-fibred woods. This is very important as affecting pulp yield per cubic metre of wood, particularly in the manufacture of mechanical pulps. For chemical pulps, however, the low density is offset by the greater cellulose content, so that pulp yield per cubic metre is comparable with that from some long-fibred woods. The average length of fibres is about 1 mm and average diameter about 0.03 mm.

The pulps manufactured from this wood, like those made from poplar and willow-poplar, contain small fragments of woody tissue; these exert a definite influence on the characteristics of the finished paper. These pulps are generally suitable for soft paper, of high bulk and opacity, with good texture and excellent printing properties.

Tests made in the laboratory of Celulosa Argentina S.A. showed that red willow presents no difficulties for sulphate cooking. The pulps obtained bleach normally and the bleached pulps are short-fibred and strong. This type of cellulose gives paper good opacity, bulk and good absorption. It is principally used in combination with bleached spruce pulps for book paper.

2. *Semi-chemical pulp from willow-poplar (Salix alba* var. *calva)*

Tests at the Forest Products Laboratory, Madison, U.S.A., on different varieties of poplar have shown that it is feasible to use this species for the manufacture of semi-chemical pulps. They have a high cellulose content, low lignin content, and give very light-coloured pulps.

The process consists of a partial cooking of the chips, followed by mechanical beating. High yields are obtained, from 70 to 80 per cent. According to the degrees of cooking, pulps bleached to varying degrees can be obtained, and when mixed with other pulps they can be employed even for printing and book paper.

It is worthwhile to manufacture semi-chemical pulps from these types of wood, and from all short-fibred woods, because the resulting pulp is relatively strong, in spite of the short fibres. Semi-chemical pulps from poplar and willow-poplar are being increasingly used for the partial substitution of chemical pulps in several kinds of paper, including newsprint. It is now possible to bleach these semi-chemical pulps completely, with high yields and very good resistances.

Cooking with the neutral sulphite semi-chemical process eliminates from one third to one half of the lignin content, and converts the chips into a fibrous mass from which the remaining lignin can be eliminated with chlorine and hypochlorite. As a result of the elimination of all the lignin, the resistance of the unbleached pulp increases and bleaching can be done to achieve the desired brightness.

Poplar and willow-poplar, due to their high cellulose content, low lignin content and easy conversion, are very suitable woods for this purpose. Yields of from 55 to 58 per cent of bleached cellulose have been obtained from these woods, with resistances sometimes similar to those of long-fibred woods.

A series of tests on willow-poplar samples was carried out at the laboratories of Celulosa Argentina S.A. They demonstrated that a neutral sulphite semi-chemical pulp can be obtained from willow-poplar, the degree of brightness depending on the cooking. With less sulphite and sodium hydroxide or darker and cruder pulp, which is harder to beat, is obtained.

With an adequate percentage of sodium sulphite (10 per cent on dry chips) good cooking is possible; as the time of exposure at maximum temperature increases, better pulps, more easily bleachable and with a higher degree of brightness after bleaching, are obtained.

Bleaching of semi-chemical pulps by oxidation is cheaper than bleaching by chlorination in several stages as it permits higher yields and relatively lower costs. Nevertheless there is a limit to the final degree of brightness that can be obtained and the colour will not be as stable as in multi-stage bleaching. Since the use for which these pulps are intended does not require exceptional brightness or resistance, the one-stage bleaching process with calcium hypochlorite has been adopted.

3. *Bleaching mechanical willow-poplar pulps*

The natural whiteness of willow-poplar wood greatly facilitates the bleaching of the mechanical pulp obtained from it. Tests at the Celulosa Argentina Laboratories showed that a brightness of 70 can be achieved by bleaching for six hours at a constant temperature of 32° C. with 3 per cent sodium peroxide (based on dry weight of pulp) and with an initial alkalinity of 1.8 per cent NaOH.

In the manufacture of mechanical pulp, a yield of 95 per cent on moisture-free wood is obtained and this percentage drops only 1 per cent after peroxide bleaching. It is worthwhile to manufacture a number of papers from a relatively good pulp, with high yields after bleaching, and low costs, particularly in those countries where bleaching agents are abundant and cheap.

However, peroxides are not produced in Argentina, and their consequent high cost prohibits their use. Therefore at the Zarate mechanical willow-poplar pulp plant sodium peroxide has been replaced by sodium bisulphite, which is abundant and cheap.

Bleaching is carried out by applying a fine spray of sodium bisulphite solution to the wet machine roll after the sheets have been formed and before they are folded.

This solution begins to bleach while it is wet and this bleaching action continues in storage. There is no need for subsequent washing and the mechanical pulp can be used just as it is, although it is advisable to dry it or use it within a few days for the manufacture of paper as if it is left in storage for a long time while wet the pulp becomes darker again.

III. Effect of the burring of the pulpstone on the quality of mechanical willow-poplar pulp

Tests were made to determine the variations in the quality and the characteristics of mechanical pulp obtained by burring the pulpstone of the grinder at different speeds.

The fundamental aim is to obtain a mechanical pulp which, in combination with chemical pulp, has an initial wet strength sufficient to prevent breakage on the paper machine. This condition must be satisfied even if it involves increasing the percentage of the more expensive chemical pulp in the mixture.

The factors that were kept constant during the grinding tests were: (*a*) pulpstone: diameter, grain, state of the stone surface, and number of revolutions; (*b*) general: number of pressings, useful pressure, flow of water supplied by the shower pipes to wash the stone surface, power absorbed, etc. In addition, in each test an effort was made to keep constant the type and quality of wood, not only as regards species, but also as regards moisture (whether green or dry wood); the temperature in the pit; and the consistency and concentration of the pulp in the pit. Since the stone surface, and hence the stone dressing, is important to the quality of the pulp, four series of tests were carried out: (1) after dressing the stone for 4.3 seconds with burr No. 12; (2) after dressing the stone for 62 seconds with burr No. 12; (3) after dressing the stone for 30 seconds with burr No. 12; and (4) after dressing the stone for 10 seconds with burr No. 13.

The highest strength (1,040 metres) in laboratory sheets of finished pulps corresponded to slow-speed sharpening (62 seconds) on dry woods, using burr No. 12. The lowest strength (454 metres) corresponded to green woods with a sharpening speed of 30 seconds. The duration of the sharpening process has a graded effect on the resistances obtained, from the most rapid to the slowest (4, 30, and 60 seconds respectively from dry wood). Taking a test period of seventy-two hours after sharpening as the limit, in general the highest resistance values are obtained, both for dry and green wood, two to three days after sharpening.

As regards the Schopper-Riegler degree, in every test dry woods gave higher values than wet; the highest with slow sharpening for 62 seconds, and lower values for 30- and 4-second sharpenings. The results suggested that the Schopper-Riegler degree is higher in the pulps obtained in the first few hours after sharpening, thereafter declining.

In the case of dry woods, slow and rapid sharpening influences the percentage of flour or fine stock in the following manner: (*a*) slow sharpening during sixty-two seconds gives the highest percentage of fine stock or flour; (*b*) the percentage of fine stock rises when the stone loses its sharp edges; (*c*) sharpening for thirty seconds produces a smaller amount of fine stock.

Under similar conditions, green wood gives a greater percentage of fine stock with rapid sharpening (4 seconds), although this percentage remains stationary after forty-eight hours. In contrast, for 30- and 62-second sharpening speeds a higher percentage of fine stock is obtained from dry wood.

The highest percentages of fine fibres and the best technological characteristics of pulps are obtained with the highest pit concentration, with higher temperatures during the grinding process.

If the other factors are kept constant, the highest Schopper-Riegler values and the greatest resistance are obtained when the average temperature and concentrations are high. Conversely, with low pit concentration and low temperatures, the pulp obtained in the pit is much coarser.

Maximum hourly output with 100 per cent dry wood occurs during the first forty-eight hours after sharpening, then decreases.

These conclusions may be summarized as follows:

Slow sharpening: gives lower hourly output, greater burr wear, higher Schopper-Riegler, higher resistance, higher percentage of fine fibres in pulp, more stops to dress the stone, greater stone wear, superior technological characteristics in the pulp; is less economical. *Rapid sharpening:* gives exactly the opposite results. All these conclusions refer to tests made under the same working conditions, the grinding variables being kept constant.

PULP AND PAPER MAKING FROM EUCALYPTS IN AUSTRALIA[1]

R. B. Jeffreys

I. Introduction

Although scientific experiments to ascertain the suitability of eucalypts for the manufacture of pulp and paper were begun in 1920, it was not until 1938 that the first commercial production of eucalypt pulp began. Prior to that year only one paper company—Australian Paper Manufacturers Ltd.—was operating in Australia making a variety of wrapping papers and cardboards. All the chemical and mechanical pulps used were imported, mainly from the Scandinavian countries. Three years later three major companies were operating, all using eucalypt pulp as a part of the furnish. In 1938, Associated Pulp and Paper Mills Ltd. began operations at its mill in Burnie, Tasmania, using bleached soda eucalypt pulp as the major part of the furnish in the manufacture of writing and printing paper.

Australian Paper Manufacturers which had operated a pilot mill with a capacity of 10 tons per day since the

[1] Originally issued as ST/ECLA/CONF.3/L.4.9.

beginning of 1938, started its commercial kraft pulp mill in September 1939. Since that time it has used kraft eucalypt pulp in an unbleached, semi-bleached, or fully bleached form as a part of the furnish in wrapping papers and boards. This kraft pulp mill is located at Maryvale, between Morwell and Traralgon, in Gippsland, Victoria.

Early in 1941, Australian Newsprint Mills Ltd. began operations at its mill in Boyer, near New Norfolk in Tasmania. This company makes newsprint containing a high percentage of eucalypt mechanical pulp in the furnish.

There were many reasons for the long delay between the beginning of scientific experiments and the first commercial use of eucalypts as raw material for pulp and papermaking in Australia. Being hardwoods, the eucalypts have short fibres, and it was natural that the first experiments concerned their use in those types of papers where short-fibred pulps were already being employed elsewhere in the world, namely, in fine writings and printings. It was soon proved that eucalypt soda pulps could be used for this purpose and it was other considerations that caused delay in establishing the mill at Burnie.

The next experiments were mainly devoted to the sulphite and mechanical processes, with the object of making newsprint, and it was many years later that experiments were started which finally proved that eucalypt kraft pulp could be used as a major part of the furnish in the manufacture of wrapping papers and in the liners of boards.

The problem, as far as newsprint is concerned, is an obvious one: in normal practice, to make this product economically at least 80 per cent of mechanical pulp must be used. It was natural, therefore, that there was much hesitation before a mill was erected to make newsprint containing 80 per cent of mechanical pulp made from timber with an average fibre length of approximately one millimetre.

There appears to be no doubt that the unsettled conditions in Europe in the middle 'thirties with the possibility of war and the consequent interruption in the supply of paper to the Australian market, did much to hasten the plans of the companies concerned to reduce the dependence of Australia on overseas supplies.

There are about 400 species of eucalypts and in their native state they appear to be very selective with regard to climate, soil and aspect. Generally, two or more species are found growing together. Pure stands are rare although sometimes a single species is dominant. Frequently the cohabiting species are of a different type. However, there are some notable exceptions to the rule that pure stands do not occur. Of particular interest to paper makers are *Eucalyptus regnans* and *E. gigantea*, which in the main do occur in pure stands. Another exception is *E. eugenioides*, which is found in relatively pure stands in East Gippsland.

Basically there are five different types of eucalypts:

(i) *The gums*, which have thin smooth barks and are usually fast growers. Because of their thin barks they are very sensitive to fire.

(ii) *The stringy-barks*, which in some respects resemble the gums but are more fire resistant.

(iii) *The iron barks*, which have a very hard fire-resistant bark and can survive in areas of low rainfall.

(iv) *The boxes*, which have a dense fibrous bark and which are usually found on steep slopes where the soil is poor.

(v) *The peppermints* which are a small group intermediate between the gums and the stringy-barks.

Although, as has already been stated, there are about 400 species of eucalypts, less than twenty are used in the manufacture of pulp and paper in Australia. This does not mean that the remaining species are unsuitable. Economic conditions, such as quantity, percentage in mixed forests, and distance from existing markets and existing pulp and paper mills have, up to the present, precluded the use of some suitable species. Of the five basic types of eucalypts, the three that are used for papermaking, in order of importance, are the gums, stringy-barks and peppermints. One important species —*E. gigantea*—which is used at all three of the abovementioned mills is sometimes classed as a gum and sometimes as a stringy-bark. This species has a stringy bark part way up the trunk, and a smooth (or gum) bark at the top of the trunk and on the branches. It is known as a gumtop stringy-bark in the south of Tasmania, as white top stringy-bark in the north of Tasmania, and as woollybutt in Victoria.

The species used for pulp and paper making in Australia, listed in their approximate order of importance (though their relative importance varies of course from mill to mill) are:

E. regnans	*E. capitellata*	*E. bridgesiana*
E. gigantea	*E. radiata*	*E. nitens*
E. obliqua	*E. viminalis*	*E. rubida*
E. eugenioides	*E. goniocalyx*	*E. lindleyana*
E. sieberiana	*E. consideniana*	*E. globulus*
	E. muelleriana	*E. fastigata*

It will be noted that the gums are placed first in order of importance in the Australian pulp and paper making industry; it is this type that is grown extensively in plantations overseas and is being used or is proposed for use in pulp and paper mills elsewhere. In this connexion, important species are *E. saligna, E. grandis, E. rostrata* and *E. globulus*. With the exception of small quantities of *E. globulus*, none of these species is used in Australia for one or other of the reasons already given. They are, however, used in other countries and do appear to be quite suitable, at least for chemical processes.

There are two important differences between the pulping of eucalypts in Australia and in other parts of the world. In Australia most of the pulpwood is extracted from mature and overmature forests, some of which were standing when the white man first inhabited Australia. In contrast, the overseas plantations are all young and immature.

The other important difference concerns the growth rate. With one or two exceptions, the forests of Australia have probably been grown at a much slower rate than the plantation timbers overseas. The exceptions are the *E. regnans* and *E. gigantea* forests found in districts of Victoria and Tasmania. These species, usually found in fairly even stands, have been known to grow some 15 to 18 metres high, with diameters up to 30 centimetres breast-high, in ten years from the time the original forests were destroyed by fire. Other species tend to grow at a very much slower rate than this, and it is fairly safe to assume that the plantation timbers of South America have grown much more quickly than the same species in their natural habitat.

The foregoing is a sweeping statement to which there are no doubt many exceptions. Sometimes in a forest in which most of the trees have grown at a very slow rate there are isolated plots of richer soil and with a more favourable aspect in which the trees have grown very rapidly. On the other hand, it is improbable that all eucalypts in plantations elsewhere in the world show a uniformly rapid rate of growth.

The effect of the above two factors needs to be assessed in the light of the use to which the timber is to be put. In general, the rate of growth is a determining factor as far as chemical pulping properties are concerned, for fast grown timber makes the best chemical pulp. Fast grown and young timber produces chemical pulps with very high bursting and tensile strengths, but with comparatively low tear—a property which develops with age. In the case of *E. regnans* optimum all-round strengths are obtained with timber at perhaps fifty to sixty years of age, after which the bursting and tensile strengths tends to decline while the tear increases slightly. In Australia *E. regnans* from forests over 200 years old has been pulped and found to be still a good pulpwood.

On the other hand, the slower growing species, when young, produce pulps which have a higher tearing strength than young *regnans*, but have lower bursting and tensile strengths. The pulp from the young wood of these species is quite suitable for use, but that from the mature and overmature wood is usually much too low in bursting and tensile strength development to be used as a major part of the furnish of wrapping papers.

An example of the differences in the strength development of pulp from typical young fast grown timber and overmature slow-grown timber is given in table 1.

Table 1

Timber	Freeness (ml) C.S.F.[a]	Tear factor	Breaking (m) length (m)	Burst factor
Young *E. regnans*........	350	103	11,100	98
Overmature *E. sieberiana*..	350	110	7,800	55

[a] Canadian Standard Freeness.

The strength developments of the eucalypt pulps are compared at 350-375 C.S.F. because within that range of freeness the pulps when beaten in the Lampen Mill develop approximately the same strengths as they do when beaten in the Sutherland refiners to a lower freeness (200-300 C.S.F.) at which they are used on the paper machines.

It will be noted from table 1 that the young *regnans* pulp develops very high bursting and tensile strengths, thus enabling the long-fibred kraft with which it is to be blended to be very lightly beaten and retain a high tear; thus the paper made from the blend has satisfactory all-round strength properties. On the other hand, the overmature *sieberiana* pulp develops very poor bursting and tensile strengths, and, although it has a higher tearing strength than the young *regnans* pulp, it is unsatisfactory for blending.

The faster growing and less dense eucalypts also make the best mechanical pulp, but it is not until the trees are mature or overmature that satisfactory pulps for newsprint can be made. At Australian Newsprint Mills the mechanical pulp is obtained mainly from *E. regnans*, with smaller quantities from *E. gigantea* and *E. obliqua*. The forests in this Company's timber concessions are, in the main, probably over 200 years old.

The following pages give some details of manufacture and endeavour to point out the difficulties experienced and to indicate where differences might occur when using plantation timbers of Latin America. Because of the writer's familiarity with the kraft process, comments are mainly confined to this process.

II. The manufacture of kraft pulp and its use in paper and boards by Australian Paper Manufacturers Limited

1. *The pulping process*

(a) *The forests*

All of the species previously listed are used in the pulp mill at Maryvale. The relative importance of the first five species is slightly different from the over-all Australian importance, their order being *E. gigantea, E. eugenioides, E. regnans, E. sieberiana* and *E. obliqua*. The order of importance of the remaining species is as shown previously.

The Maryvale pulp mill was established on the basis of the *E. regnans* and *E. gigantea* forests as the main source of pulpwood. However, in 1939, before the mill was completed, one of the most disastrous bush fires in Australia's history almost completely destroyed these forests, including young forests which had regenerated after previous fires. The fire-killed *E. regnans* and *E. gigantea* were used for many years, and in fact some mature wood is still being extracted, but is showing signs of deterioration. The young pole timber, some of it only ten years old, was used for approximately ten years after the fire. The *E. gigantea* forests, growing at a higher elevation, have deteriorated less, and this species is at the present time more important than *E. regnans*.

The destruction of the *E. regnans* and *E. gigantea* forests caused the Company to rely more and more on other species as a source of supply. It soon became apparent that in the area closest to the mill these other species were old and overmature and produced a low-grade pulp. The company is entitled by a special Act of Parliament to extract its pulpwood supplies from certain State forests, using timber unsuitable for lumber. The burnt forests and the old and overmature forests, containing other species, constitute the major part of the Company's concession area. Over the last four years the Company has been buying mixed species forests containing relatively young timber in order to assure itself of a supply of good quality pulpwood. A large proportion of these Company-owned forests are almost pure stands of *E. eugenioides*.

For the sake of simplicity, three general terms will be used in the following pages. In Victoria, the common name for *E. regnans* is mountain ash. The pulping properties of *E. gigantea* are similar to those of *E. regnans* and these two species will be referred to as ash. All other species are referred to as mixed species. Old mixed species refers mainly to *E. sieberiana* and *E. obliqua* with varying small quantities of other species. Young mixed species refers mainly to *E. eugenioides* with varying quantities of other species.

(b) *Bush operations*

The great variety in the forests necessitates the use of many logging methods. In the mountain forests, where fire-killed ash is being salvaged among dense regrowth, small tractors are used. Rope logging or heavy tractor equipment—which would be ideal for this type of logging—cannot be used now because of damage to the regrowth. In old mixed species forests, tractor arch logging and portable high lead rope logging are the main methods now used.

The terrain covered by the young mixed species forests is generally fairly flat, and the small trees are barked and billeted to 1.8 metre lengths at the stump. The billets are then collected by motor trucks and delivered to rail head or mill.

All barking is done by hand. The fire-killed ash has long since lost its bark and no problem arises. The mixed species pulpwoods are readily barked, except in the summer months when the bark is very tight. Some cutters will not work in the young mixed species forests in the summer because of the difficulty in barking the timber. As the ash forests cannot be logged in the winter, contractors tend to spend their summer in the ash forests, and winter in the young mixed species forests.

No attempt has been made to bark the mixed species billets in barking drums as it is feared that the thick stringy-bark would block up the outlets from the drums. Two drums are installed at the mill, but they are used only for barking the small amount of pine that is used, and for washing and removing remnants of bark from the eucalypts.

Chemical barking has been tried, but to date the results have not proved very satisfactory. Experiments have been carried out to ascertain whether young gums with a thin smooth bark can be cooked satisfactorily without barking. The results have indicated that this can be done with some small loss in the strength of the resultant pulp, and with a slightly increased alkali consumption.

(c) *Chipping*

The first chipper used at the mill was a four-knife unit made in Canada. It was equipped with carbon steel knives that had proved satisfactory when chipping softwoods. These knives could be used only for thirty minutes before they had to be resharpened. In addition there was frequent trouble owing to the knives cracking. This was found to be due, at least in part, to grit in the billets, and was considerably reduced after the washing drums were installed.

After the first experience with the knives, many other types were tried, and it soon became obvious that knives of plain carbon steel would not meet the conditions. Eventually, an English company manufacturing in Australia—the Eagle and Globe Steel Co.—devoted much attention to the problem and finally produced knives that gave satisfactory results. These knives are made from steel with a 2 per cent carbon and 12 per cent chromium content. The knives on this chipper are currently running for twelve hours before they need resharpening.

The solution of the whole problem of knife failure by cracking has been assisted by the routine use of a magnetic crack detector. The use of this equipment makes it possible to detect cracks in their very early stages, and to grind them out.

An American ten-knife chipper is now in use with the same type of steel in the knives as for the four-knife chipper. The knives on this chipper run for as long as twenty-four hours before they need to be resharpened.

The average output of the four-knife chipper is just under 19.8 m^3 per hour, and the power consumption just over 2.8 kWh per m^3. The average output of the ten-knife chipper is approximately 36.8 m^3 per hour, and the power consumption 2.5 kWh per m^3. The output of the ten-knife chipper is limited by inadequate feeding arrangements rather than by the chipper capacity.

There is a wide variation in the chipping properties of the eucalypt used. Young green ash, the softest and lightest, is not much harder to chip than pine. Probably the most difficult is old *E. goniocalyx* which contains silica deposited through its fibre structure, is very hard to chip and very rough on chipper knives.

One further point should be mentioned. The larger trees are split in the bush with explosives or by hand with mauls and wedges. Sometimes the splitters are careless and leave wedges embedded in the billets. As a result, chipper knives were often badly damaged. Our Research Division has now developed a metal detector that operates satisfactorily. When a billet containing a wedge passes along the conveyor to the chippers the motor driving the conveyor is automatically stopped and the offending billet located.

(d) *Digester operations.*

The cooking of eucalypts presents some problems not encountered in the cooking of softwoods. The problems are accentuated when mixtures of various types of eucalypts are cooked together. Some of these problems are discussed below.

(i) *Charge to the digester.* The basic density (dry weight on green volume) varies considerably with the different types of pulpwood used. At the two extremes are young ash with a basic density of 384 kg per m^3, and old *sieberiana* with a basic density of 609 kg per m^3. In order to ensure that the correct charge of alkali is added to the digesters, the oven dry weight of each digester charge is determined.

The chips are stored in a ground level storage from which they are conveyed to the digester. A weightometer is installed at a point on a horizontal part of the conveyor just before it begins to rise to the digesters. The operator at the chip store takes a sample from each charge to the digesters and makes a rapid determination for moisture. The calculated moisture content of a charge is taken as the average of the two previous charges. From this average and the weightometer reading, the oven dry weight of the charge is calculated and alkali added accordingly.

(ii) *Variation in alkali demand.* The young ash pulpwood requires little more than half the alkali required for some of the old mixed species. Young ash with a basic density of 384 kg per m^3, can be cooked with approximately 10 per cent of active alkali expressed as sodium oxide on the oven dry weight of the charge. On the other hand, old mixed species with a basic density of

609 kg per m^3, requires approximately 18 per cent of active alkali to cook to the same degree.

In a mixed charge to the digester the active alkali is calculated according to the mixture. An endeavour is made to keep the proportions fairly constant so that neither the oven dry weight of the chips to the digesters, nor the active alkali will vary too considerably.

(iii) *Effect of cooking mixed charges.* The alkali demand of eucalypts when cooked to the same degree ranges from 10 to 18 per cent on the oven dry weight of the wood. We have found that when cooking old ash, of say 14 to 15 per cent alkali demand, with mixed species of comparatively low alkali demand, say below 16 per cent, the charge is evenly cooked and the strength obtained from the pulp is the same as that which would be acquired by cooking the woods separately and blending the pulps in the correct proportions.

One of the most important questions in this connexion has never been satisfactorily answered, that is, the effect of cooking very young ash with any other eucalypts. This wood produces a pulp that develops a very high burst and tensile strength provided it is cooked under the correct conditions of alkali charge, pressure and time. In the early days of the pulp mill operations there was a considerable amount of this type of wood available, but because of war conditions, output from the mill was more important than the production of the very highest quality pulp, and the young ash was cooked together with other wood of all ages. Today there is practically no young ash available, and so the question is not of such immediate practical importance. We hope that in a few years' time this type of wood will again be available; and we have yet to determine whether it should be cooked separately or in a mixture with other species of low alkali demand.

At the present time we are cooking a mixture containing approximately 40 per cent mature ash, 50 per cent young mixed species and 10 per cent old mixed species.

(iv) *Cooking schedules.* The present standard cooking conditions in the mill for the above-mentioned mixture, together with the average yield and permanganate number, are given in table 2.

Table 2

Active alkali (as Na_2O) % on oven dry wood	14.5
Cooking pressure	5.6 kg/cm^2
Time to pressure	2 hours
Time at pressure	1¼ hours
Liquor ratio	2.7:1
Sulphidity	25 per cent
Oven dry content of wood	66 per cent
Average basic density (kg per m^3)	561
Pulp yield—O.D. pulp on O.D. wood	47 per cent
Permanganate number of pulp	15.5

(v) *Strength characteristics.* To determine their strength characteristics, the pulps are beaten in a Lampen mill and sheeted on a British standard sheet machine. The sheets are then dried and conditioned at 20°C and 65 per cent relative humidity.

Average strengths for the pulps produced with wood furnish as in (iii) above, and when cooked under conditions as in (iv) above, are as shown in table 3.

(vi) *Blowing the pulp from the digesters.* Experience has shown that eucalypt pulps are more difficult to blow clean from the digesters than pine pulp. We are making approximately 30 tons of pine pulp per day at the present time and it is very rarely that a charge has to be reblown. On the other hand, reblows of eucalypt pulp are quite frequent. Reblows are more common when a soft pulp is being made than when the pulp is hard.

Table 3

Beating (rev.)	0	7,500	15,000	22,500
Freeness (ml) C.S.F.	515	375	280	220
Tear factor	82	105	103	103
Breaking lengths (m)	5,000	9,900	10,800	10,900
Stretch	2.3	3.6	4.0	4.1
Burst factor	31	71	81	83
Density (cc/g)	1.81	1.48	1.41	1.37
Air resistance (sec/100 ml)	11.5	54	148	320
Log air resistance	1.06	1.73	2.17	2.51

Note: 375 C.S.F. is considered to indicate mill strength of this pulp.

With the exception of young ash, the eucalypts are much denser than pine. For example, the basic density of our current furnish is 561 kg per m^3, while the basic density of the pine we are at present cooking is 392 kg per m^3. In addition to this, the eucalypts on the whole make finer chips and pack more closely into the digesters. Because of the closer packing the circulation in the digesters tends to be more difficult in the cooking of eucalypts than pine. Failure of liquor circulation to the bottom of a digester because of mechanical trouble invariably causes dirty blowing, and uneven cooking is suspected as a cause. It is now thought that a lower liquor ratio assists in clean blowing with eucalypt pulp, but that a higher liquor ratio gives better strengths. Hence the present figure of 2.7:1 is a compromise.

(vii) *Corrosion.* After the pulp mill had been operating for four years it became apparent that digester corrosion was so high that all the digesters would have to be replaced in approximately ten years if the corrosion rate was not reduced. Initial work indicated that most corrosion was due to the presence of oxygen. Later work indicated that sulphides and thiosulphates were also partly responsible.

The corrosion rate was reduced from 1.27 mm per year to approximately 0.76 mm per year by the following means:

(a) Leaving digesters empty and clean during shutdown periods. Originally the digesters were left charged with chips at shut-downs in readiness for the start-up;

(b) Relieving the gases from the digesters in the early stages of the cooking to reduce the amount of oxygen and the time in contact with the digesters.

In addition to the above, the sulphidity of the liquors was automatically reduced from 30 per cent to approximately 20 per cent as the chemical losses throughout the mill were reduced. This undoubtedly helped to decrease the corrosion rate. More recently the sulphidity has tended to increase once more owing mainly to soda losses rising again and partly to the operation of the oxidation tower before the evaporators. The corrosion rate is being closely watched.

Consideration was given to the use of stainless steel or stainless clad digesters. One of the latter was installed, and one old digester was lined with stainless plate. Both have proved satisfactory, but it is considered cheaper to have the digesters made of good quality boiler plate of welded construction in accordance with Lloyd's rules Class II, but with sufficient thickness to allow a large margin for corrosion. The old 57 m^3 digesters are to be replaced with one of 78 m^3 capacity made of 1⅜ inch (35 mm) thick plate. This thickness compares with a maximum of 1 inch (25 mm) in the old digesters.

(e) *Washing the pulp*

In the pilot mill, washing was carried out in diffusers. As the diffusers were small, satisfactory washing was obtained although the process was slow. During the war some large diffusers were installed at the main mill as part of a plant to make special pulps. The operation of these diffusers when washing eucalypt pulp was unsatisfactory the pulp being imperfectly washed after over fifteen hours' washing. Modern diffusers may give better results, but our experience shows that fine pulps like those from the eucalypts should be washed on rotary vacuum washers.

Our original vacuum washer installation consisted of three units, 2.4 metres in diameter by 1.8 metres in width, the primary and secondary units having Oliver Young valves and the tertiary an Oliver Ring valve. The washers are equipped with vacuum pumps.

The size of these units was slightly larger than the estimated size required to wash 90 tons of long-fibred pulp per day as it was assumed that the eucalypt pulp would be more difficult to wash. The contrary has proved to be the case.

Before new washers were installed to handle increased production, the three 2.4 by 1.8 metre units were regularly washing 145 tons of pulp per day with a loss per ton of 20.4 kg of soda (in terms of sodium sulphate). The wash liquor to the evaporators contained 17 to 18 per cent total oven dry solids. Of the 20.4 kg soda loss, 15.9 kg was in the liquor associated with the pulp and the remainer in the pulp itself.

The degree of dilution of black liquor by wash water calculated from an average spray water usage of 10.5 kg of water per kg of pulp and 11 per cent for O.D. value of pulp sheet leaving the washer is 3.4 kg of water per kg of A.D. pulp. This dilution is fairly high, but is compensated by a low liquor ratio in pulping so that the solids content of the feed to the evaporators is at a reasonable level.

When *Pinus radiata* kraft has been washed on these washers the maximum washing rate has been 120 tons per day with a higher soda loss and a lower concentration of feed liquor going to the evaporators.

The easier washing of eucalypt pulp is attributed to the lesser tendency of eucalypt liquor to foam; to easier disintegration of the web after each washer; and to closer and more even formation on the washer drums.

The efficiency of the washer depends on the nature of the eucalypt pulp, associated with the wood furnish. The 20.4 kg per ton loss was a regular figure obtained over a long period during which there was no old mixed species wood in the furnish. More recent figures showed a loss between 25 and 27.3 kg per ton, an increase which may be associated with the presence of 10 per cent of that wood in the current furnish.

Although eucalypt pulp is easier to wash on vacuum washers to a low soda content than pine pulp, the colour of the wash liquor presents a problem, particularly if the effluent is to be discharged into a small river. At the same solids content, the colour of the liquor with the pulp from the third washer when washing eucalypt pulp is between three and four times as intense as that of pine. This applies to our present wood furnish. The colour varies considerably with the type of eucalypt from which the pulp is made.

(f) *Screening the pulp*

The unbleached pulp is passed through Trimbey knotters with ¼ to ⅜ inch (6.4 to 9.5 mm) perforations and then through Trimbey fine screens with .040 to .035 inch (1.02 to 0.89 mm) perforations. The throughput of each knotter is approximately 130 tons per day and of the fine screens 40 to 50 tons per day.

(g) *Bleaching the pulp*

The greater part of the pulp is used unbleached, but some is semi-bleached to replace strong sulphite and some fully bleached to replace bleached sulphite and imported bleached kraft.

The process used at present is a two-stage batch process for both semi and full bleaching. In the first stage the pulp at 3.5 per cent consistency is treated with hypochlorite, followed by the addition of chlorine, after which the pulp is neutralized with lime and washed. In the second stage, the pulp at 14 per cent consistency is treated with hypochlorite only and then washed.

The semi-bleached pulp has a photovolt brightness of 56 and the loss of strength compared with the unbleached pulp is small. The fully bleached pulp has a photovolt brightness of 78, and the loss of tearing, bursting and tensile strengths is each about 25 per cent. We are proposing to use caustic soda instead of lime to neutralize after the first stage as the use of lime causes colour regression.

Modifications are to be made to the bleach plant to enable part of the process to be carried out continuously and to permit a three- or, if necessary, a four-stage process to be used.

Laboratory work has indicated that by interposing a hot alkali extraction as a second stage, bleached pulps of 80 photovolt brightness can be produced with little loss of strength, and by using a four-stage process with two hypochlorite stages a brightness of 85 can be achieved, again with comparatively little loss of strength.

(h) *Evaporators*

The original evaporator installation was a six-body long tube vertical quintuple effect unit. The liquor was concentrated in this unit to firing density (60 to 62 per cent total solids). Under these conditions the tubes in the high density bodies fouled badly and it was necessary to boil them out frequently to maintain production. On occasions it was necessary to perform this operation two or three times per week.

Subsequently a forced circulation effect was added to make a seven-body quintuple effect evaporator. The inclusion of the forced circulation effect through which the most concentrated liquor passed, did improve operations, but fouling still occurred in the long tube vertical bodies. Cascade evaporators were then installed behind the recovery unit, and with this arrangement, runs of two weeks could generally be made with very little drop in throughput. The cascade evaporators concentrate the liquor from approximately 45 per cent total solids to firing density.

Experience has proved that there is a great variation in the behaviour of black liquors from different eucalypts. The liquor from the cooking of ash gives much less trouble than that from young mixed species which in turn give much less trouble than that from old mixed species. The original difficulty was experienced with evaporator liquor from a mixture of ash and young mixed species, and the higher the percentages of mixed species, the greater were the difficulties experienced.

Some time after the installation of the cascade evaporators, an attempt was made to use 100 per cent mixed species, mainly young wood, in the mill. The throughput of the evaporators fell from 66 tons per hour to 54 tons in four days' operation. It has been found when cooking pine in the mill and evaporating the mixed pine and eucalypt liquors that the operations of the evaporators is more satisfactory than when cooking eucalypt alone.

Some tests carried out in 1947 when 100 per cent pine was being cooked in the mill, indicated that the evaporators had a 10 to 15 per cent greater output on pine liquor than on eucalypt liquor. This has been attributed to the lower viscosity of pine liquor when concentrated. The following viscosities, expressed in centistokes, were determined during one test.

	Eucalypt liquor 60 per cent total Solids	*Pine liquor 60.8 per cent total Solids*
93° C.	66	23
99° C.	54	19

The variations in viscosity of eucalypt liquors in relation to density were also determined as follows, results again being expressed in centistokes.

	Total solids				
	60 per cent	*55 per cent*	*50 per cent*	*45 per cent*	*40 per cen*
93° C.	66	44	12.8	6.5	3
99° C.	54	34	10.8	5.7	2.6

The difference in viscosity can be observed visually and can also be noted in motor loads. The viscosity of eucalypt liquor varies from time to time according to the wood furnish and the conditions of cooking.

There is a stronger odour from a eucalypt kraft mill than from a softwood mill. At a production rate of 150 tons per day, 28.3 m^3 of gases are given off per hour from the digesters. Of this volume, between 5.7 and 8.5 m^3 consist of sulphur gases (mercaptans, sulphides and sulphuretted hydrogen). We have no comparable figures for pine.

At the same production rate, 8.5 m^3 of non-condensible gases are given off from the evaporators consisting of 30 per cent sulphuretted hydrogen, 20 per cent carbon dioxide, and the remainder oxygen and nitrogen. When the evaporators are run on pine liquors the gas volume is the same as for eucalypt, but it contains only 5 per cent sulphuretted hydrogen.

We have installed an oxidizing tower to stabilize the sulphur in the liquor before it goes to the evaporators. This operation reduces the sulphuretted hydrogen content of the liquor to zero.

(i) *Recovery furnace operation*

Eucalypt black liquors are more difficult to burn in the recovery furnace than are pine liquors, and there is a very wide variation in the burning properties of different types of eucalypts. Liquor from ash burns more readily than liquor from young mixed species, while up to the present it has not been proved that liquor from 100 per cent old mixed species can be burnt at all in the recovery furnace.

When pine liquor or ash liquor is burnt it dries on the walls of the furnace and swells to give a fluffy char. The char bed appears to be porous and moving as it burns and is practically all incandescent. Poor burning liquor does not dry out. It runs down the wall or falls off in tacky lumps. When it reaches the char bed it lies in a solid mass into which the air cannot penetrate. The bed is not moving and looks completely dead. Less than half appears to be incandescent.

It has been noted in the laboratory that the dried solids of black liquors, which burn readily in the furnace, swell to several times their original volumes after heating to 300°C. The solids from poor burning liquors either do not swell at all or do so only to a very small extent.

The possible reason for this relationship is that in swelling, the black liquor solids increase their surface area and this is considered to be an important factor when burning liquor in the recovery furnace. Laboratory experiments have indicated that certain materials added in small quantities to the poor burning black liquors before drying out induce the swelling which is thought to be necessary for good burning. So far the addition of these materials to the black liquor has not yet been tried at the mill.

The calorific values of eucalypt black liquors are generally lower than those of pine and again appear to vary considerably. Tests carried out in the early days of the mill's operation, when a very high percentage of ash was being used in the furnish, showed that the calorific values were approximately the same as those of pine, i.e., 3,560 kcal/kg oven dried. The black liquor from the furnish at present used has a calorific value of approximately 3,330 kcal/kg oven dried.

During one attempt to burn liquor from a blend of young and old mixed species, it was found to be impossible to operate the recovery furnace with a spray tip larger than 12 mm at a spraying rate of 6,800 to 7,700 kg per hour which corresponds to approximately 75 tons of pulp per day, and even then it was necessary to spray oil continuously to the furnace to assist combustion. When liquors containing a high percentage of ash are burnt, the capacity is at least 30 per cent higher than the above figure, and no oil is necessary once the furnace has been heated to working temperature.

Direct steam heating to increase the temperature of the liquor to 112°C so that it would flash when sprayed has been tried and a minor improvement made.

The steam generated from eucalypt liquors is less than from pine liquors, the difference being greater than would be expected from the respective calorific values. On the average, only slightly more than 3,400 kg of steam per ton of pulp are generated. This compares with the reported figures of between 4,000 and 4,500 per ton of softwood pulp in overseas mills.

(j) *Lapping the pulp*

Pulp to be sent to other mills, or held in storage at Maryvale, is lapped on one or other of three Kamyr machines, two of which are 2.03 metres wide and the other 3.35 metres wide. Certain pulps give trouble due to the sheet cracking as it comes off the pick-up roll at the drum. Poorly washed pulp gives a lot of trouble, which the use of a hot water shower on the sheet seems to increase. Two additional rolls were added between the drum and the first press to help support the sheet and the tail when leading through. Bleached and semi-bleached pulps run easily on the machine; it is unbleached pulp that gives the trouble.

The dryness of the pulp after the Kamyr machines is: unbleached pulp, 48 to 51 per cent (oven dry basis); semi-bleached pulp, 50 to 52 per cent (oven dry basis); fully bleached pulp, 51 to 53 per cent (oven dry basis).

III. Paper making

The eucalypt pulp made at Maryvale is used either on the M.F. paper machine there, or lapped and sent to the Company's other mills, mainly to Fairfield (Victoria) and Botany (New South Wales). At Maryvale it is used in the manufacture of corrugating paper, liner board and heavy-weight kraft papers. At the other mills it is employed in the manufacture of M.F. and M.G. kraft wrapping and bag papers, M.G. lithos, etc., and as part of the furnish in various types of lined boards. In all these products the eucalypt pulp is blended with long-fibred pulps, mainly imported, to produce papers with the desired properties. Satisfactory bursting and tensile strengths can be obtained from the eucalypt pulps, but the long-fibred pulp is needed to impart the necessary tearing strength to the paper.

The eucalypt pulps cannot be beaten satisfactorily with the long-fibred pulp and two-line preparation is necessary. The uniformity of both components must be controlled and metering devices used for accurate blending.

In our experience, the Sutherland refiner has been found to be the most satisfactory unit for the preparation of the eucalypt pulps. Broad tackle beaters are quite unsuitable and fine tackle beaters are unsatisfactory unless they are maintained in good condition all the time.

The eucalypt pulp is refined to 200 to 300 C.S.F., which gives the optimum condition of bursting and tensile strength developed, good running on the machine and satisfactory paper properties. The long-fibred pulp for making strong papers is treated in blunt tackle. It is left free and near the peak of its tearing strength. The blending of the "wet" eucalypt pulps with the "free" long-fibred pulps results in a stock of the correct freeness for paper making and a sheet of paper with well-balanced properties.

The quality of the long-fibred pulps is important. As a result, we are careful in selecting the pulps we buy from overseas and evaluate them according to the results obtained when they are blended with eucalypts. The proportion of eucalypt pulp that can be used varies with the type of papers being made. On kraft papers the range is from 30 to 70 per cent. The lowest percentage is used with multi-wall bag paper which is made to very rigid specifications. In strong light- and medium-weight kraft papers about 50 per cent of eucalypt pulp is used, while on heavy weight kraft of 25 D.C. or more, at least 60 per cent is used.

For M.F. corrugated paper the eucalypt pulp content ranges from 75 to 95 per cent, the balance being printed news in one case, and local pine kraft in the other. In M.G. lithos there is usually 50 to 60 per cent fully bleached eucalypt pulp, but it has been made with 100 per cent eucalypt.

On the board side, the percentage of eucalypt pulp varies widely according to the type of product being made. We use as much as 55 per cent of it in the liner of some grades and as little as 25 per cent in others. The exact percentage that can be used can be determined only when it is known what properties are desired in the boards and also what other fibrous raw materials are to be used in the furnishes.

Many problems had to be overcome before we were able to obtain reasonably trouble-free operation when using high percentages of eucalypt pulp. One of the worst of these was sticking at the press. At times this limited the proportion of eucalypt pulp used to 25 per cent at Maryvale, where this difficulty was felt most severely—mainly because slush pulp from the pulp mill was used there. The lapped pulp used at the other mills gave less trouble, probably owing partly to the loss of fines during lapping and partly to the final washing it receives on the lap machines. In addition, the Maryvale machine is the fastest of all of our machines and has a dual press. It runs at approximately 300 metres per minute on some grades of paper.

Sticking at the press was at its worst when undercooked pulps were being used; consequently, until the difficulty was surmounted, there was a tendency to overcook the pulp which increased the cost and produced a poorer pulp. Lightly beaten pulps gave more trouble than well-beaten ones, therefore there was a tendency to overbeat the pulp to improve running.

The use of soda ash and kerosene was tried with little or no success. Finally, the problem was solved by the use of sodium hexametaphosphate which renders iron and aluminium inactive. At Maryvale, sodium hexametaphosphate is applied to the press doctor in a dilute solution at the rate of one kg per shift.

The freeness of 200 to 300 C.S.F. to which the eucalypt pulps are beaten in the mills is a compromise which gives the best over-all results. If they are left freer, adequate strength development is not obtained, sticking at the press becomes worse, and in the case of papers made from bleached grades to be used for printing—especially M.G. lithos—fibres and the small vessels which are present in eucalypt pulps are picked out during the printing process, thus spoiling the appearance of the printed sheet and ruining the ink. On the other hand, while further beating increases the bursting and tensile strengths without any marked loss in tearing strength, it would also produce a tendency for the papers to curl and cockle and for M.G. papers to develop a blistered appearance.

The use of eucalypts by other companies

The foregoing is a very brief account of the manufacture of kraft pulp and paper from eucalypts. It outlines some of the main problems that have arisen since the pulp mill was started in 1939. Space does not permit a similar account of the problems at the other mills, even if the writer was thoroughly familiar with them.

At Burnie, Associated Pulp and Paper Mills Ltd. uses bleached soda pulp to make fine writing, printing, and body paper. The species used are *E. gigantea* and *E. obliqua* with varying quantities of other species.

The problems that have arisen are probably not so acute as those previously described in connexion with the kraft process. The pulpwood is more even, because there is no timber similar to the young *E. regnans* or to the old mixed species used at Maryvale.

Until comparatively recently, a single-stage cooking process was used and although the peculiar characteristics of the eucalypt liquors were apparent in the evaporators and recovery furnaces, they did not cause quite the same trouble as at Maryvale. Now, a two-stage process is being used with the object of reducing soda consumption, and the troubles are more acute. This is in line with Maryvale experience, where it has been noted that in the evaporators there is less fouling of the tubes when there is excess alkali present. At Burnie the change from the single to a two-stage process with a reduced alkali usage has resulted in a black liquor with little or no excess alkali.

The problems on the paper machine are those likely to be experienced by any company making a wide variety of writing and printing papers containing a high percentage of hardwood pulps. Sticking at the press, which was the worst trouble experienced by Australian Paper Manufacturers, is not so serious, as bleached pulps are used, the machines are slower than the Maryvale machine on which sticking gave the most trouble, and the use of clay in the furnish of some papers would help to prevent it.

At Boyer, Australian Newsprint Mills Ltd. make only eucalypt mechanical pulp, mainly from old *E. regnans* with smaller quantities from old *E. gigantea* and *E. obliqua.* When the mill first started the only wood that could be used was *E. regnans,* and the use of the other two species is a subsequent development. The pulp produced from these mature woods is too dark in colour to be used without some further treatment. The necessary brightness is obtained by the use of zinc hydrosulphite.

The variability of the eucalypts as pulpwood is well illustrated by the experience at Boyer since the mill started. It has been found that, even in mature stands of *E. regnans* of the same size and in apparently the same condition, there is a wide variation in the grinding properties, and in the quality of the pulps produced.

The Boyer mill has been so designed that the pulp does not come in contact with iron until the web of paper is formed and pressed. The eucalypts have a high tannin content which increases with age and wet mechanical pulp in contact with iron is stained a bluish grey colour due to the formation of iron tannate. When some of the early experiments were being conducted, the sulphite process was used. Unbleached sulphite pulp, particularly from mature woods, was also stained when left in contact with iron.

Pulping of South American eucalypts

At the time of writing this paper, detailed information concerning the eucalypt plantations in South America was not available. It is understood, however, that in the main the growth has been very rapid and that *E. saligna* is one of the important species. Without knowing the details and without having carried out tests to determine the pulping properties of the wood, it might be unwise to make any definite statements. However, Australian experience suggests that the age and rate of growth are the important factors in chemical pulping, and not the actual species.

Early indications in Australia were that young *E. regnans* was outstanding in the strength development of the pulp. On the whole, it is still considered to be the best pulpwood. Two factors contribute to this. First, it is practically always a fast growing species. Secondly, an old *regnans* tree is likely to be much sounder than trees of many other species of the same age. It has already been mentioned that *E. regnans* over 200 years old was found to be good raw material for chemical pulp, and that at Boyer, where mechanical pulp is produced, the forests are probably older than this. It is often difficult to determine the age of many of the other species, such as the stringy-barks.

E. regnans, being one of the gums, is very sensitive to fire—probably one of the most sensitive of all the eucalypts. Consequently it is safe to say that no living *regnans* forests have been swept by a fire of any magnitude. On the other hand, the other species with their thick barks withstand fires very well. It is not uncommon to see such forests that have been completely blackened by fire, sprouting new growth within a few months of the conflagration. The timber of the mixed species forests shows evidence of repeated fires by the presence of numerous gum veins. These fires have almost certainly affected the wood and are probably partly the cause of the poor pulping properties of some of the old mixed species forests. They are not the entire cause, as mature *E. goniocalyx,* which is also a gum and therefore fire sensitive, is a very poor pulpwood.

While young *E. regnans* as a rule does produce kraft pulps with higher strength development than other species, there are exceptions to the rule. Pulps produced from young fast-growing wood of other species have developed higher strengths than the young *E. regnans* pulps, but these species are normally slow growing and occur mainly in mature and overmature forests so that the young fast-growing trees are too rare to be economically important.

The overseas plantations are young and fast growing and it seems safe to forecast that they will produce kraft pulps with very high bursting and tensile strengths and that if beaten correctly and blended with lightly beaten long-fibred pulps, they should produce strong wrapping papers. The bleached pulps should be suitable for use in most types of writing and printing papers.

To obtain the best strength results cooking should be carefully controlled and the pulp slightly undercooked rather than overcooked. Under these conditions, sticking at the press is likely to occur when making wrapping papers from the unbleached pulps and a corrective, such as sodium hexametaphosphate, may have to be used.

Judging from Maryvale experience, the black liquor evaporators could be expected to operate without serious trouble, provided a cascade or cyclonic evaporator were used to concentrate the liquor to firing density. The black liquor should burn readily in the recovery furnaces.

It is unlikely, on the basis of Australian experience, that good quality mechanical pulp can be made. Until the plantations are very much older the mechanical pulp is likely to be fine and floury and suitable only as a filler for certain types of paper, and quite unsatisfactory for use as a high percentage of the furnish on a fast running newsprint machine.

RESEARCH INTO THE USE OF *TRITHRINAX CAMPESTRIS* (PALMA, PALMERA, CARANDAY) LEAVES AS RAW MATERIAL FOR PAPER[1]

WALTER GINZEL

The palm, *Trithrinax campestris,* grows in natural stands in various parts of Argentina, such as Santa Fé, Córdoba, San Luis, Santiago del Estero, Tucumán, Corrientes and the province of Entre Ríos, where the largest stands are found. This palm, which is popularly known as the "palma", "palmera" or "caranday" according to the area where it is found, grows to a height of 2 to 4 metres, the trunk being covered with remains of foliage; the leaves are flabellated and divided into segments. It is these leaves which can be used, not only in the textile industry, but also, when green and well-developed, in the paper industry.

The fibres are from 0.7 to 2.5 mm long and from 8 to 20 micra wide; thus the average length/width ratio is 100:1 making them suitable for use in paper. Their structure is cylindrical, with very thick walls, so that they are suitable without much refining, for making bulky, absorbent papers; because of their fibrillating capacity, they can also be used to obtain strong papers.

The alkaline process, with caustic soda, was used for tests on a laboratory and on a semi-industrial scale. Air-dried leaves with 10 per cent moisture were cut up into sizes of 2 to 3 cm and treated in the digesters. Caustic soda consumption ranged from 8 to 10 per cent, calculated on dry raw material, depending on the method of cooking used. The pulp yield was 40 to 50 per cent, which is similar to that of straw and other annuals already used industrially on a large scale. The completely dry pulp analysed as follows: 73 per cent cellulose; 17 per cent pentosans; 7 per cent lignin and 3 per cent ash. Because of the process used and the composition of the pulp, this may be classified as a type of "semi-chemical pulp".

Trithrinax palms grow abundantly in several parts of Argentina; this, coupled with their easy exploitation and the successful tests made, indicates that this new raw material for pulping can be used on an industrial scale.

[1] A shortened version of the original paper (ST/ECLA/CONF.3/L.4.10).

V. Economics of pulp and paper manufacture from sugar cane bagasse

BAGASSE FOR PULP AND PAPER[1]

THE SECRETARIAT WITH SPECIAL ASSISTANCE FROM THE BANCO DE FOMENTO AGRÍCOLA E INDUSTRIAL DE CUBA[2]

Section I

INTRODUCTION

Interest in bagasse as a raw material for pulp and paper extends over a period of more than 100 years. As far back as 1844, there is a report of sugar cane being shipped to France from the island of Martinique for utilization in the manufacture of paper. In the 1860's and 1870's several accounts were recorded in the United States of the use of bagasse for production of newsprint. In the 1880's a number of mills to make paper from bagasse are said to have been planned and one or two actually built in or near New Orleans. These and many other early endeavours, however, all failed to produce a satisfactory and marketable product.

The first reference to bagasse pulping in Latin America is in 1908, when a company started a bagasse mill at Rio de Janeiro, Brazil. This plant is said to have produced about one ton of paper per day for three years, but it finally had to close down. Other efforts followed in various parts of the world, but up to just before the Second World War, despite the many attempts to pulp bagasse, the only successful commercial ventures were wallboard mills, notably that of the Celotex Corporation at Marrero in Louisiana. It was not, in fact, until 1939—following a great deal of further experimental work, particularly in the United States, the Philippines, Japan, Peru, England and Hawaii—that the first two plants for manufacturing pulp and paper from bagasse on an industrial scale were finally established.

One of these was the integrated pulp and paper mill of W. R. Grace & Co., at Paramonga in Peru, the other that at Tatu, near Taichung in Formosa, owned by the Taiwan Pulp and Paper Corporation. A third mill, producing bleached pulp, was established very shortly afterwards in the Philippines. At present, there are altogether some twelve commercial-size plants throughout the world producing pulp and paper from bagasse; eight of them are situated in Latin America.[3]

In the last few years interest in bagasse as a source of pulp and paper has intensified, and the reasons are not far to seek. Bagasse fibre has very good paper-making characteristics; in certain areas it is produced regularly and in abundance; as a by-product of cane sugar production it is, at any rate at first sight, very cheap; some of the areas where bagasse is produced most abundantly are areas which are lacking in other fibrous material suitable for paper making.

The literature on bagasse pulping has multiplied rapidly in recent years. This paper does not attempt to summarize all that has been written on this subject or to provide an informed evaluation of the various processes, several of them patented, which are available today for pulping bagasse. Indeed, such an assessment—which in some cases would call for the drawing of arbitrary distinctions between claims and achievements—would require a good deal more information regarding processes, investment and production costs than has yet been made public. This paper is therefore confined to a brief description of the principal processes available.

The main emphasis is rather on the factors affecting the supply of bagasse which can be made available for paper making, an equally important aspect of the bagasse problem. The argument is based partly on the background papers which have been submitted to this meeting and partly on a series of investigations which were conducted into the potential bagasse supply position in six Latin American countries. These case studies are discussed in section *V*, while much of the material collected is presented in the form of appendices to the present paper.

Many of the points dealt with in this paper are supported by original material, sometimes including lengthy computations and unwieldy tables. So far as possible these have been relegated to appendices, which are, however, an essential part of the paper; to those familiar with bagasse problems they will perhaps assume more importance than the main text.

Section II

CANE SUGAR PRODUCTION IN LATIN AMERICA

The production of sugar from cane is widely distributed in Latin America; figures for recent years are given in table 1 on page 251. It should be pointed out that production figures for the individual countries may or may not include purely local types of sugar-cane products (piloncillo, panela, papelón, chancaca, raspadura, etc.) which are used for home consumption. For a variety of reasons (small producing units, absence of product from the international market, lack of standard grades, etc.) production figures of such local types of sugar-cane products are often reported incompletely or not at all.

Direct statistics of quantities of bagasse produced are generally lacking, so that this information must be calculated indirectly. This calculation may be made by combining (*a*) statistics of sugar produced, with (*b*) average yield of sugar per cent of cane ground, to arrive at (*c*) quantity of cane ground; the quantity of cane ground (*c*) may now be combined with (*d*) average total fibre content (including pith) of cane ground, (*e*) average sugar content of fresh bagasse, and (*f*) assumed moisture content of bagasse, to arrive at (*g*) the quantity of fresh bagasse produced.

[1] Originally based as ST/ECLA/CONF.3/L.5.0.

[2] This bank commissioned Ing. Jorge Guerra to carry out the field survey referred to in this report.

[3] The location of the mills and some operating details are given in appendix VIII.

Table 1

LATIN AMERICA: ANNUAL SUGAR PRODUCTION FROM CANE DURING THE FIVE-YEAR PERIOD 1949-1953

(*thousands of tons*)

	1949/50	1950/51	1951/52	1952/53	1953/54	Five-year average
1. *Mexico*	604	667	681	775	813	708
2. *Caribbean*						
Cuba	5,570	5,770	7,230	5,170	5,160	5,780
Dominican Republic	476	537	589	632	636	574
Haiti	50	58	58	55	36	51.4
3. *Central America*						
Guatemala	60	51	50	56	49	53.2
El Salvador	23	26	26	25	27	25.4
Others	62	69	66	71	94	72.4
4. *South America*						
Argentina	557	623	661	568	721	626
Brazil	1,514	1,798	1,898	2,150	2,180	1,908
Colombia	149	184	160	168	198	171.8
Ecuador	49	46	47	57	56	51
Peru	458	497	500	518	634	521.4
Venezuela	49	47	61	51	66	54.8
TOTAL, LATIN AMERICA	9,621	10,373	12,027	10,296	10,670	10,597

Source: Willet and Gray, New York. Figures for 1953/54 are partly estimated.

The following table gives data for items (*b*), (*d*) and (*e*) gathered during the field survey.

Table 2

DATA USED IN CALCULATING AMOUNT OF BAGASSE PRODUCED

(*Percentages*)

	Yield of sugar on cane ground	Average total fibre in cane ground[a]	Average sugar content of fresh bagasse
Argentina	7.2	13.0	4.2
Brazil	10.5	12.7	4.3
Cuba	12.7	12.5	3.4
Mexico	9.1	13.2	3.5
Peru	11.3	14.8	2.7
Venezuela	11.0	12.8	3.4
AVERAGE	10.3	13.1	3.6

[a] Including pith.

Bagasse production can now be estimated on the basis of the data given in the two previous tables; the results are presented in table 3. For those countries not surveyed, the average values indicated in table 2 were assumed.

Thus in recent years Latin America has produced annually over 26 million tons of fresh bagasse. This volume would be sufficient to produce annually over 4 million tons of pulp—enough to meet the region's current paper requirements three times over—if it were all available for paper making. In fact, of course, only a small fraction of this total can at present be used for paper making. Existing bagasse mills in Latin America probably consume somewhere between 300,000 and 400,000 tons of fresh bagasse annually, i.e., between 1 and 1.5 per cent of the total available. Nearly all the bagasse produced is used as fuel in the sugar mills themselves. The essence of the supply problem (though by no means the whole of the problem) is to free bagasse from its present use as fuel in order to make it available for paper manufacture. The very approximate figures quoted above suggest that it would not be difficult to achieve a rapid increase in supplies of bagasse for pulping. Though a substantial increment may be possible, there are many factors which set a limit to what can be achieved. Some of these are discussed in the following sections.

Table 3

LATIN AMERICA: ESTIMATED ANNUAL PRODUCTION OF BAGASSE

(*Average 1949-53*)

	Fresh bagasse 50 per cent moist (Thousand tons)	Total fibre in bagasse (Percentage)	Bagasse on cane ground (Percentage)
1. *Mexico*	2,210	46.5	28.3
2. *Caribbean*			
Cuba	12,200	46.6	26.8
Dominican Republic[a]	1,570	46.4	28.3
Haiti[a]	141	46.4	28.7
3. *Central America*[a]			
Guatemala	146	46.4	28.7
El Salvador	69	46.4	28.7
Others	198	46.4	28.7
4. *South America*			
Argentina	2,470	45.8	28.4
Brazil	5,050	45.7	27.7
Colombia[a]	470	46.4	28.7
Ecuador[a]	139	46.4	28.7
Peru	1,450	47.3	31.4
Venezuela	137	46.6	27.6
TOTAL, LATIN AMERICA	26,250	..	..

[a] Countries not actually visited during the field survey.

Section III

RELEASING BAGASSE FOR PULP

Among agricultural products requiring considerable mechanical and thermal processing before reaching the final consumer, sugar-cane is one of the few that provide at one and the same time—and in roughly the proportions desired—both the raw material ingredient sought in the process (sugar) and the fuel (bagasse) needed for industrial treatment.

The general question of availability and cost of bagasse as a raw material for pulp is, therefore, intimately bound up with sugar-cane milling operations. Individual sugar-mill installations differ from country to country, within the same country and even within the same district both as to the type of production operations they carry out and the kinds of end-products they make.[4] There is no such thing as a standard or uniform type of sugar-mill production operation or, in consequence, of sugar-mill installation.[5]

Only a small part of the 26 million tons of fresh bagasse[6] produced annually in Latin America can be regarded as potentially available for paper making since, firstly, bagasse provides the main source of fuel in the sugar mills themselves, being available on the spot in a quantity sufficient to meet requirements, and, secondly, most of the sugar mills are too small to supply enough bagasse to feed a pulp mill of minimum economic size, while it may not be economic to procure bagasse from other sugar mills in the same region.

However, in some large and modern sugar mills with good boiler efficiency a surplus does arise, while it can often be obtained in others by a combination of improved boiler efficiency and more efficient steam usage. Thus in a mill for raw sugar, for example, a surplus of up to 30 per cent or more of the bagasse produced might be achieved; this, providing the sugar mill is big enough, could liberate sufficient bagasse for a pulp mill of economic size.

Improved thermal efficiency, then, represents one way in which additional bagasse can be released for paper making. Another is the replacement of bagasse by an alternative fuel in the sugar mills. This holds an obvious attraction for countries such as Mexico, Peru and Venezuela, where sugar-producing areas provide a cheap, indigenous fuel as an alternative. These two approaches —improved thermal efficiency and the use of an alternative fuel—will be discussed in turn.[7]

Improved thermal efficiency

It is claimed that a raw sugar mill, operating with ideal efficiency, can provide its factory power and steam from only 8 per cent fibre content in the cane. Since cane contains an average of 13 per cent fibre, it suggests that about 60 per cent only of the heating value need be utilized, and that conceivably 40 per cent of the bagasse may be freed for paper making. However, fuel practices and steam economies in raw sugar mills vary so much from mill to mill that while under ideal conditions some may be able to attain a surplus approaching this figure, others may need to use supplementary fuel.

An extremely important point—and one with significant economic implications—is made in one of the background papers submitted to this meeting.[8] Whatever the types and combination of power installations in a raw sugar mill, the mill is generally designed to provide a margin—which may be considerable—between the steam which passes through the prime movers and the total required for process heating. For a proper balance it is generally recognized that only three-quarters, and perhaps less, of the steam produced passes through the power units; the rest is supplied as process steam direct from the boilers. Hence, so long as all exhaust steam from the turbines and engines is used for process heating, their efficiency is relatively unimportant. The really heavy losses arise from failure to use the exhaust steam for process heating and through leaving steam lines unlagged. In other words, it is in such process steam that effective economies must be made if bagasse is to be saved.

The implication is that it is not necessary to contemplate the very heavy capital investments (and other costs) that would be involved in scrapping heavy, direct-action steam-driven prime movers and drives of older-type cane-grinding equipment and in replacing them by modern and more efficient turbine-type or electrified prime movers and their corresponding drives. More efficient mechanical utilization of steam (and the high capital cost of securing it) can make but a negligible contribution towards bagasse saving.

This may seem surprising; and certainly for those concerned with freeing supplies of bagasse for paper making it is reassuring to know that a measure of success may be achieved at less cost than might appear at first sight.

It follows that attention must be concentrated on measures to improve the efficiency of the over-all generation of steam and of the thermal utilization of process, low-pressure steam. Both in the older and in the more modern installations, these are the main directions in which bagasse saving must be sought.

A variety of measures are discussed in the background paper to which reference has already been made and for the convenience of the reader they have been summarized and listed in appendix III. The costs, direct and indirect, of introducing these measures are likely to be considerably lower than those involved in improving the mechanical utilization of steam. Moreover, they offer another important advantage. They can be put into effect gradually and successively over a period of years; they can form separate but complementing elements in a long-term bagasse-saving programme.

Of course, not all the measures listed are equally applicable to the different types of sugar-mill installations. The five examples worked out in appendix VI show that steam requirements vary according to the operations undertaken. The figures given are not, as is pointed out, universally valid, but they do suggest that steam requirements are lowest in plain sugar mills and highest in mills with refineries and distilleries. In general, therefore, mills of the former type will not have been hard pressed for fuel in the past; incentives to adopt the measures listed will thus have been lacking.[9] It is in sugar mills of this type that the greatest opportunities for improvement may be found. At the other extreme, existing mills with a refinery and distillery will have been hard pressed for

[4] See appendix I: *Yield Relationships in Sugar-Cane Grinding Operations.*

[5] See appendix II: *Different types of Sugar-Mill Installations and their relative prevalence in Argentina, Brazil, Cuba and Peru.*

[6] In terms of 50 per cent moisture content.

[7] Bagasse released in these two ways is frequently referred to as "surplus" bagasse and "substitute" bagasse, respectively.

[8] *Saving of Bagasse for Paper making—Thermal Considerations:* Cellulose Development Corporation and John Thompson Water Tube Boilers Ltd.

[9] This is a very broad generalization. Much depends on the fuel practices adopted. As pointed out earlier, even some of the plain sugar mills may have had to purchase supplementary fuel.

fuel, perhaps purchasing additional supplies. Here many bagasse-saving practices will already have been adopted and opportunities for further savings will be few.

Alternative fuel

Any materials ordinarily used as fuel can conceivably take the place of bagasse; only three will be considered here—wood, natural gas and fuel oil—since these alone seem to offer *prima facie* possibilities in Latin America.

The possibilities of substituting *wood* for bagasse are extremely limited. Sugar-cane cultivation calls for considerable areas of cleared tillable lands in close proximity to the sugar mills; it is therefore exceptional, in traditional sugar-growing regions, to find large stands of timber side by side with cane plantations. Timber is absent altogether, except in the few isolated instances where land has been only recently planted to cane or where reafforestation has taken place. In the latter case, since wood is scarce, competing uses and the consequent price of wood generally rules it out of consideration as a fuel for the sugar mill.

In the area of Tucumán in Argentina, wood and fuel oil are being used together in sugar mills as supplementary fuels to make up the bagasse deficit; here it is probable that fuel oil was introduced recently as wood became increasingly scarce. In some well-established sugar-producing regions of Brazil, especially in the State of São Paulo, there has been extensive reafforestation with eucalypts and sugar mills there may be found burning both fuel oil and wood as supplementary fuel.

Sugar mills in countries with gas-producing wells within economic pipeline distance of the plantation areas may be able to use *natural gas,* either as supplementary or as additional fuel. However, only in Venezuela, of the six countries surveyed, did natural gas seem to offer attractive possibilities in the near future. And even here, in the case of the particular sugar mill investigated from this aspect, the information indicated that the cost of using natural gas would prove higher than that of fuel oil.

Broadly speaking, this implies that *fuel oil* is likely to be the only practicable alternative to bagasse. The cost of switching to fuel oil will vary considerably from place to place; in some countries with a high duty on oil, replacement of bagasse by fuel oil will be quite out of the question. It should be noted, however, that a simple cost comparison does not tell the whole story, since fuel oil—like natural gas—offers the additional advantage of facilitating improved sugar-mill operations; not only does it give improved boiler efficiency, but it enables the steam demand to be matched more closely than does bagasse.

Fuel oil is a well-established commodity on the international market sold in clearly defined standard grades. It can be transported easily, either in bulk by ocean-going tankers or overland by road or rail. The main items to be considered when contemplating its use as an alternative fuel are (*a*) ease of transport to the sugar mills; (*b*) its cost as a substitute for bagasse (on the basis of relative steam generation equivalents); and (*c*) the capital cost of converting the installation to use fuel oil.

Generally speaking, transport will not present any difficulty, since the sugar mills, though located in rural areas, have already a well-organized system for moving their sugar output to the internal consuming centres or to shipping points. In fact return-load considerations may mean that the cost of fuel oil delivered to the mill may be slightly discounted. It is perhaps worth noting that, for a sugar mill using oil as its only fuel, the ratio by weight between sugar produced and fuel oil consumed is roughly 2.5 to 1.

The relative values of bagasse and fuel oil as fuels are dealt with in appendix V. Roughly speaking, a ton of fresh bagasse will generate 2.5 tons of steam, as against 14.4 tons of steam generated by a ton of fuel oil. *Thus one ton of fuel oil will replace six tons of fresh bagasse.*

The replacement ratio will, of course, vary according to the conditions encountered in the particular mill. Moreover, as already indicated, the simple replacement ratio is not the only factor to be considered, since fuel oil offers other advantages.

The cost of conversion to an oil-burning installation is dealt with in appendix VII. The investment depends only on the size of boiler required, which in turn is dependent on the rate at which the bagasse is to be released. But the capital cost per ton of bagasse consumed by the pulp mill depends also on the length of the grinding season. By way of illustration, the cost of equipment (including freight and installation) would amount to 58,000 dollars for a sugar mill with a six-month grinding season, or sufficiently large to release 90,000 tons of fresh bagasse, i.e., to feed, throughout the year, a 50-tons-a-day capacity pulp mill. Making allowance for depreciation, interest, maintenance, spares and insurance, the conclusion is reached that the cost of conversion would represent a charge of 12 cents for each ton of fresh bagasse released. To feed the same sized pulp mill, i.e., to release the same quantity of bagasse, in a shorter grinding season would call for a higher capacity installation, while lower capacity would suffice for a longer grinding season. Thus, in the instance just quoted, the capital charge on each ton of fresh bagasse released would be, for grinding seasons of three and nine months, 21 and 9 cents respectively. The capital charges per ton drop fairly sharply as the size increases. Thus, against 12 cents a ton for a 50-ton daily capacity pulp mill (six-month grinding season), for a 20-ton mill (same grinding season) the charge would be 18 cents per ton.[10]

The three items just discussed have all to be taken into account when considering a change-over to fuel-oil burning. They do not of themselves allow an estimate of the cost of bagasse as a pulping material. Essentially, of course, the cost of bagasse for pulping is the cost of replacing it by another fuel in the sugar mill, but it is also necessary to take into account the extra costs which arise from the need to handle, bale and store the bagasse. These too depend on the length of the grinding season, as well as on the extent to which the pulp mill operates on fresh, as distinct from dry, bagasse. Therefore, before the cost of bagasse to the pulp mill can be discussed, it is necessary to consider the problems which arise from the need to bale and store bagasse. But it is convenient first to summarize the saving that may attend the adoption of the measures discussed so far.

[10] Of considerable interest is the raw material procurement practice adopted by two companies pulping bagasse in Mexico. Each of these companies has paid for conversion to fuel-oil burning at the sugar mills supplying them with bagasse, and each also pays for the fuel oil consumed. In addition, each company maintains baling stations at the sugar mills concerned and meets the cost of transport of the baled bagasse from the sugar mills to their respective pulp mill sites.

Potential surpluses

The potential surpluses that can result from the adoption of measures to improve thermal efficiency or from a switch to fuel-oil burning are summarized in the following table.

Table 4

POTENTIAL BAGASSE SURPLUSES

Type of operation	Improvements needed in steam generation and usage: General	Specific	Potential bagasse surplus[a] (Percentage)
1. *Improved thermal efficiency* (without fuel substitution)			
"Direct" alcohol mills	No	No	40 to 50
"Plain" sugar mills:			
(*a*) Modern	Yes	No	20 to 30
(*b*) Older	Yes	Yes	20 to 30
Mills with refinery, or with distillery, or both	Yes	Yes	0 to 15
2. *Alternative fuel*			
All types	Conversion	Conversion	Up to 100

[a] As a percentage of total bagasse produced.

It is clear that the possibilities of freeing bagasse for paper making are very great. It is equally clear that in every individual case there will be a limit to what can be achieved, short of a complete change to fuel oil. Whether this will prove an economic proposition in any particular instance can only be determined after a series of complex calculations have been made.[11] The foregoing paragraphs have simply pointed out some of the more important considerations which must be borne in mind, while the appendices contain material, some of it original, illustrating these points.

Apart from the two main approaches to the problem of freeing bagasse which have been discussed here, there is another which, though referred to in appendix III, falls into an entirely different category. It represents securing savings by varying the pattern of the mill's output. Since steam requirements vary according to the type of operation undertaken, clearly any change in the pattern of output involving a reduction in the yield of sugar (as an end-product) obtained per ton of cane ground will give rise to a bagasse saving. How far savings of this kind can be obtained at a particular mill will depend on many wider economic considerations, e.g., respective markets, and hence the relative profitability to the enterprise of sugar produced and bagasse saved.[12] Moreover, for a particular mill, the relative weight of these considerations will vary from time to time as market conditions change.

A discussion of these bagasse-saving possibilities lies outside the scope of this paper; nevertheless, it may be important in certain circumstances and at particular times and therefore cannot be entirely disregarded.

[11] Although the economics of bagasse release are complex, the calculation of the amounts which can be released by the adoption of particular measures is fairly simple, and appendices V and VI provide data which will enable a rough estimate to be made.

[12] General speaking, bagasse releases of this kind will be incidental to changes in the production pattern at the sugar mill; rarely will the production pattern be modified to secure a release of bagasse.

Problems of handling, baling and storage

In most countries cane-sugar manufacture is seasonal. In the main sugar-producing countries of Latin America the grinding season varies from 75 days in Cuba and Venezuela, to 150 days in Argentina, Brazil and Mexico and 225 days in Peru.

Since a pulp and paper mill should operate on a year-round basis, this means that provision must be made to meet operational contingencies and to enable production to be maintained at the level required. It is possible for a pulp mill to operate on fresh run-of-the-mill bagasse during the grinding season. But unless the grinding season extends throughout the year—and there are few, if any, areas where it does—this means that some of the material must be baled in any case. This factor, along with considerations of ease of handling, storage and transport, largely accounts for the fact that a common practice in bagasse pulping is to bale all the material as it comes from the sugar mill and store it against demand.

A baling station is therefore needed on land adjacent to the sugar mill. The baling equipment must be of robust construction and the number of balers required will depend on the amount of material to be handled and the speed at which the units can be operated.

Baler capacity and bale size vary but several balers are designed to deal with up to 150 to 200 tons of fresh or wet bagasse per twenty-four hours. For a baling station in the United States[13] a standard crew would consist of a mechanic in charge of baler operation, a man checking the flow of bagasse to all the balers, a clean-up man handling loose bagasse and, for each baler, a wire-tier and an individual to load the bales for transport.

After the bales are formed and tied they expand in volume, so that strong, good quality galvanized wire is essential for binding. Otherwise, after several months' storage, difficulties are likely to arise from premature breakage of the bales and the consequent need to handle much loose bagasse. The bales are stored in stacks (about 36 x 20 x 9 metres high) with air spaces between the bales to avoid overheating (caused by fermentation processes) and to allow the material to dry out quickly. Adequate spacing between the stacks acts as a protective measure against fire as well as providing access for transport. With suitable precautions, such as efficient drainage at the bottom of the stacks and appropriate covering on top, the loss of actual fibre after eighteen months in store should not exceed 10 per cent.[14] Open storing is not to be recommended since it usually leads to discolouration due to rotting.

Handling, baling and storing bagasse are expensive operations. Estimates of some of the elements of cost involved are given in appendix VII. The cost of baling wire is reckoned at 28.5 cents per ton of fresh bagasse baled. The number of man-hours required per ton of bagasse baled, stored and delivered to the pulp mill will depend on the baling rate and on the type of baling equipment used; in general it will vary between one-and-a-half and three hours. The capital cost of equipment for baling, conveying, storing and transporting is the item which varies most with the scale of operations. From

[13] See *Purchasing, Handling and Storing of Bagasse* by A. Watson Chapman.

[14] See *Economic and other Factors to be considered in the Use of Sugar-cane Bagasse as a Raw Material for Pulp and Paper Manufacture,* by E. C. Lathrop.

the cost estimates set out in appendix VII it will be seen that for the example already cited (a 50-ton daily capacity pulp mill and a six-month grinding season) the capital cost of equipment per ton of fresh bagasse consumed represents 23 cents if working entirely on baled bagasse and 15 cents if using fresh bagasse during the grinding season. The corresponding figures for a 20-ton mill are 38 and 26 cents. The cost per ton *baled,* of course, declines far more steeply with an increasing scale of operations. For a 40-tons-per-day baling rate (20-ton mill operating on fresh bagasse during a nine-month grinding season, for example) it may reach 96 cents; for 50- and 100-ton mills operating under the same circumstances, it falls to 50 and 42 cents, respectively. In other words, as stated by Professor A. G. Keller of Louisiana State University,[15] "there is little difference in the initial cost of a station to process 10 thousand tons of fibre and one to handle 30 thousand tons of the material".

This means that good use of capital invested in baling station equipment requires operation at high baling rates, and that the baling of bagasse at low rates in small, separate baling stations is wasteful in terms of capital. The effect of this element of cost, therefore, is to make it advantageous for a pulp mill to obtain all its bagasse from a single sugar mill, where it can be baled and stored at a single baling station operating at a high rate of output.

It follows that a small capacity pulp mill, operating in the 25 to 50 daily tons range, will be using its capital wastefully, and adding to its bagasse costs, if it draws its supplies from several sugar mills. A larger pulp mill, manufacturing say 100 tons a day, will be less handicapped, although it will also have to reckon with the extra cost of haulage from several sugar mills to the central pulping plant.

Other cost items involved are the capital cost of baling station building and the site where the bagasse is to be stored, insurance of the stored bagasse and interest on the capital which the stored bagasse represents. Estimates of these items are given in appendix VII.

For a given annual production of bagasse at the sugar mill, the shorter the grinding season, the higher the rate at which bagasse must be baled during this period, and hence the greater must be the baling capacity installed. This is true whether the pulp mill operates entirely on dried bagasse or whether it uses fresh bagasse during the grinding season. In so far as fresh bagasse is used, the volume to be baled, stored and used in dried form is reduced; hence lower capacity baling equipment and less extensive storage facilities will be needed. The saving in the cost of bagasse as a pulping material (i.e., in those elements of cost now under discussion) as between (*a*) operating totally on dried bagasse and (*b*) operating on fresh bagasse in season and dried bagasse out of season will, generally speaking, be greater the longer the grinding season. These savings may be considerable, as shown by the following table, which gives estimates for the six countries surveyed.

The saving is greatest for Peru, with the longest grinding season, and relatively low for Cuba, with the shortest grinding season. The correlation between grinding season and saving is not complete, since bagasse handling costs represent only a part of the total included in table 5. Nevertheless, the savings possible by using fresh bagasse, and the influence of the grinding season on those savings, are clearly demonstrated.

Table 5

SAVING IN BAGASSE COST USING FRESH BAGASSE

Country	Length of grinding season (days)	Cost per ton of bagasse to 20-ton daily capacity pulp mill operating: Wholly on baled bagasse (dollars per ton)	Partly on fresh, partly on baled bagasse (dollars per ton)	Saving (dollars per ton)	Saving (percentage)
Peru	225	2.60	2.15	0.45	27
Mexico	150	2.40	2.00	0.40	17
Argentina	150	8.31	7.35	0.96	12
Brazil	150	8.05	7.45	0.60	7
Venezuela	75	4.01	3.50	0.51	13
Cuba	75	6.55	5.96	0.59	9

These savings, it should be noted, are effected on the fibre delivered to the pulp mill. To the extent that fibre losses occur during storage, these savings will be slightly enhanced. On the other hand, no account has been taken of cost offsets which arise from the arrangements which must be made at the pulp mill to handle alternatively fresh and baled bagasse.

Having discussed some of the cost considerations which spring from the need to bale, handle and store bagasse, it is now possible to revert to the main theme —the cost of releasing bagasse for pulp manufacture when sugar mills are converted from bagasse burning to fuel-oil burning.

Some estimates of bagasse costs

Prior to this meeting, a survey was conducted on the situation in six Latin American countries, and detailed estimates have since been prepared of the cost likely to be involved in releasing bagasse by switching from bagasse to fuel-oil burning in the six countries. The results of these calculations, which were made on the basis of information previously available or specially collected, are set out in appendix VII. In this appendix, the treatment of the various elements of cost is generalized; it is thus possible to arrive at estimates for any given mill size, length of grinding season and mode of operation by calculating the appropriate baling and consumption rates, interpolating from the charts presented and inserting the appropriate local costs. At the end of the appendix estimates have been prepared for each country for six hypothetical cases: for three different mill sizes (20-, 50- and 100-tons daily capacity) and two alternative modes of operation (exclusively on baled bagasse, and on fresh bagasse during the grinding season and baled bagasse during the non-grinding season).

Some of the salient figures are given in the following table; they relate to hypothetical pulp mills of 20-, 50- and 100-tons daily capacity operating on fresh bagasse during the grinding season. The unit cost is for a ton of fresh bagasse (50 per cent moist) or its equivalent in baled form.

This table clearly shows that the dominant element in the bagasse cost is the alternative fuel itself. Thus for those countries possessing cheap indigenous fuel (Mexico, Peru and Venezuela, with fuel oil costs from

[15] *A Study of Newsprint Expansion,* United States Government Printing Office, Washington, D.C., 1952.

Table 6

EXAMPLES OF BAGASSE RELEASE COSTS IN SIX LATIN AMERICAN COUNTRIES

(*Thousand dollars*)

Cost of releasing bagasse to satisfy annual requirements of:	*Argentina*	*Brazil*	*Cuba*	*Mexico*	*Peru*	*Venezuela*
(*a*) *20-ton mill*						
TOTAL	265	268	215	72	77	126
Substitute fuel..........	187	216	134	38	54	57
All other costs...........	78	52	81	34	23	69
(*b*) *50-ton mill*						
TOTAL	604	636	514	155	171	292
Substitute fuel..........	468	540	335	94	134	143
All other costs...........	136	96	179	61	37	149
(*c*) *100-ton mill*						
TOTAL	1,180	1,250	1,000	295	332	567
Substitute fuel..........	936	1,080	670	187	268	286
All other costs...........	244	170	330	108	64	281
COST PER TON OF FRESH BAGASSE (dollars)						
(*a*) *20-ton mill*						
Total of which	7.35	7.45	5.96	2.00	2.15	3.50
Substitute fuel percentage.	71	81	63	52	69	45
(*b*) *50-ton mill*						
Total of which..........	6.72	7.07	5.72	1.72	1.90	3.24
Substitute fuel percentage.	77	85	65	60	78	49
(*c*) *100-ton mill*						
Total of which..........	6.57	6.96	5.57	1.64	1.84	3.15
Substitute fuel percentage.	79	86	67	63	81	51

6 to 9.5 dollars per ton), the cost per ton of bagasse is low; for other countries (Cuba, Argentina and Brazil, with fuel oil at 22, 31 and 36 dollars per ton respectively) the cost per ton of bagasse is very much higher.

The key consideration, then, when a switch from bagasse to fuel-oil burning is being contemplated to release bagasse for pulp manufacture, is the cost of fuel oil. It is this that will primarily determine the cost of bagasse to the pulp mill;[16] this in turn determines bagasse's suitability as compared with any alternative domestic fibre resources which may be available and, likewise, the potential of bagasse-made paper to compete with other domestic or imported papers.

It will be observed that the size of the pulp mill itself, since it determines the scale of bagasse operations required, exercises an influence on bagasse costs. Thus table 6 shows that, for the case therein considered, the cost per ton of bagasse for a 50-ton daily capacity pulp mill will be 5 to 15 per cent lower than for a 20-ton mill; for a 100-ton mill the cost will be slightly lower still.

Finally, it should be stressed that all these are hypothetical cases only, and the figures quoted cannot be regarded as generally applicable; in practice, everything will depend on the location of the pulp mill and the number, size and mode of operations in the sugar mills which are to supply it with bagasse.

Section IV

THE PULPING OF BAGASSE

Characteristics of bagasse fibre

Bagasse as produced from the extraction rolls in a sugar mill varies in colour (from greyish white to a very dark green) and in composition, depending upon the variety of cane, the method of harvesting and the way the cane is crushed at each particular installation.

Two of the three main constituents which make up the material-substance of the residue are fibrous, namely the fibrovascular bundles, containing rather short fibres, and the rind fibres, which are distinctly longer. The third main constitutent is parenchymatous material, or pith. According to Aronowsky,[17] a typical bagasse contains about 20 per cent fibrovascular bundles, 55 per cent rind fibres and 25 per cent pith.

In the living plant the pith constitutes the walls of the cells in which the sugar-bearing juices are stored. Chemically it is cellulose, just as is the fibre fraction, but it does not have a fibrous structure and has no fibre length.[18] Moreover, because of the greater surface area of the pith, which absorbs more dirt, it has a higher ash content. Here the main concern is with the physical and chemical characteristics of the bagasse fibre itself. The questions of pith separation and possible uses for the pith are dealt with later.

Table 7

SOME PHYSICAL AND CHEMICAL CHARACTERISTICS OF BAGASSE AND WOOD

	Fibre					
	Average length mm	*Average diam. micron*	*Ash*	*Lignin*	*Alpha cellulose*	*Pentosans* [a]
			(*per cent*)			
Bagasse (depithed)	1.7	20	2	19–21	40–43	30–32
Temperate coniferous woods......	2.7–1.6	32–43	1	26–30	40–45	10–15
Temperate broad-leaved woods...	0.7–1.6	20–40	1	18–25	38–49	20–25

[a] In non-wood materials the hemi-cellulose fraction consists chiefly of pentosans, whereas in wood other carbohydrates are also present.

[16] Generally speaking, it takes about six tons of fresh (50 per cent moist) bagasse to make one ton of pulp, less for high-yield processes, more for low-yield processes.

[17] Aronowsky, S. I.: *Bagasse, Pulp and Paper Manufacture*, vol. 2, ch. 1, part 3, pp. 79-81, 1951.

[18] Keller, A. G., "Louisiana Sugar Cane Bagasse", *Paper Trade Journal*, 2 May 1952.

As may be seen from this table, the bagasse fibre is shorter in length than that of the temperate coniferous woods and considerably smaller in diameter. The cellulose content, however, compares favourably. In terms of chemical composition generally, it may be said that bagasse more closely resembles the broadleaved woods than it does the softwoods; therefore its paper-making properties are more akin to those of the broadleaved species.

Since bagasse fibres are short and thin, and the hemicellulose content comparatively high, pulps made from this material tend to form dense papers with low tear resistance and low opacity. Nevertheless, when blended in suitable proportion, bagasse pulps will improve sheet formation, surface characteristics and printability. For strong wrapping and bag papers they need to be mixed with long-fibred pulps. It is, however, possible to make good greaseproof and glassine using bagasse pulp alone.

Pulping methods for bagasse[19]

The most important methods in commercial operation for the pulping of bagasse at the present time are the following: (1) Soda process; (2) Sulphate process; (3) Neutral-sulphite or monosulphite process; (4) Caustic soda-chlorine or Celdecor process; (5) Mechano-chemical process.

For the first three methods pressure digesters are necessary. In the Celdecor and the mechano-chemical processes, however, digestion is carried out at or near atmospheric pressure, though the processes are quite different in character, as are the pulps they produce.

1. *Soda process:* In this method the bagasse is cooked in pressure digesters with a solution of caustic soda. The cooking time and amount of chemicals used depend very much on whether or not a chemical recovery system is employed. With such a system, the chemical concentration used may be as high as 24 per cent[20] (on dry weight of bagasse), with a short cook at relatively low pressures. When chemical recovery is not employed, digestion is carried out at a much lower chemical concentration—usually about 14 to 16 per cent in the case of bleached pulp—in order that chemical costs may be limited.

With a cook of, say, two hours at a maximum temperature of 170°C, and using 15 per cent caustic soda, the maximum yield which may be expected is about 53 to 55 per cent for unbleached pulp (based on dry weight of depithed bagasse) or an over-all yield of about 48 to 50 per cent after bleaching. The bleached pulp may be used for fine writing papers and in blends for printing papers.

For a high-yield coarse pulp, chemical requirements are about 7 to 9 per cent, under conditions similar to those described above. Yields of 70 to 75 per cent of good-quality pulp, suitable for corrugating medium, boards and lower-quality wrapping, may be obtained.

2. *Sulphate process:* The sulphate process uses liquor containing caustic soda and sodium sulphide, with digestion conditions similar to those for the soda process. Where a chemical recovery system is employed loss of soda is made up by the addition of salt cake (sodium sulphate) instead of soda ash (sodium carbonate) or caustic soda. A modification of the process—involving the use of caustic soda and sulphur—has been successfully employed for a number of years by one Latin American mill to produce from bagasse a sulphate-type pulp, which is used in the manufacture of paper board, liner board, sack and wrapping papers, etc.

With a total chemical concentration (caustic soda plus sodium sulphide) of about 14 to 16 per cent (based on dry weight of depithed bagasse) and a cook of two hours at 170°C, an unbleached yield of about 53 to 55 per cent may be expected. About 8 to 9 per cent of chlorine (based on dry weight of pulp) is needed for bleaching, with a resulting yield of about 48 to 50 per cent.

Like the soda process, the sulphate method as commonly used involves a high initial capital cost in plant and equipment. A further disadvantage is the disagreeable odour of hydrogen sulphide, mercaptans, etc., normally associated with this operation.

3. *Neutral-sulphite or monosulphite process:* The principal chemical used is sodium sulphite, which is buffered during the cooking operation with sodium bicarbonate or caustic soda.

The most favourable conditions for digestion involve the use of about 12 to 14 per cent sodium monosulphite and 3 to 4 per cent sodium carbonate (based on dry weight of depithed bagasse). A normal cook would be of two hours' duration at 170°C, resulting in an unbleached yield of about 55 to 58 per cent. Such pulps are easily bleachable and give a bleached yield of about 48 per cent.

The process differs from the alkaline methods in that the hemi-celluloses are not so readily attacked and removed. Thus higher yields are obtained, and though the pulps are not quite so strong, they are lighter in colour and need not be bleached when used to make papers with a brightness of about fifty.[21] When bleached they may be employed to 100 per cent in the manufacture of greaseproof and glassine. They are customarily used in admixture with other pulps for the production of fine writing and printing papers.

For the production of high-yield coarse pulp, suitable for corrugating medium, folding box board, etc., chemical requirements are about 6 to 8 per cent of sodium sulphite and about 3 per cent of sodium carbonate.

As with the soda and sulphate processes, initial capital investment is high since pressure digesters are needed. Moreover, the process is operated without a recovery system and consequently its economic success depends very largely upon the local cost of chemicals. The most notable commercial example at the present time of bagasse (bleached) pulping by the monosulphite process is at the mill of the Taiwan Pulp and Paper Corporation in Formosa.

4. *Caustic soda-chlorine or Celdecor*[22] *process:* This process, which is continuous, uses not pressure digesters

[19] For detailed discussion see *Factors influencing the selection of processes and choice of equipment for bagasse pulp manufacture,* by J. E. Atchison.

[20] Approximately 80 to 90 per cent of the chemical utilized may be recovered.

[21] Among recent developments or modifications of the neutral-sulphite process is the Aschaffenburger process developed by Aschaffenburger Zellstoffwerke A.G., of Redenfelden, Germany. This method involves a careful pre-hydrolysis of the bagasse with water or dilute acid. A yield of about 60 per cent is claimed, with a brightness as high as 56 without bleaching. See also discussion on *Newsprint from bagasse,* below.

[22] Cellulose Development Corporation, Hatch End, Middlesex, England.

but open towers with buffer tanks in between. It was originally designed to enable the products of an electrolytic plant to be utilized in approximately the same proportions as they are produced.

Primary delignification is carried out by treatment with a mild solution of caustic soda in a steam-heated tower, and the digested material, or semipulp, thus obtained may be used in the manufacture of corrugating medium, boards and some types of wrapping papers. Yields of 65 to 75 per cent (based on the dry weight of depithed bagasse) can be expected.

For making bleached pulp the digested material is washed, pressed to a consistency of about 30 per cent and then fluffed in an opening machine; it next passes through a tower (about 20 to 30 minutes) into which chlorine gas is injected. After chlorination the pulp is submitted to extraction with caustic soda, screened and finally bleached with hypochlorite in one or two stages. The result is a high-quality pulp with a yield of about 45 per cent.

The caustic soda-chlorine process has both advantages and disadvantages over the conventional methods using pressure digesters. While chemical consumption is relatively high, the process has the distinct advantage of operation at near atmospheric pressure, so that the initial investment cost may be lower.

5. *Mechano-chemical process:* In this process, developed by the United States Northern Utilization Research Branch, either caustic soda alone or a combination of caustic soda and sodium sulphide (as in the sulphate process) may be used. The pulping operation is carried out in a hydrapulper at atmospheric pressure and at a temperature of 98 to 99°C. The hydrapulper needs to be fitted with an oversize rotor and with a more powerful motor than is used for pulping waste papers.

With the same amount of chemicals the mechano-chemical process requires a cooking period of only about one hour at 98 to 99°C, as compared with about two hours at 170°C in conventional pressure digesters. Moreover, it is claimed that the yield of mechano-chemical soda and sulphate pulps from bagasse may exceed by 6 to 8 per cent those obtained from cooking by the conventional pressure digestion methods.

When using the process to obtain bleachable pulps from depithed bagasse, chemical requirements amount to between 14 and 16 per cent of the dry weight of raw material. Unbleached yields averaging almost 60 per cent and bleached yields of over 50 per cent have been reported. For a coarse-grade board pulp, about 7 to 9 per cent of chemicals are required and yields up to 75 per cent are quite possible.

The unbleached pulps may be used for high-grade corrugating liner or coarse wrapping, while the bleached pulps may be used for a wide variety of fine papers. Their best use, however, is in blends with other pulps.

The process is exceedingly simple to control and very rapid. The high strength of the pulps obtained is attributed to the fact that the mild conditions employed do not degrade the cellulose and hemi-cellulose as much as pressure cooking.

Pith separation

The amount of parenchymatous substance or pith contained in bagasse varies with the variety of cane and where it is grown but, as the following table[23] indicates, it can represent up to 30 per cent or more of the bagasse.

Table 8

PROXIMATE PHYSICAL ANALYSIS OF VARIOUS SAMPLES OF WHOLE BAGASSE

(*Percentages*)

	Florida variety F. 31-962 (1952)	*Florida variety C1.41-223 (1952)*	*Louisiana Thibodaux stored (1952)*	*Hawaiian variety 8560 (1952)*	*Puerto Rico Aguirre (1951-52)*	*Philippine Islands Negros (1952)*
	(*Per cent*)					
Fibre	58.0	60.7	64.4	60.5	60.1	68.6
Pith	22.8	24.3	25.2	32.9	25.5	23.8
Solubles, dirt and loss	19.2	15.0	10.4	6.6	14.4	7.6
	100.0	100.0	100.0	100.0	100.0	100.0

Because the physical structure of pith is quite different from that of bagasse fibre, the chemicals used in pulping attack it in a different manner. In fact the pith is attacked much more readily, thus increasing chemical consumption. Moreover, since pith contains a high proportion of the residual sugars and other water-soluble materials remaining in the bagasse, these substances also react with and further increase the consumption of chemicals.

Apart from raising the chemical consumption and leading to a lack of uniformity in the pulping operation, the presence of pith: (1) hinders filtration and washing of the pulp; (2) results in slower drainage on the wire; (3) leads to sticking at the press rolls; (4) gives rise to difficulty in bleaching because of the dirt absorbed on its surface.

As a rule, pith renders the pulp unsuitable for conversion into high-grade products and reduces the rate at which the paper can be made.

Mr. Joseph E. Atchison records[24] some valuable work carried out by the Taiwan Pulp and Paper Corporation in Formosa to determine the effect of leaving varying proportions of pith in the bagasse going to the pulp mill. Results in the particular tests carried out showed that:

(a) The strength of the pulp continued to increase until all the pith was removed (before pulping), the increase being much sharper once the first half of the pith had been removed.

(b) When using whole bagasse a yield of only about 37 per cent was obtained, as against 50 per cent with the pith wholly or partly removed;

(c) With whole bagasse, requirements of chemicals for bleaching were exorbitant (about 30 per cent total chlorine on weight of pulp), but requirements decreased to as little as 5 per cent when all the pith was removed.

It is, however, only fair to mention that these results —in relation to the merits and demerits of depithing bagasse—do not altogether coincide with some of those

[23] See *Economic and other factors to be considered in the use of sugar-cane bagasse as a raw material for pulp and paper manufacture*, by E. C. Lathrop.

[24] See paper: *Factors influencing the selection of processes and choice of equipment for bagasse pulp manufacture.*

found in research undertaken by Celulosa Argentina.[25] Nevertheless, while some mills do successfully produce coarser-grade products from bagasse without resorting to pith separation, the general view is that some depithing is desirable to secure improved operation of the paper machine and a better quality product. Most authorities maintain that optimum values in machine operation, product quality and low chemical cost per ton of pulp produced will only be achieved by using bagasse fibre from which the maximum amount of pith has been removed.

Two general methods have been developed for separating the pith; they are usually known as the dry and wet methods. In the dry method, the bales are fed through special disintegrating equipment and then screened, the relative proportions of fibre and pith removed depending upon the particular type of equipment and operational methods employed. This system has the advantage that the pith is obtained in a dry state and can therefore be conveyed direct to the mill boiler plant.

In the wet method two machines have been found which will effectively loosen and separate the pith from the fibre; (a) the hydrapulper; (b) the single-disk attrition mill.

According to work carried out by the Northern Utilization Research Branch, Peoria, Illinois,[26] the hydrapulper is best suited for the separation process starting with baled, dry bagasse, while the single-disk attrition mill is most appropriate for treating wet bagasse direct from the sugar mill.

A depithing process of recent development, and of particular interest to this meeting, is that developed by a mill[27] in Mexico. The equipment used is of high capacity, relatively inexpensive to build, has a small power consumption and requires little maintenance. Moreover it is reported to be suitable for depithing bagasse either in the wet state, as it comes from the sugar mill, or dry from bales.

Opinions differ as to where the separation may be carried out most conveniently and most economically. According to Dr. E. C. Lathrop,[26] from the standpoint of low costs and utilization of pith, separation is best undertaken at the sugar mill during the cane-grinding season. In this way it is possible to recover about two-thirds of the sugar left in the bagasse, while the bagasse is upgraded into clean fibre and pith, so that these products may be used to their best advantage.

The cost of depithing and the advantages to be gained therefrom will depend upon a number of factors. In some cases it may be important to find a suitable outlet for the pith in order to meet the cost of separation.

Pith may, of course, be used as fuel for the mill boilers, and its calorific value is only slightly less than that of whole bagasse. Elsewhere, Dr. E. C. Lathrop describes in considerable detail some of the work which has been done, and various uses, other than fuel, for pith. The pith itself is highly absorbent; perhaps the best-known example of profitable utilization is in admixture with molasses to prepare fodder. This particular solution, in fact, seems to hold considerable promise as an outlet both for pith and for molasses, and deserves much wider attention.

Finally mention must be made of the interesting possibilities which have been suggested by Wells and Atchison[28] for utilizing the pith, after separation, in the manufacture of those papers which may be produced from the bagasse fibre itself.

Newsprint from bagasse

It would be wrong to end this very brief résumé of some of the problems involved in pulping bagasse without mention of the possibilities of manufacturing newsprint from bagasse. Much has been written, both in the technical press and elsewhere, on this subject. Numerous tests have been carried out, results reported, and claims made. The debate will continue, and it is perhaps too early as yet to set down any final conclusions.

Much depends on what is meant by the word "newsprint". It is now well established that paper on which newspapers are to be printed can be produced from bagasse. It has been made on occasion by W. R. Grace and Co. in their mill at Paramonga in Peru, though only on a limited scale; and newspapers have been printed on bagasse pulp manufactured by the Aschaffenburger process, though not—it is understood—on high-speed machines.

Whether, however, newsprint from bagasse can be produced commercially to compete both in price and in quality with the standard article which is universally accepted by the trade today is, perhaps, still an open question. Conventional newsprint is one of the cheapest forms of paper—indeed, cheapness is of paramount importance—and is manufactured from mechanical woodpulp with the addition of 15 to 20 per cent of chemical woodpulp to provide the necessary strength. Qualities of opacity, ink absorbency, softness and bulk are derived mainly from the mechanical pulp fraction.

In the mechanical process, where logs are ground against a revolving stone, the yield of pulp averages around 95 per cent; the high losses that occur in chemical digestion are avoided.

Bagasse needs to be treated chemically if pulps suitable for paper are to be produced; consequently, yields are lower. Nevertheless, recent advances in bagasse pulping, mainly involving the use of pre-hydrolysis, have shown that higher yields and increased brightness may be achieved, the latter without necessarily resorting to bleaching in every case.

Among these developments may be mentioned the de la Roza process and the Aschaffenburger process. The former employs a steam hydrolysis followed by a sulphate type of cook, but bleaching is required to meet newsprint specifications. In the Aschaffenburger process[29] pre-hydrolysis is carefully carried out with water or dilute acid and followed by a neutral-sulphite cook; bleaching is not considered necessary. This may be re-

[25] See paper: ***Industrial experience in bagasse pulp manufacture in Argentina.*** The Aschaffenburger paper, already referred to, also suggests that the consequences of failure to depith are less serious than is commonly supposed.

[26] See paper: *Economic and other factors to be considered in the use of sugar-cane bagasse as a raw material for pulp and paper manufacture.*

[27] Sr. Dante S. Cusi, Director of the Compañía Industrial de San Cristóbal, S.A.

[28] Wells, S. D. and Atchison, J. E., "Production of pulp from the fibrous elements of sugar-cane bagasse", *Paper Trade Journal,* 111 (13), 27 March 1941.

[29] See paper *The Aschaffenburger process for manufacturing bagasse pulp for newsprint,* by Aschaffenburger Zellstoffwerke A.G., Germany.

garded as a considerable step forward, indicating the possibility of eventually manufacturing a trade-acceptable newsprint from bagasse. Several commercial trial runs have been made, and accounts of the printing results are promising.

Chemical pulp from bagasse can be used to replace the chemical woodpulp fraction of newsprint—i.e., 15 to 20 per cent of the standard furnish currently employed. But the basic problem, that of replacing the mechanical pulp fraction—of producing a whole bagasse newsprint which has the requisite printing qualities, which is sufficiently strong to be run successfully on modern high-speed rotary printers, and which, above all, is cheap enough to compete with the standard article—will continue to absorb attention.

Section V

Six case studies

As part of the preparations for this meeting, it was decided to conduct a survey of the possibilities of developing new pulp and paper industries, or expanding existing ones, in Latin America, based on bagasse. In this survey the secretariat was assisted by Ing. Jorge Guerra,[80] who carried out the field research in Argentina, Brazil, Mexico and Peru, four of the five countries in the region[81] where bagasse mills are already operating, as well as in two other important sugar-producing countries, Cuba and Venezuela.

The survey endeavoured to collect information regarding current bagasse production, and to shed light on the problems of releasing bagasse for paper making. It also included a preliminary reconnaissance of the situation regarding other factors relevant to the production of paper from bagasse (though not an appraisal of the pattern and extent of the market for pulp and paper[82]) and sought to indicate areas which seemed to offer promising prospects for the establishment of bagasse-based mills.

It was originally intended that the material compiled should be used to prepare estimates of investment and production costs for the manufacture of pulp and/or paper in each of the six countries by at least one of the more familiar processes for pulping bagasse. Unfortunately it has not proved possible to complete this aspect of the survey in the time available. For this reason, as explained in the Introduction, the present paper deals primarily with problems of bagasse supply, and it is this aspect of the six-country survey which is discussed in the present section.

Some of the conclusions reached have already been mentioned in earlier sections of this paper, while much of the material collected has been presented in appendices to which reference has already been made, notably appendix VII. This section is therefore limited to a short summary of the situation in each of the six countries in turn. Since most of the basic tables are rather lengthy, they have been relegated to appendix VIII; that appendix should be read in conjunction with the present section. It should be pointed out that two of the final tables (No. 5, "Assessment of the bagasse surplus/deficit situation", and No. 6, "Availability of chemicals, fuel oil, power and water") give in a condensed form the main findings in each country, while tables 7 and 8 provide information concerning cost of chemicals, fuel oil, labour, etc.

Argentina

The general region of the province of Tucumán accounts for approximately 70 per cent of the sugar cane grown in Argentina. The grinding season extends from late May to early October, and in 1953 averaged 138 days. During that year, twenty-seven sugar mills[83] were in operation in the province, out of a total of thirty-nine for the entire country of Argentina, and production of fresh bagasse averaged about 79,000 tons, ranging from 48,600 tons in the case of the smallest plant to 227,600 tons for the largest producing unit. Theoretically, the output of bagasse from any one of the twenty-seven mills would be large enough to meet the raw material requirements of a 20-ton pulp mill and each of the five largest could, in fact, supply the needs of a 50-ton pulp mill. In practically all cases, however, release of bagasse for paper making would have to be effected by resorting to "fuel substitution", for besides the bagasse they produce—and at present consume as fuel—all the mills burn wood[84] in addition, while ten of them also use fuel oil.

Sixteen of the mills carried out sugar-refining operations; seventeen produced alcohol; some combined both. The possibilities of freeing bagasse for paper making other than by changing fuel are limited; the Concepción sugar mill, with a bagasse production (1953) of 227,600 tons, is the only installation where sufficient might be obtained (at 20 to 25 per cent surplus) to supply the needs of a 20-ton pulp mill.

Though about 900 km distant, Tucumán has good rail connexions with Buenos Aires and is well-served internally by local branch lines.

The Marapa river, beside which are located some of the existing sugar mills, would provide the most convenient source of water for a pulp mill. The Government also plans to construct a dam and reservoir for flow control and irrigation purposes within three to four years.

Brazil

In recent years, about 30 per cent of all the sugar produced in Brazil has come from the general region of the State of São Paulo,[85] relatively close to the large population centres of Rio de Janeiro and the city of São Paulo itself.

In 1953, the State had 99 sugar mills[86] (including one "direct" alcohol mill) in operation, with an average bagasse production of 21,300 tons, ranging from 500 tons for the lowest producing unit to 110,000 tons for the largest. The relatively small size of the units would make "fuel substitution" imperative if sufficient bagasse is to be released for a 20-ton pulp mill. Even then, only fifteen of the ninety-seven mills would be able to supply individually the total amount of raw material required, and only

[80] Commissioned by the Banco de Fomento Agrícola e Industrial de Cuba.

[81] Table 1 of appendix VIII gives particulars of all existing bagasse pulp and paper mills in Latin America, including the one at Cali, Colombia, about which little is known. Colombia was not visited in the course of the survey.

[82] This ground has been largely covered in a secretariat paper: *Pulp and paper consumption, production and trade in Latin America.*

[83] See table 2 of appendix VIII.

[84] From the nearby province of Santiago del Estero.

[85] More precisely within about a 200-km radius of the city of São Paulo.

[86] See table 3, appendix VIII.

three might come close to, or perhaps exceed, the bagasse requirements for a 50-ton mill.

Elsewhere in this paper the possibility has been discussed of operating sugar mills solely for "direct" alcohol production from sugar-cane juice, and how under these conditions "surplus" bagasse may be obtained quite easily. It may be pointed out that if it were sustained government policy to provide a stimulus to alcohol production, more than thirty mills would be able, with "direct" alcohol production operations, to supply, as surplus, the amount of bagasse required to maintain a 20-ton pulp mill.

So far as communications are concerned, the central part of the State is well connected with São Paulo and other population centres by the Paulista and Sorocabana railways. Water supply should present no difficulties since there are several large rivers traversing the region.

Cuba

In this survey attention has been focused on the possibility of establishing a pulp and paper mill in the northern part of the province of Camaguay, served by the Ferrocarril del Norte de Cuba.

In 1953, production of bagasse from seven very large mills[37] in this region averaged 148,000 tons, ranging from 83,000 tons in the smallest unit to 247,000 tons in the largest. Assuming a *surplus* of 20 per cent of the bagasse they produced, at least two of the mills could each supply the raw material requirements for a 20-ton pulp mill, as also could the combined tonnage of 20 per cent *surpluses* from any two of the others. At any one of them, partial or total "fuel substitution" would release sufficient bagasse for a 50-ton pulp mill, and in the case of the largest mill, total substitution would provide enough bagasse to make 135 tons of pulp per day.

The Ferrocarril del Norte de Cuba is linked with the general Cuban railroad system and the average distance of all seven mills from their common sugar shipping seaport of Nuevitas is 117 km.

Water supplies might present a serious problem and would have to be obtained from wells at all locations.

Mexico

Since the general region of the coastal State of Veracruz, on the Gulf of Mexico, supplies about 40 per cent of the sugar produced in the country, particular attention has been devoted to this area in the present study.

Production of bagasse at the twenty-seven sugar mills in the region averages around 34,000 tons a year, ranging from 1,500 tons in the case of the smallest unit to 270,000 tons for the largest. Only four of the individual units[38] could, even by converting to fuel-oil burning, release enough bagasse to supply a 20-ton mill. The largest of these four, however, could provide an adequate supply to feed a 150-ton daily capacity pulp mill if it were converted to fuel-oil burning; even without conversion, if economies leading to a 20 per cent release were effected, the bagasse so freed would supply the needs of a 30-ton mill.

In general, this area is well connected by rail and road networks with Mexico City and the Gulf ports of Veracruz and Puerto México. Three petroleum refineries, at Tampico, Tuxpan and Minatitlán, serve the area and there is railway connexion across the isthmus of Tehuantepec to the newly-discovered sulphur domes on the Pacific coast.

Water is available from rivers at some locations, and underground supplies are also said to be plentiful.

Peru

In Peru, sugar cane is grown in independent coastal valleys, often far apart from one another, and not in one continuous agricultural region. Six of the seven more important valleys are located north of Lima, and the seventh far to the south. Unfortunately, production statistics could be obtained only for individual valleys (comprising in one case as many as 5 mills) and not for each sugar mill. Thus, in the paragraphs which follow on production capacity of bagasse, the capacity of each valley is referred to as a unit.

In 1952, bagasse production for all seven valleys[39] averaged 73,000 tons, ranging from 7,000 tons for the smallest to 540,000 tons for the largest. Provided the mills were converted to use an alternative fuel, production of bagasse in three of the valleys would be enough for each valley to supply a pulp mill with a capacity of up to fifty tons per day. A fourth valley could also meet the needs of a 25-ton plant. In Peru, the average grinding season lasts about ten months, so that here the economies to be gained from pulp and paper mill operation on fresh bagasse straight from the sugar mill, instead of on baled material, could be realized, with minimum expenditure on baling.

Water is at a premium in the coastal valleys, and the water available from rivers and wells is carefully used for irrigation of sugar cane and other crops, under intensive cultivation. Thus the water-supply problem for pulp mills in these areas seems likely to be acute.

Land communications to the valleys are more or less limited to highways, while the distances to the consuming and supplying centres are great. For some of the valleys, however, small seaports exist within shorter road distances.

Venezuela

Venezuela has the smallest sugar production of all six countries studied. A large number of small, widely scattered sugar-mill installations operate in rather a primitive fashion to produce a typical, traditional sugar product instead of standard sugar grades.

From the standpoint of bagasse supply for paper making these particular units may be discounted. Modern-type, medium- to high-capacity installations are very few in number. However, under the government policy of stimulating sugar production, one of the existing mills is being enlarged, and five new ones are in various stages of development; the entire programme is scheduled for completion in 1956-58. The capacity of one other mill may also be expected to increase in the near future.

Three of the five sugar-mill development projects, Motatán in the State of Trujillo, Cumanacoa in Sucre and Urena in Táchira are in rather remote locations with difficult communications. In the central part of the country, comprising the States of Aragua, Carabobo, Lara and Yaracuy, highway communications are good and distances to supplying and consuming centres are reasonable.

[37] See table 4, appendix VIII.

[38] Cuatotolapan, San Cristóbal, Motzorongo and El Potrero.

[39] Comprising fifteen sugar mills.

Present bagasse production capacities of each of the three more remote installations in operation are enough to meet—with fuel substitution—the raw material requirements for a 25-ton pulp mill; one of them could supply a 40-ton mill. Expected increases in production by 1955 for two of these sugar mills would meet the requirements of a 40-ton and a 50-ton pulp mill respectively, again assuming that the mills were converted to fuel-oil burning.

As for the two sugar-mill projects under way in the central part of the country, it is expected that by 1956 each might supply, by fuel substitution, the bagasse requirements of a 40-ton pulp mill, with slight increases in subsequent years.

Considering all five installations—three in operation, two under construction[40]—from the standpoint of water availability, one, on the shore of Lake Valencia, has an abundant supply at hand; three are located on or close to the rivers Yaritagua, Turbio and Tocuyo respectively, with apparently enough flow throughout the year to meet the needs of moderate-size pulp and paper mills; the fifth one is located in a narrow valley where sufficient water does not appear to be available.

Section VI

General conclusions

1. For a pulp mill with a capacity of twenty tons per day, annual requirements of fresh bagasse (50 per cent moisture content) amount to approximately 36,000 tons, or roughly six tons of fresh bagasse for every ton of pulp produced. A 50-ton daily capacity pulp mill would require annually 90,000 tons of fresh bagasse.

2. Since bagasse is today used as fuel in the sugar mills, to free additional bagasse for pulping it is necessary either to introduce measures for economizing fuel in the sugar mills or to substitute an alternative fuel.

3. The first course can liberate substantial quantities of bagasse, but the actual amount freed will depend on the type of operation undertaken at the sugar mill, and on the degree of thermal efficiency already reached. The savings are not likely to exceed 20 to 30 per cent of the bagasse produced, even in the most promising cases. On the other hand, the measures that need to be adopted are not unduly expensive and are capable of being applied singly or in concert.

4. The second course—using an alternative fuel—will free all the bagasse produced. It will, however, call for comparatively large investments in boiler conversion, etc.

5. Nevertheless, these investments, when amortized, do not constitute the dominant element in the "substitute cost" of bagasse; the major determinant is the price of fuel oil, the only really practicable alternative to bagasse for sugar-mill fuel in this region. Whether bagasse is to be a cheap or dear raw material for pulping depends on the presence or absence of cheap and adequate supplies of fuel oil.

[40] In operation: Tacarigua, Santa Teresa and Matilde mills. Under construction: Tocuyo and Rio Turbio sugar mills.

6. Other conditions being equal, the lowest cost at which bagasse may be made available for pulping will be achieved when all the bagasse required is released from one single sugar mill. This will enable the baling station to operate at the highest possible rate and the boiler conversion or sugar-mill improvement capital to be utilized to the full.

7. The cost of bagasse will be further reduced if the pulp mill is located in close proximity to the sugar mill, thus limiting raw material transport costs to a minimum.

8. Integration of pulp-mill operations with those of the sugar mill can permit the use of fresh run-of-the-mill bagasse during the cane-grinding season—a very great saving indeed. Partial operation on fresh bagasse will, of course, necessitate the adoption of wet depithing methods.

9. Bagasse surpluses of from 40 to 50 per cent may be achieved at sugar-mill installations of relatively small capacity if these operate to produce "direct alcohol" from sugar cane juice. However, under present government policies regarding alcohol production in Latin America, this "possible" method of release applies only in Brazil.

10. Bagasse surpluses of 20 to 30 per cent may be achieved only at "plain" (raw) sugar mills of rather large capacity. The larger raw sugar mills in Cuba seem to offer considerable promise from this point of view. Moreover, the high prevailing cost of fuel oil in that country would make it imperative for releases of bagasse for paper making to be obtained in this way rather than by recourse to an alternative fuel.

11. At sugar mills possessing their own refinery or distillery, or both, surpluses are small or non-existent. Only recourse to an alternative fuel can free significant amounts of bagasse for pulping. This method would find application in countries where the cost of feul oil is low, as in Mexico, Peru and Venezuela.

12. In Argentina, however, where fuel oil is expensive, and sugar installations are relatively small (and generally also include a refinery or a distillery, or both) the question of economic release of bagasse for paper making poses a different and more difficult problem. Two possibilities present themselves (*a*) confining production from the small mills to the manufacture of raw sugar, and pooling the small surpluses of bagasse which would thus arise; (*b*) stimulating the production of "direct alcohol" and consequently releasing large surpluses from the existing installations.

Summing up, it is clear that the limitations imposed by the regular and logical use of bagasse as fuel in sugar-mill operations, and the costs involved in releasing bagasse for paper making—either by creation of surpluses (through improved sugar-mill operation) or by substitution of another fuel—lead to the conclusion that the contribution which this raw material can make to the pulp industry of Latin America will be limited largely to meeting local and specialized needs; it can provide only a small part of the increased expansion required. Nevertheless, within these limitations, bagasse has its part to play. Its role has an obvious significance in those cane-producing countries where supplies of other fibrous raw materials are lacking.

Appendix I

Yield relationships in sugar-cane grinding operations

The following *simplified* example illustrates some of the relationships between the yield of sugar, bagasse, final molasses and "residual alcohol" in sugar-cane operations. It is based on Cuban raw sugar and final molasses production figures in 1953.

Sugar produced (raw sugar, 96° equivalent) = 34,509,473 bags[1] = 5,160,000 tons (96°).

Conversion of 96° raw sugar to pure (100 per cent) sucrose gives 5,160,000 × .96 = 4,960,000 tons sucrose (1)

Molasses produced = 278,218,485 U.S. gallons.

Assuming a weight of 12 lb. per gallon of molasses, equivalent to a specific gravity of $\frac{12}{8.345} = 1.44$ kg/litre:

278,218,435 × 3.785 (litres/gallon) × 1.44 kg/litre = 1,510,000,000 kg

Assuming 55 per cent total sugars (as sucrose) in molasses:

1,510,000 × 0.55 = 830,000 tons sucrose in molasses (2)

Adding together (1) and (2) above:

4,960,000 tons sucrose in sugar produced
+ 830,000 tons sucrose to molasses

Total 5,790,000 tons sucrose in sugar-cane juice to sugar house.

An assumed 92 per cent extraction of sucrose in cane at the crushing rolls gives:

$$\frac{5{,}790{,}000}{0.92} = 6{,}300{,}000 \text{ tons sucrose in cane ground.}$$

Therefore 6,300,000 — 5,790,000 = 510,000 tons sucrose to bagasse.

Commercial yield of sugar = 12.75 kg 96° raw sugar per 100 kg of cane ground

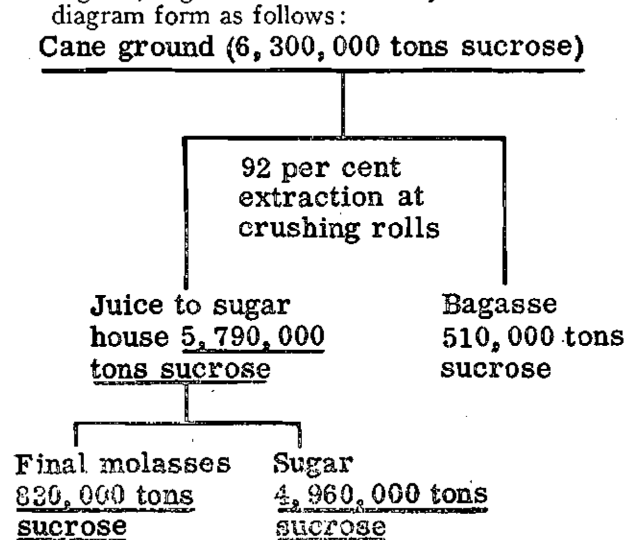
$$\text{Cane ground} = \frac{5{,}160{,}000 \text{ tons } 96° \text{ raw sugar}}{0.1275}$$

= 40,400,000 tons cane ground

Percentage sucrose in cane ground =

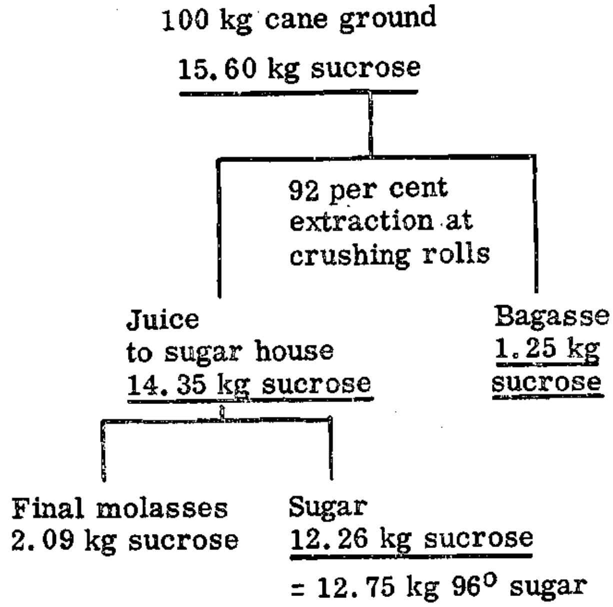
$$\frac{6{,}300{,}000 \text{ tons}}{40{,}400{,}000 \text{ tons}} \times 100 = 15.6 \text{ per cent}$$

The above weight relations of sucrose in cane, bagasse, sugar and molasses may be illustrated in diagram form as follows:



[1] One bag weighs 0.1495 tons.

Or, on a percentage basis (per 100 kg of cane ground):



The respective percentages of sucrose in cane to bagasse, juice to sugar house, sugar and molasses are:

		Per cent
Sucrose to bagasse	$\frac{1.25}{15.6} \times 100 =$	8.0
Sucrose to sugar	$\frac{12.26}{15.6} \times 100 = 78.6$	
Sucrose to final molasses	$\frac{2.09}{15.6} \times 100 = \frac{13.4}{92.0}$	
Sucrose to sugar house juice =		92.0
		100.0

Therefore, composition of resulting bagasse:

[Assuming 13 per cent fibre (including pith) in cane, and bagasse at 50 per cent moisture content] is per 100 kg of cane:

	Kg	*Per cent*
Fibre in bagasse	13.00	45.6
Sucrose in bagasse	1.25	4.4
	14.25	
Water in bagasse	14.25	50.0
Total	28.50	100.0

If cane is ground not for sugar production, but to manufacture "direct" alcohol from juice, it follows from the above that the *commercial* yield of sugar from cane ground must not be taken as a basis for the calculation of the amount of alcohol that can be produced, because sucrose losses to final molasses are in that case non-existent. It is in fact the yield of sucrose to sugar house juice that should be used for the calculation. In the above example, the ratio of both yields is:

$$\frac{\text{Sucrose to sugar house juice}}{\text{Sucrose to sugar produced}} = \frac{92.0 \text{ per cent}}{78.6 \text{ per cent}} = 1.17$$

However, in the case of cane grinding, both for sugar production and for "direct" alcohol production from cane juice, it appears likely that the same percentage extraction during the grinding operation may be assumed, i.e., about 92 per cent.

APPENDIX II

Different types of sugar-mill installations and their relative prevalence in Argentina, Brazil, Cuba and Peru

A survey of the sugar-cane industry reveals that there are installations for:

1. The exclusive production of raw sugar as an end-product (and of final molasses as a by-product). From the standpoint of process operation these are the simplest installations and may be referred to as "plain sugar mills". If special market conditions require it, these types of installation may stop short their regular production operation and manufacture high-test liquid molasses (and/or invert liquid molasses) instead of raw sugar.

2. The production of raw sugar and the refining of this raw sugar as a subsequent operation. These may be referred to as "sugar mills with refinery". They may of course produce either raw sugar, refined sugar, or both in varying ratios, depending on market conditions or other circumstances. They may also refine raw sugar from other "plain sugar mills". Thus operational practice may differ from one refinery to another, since there are several different processes for refining.

3. The production of raw sugar and the fermentation of sugar (in by-product final molasses) to alcohol, including distillation. These may be termed "sugar mills with distillery". Here again in the case of alcohol production different practices may be found; the end-product of molasses fermentation and distillation may variously consist of either rich wines (aguardientes), standard 96° alcohol, or anhydrous alcohol, or of any two of them or even all three in different ratios, depending on the type of installation and market conditions.

4. Installations combining (2) and (3) above, or in plain terms "sugar mills with refinery and distillery". All the alternatives already pointed out for (2) and (3) are open to these installations as possibilities.

5. A fifth type of installation in which no sugar at all is produced, but only alcohol, by fermentation of sugar in juice coming directly from the cane milling operation. Such installations may be called "direct alcohol mills". It is obvious that an installation of types (3) or (4) above may also operate in this fashion, since it has available both the cane milling and the distillery equipment.

The relative prevalence of the above five types of installations in different sugar-cane producing countries depends largely on the internal and external economic factors operating in each country:

(*a*) Since the greater proportion of sugar consumed reaches the ultimate consumer in refined as opposed to raw form, cane sugar production for local internal markets tends to be mostly in the form of refined sugar.

(*b*) Since a large percentage of the sugar entering the international market is sold in raw form by the exporting countries, to be subsequently refined in the importing countries, it follows that a rather large proportion of the cane sugar produced in exporting countries will be in the form of raw sugar. It thus follows that in general:

(1) Non-producing countries will operate "independent" refineries:

(2) Sugar-cane producing countries which also import sugar will operate sugar-mill refineries on imported raw sugar.

(*c*) Since consumption of alcohol is closely connected with size of consumer market and degree of industrial development, production of alcohol (whether "residual" from sugar-mill final molasses or "direct" from cane juice) will be relatively greater in countries with a higher degree of industrial development and a large market for alcohol (provided, of course, that no alternative cheaper sources of alcohol are available, e.g., petroleum).

(*d*) Since alcohol (anhydrous) may be partly substituted for gasoline (in gasoline-alcohol mixtures) for use in automobiles, alcohol production ("residual" or "direct") from sugar cane will be relatively larger in those countries lacking petroleum.

These economic considerations, modified or reinforced by special government measures, account for the widely different distribution of the five types of sugar-cane mill installations and for the different proportions in which the different sugar-cane end products are produced from country to country. Table II-1 shows how these considerations have affected the distribution of mill types and the proportion of refined sugar produced in Argentina, Brazil, Cuba and Peru.

The table is far from complete in that for Brazil and Argentina only about 33 per cent and 88 per cent respectively of total sugar produced is included there; also, no data on sugar-mill "types" could be obtained for Peru. Nevertheless, the data contained in this table reflect the considerations set out above.

In Cuba, a very substantial sugar exporter, 88 per cent of the sugar-mill installations are "plain sugar mills", while for Tucumán and São Paulo the corresponding figures are 37 and 29 per cent. In Cuba, 8 per cent of its sugar mills have "distillery" installations, the corresponding figures for Tucumán and São Paulo being 63 and 71 per cent respectively.

The ratio of alcohol to sugar production—at a value of 0.97 litre of alcohol per ton of sugar produced—is lowered for Cuba by the combined effect of its large proportion of sugar exports, a small population in absolute numbers and a relatively low level in industrialization. For Argentina (Tucumán), with no sugar exports, a larger population and a higher degree of industrial activity, this ratio rises to 130 litres of alcohol per ton of sugar produced. Finally, for Brazil, also with no sugar exports, a still larger population, a fair degree of industrial activity and a government policy of stimulating alcohol production, the ratio is higher still, 173 litres of alcohol per ton of sugar produced.

Table II—1

PRODUCTION AND NUMBER OF MILLS PRODUCING RAW AND REFINED SUGAR IN ARGENTINA, BRAZIL, CUBA AND PERU [a]

Country	Sugar: Raw sugar	Sugar: Refined sugar (tons)	Sugar: Total sugar	Ratios: Raw / Total	Ratios: Refined / Total	Alcohol (litres)	Ratio alcohol / Total sugar (l/t)	No. of sugar mills: (a) Plain	No. of sugar mills: (b) With refin.	No. of sugar mills: (c) With dist.	No. of sugar mills: Total	Ratios: (a) / Total	Ratios: (b) / Total	Ratios: (c) / Total	Observations
Argentina[b]	276	225	501	0.55	0.45	65,077	130	10	16	17	27	0.37	0.59	0.63	Practically self-sufficient as to sugar production
Brazil[c]	607	95	702	0.87	0.13	121,856	173	29	23	70	99	0.29	0.23	0.71	Practically self-sufficient as to sugar production
Cuba[d]	6,518	712	7,230	0.90	0.10	6,980	0.97	143	18	13	161	0.88	0.11	0.08	Heavy exporter of sugar: Exports, 95 per cent of production, on average
Peru[e]	363	108	471	0.77	0.23	—	—	—	—	—	—	—	—	—	Heavy exporter of sugar: Exports, 65 per cent of production in 1952

[a] For the purposes of the table, only those mills that actually produced refined sugar in the period are considered as "mills with refinery", and the same applies to "mills with distillery". Productions of alcohol are those attained at sugar-mill distilleries only; alcohol production by independent distilleries is not taken into account.

[b] Province of Tucumán only, 1953. In this year the province of Tucumán produced 88 per cent of all sugar made in Argentina.

[c] State of São Paulo only, data for 1953. In this year the State of São Paulo produced 33 per cent of all sugar made in Brazil. Source: Associacão de Usineiros de São Paulo.

[d] Entire country of Cuba, 1952. Source: Anuario Azucarero de Cuba, 1953.

[e] Entire country of Peru, 1952. Source: Sociedad Nacional Agraria; no data available on alcohol production and types of sugar-mill installations.

Appendix III

Measures for reducing fuel requirements at sugar mills

For convenience, the various measures which may be taken at sugar-mill installations in order to reduce overall fuel requirements (whether of bagasse, of additional or supplementary fuel, or of both) are summed up in the list below. It is based essentially on the discussion contained in the paper *Saving of bagasse for paper making—thermal considerations*,[1] and reference should be made to that paper for further details, including estimates of percentage savings in steam and bagasse.

1. *Savings in steam generation*

(*a*) *General improvement of steam generation conditions:*

(i) Adoption of measures for improved control and regulation of combustion (CO_2 indicators, draft gauges and controls, soot blowers, etc.);

(ii) Insulation of boilers and main steam distribution lines;

(iii) Insulation of main return condensate lines and feedwater tanks;

(iv) Adoption of measures for minimizing boiler scale formation (water treatment, blowdown control, etc.)

(*b*) *Specific improvement ("modernization") of steam generation conditions:*

(i) Adoption of improved types of furnaces and stoking practices;

(ii) Installation of air preheaters;

(iii) Installation of economizers;

(iv) Installation of superheaters.

[1] Cellulose Development Corporation and John Thompson Water Tube Boilers Ltd.

2. *Savings in steam usage*

(*a*) *General improvement of steam usage conditions:*

(i) Insulation of secondary distribution lines, process equipment, tanks, heat exchangers, etc.;

(ii) Installation of steam traps wherever feasible;

(iii) Collection of all exhaust steam in a closed, well-insulated, back-pressure system or circuit;

(iv) Collection of all hot water condensates in a closed, well-insulated, return feedwater system.

(*b*) *Specific improvement ("modernization") of steam usage conditions:*

(i) Off-bleeding of steam, between the effects, for juice heating;

(ii) Increasing the number of effects;

(iii) Circulation and flashing of condensates from the early effects into the subsequent effects;

(iv) Installation of thermocompressors;

(v) Installation of steam accumulators against sudden changes in steam demand;

(vi) Reduction of the moisture content of bagasse by improved operation of the discharge cane crushing rolls.

(*c*) *Changes in process operation conditions:*

(i) Reduction of imbibition water;

(ii) Reduction of the exhaustion of sugar from intermediate and final molasses.

Appendix IV

Steam requirements for different kinds of sugar mill operation

1. *Mills producing only raw sugar*

Depending on the conditions of steam generation and consumption, steam requirements for the operation of cane sugar mills producing only raw sugar ("plain sugar mills") have been estimated as follows:[1]

Type of mill	*Kg steam per ton of cane*
(*a*) Completely unelectrified, direct action, steam-driven pumps	600 to 700
(*b*) Modern, with a turbo-generator supplying current for all small machines, particularly pumps; steam carefully used	500 to 600
(*c*) With quintuple effect, steam bleeding from the evaporators, thermocompression or evaporation under pressure; with high pressure steam, superheated	400 to 500

[1] *Saving of bagasse for paper making—thermal considerations* (doc. 5.3), *op. cit.*

2. *Sugar mills with refinery*

In this kind of installation steam requirements for the additional operation of refining may be estimated on the basis of the following data:[2]

From raw sugar to refined sugar:

Process steam, Power steam } 175 kg per 100 kg of refined sugar.

[2] R. Norris Shreve, *The Chemical Process Industries*, McGraw-Hill, New York, 1945.

Yield of refined sugar based on raw sugar of 96° is 93 to 94 per cent (average 93.5 per cent).

The computed quantity of steam required for that part of raw sugar used for refining must be added to that required for raw sugar production in order to arrive at the total steam requirements of the installation. It is obvious that the aggregate steam requirements of this type of installation will vary from a minimum, when, for example, no refining is done at all (refinery not operating), to a maximum, when all the raw sugar being produced is also refined.[3]

3. *Sugar mills with distillery*

Steam requirements for the additional operation of distilling alcohol may be estimated on the basis of the following:

From final molasses to alcohol:

Steam: 50 lb. per U.S. gallon of 190° proof alcohol=6.0 kg/litre of 190° proof alcohol.[4]

Mariller[5] gives a figure of 5.0 kg steam/litre.[5]

For estimation purposes it seems reasonable to use the average of these two values: 5.5 kg steam/litre.

This figure applies to production of 190° proof alcohol (95° Gay Lussac approx.); if cane brandy (aguardiente) or anhydrous alcohol is produced, lower and higher steam requirements per litre of product respectively may be expected.

4. *Sugar mills with refinery and distillery*

For this type of installation total steam requirements may be calculated quite simply by adding together the corresponding partial requirements for raw sugar production, refining and distilling given above.

5. *Mills producing direct alcohol*

There are few direct alcohol mills (where no sugar whatever is produced) in Latin America; so far as the secretariat is aware, these few are all located in Brazil. There appear to be no published data showing steam requirements in this type of installation. The general impression gathered in Brazil from persons connected with the industry is that the amount of steam required in direct alcohol operations is similar to that required in the more ordinary case of alcohol production from final molasses (5.5 kg of steam per litre of direct alcohol produced), no additional steam being required for the cane milling or grinding operation. This impression agrees with the important general conclusion[6] that in "plain sugar mill" operation *"only three-quarters at most of the steam produced passes through the power units"*. In "direct" alcohol production from cane juice the yield of alcohol per ton of cane is such that, with a steam requirement of 5.5 kg steam/ton of alcohol produced, sufficient steam is practically assured for the operation of the mill prime movers.

Reference to case II in appendix VI (mill producing "direct" alcohol from ground cane juice, but manufacturing no sugar) may help to make this clear. In that example the amount of steam required for distillation is estimated at 410 kg steam/ton of cane ground.

Steam requirements for "plain sugar mill" operation (appendix VI, case I) including motive steam for the cane grinding power units, are estimated at 600 kg steam/ton of cane ground.

Since only three-fourths (at most) of total steam requirements for "plain sugar mill" operation need pass through the power units, this means that 450 kg steam/ton of cane ground are required for actuating the cane-grinding power units and all other steam-driven power units in the sugar mill.

Comparing these two figures (*a*) 410 kg steam/ton of cane ground required for "direct" alcohol production, and (*b*) 450 kg steam/ton of cane ground required (at most) to actuate *all* the steam-driven equipment (cane-grinding power units *plus* all other mill power units), it may be concluded that cane-grinding power steam requirements in "direct" alcohol production can certainly be covered solely by the process steam requirements for alcohol production, and that no additional power steam will be required.

The example quoted concerned an unimproved sugar mill, with a total steam requirement of 600 kg steam/ton of cane ground. If an improved sugar mill were to be considered, with a total steam requirement of the order of 500 kg steam/ton of cane ground, the conclusion would be strengthened.

[3] Steam requirements will of course be even higher if the refinery processes not only all its own raw sugar but raw sugar from other mills. However, since we are concerned with steam requirements per ton of cane ground, this case is not relevant here.

[4] R. Norris Shreve, *loc. cit.*

[5] Mariller: *Distillerie agricole et industrielle.*

[6] *Saving of bagasse for paper making—thermal considerations, op. cit.*

Appendix V

Bagasse as fuel: steam generation equivalent and fuel oil value

The steam generation equivalent of bagasse, or the number of kg of steam that may be raised in a sugar mill boiler installation from the burning of one kg of bagasse depends on three main factors: (1) the gross calorific value of the bagasse being burned, (2) the gross efficiency of the boiler; and (3) the enthalpy gain at the boiler (the enthalpy of the steam leaving the boiler minus the enthalpy of the feedwater entering the boiler).

The gross calorific value of the bagasse being burned may be estimated from a knowledge of its moisture content.

The gross boiler efficiency, for two different types of boilers (stepped-grate and hearth type), at various bagasse moisture contents and final exit gas temperatures may be estimated by referring to figures 1 and 2 of paper 5.3, *Saving of bagasse for paper making—thermal considerations.*[1] The enthalpy gain at the boiler may be

[1] Cellulose Development Corporation and John Thompson Water Tube Boilers Ltd.

obtained by reference to ordinary steam tables. The following example illustrates the procedure:

Assume:

(i) Moisture content of bagasse: 50 per cent;
(ii) Boiler furnace: hearth type;
(iii) Final exit gas temperature: 250°C;
(iv) Condition of steam leaving boiler: 10 kg/cm² absolute pressure saturated, and
(v) Temperature of feedwater entering boiler: 95°C;

Then:

(*a*) Gross calorific value of bagasse at 50 per cent moisture content=2,300 kcal/kg of bagasse;
(*b*) Gross boiler efficiency, hearth type furnace, bagasse at 50 per cent moisture content, final exit gas temperature 250°C=63 per cent;
(*c*) Heat transferred at the boiler$=\frac{(a) \times (b)}{100}=$

$$2{,}300 \text{ kcal/kg bagasse} \times \frac{63}{100}=1{,}449 \text{ kcal/kg bagasse}$$

(*d*) Enthalpy gain at the boiler:
enthalpy of steam, 10 kg/cm² abs., saturated=664.4
minus enthalpy of feedwater, 95°C=95
664.4
95.0
569.4 kcal/kg of steam;

therefore:

(*e*) steam generation equivalent of bagasse$=\frac{c}{d}$

$$=\frac{1{,}449 \text{ kcal/kg bagasse}}{569.4 \text{ kcal/kg of steam}}=2.5$$

That is to say, under the conditions assumed, *2.5 kg steam will be generated per kg of bagasse (containing 50 per cent moisture) burned.*

Turning to the fuel oil value of bagasse, the fuel oil replacement ratio can be calculated very simply. The following example illustrates the procedure:

Typical bagasse-burning boiler specifications are: 61,000 lb. steam per hour=27,500 kg/hr; 100 psi gauge (114.7 abs)=8.06 kg/cm²; 212° F feedwater=100° C feedwater.

Assuming a steam consumption of 600 kg per ton of cane crushed (the case of an unimproved sugar mill) this corresponds to $\frac{27{,}500}{600}=45.8$ tons of cane crushed per hour. If all the bagasse produced is burned in the boiler, this means 45.8 x .25=11.4 tons of fresh bagasse (50 per cent moist) burned per hour.

Fifty per cent moist fresh bagasse has a gross calorific value of 2,300 kcal per kg. Taking a boiler efficiency of 58 per cent (hearth-type furnace, Celdecor-Thompson value, figure 1, with allowance for a slight drop in efficiency due to higher moisture content of bagasse) the result is a heating value of 1,335 per kg.[2]

Taking now the gross calorific value of fuel oil at 10,000 kcal per kg and assuming 80 per cent boiler efficiency (Celdecor-Thompson values) we have a heating value for fuel oil of 8,000 kcal per kg.

Thus, if fuel is substituted for bagasse, and no other "modernization" is carried out at the sugar mill, *one ton of fuel oil will replace six tons of 50 per cent moist fresh bagasse.*

[2] Total heat transferred at the boiler is 1,335 x 11.4=15.2 million kcal per hour. This corresponds to 27,500 kg per hour of steam generated, giving 554 kcal per kg of steam. A check from the steam tables (Marks) gives 557 kcal. Elsewhere in this study, therefore, a rounded figure of 555 kcal per kg of steam generated is used.

APPENDIX VI

Cane ground for sugar and for alcohol in Brazil

This note examines the proportions in which cane is ground for sugar and for alcohol in Brazil as a whole and in the State of São Paulo. It continues with an assessment of the bagasse surpluses and deficits which arise in different types of sugar mills.

1. *Amounts of cane ground for sugar and for alcohol*

For Brazil, from information gathered from Sr. Lino Morganti[1] and other sources, it may be estimated that the yield of sugar (raw and refined) is about 10.5 kg per 100 kg of cane ground solely for sugar production, or 10.5 per cent.

Multiplying this yield by the ratio$\frac{(92.0}{(78.6}=1.17)$ of sucrose in juice from grinding operations, to sucrose in sugar, gives a sucrose yield of cane of 10.5 x 1.17= 12.4 per cent, or *124 kg sucrose per ton of cane.*

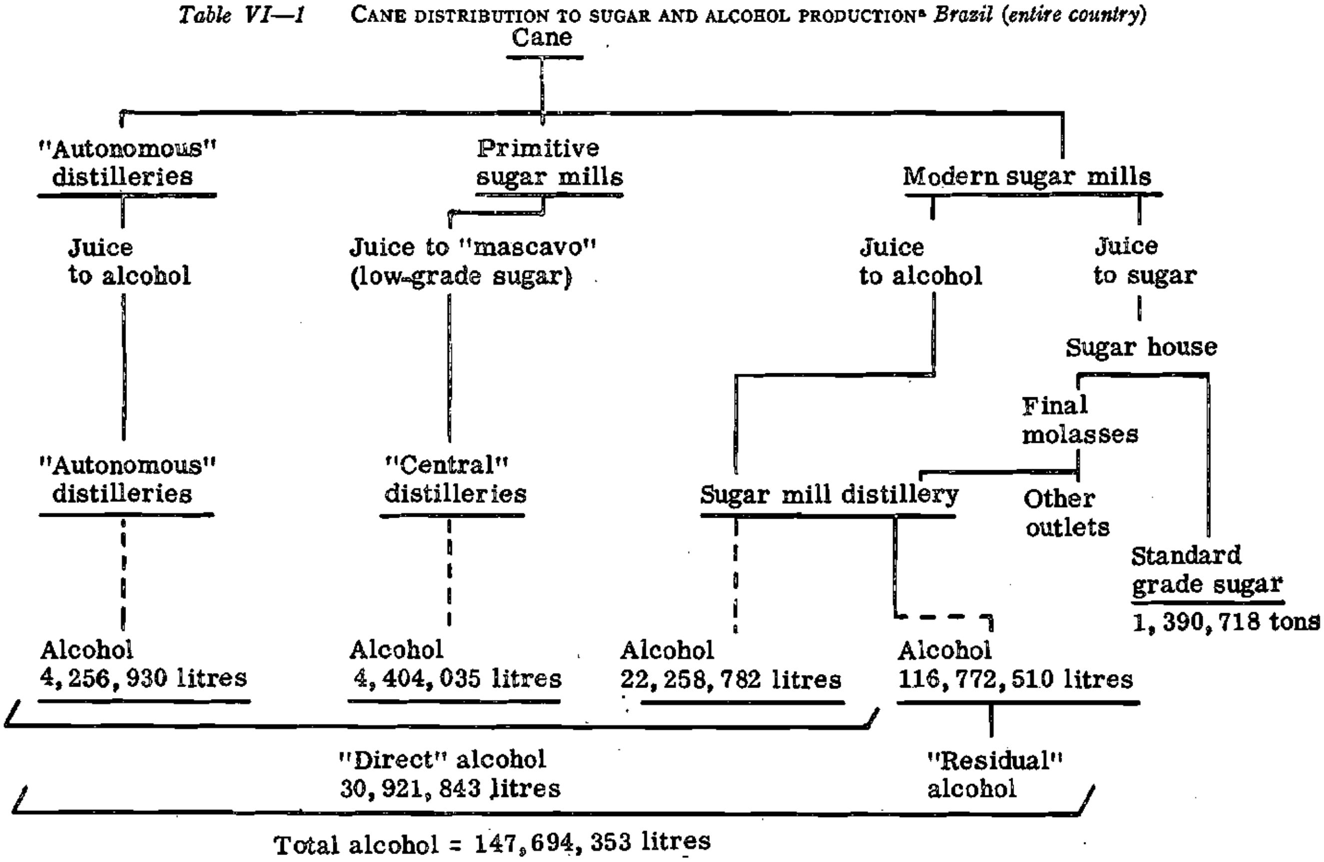
[1] Technical Director, *Refinadora Paulista*, São Paulo.

Mariller, in his *Distillerie agricole et industrielle,* points out that 100 kg of invert sugar (glucose) will theoretically produce sixty-one litres of alcohol; in practice, say fifty-seven.

The juices contain predominantly sucrose, and 100 kg of sucrose will produce 105 kg invert sugar. Therefore 100 kg sucrose will produce $57 \times \frac{105}{100}=60$ litres of alcohol. Hence one ton of cane will produce $60 \times \frac{124}{100}$ =74.5 litres of direct alcohol.

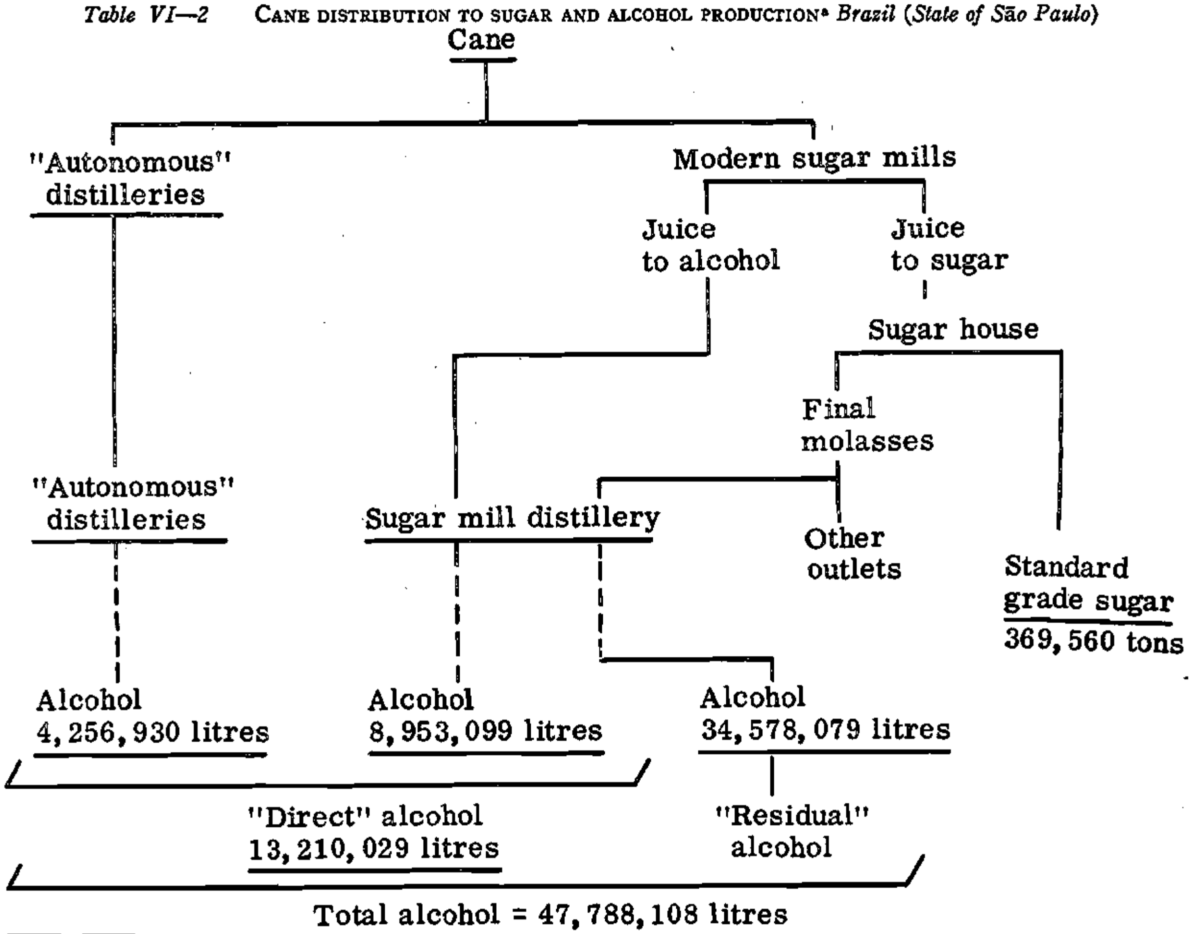
Tables VI-1 and VI-2 which follow show respectively, for the entire country of Brazil and for the State of São Paulo, the average figures for sugar, "residual" alcohol and "direct" alcohol production for the three crop years 1948/1949, 1949/1950 and 1950/1951 (Source: *Análise de tres zafras de álcool*, by Moacir Soares Pereira, *Brasil Açucareiro*, 1953).

Table VI—1 CANE DISTRIBUTION TO SUGAR AND ALCOHOL PRODUCTION[a] *Brazil (entire country)*



[a] Average figures for three sugar crops 1948/49, 1949/50, 1950/5 1.

Table VI—2 CANE DISTRIBUTION TO SUGAR AND ALCOHOL PRODUCTION[a] *Brazil (State of São Paulo)*



[a] Average figures for three sugar crops, 1948/49, 1949/50, 1950/51.

Using the yields of sugar and direct alcohol per ton of cane given above, the amounts of cane ground (average for the three years mentioned) are as follows:

	Brazil (entire country) (Tons cane ground)		State of São Paulo (Tons cane ground)	
For sugar $\frac{\text{(tons sugar)}}{0.105}$		13,150,000		3,520,00
For "direct" alcohol production at sugar mills $\frac{\text{(litres alcohol)}}{74.5}$	297,000		120,000	
For "direct" alcohol production at "central" distilleries $\frac{\text{(litres alcohol)}}{74.5}$	59,200		—	
For "direct" alcohol production at "autonomous" distilleries $\frac{\text{(litres alcohol)}}{74.5}$	57,200		57,200	
	413,400	413,400	177,200	177,200
Total cane ground		13,563,400		3,697,200

Or, expressed as a percentage of total cane ground:

	Brazil (entire country)		State of São Paulo	
Cane ground for sugar		97.0		95.2
For "direct" alcohol:				
At sugar mills	2.19		3.25	
At "central" distilleries	0.44			
At "autonomous" distilleries	0.42		1.55	
	3.05	3.0	4.80	4.8
Total cane ground		100.0		100.0

Thus, during the period considered, only 3 to 5 per cent of the total cane was ground for the production of "direct" alcohol.

The over-all yield of sugar from cane ground for all purposes during these three crop years amounted to 10.3 per cent for the country as a whole and 10 per cent in São Paulo.

2. *Recent trend of alcohol production in the State of São Paulo*

The following table shows the ratio of total alcohol (residual plus direct) to sugar produced in the State of São Paulo in recent years. [Sources: for 1948/49, Moacis Soares Pereira, *loc. cit.*; for others, *Associação de Usineiros de São Paulo,* circular No. 110/54].

No recent data are available for Brazil as a whole.

Table VI—3

TREND OF ALCOHOL PRODUCTION IN THE STATE OF SÃO PAULO

Crop year	(a) Total alcohol produced million litres	(b) Sugar produced million tons	(c) Radio, litres alcohol/ton sugar
1948/49	48.9	0.348	141
1949/50	42.6	0.357	119
1950/51	50.8	0.404	126
1951/52	63.4	0.486	131
1952/53	82.5	0.565	146
1953/54	121.9	0.702	174

Figures for the last crop year (1953/54) are available. Assuming the same yield of residual alcohol per ton of sugar $\left(\frac{34,578,079}{369,560} = 93.5 \text{ litres}\right)$ as for the three crop years already discussed, this gives:

(i) $\frac{702,000 \text{ tons sugar}}{0.105} = 6,680,000$ tons sugar cane ground for sugar production.

(ii) 702,000 tons sugar x 93.5 litres res. alc/ton sugar = 65,600,000 litres residual alcohol produced.

(iii) Less 121,900,000 litres total alcohol
65,600,000 litres residual alcohol
gives 56,300,000 litres direct alcohol produced.

(iv) At a yield of 74.5 litres direct alcohol/ton of cane, the amount of cane ground for direct alcohol is $\frac{56,300,000 \text{ litres direct alcohol}}{74.5 \text{ litres/ton of cane}} = 756,000$ tons

		Tons	Per cent
(v)	Cane to sugar	6,680,000	89.8
	Cane to direct alcohol	756,000	10.2
	TOTAL CANE GROUND	7,436,000	100.0

Thus for the State of São Paulo, in the best crop year, 10.2 per cent of the total cane ground went into direct alcohol production as compared with 4.8 per cent on average in the three crop years 1948/51, while the over-all yield of sugar, as a percentage of total cane ground for all purposes, was 9.45 per cent as compared with 10.0 per cent for the earlier period.

3. *Steam requirements and bagasse consumption*

R. Norris Shreve gives the following steam requirements data for sugar refining and for the production of alcohol from final molasses (residual alcohol):[2]

From raw sugar to refined sugar:
Process steam } 175 lb/100 lb of refined sugar.
Power steam } = 175 kg/100 kg of refined sugar.

Yield of refined sugar based on raw sugar of 96° is 93-94 per cent (average 93.5 per cent).

From final molasses to alcohol:
Steam: 50 lb per U.S. gallon of 190° proof alcohol = 6.0 kg/litre of 190° proof alcohol.

[2] *The Chemical Process Industries, op. cit.*

Mariller, however, gives a steam requirement of 5.0 kg steam/litre of alcohol. In the following calculations, an average of these two values (5.5 kg steam/litre alcohol) is used.

Sugar production for the State of São Paulo in 1953/54 was as follows:

	Tons	*Per cent*
Raw sugar	606,918	86.5
Refined sugar	94,708	13.5
TOTAL	701,626	100.0

In the following pages, calculations are made to show the surplus or deficit of bagasse which may arise from the five different types of mill operations mentioned.

Case I. Mill producing raw sugar and "residual" alcohol from its final molasses (the latter in the proportion of 93.3 litres per ton of sugar produced)

(i) Steam for sugar production: assume 600 kg/ton of cane ground (i.e., relatively unimproved sugar mill) at a yield of 10.5 per cent sugar on ground cane this means 105 kg sugar/ton of cane ground, or 0.105 tons.

(ii) Alcohol: 93.3 x 0.105 = 9.8 litres/ton of cane ground. Using the mean figure of steam consumption for alcohol production: 9.8 litres alcohol x 5.5 kg steam/litre = 53.9 kg of steam for alcohol production.

(iii)

Steam for raw sugar production	600.0	kg/ton of cane
Steam for alcohol production	53.9	kg/ton of cane
TOTAL	653.9	(Say 654).

(iv) With cane at 13 per cent total fibre (including pith) and bagasse at 4.4 per cent sugar and 50 per cent moisture content, this means, per ton of cane:

	Kg	*Per cent*
Fibre	130.0	45.6
Sugar	12.5	4.4
Water	142.5	50.0
TOTAL	285.0	100.0

(v) Evaporation (steam generated)

$$= \frac{1{,}335 \text{ kcal/kg bagasse}}{555 \text{ kcal/kg steam}} = 2.4 \text{ kg steam/kg bagasse (50 per cent moist)}$$

Total steam from bagasse
= 285 x 2.4 = *684 kg/ton of cane ground.*

(vi) The surplus is therefore:

684—654 = 30 kg steam surplus/ton cane ground.

$$\frac{30 \text{ kg steam surplus/ton cane}}{2.4 \text{ kg steam/kg bagasse}} = \text{12.5 kg bagasse surplus/ton can ground}$$

$$\frac{\text{12.5 kg bagasse surplus}}{\text{285 kg bagasse produced}} \times 100 = \textit{4.4 per cent surplus of bagasse}^{3}$$

³ As percentage of total bagasse produced.

Case II. Mill producing "direct" alcohol from ground cane juice, but manufacturing no sugar

(i) Production = 74.5 litres alcohol/ton of cane ground.

(ii) Steam required 74.5 litres/ton cane x 5.5 kg steam/litre = 410 kg/ton cane.

(iii) Bagasse production, composition and steam evaporation equivalent as in case I, i.e.: 684 kg of steam/ton of cane ground.

(iv) The surplus is therefore:

684—410 = 274 kg steam surplus/ton cane ground

$$\frac{274 \text{ kg steam surplus/ton cane}}{2.4 \text{ kg steam/kg bagasse}} = \text{114 kg bagasse surplus/ton cane ground}$$

$$\frac{\text{114 kg bagasse surplus}}{\text{285 kg bagasse produced}} \times 100 = \textit{40.0 per cent surplus of bagasse}^{4}$$

Case III. Mill producing only raw sugar

(i) Steam for sugar production: as in case I.

(ii) Bagasse production, composition and steam evaporation equivalent: as in case I.

(iii) The surplus is therefore:

684—600 = 84 kg steam surplus/ton cane ground

$$\frac{84 \text{ kg steam surplus/ton cane}}{2.4 \text{ kg steam/kg bagasse}} = \text{35 kg bagasse surplus/ton cane ground}$$

$$\frac{\text{35 kg bagasse surplus}}{\text{285 kg bagasse produced}} \times 100 = \textit{12.3 per cent surplus of bagasse}^{4}$$

Case IV. Mill producing raw sugar and refining one-half of its output

(i) Steam for raw sugar production: as in case I.

(ii) Yield of raw sugar per ton of cane ground: as in case I. Using Shreve's figure of 93.5 per cent for yield of refined sugar from raw sugar, and remembering that only half of raw sugar produced is refined, this gives:

$$\frac{105}{2} \times 0.935 = 49.1 \text{ kg of refined sugar produced}$$

With Shreve's figure of 175 kg of steam per 100 kg of refined sugar:

$$175 \times \frac{49.1}{100} = 86 \text{ kg of steam for refining.}$$

(iii) Total steam required:

600 kg for producing raw sugar
86 kg for refining half of raw sugar produced.
686 kg

(iv) Bagasse production, composition and steam evaporation equivalent: as in case I.

⁴ As percentage of total bagasse produced.

(v) Calculation of surplus (or deficit):
684—686=2 kg steam deficit/ton cane ground

$$\frac{2\text{ kg steam deficit}}{2.4\text{ kg steam/kg bagasse}} = 0.83\text{ kg bagasse deficit/ton cane ground}$$

$$\frac{0.83\text{ kg bagasse deficit}}{285\text{ kg bagasse produced}} \times 100 = \textit{0.3 per cent deficit of bagasse}^{5}$$

Case V. Mill producing raw sugar and refining all its output

(i) Steam for raw sugar production: as in case I.

(ii) Yield of raw sugar per ton of cane ground: as in case I.

105 x 0.935=98.2 kg refined sugar produced

$$175 \times \frac{98.2}{100} = 172\text{ kg of steam for refining.}$$

[5] As percentage of total bagasse produced.

(iii) Total steam required:

600 kg for raw sugar production
172 kg for refining
772 kg

(iv) Bagasse production, composition and steam evaporation equivalent: as in case I.

(v) Calculation of surplus (or deficit):

684—772=88 kg steam deficit/ton cane ground

$$\frac{88\text{ kg steam deficit}}{2.4\text{ kg steam/kg bagasse}} = 36.6\text{ kg bagasse deficit/ton cane ground}$$

$$\frac{36.6\text{ kg bagasse deficit}}{285\text{ kg bagasse produced}} \times 100 = \textit{12.9 per cent deficit of bagasse}^{5}$$

Appendix VII

The substitution cost of bagasse

This appendix attempts to estimate the "substitution cost" of bagasse, i.e., the cost to the pulp mill of each ton of bagasse consumed consequent upon the conversion of the sugar mill from bagasse burning to fuel oil burning. This cost consists of the following elements, which are examined in turn: the fuel replacement value—the cost of the fuel oil which replaces the bagasse as fuel; the cost of baling wire; the capital costs of boiler conversion; the capital costs of equipment for handling the bagasse; the cost of labour for handling the bagasse; the capital costs of baling station buildings; the capital costs of the bagasse storage area; insurance on, and interest on the capital represented by, storage bagasse.

Two general cases are considered: case A, where the mill operates on baled bagasse only, and case B, where the mill operates on fresh bagasse during the grinding season and on baled bagasse during the non-grinding season. For each of these general cases, figures are adduced for pulp mills of three different sizes, viz.: of 20, 50 and 100 tons daily capacity.

For certain cost elements, notably for the capital costs of handling equipment and for the labour costs of handling, the determining factors are (i) the baling and piling rate, and (ii) the unpiling and bale-breaking rate, both of which are determined by the length of the grinding season as well as by the size of the pulp mill and whether or not the pulp mill is operating entirely on baled bagasse. It is therefore convenient to examine these two elements of cost in terms of different piling and unpiling rates.

After each of the cost elements listed above has been discussed in general terms, a set of tables is presented showing the estimated substitution cost of bagasse in each of the countries which were the object of case studies. These tables, which include figures for both case A and case B, and for all three mill sizes, are derived from the preceding general discussion with the insertion of figures relevant to the local circumstances (e.g., as to length of grinding season, local cost of fuel oil, etc.).

Fuel replacement value

One ton of fuel oil will replace six tons of 50 per cent moist fresh bagasse (see appendix V).

Hence the fuel replacement value of fresh bagasse is: $Z=\frac{S}{6}$ dollars per ton, where Z=fuel replacement value and S=cost of fuel oil per ton.

Baling wire

The bales—46×56×81 cm—are held together by two wires which circle the bale lengthwise.[1]

The length of wire required per bale is: L=2 (2×46+2×81)=508 cm or (allowing for splicing) L=5.5 m per bale or L=48 m per ton of bagasse baled.

The cost of the wire is estimated at 10 dollars per 100 lb or 1,680 m, which gives $Z=10 \cdot \frac{48}{1,680}=0.285$ dollars per ton of bagasse *baled.*

This corresponds (case B) to $\frac{12-n}{12} \cdot 0.285$ dollars per ton of bagasse *consumed* where n is the length of the grinding season in months.

Boiler conversion costs

The cost of converting the sugar mill boilers burning bagasse to operate on fuel oil may be estimated for different boiler capacities as follows:

Total fresh bagasse released, tons/day	200	400	600	1,200
Total cost, dollars[2]	30,000	45,000	58,000	98,000

The investment required may thus be arrived at approximately as a linear function of the quantity of bagasse released, as follows: $Y=18,000+66.7X_r$ —where Y=investment in dollars and X_r=quantity of bagasse released, in tons/day.

Annual costs are taken at 19 per cent of the capital (10 per cent depreciation, 5 per cent spares, maintenance and insurance, 8 per cent interest on half the capital). Thus, annual capital cost of boiler conversion $Z=3,420+12.7\ X_r$.

If n is grinding season in months and X the bagasse *consumption* rate, then: $X_r=\frac{12}{n} \cdot X$ and $Z=3,420+\frac{152}{n}X$

and the capital cost per ton bagasse *consumed*, z, is: $z=\frac{Z}{300X}=\frac{11.4}{X}+\frac{0.507}{n}$

Hence the following table, showing the capital cost of boiler conversion per ton of bagasse *consumed* for six different bagasse consumption rates and for different lengths of grinding season.

CAPITAL COST OF BOILER CONVERSION PER TON BAGASSE CONSUMED

(dollars)

	Bagasse consumption tons/day					
	120	*200*	*300*	*400*	*500*	*600*
Grinding season:						
3 months	0.264	0.226	0.207	0.198	0.192	0.188
6 months	0.180	0.142	0.123	0.114	0.108	0.104
9 months	0.151	0.113	0.094	0.085	0.079	0.075
12 months	0.137	0.099	0.080	0.071	0.065	0.061

Equipment for bagasse handling

(*a*) Equipment required

The two sets of operations—baling and piling (the transfer of fresh bagasse from the sugar mill to the storage site) and unpiling and bale breaking (the transfer of baled bagasse from the storage site to the pulp mill)—are considered separately.

The following unit capacities of bagasse-handling equipment have been assumed in the calculations:

Bale size	45 × 56 × 81 cm=0.208 m^3
Bale weight	115 kg fresh (=63.8 kg air-dry)
Baler capacity	60 bales/h=6,900 kg
Hoist capacity	1 lift of 6 bales per 3 min =120 bales/h=13,800 kg
Cart load	12 bales=1,380 kg
Tractor load	3 cartloads=4,140 kg
Tractor capacity	2 loads/h=8,280 kg
Breaker capacity	40 bales/h=110 tons/day

[1] See *Preservation, Handling and Storing of Bagasse,* by A. Watson Chapman.
[2] Allowing for fuel storage tank capacity for about one week's supply.

All the rates, etc., quoted above,[3] and in the tables and charts which follow, are given, for the sake of convenience, in terms of fresh bagasse. For example, the hoist capacity is given as 13.8 tons/h both when piling and unpiling. In either case the capacity is 120 bales/h, i.e., 13.8 tons of fresh bagasse when piling but only 7.7 tons (actual weight) of air-dry bagasse when unpiling.

On the basis of the foregoing unit capacities, the number of the various items of equipment, and the number of shifts to be worked, are given in the following tables for baling and piling (covering baling rates from 55 to 1,325 tons/d) and for unpiling and bale breaking (covering unpiling rates from 110 to 662 tons/d—fresh bagasse equivalent), respectively.

1. Baling and piling operation

Baling rate, bales/h	20	40	60	120	240	360	480
Baling rate, tons/d	55.2	110.4	166	331	662	994	1,325
No. of balers and shifts	1/3	1/3	1/3	2/3	4/3	6/3	8/3
No. of tractors and shifts	1/1	1/2	1/3	2/3	4/3	5/3	7/3
No. of hoists and shifts	1/1	1/2[a]	1/2	1/3	2/3	3/3	4/3
No. of carts	36[b]	36[c]	51[d]	21	39	57	75

[a] One hoist working one shift would suffice but storage on carts of two shifts output—630 tons—is probably not feasible.
[b] Storage of two shifts output—320 tons—on carts.
[c] Storage of one shift output—320 tons—on carts.
[d] Storage of one shift output—480 tons—on carts.

2. Unpiling and bale breaking

Unpiling rate, bales/h	120	120	120	240
Unpiling rate, tons/d	110	221	331	662
No. of hoists and shifts	1/1	1/2	1/3	2/3
No. of tractors and shifts	2/1	2/2	2/3	4/3
No. of carts[a]	21	21	21	39
No. of breakers and shifts	1/3	2/3	3/3	6/3

[a] It is assumed that when unpiling is carried out on less than three shifts, storage of bales takes place at the pulp mill, i.e., there is no storage on carts.

(*b*) Investment in equipment

Having established the numbers of the various items of equipment required for the different scales of operation, it is possible to estimate the required investment in equipment. This is done first from the case of a pulp mill operating solely on baled bagasse.

CASE A: Baled bagasse only

Bagasse, tons/d	55	110	166	221	331	662	994	1,325
1. *Piling*								
Balers	4.5	4.5	4.5		9.0	18.0	27.0	36.0
Tractors	4.0	4.0	4.0		8.0	16.0	20.0	28.0
Carts	12.6	12.6	17.9		7.4	13.7	20.0	26.3
Conveyor	11.5	14.0	15.5		19.5	25.0	28.0	30.0
TOTAL, THOUSAND DOLLARS	32.6	35.1	41.9		43.9	72.7	95.0	120.3
2. *Unpiling*								
Hoists	7.5	7.5	7.5	7.5	7.5	15.0	22.5	30.0
Tractors	4.0	8.0	8.0	8.0	8.0	16.0	20.0	28.0
Carts	7.4	7.4	7.4	7.4	7.4	13.7	20.0	26.3
Breakers	6.5	6.5	13.0	13.0	19.5	39.0	58.5	78.0
TOTAL, THOUSAND DOLLARS	25.4	29.4	35.9	35.9	42.4	83.7	121.0	162.3

These investment figures are presented graphically in chart I.

CASE B: Fresh bagasse during the grinding season

Where the pulp mill operates on fresh bagasse during the grinding season and baled bagasse during the non-grinding season, the total number of carts required for transport (and for storage when piling and unpiling takes place on less than three shifts) is determined by the piling rate during the grinding season or the unpiling rate during the non-grinding season, whichever is the higher. Thus, if the grinding season is less than six months, the piling rate will exceed the unpiling rate, and the number of carts and tractors required during the grinding season will be more than adequate for the non-grinding season. Two separate cases are therefore considered, a grinding season of less than six months and a grinding season of more than six months; in each case the investment in carts and tractors (and also that in hoists) is charged to the operation which requires most tractors and carts.

[3] Including the earlier sections of this appendix.

Chart I

EQUIPMENT INVESTMENT

(baled bagasse only)

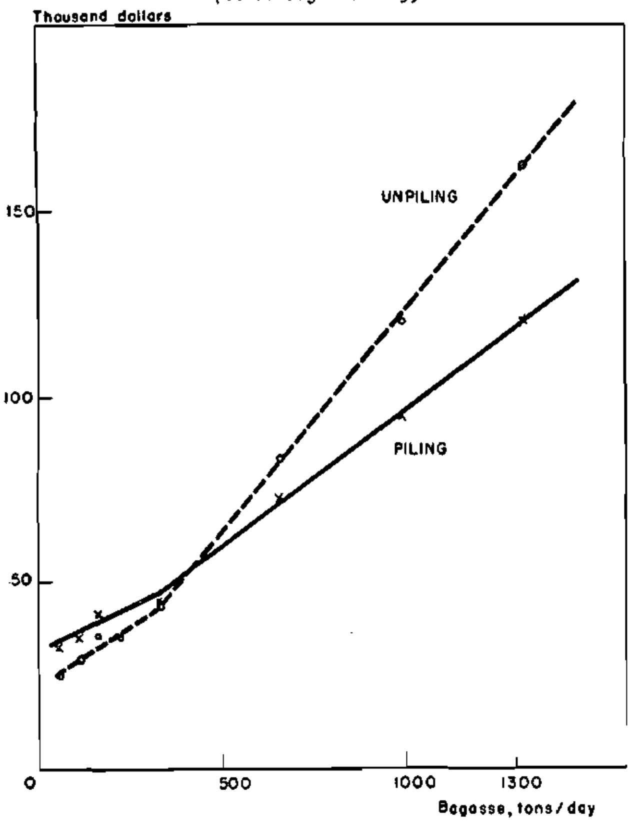
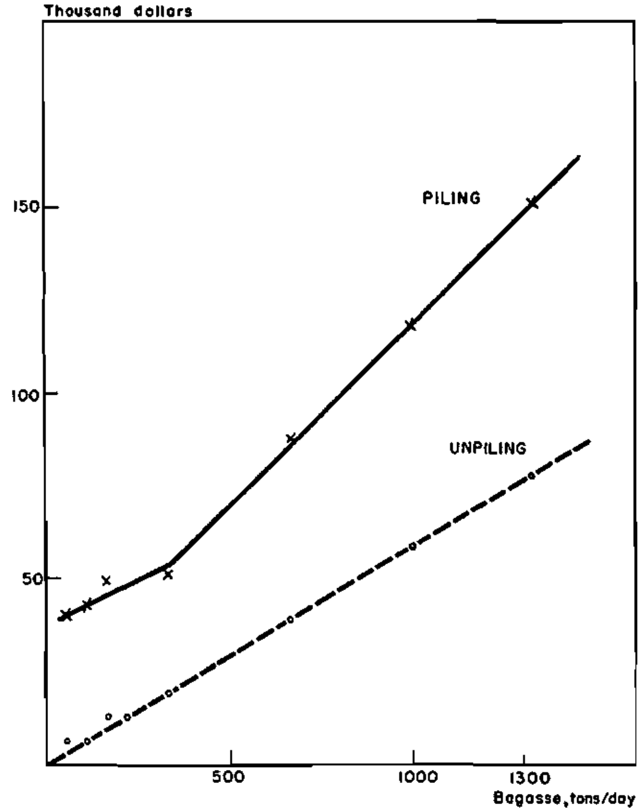


Chart II

EQUIPMENT INVESTMENT

(A) Fresh bagasse during grinding season; grinding season less than 6 months



(i) *Grinding season less than 6 months*

Bagasse, tons/d	55	110	166	221	331	662	994	1,325
1. *Piling*								
Balers	4.5	4.5	4.5		9.0	18.0	27.0	36.0
Tractors	4.0	4.0	4.0		8.0	16.0	20.0	28.0
Carts	12.6	12.6	17.9		7.4	13.7	20.0	26.3
Conveyor	11.5	14.0	15.5		19.5	25.0	28.0	30.0
Hoists	7.5	7.5	7.5		7.5	15.0	22.5	30.0
TOTAL, THOUSAND DOLLARS	40.1	42.6	49.4		51.4	87.7	117.5	150.3
2. *Unpiling*								
Breakers	6.5	6.5	13.0	13.0	19.5	39.0	58.5	78.0
TOTAL, THOUSAND DOLLARS	6.5	6.5	13.0	13.0	19.5	39.0	58.5	78.0

(ii) *Grinding season more than 6 months*

Bagasse, tons/d	55	110	166	221	331	662	994	1,325
1. *Piling*								
Balers	4.5	4.5	4.5		9.0	18.0	27.0	36.0
Conveyor	11.5	14.0	15.5		19.5	25.0	28.0	30.0
TOTAL, THOUSAND DOLLARS	16.0	18.5	20.0		28.5	43.0	56.0	66.0
2. *Unpiling*								
Tractors	4.0	8.0	8.0	8.0	8.0	16.0	20.0	28.0
Carts	7.4	7.4	7.4	7.4	7.4	13.7	20.0	26.3
Hoists	7.5	7.5	7.5	7.5	7.5	15.0	22.5	30.0
Breakers	6.5	6.5	13.0	13.0	19.5	39.0	58.5	78.0
TOTAL, THOUSAND DOLLARS	25.4	29.4	35.9	35.9	42.4	83.7	121.0	162.3

These investments are also presented graphically, in charts II and III, as functions of piling and unpiling rates. It will be observed that the functions are approximately linear, with breaking points at piling and unpiling rates of about 330 tons/d.

(*c*) Capital cost of equipment

The annual cost of the investment is estimated at 19 per cent of the capital: depreciation 10 per cent, spares, maintenance and insurance 5 per cent, and interest 4 per

Chart III

EQUIPMENT INVESTMENT

(B) Fresh bagasse during grinding season; grinding season more than 6 months

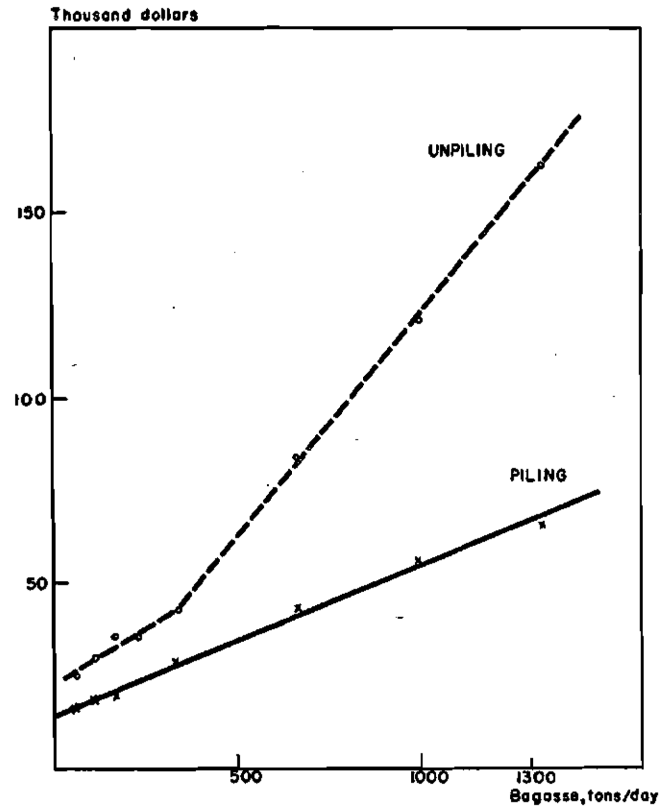
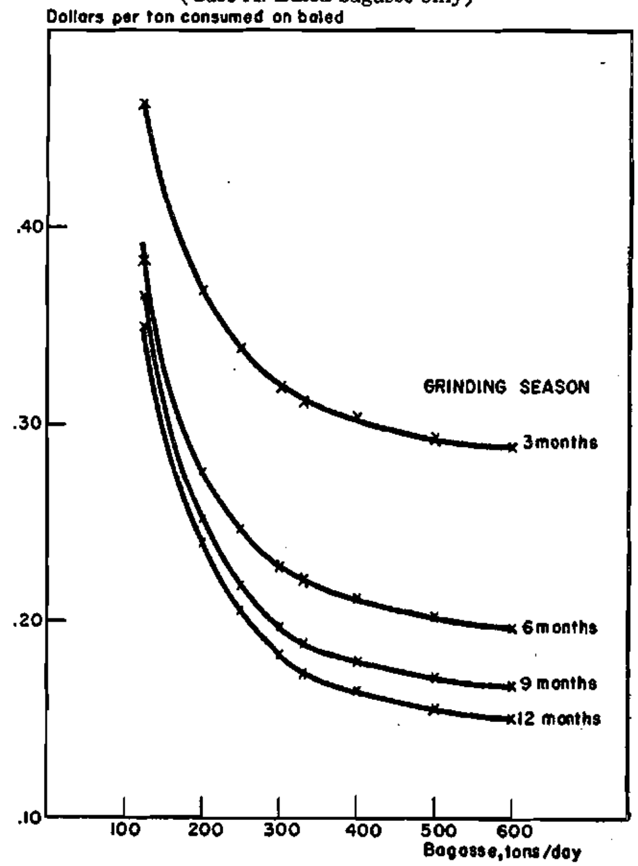


Chart IV

CAPITAL COST : EQUIPMENT
(Case A. Baled bagasse only)



cent (or 8 per cent on half the capital). Since the investment is a linear function, the capital cost is also a linear function, and the capital cost per ton of fresh bagasse baled or consumed is a hyperbolic function. Hyperbolic functions corresponding to the various cases considered are calculated below, using the diagrams. Because of the breaking points noted above, separate functions are given for piling (and unpiling) rates under and over 330 tons/d.

CASE A: Baled bagasse only

1. *Piling and unpiling rates—X—less than 300 tons/d*

	Piling operation	*Unpiling operation*
Investment dollars........................	31,500 + 50 Xp	22,000 + 63.5 X
Annual cost, dollars........................	6,000 + 9.5 Xp	4,180 + 12.1 X

When operating on baled bagasse only, the piling rate—Xp—is $\frac{12}{n} \cdot X$ where n is grinding season in months and X is the unpiling or consumption rate. Consequently the cost per ton is the following:

	Piling operation	*Unpiling operation*
Cost per ton consumed (and baled).............	$\frac{6{,}000+9.5\ Xp}{300\ X}$	$\frac{4{,}180+12.1\ X}{300\ X}$
or (assuming 300 working days in the year)......	$\frac{20}{X}+\frac{9.5}{300}\ \frac{12}{n}$	$\frac{13.9}{X}+0.04$

2. *Piling and unpiling rates more than 330 tons/d*

	Piling operation	*Unpiling operation*
Investment, dollars..........................	23,000+73.2 Xp	4,000+120 X
Annual cost, dollars..........................	4,380+13.9 Xp	760+22.8 X
Cost per ton consumed (or baled) dollars........	$\frac{14.6}{X}+\frac{13.9}{300}\ \frac{12}{n}$	$\frac{2.5}{X}+0.076$

CASE B: Fresh bagasse during grinding season

(i) Grinding season less than 6 months

$$\text{Piling rate } Xp = \frac{12-n}{n} X$$

1. *Piling and unpiling rates less than 330 tons/d*

Investment, dollars	37,500+48.3 Xp	58.8 X
Annual cost, dollars	7,120+ 9.2 Xp	11.2 X
Cost per ton consumed, z	$\frac{23.7}{X}+\frac{9.2}{300}\frac{(12-n)}{(n)}$	0.037
Cost per ton baled	$\frac{12}{12-n}\cdot z$	$\frac{12}{12-n}\cdot 0.037$

2. *Piling and unpiling rates more than 330 tons/d*

Investment, dollars	20,500+98.2 Xp	58.8 X
Annual cost, dollars	3,900+18.7 Xp	11.2 X
Cost per ton consumed, z	$\frac{13.0}{X}+\frac{18.7}{300}\frac{(12-n)}{(n)}$	0.037
Cost per ton baled	$\frac{12}{12-n}\cdot z$	$\frac{12}{12-n}\cdot 0.037$

(ii) Grinding season more than 6 months

1. *Piling and unpiling rates less than 330 tons/d*

Investment, dollars	14,000+40.7 Xp	22,000+63.5 X
Annual cost, dollars	2,660+ 7.7 Xp	4,180+12.1 X
Cost per ton consumed, z	$\frac{8.87}{X}+\frac{7.7}{300}\frac{(12-n)}{(n)}$	$\frac{13.9}{X}+0.040$
Cost per ton baled	$\frac{12}{12-n}\cdot z$	$\frac{12}{12-n}\cdot z$

2. *Piling and unpiling rates more than 330 tons/d*

Investment, dollars	14,000+40.7 Xp	4,000+120 X
Annual cost, dollars	2,660+ 7.7 Xp	760+22.8 X
Cost per ton consumed, z	$\frac{8.87}{X}+\frac{7.7}{300}\frac{(12-n)}{(12)}$	$\frac{2.5}{X}+0.076$
Cost per ton baled	$\frac{12}{12-n}\cdot z$	$\frac{12}{12-n}\cdot z$

Using the equations listed above, the capital costs of equipment may be calculated for different consumption rates and grinding seasons, the results being given below:

CASE A: Baled bagasse only

		Dollars per ton consumed or baled							
Bagasse consumption tons/d		120	200	250	300	330	400	500	600
Grinding season:	3 months	0.463	0.368	0.339	0.320	0.312	0.304	0.294	0.289
	6 months	0.383	0.276	0.247	0.228	0.221	0.212	0.203	0.197
	9 months	0.365	0.252	0.218	0.197	0.188	0.180	0.172	0.167
	12 months	0.350	0.239	0.206	0.183	0.173	0.165	0.156	0.151

CASE B: Fresh bagasse during grinding season

		Dollars per ton consumed							
Grinding season:	3 months	0.332	0.289	0.276	0.267	0.263	0.257	0.250	0.246
	6 months	0.265	0.187	0.163	0.147	0.140	0.131	0.125	0.121
	9 months	0.239	0.163	0.140	0.125	0.118	0.114	0.108	0.104
		Dollars per ton baled							
Grinding season:	3 months	0.442	0.385	0.368	0.356	0.350	0.342	0.333	0.328
	6 months	0.530	0.374	0.326	0.294	0.280	0.262	0.250	0.242
	9 months	0.956	0.652	0.560	0.500	0.472	0.456	0.432	0.416

These costs are recorded graphically in charts IV, V and VI.

Chart V

CAPITAL COST : EQUIPMENT

(Case B. Fresh bagasse during grinding season)

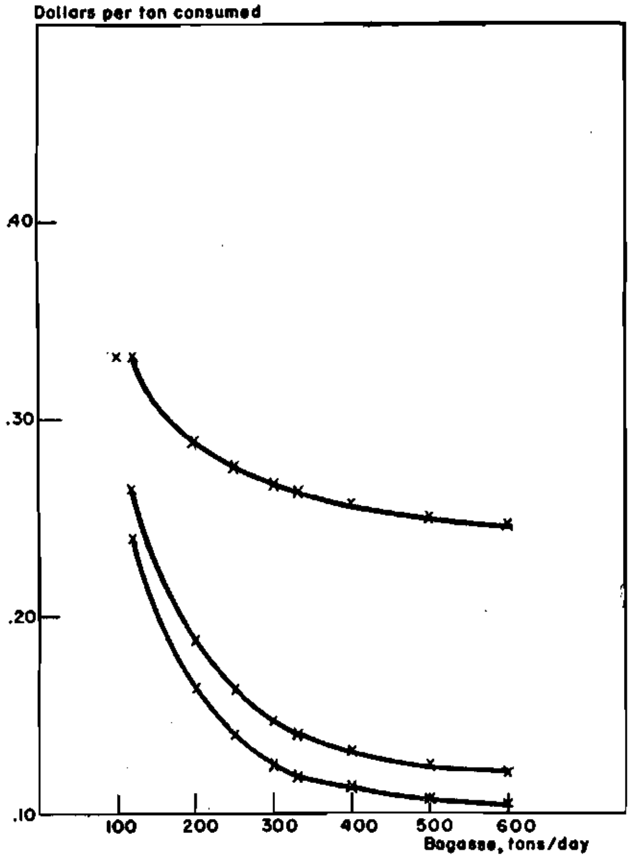
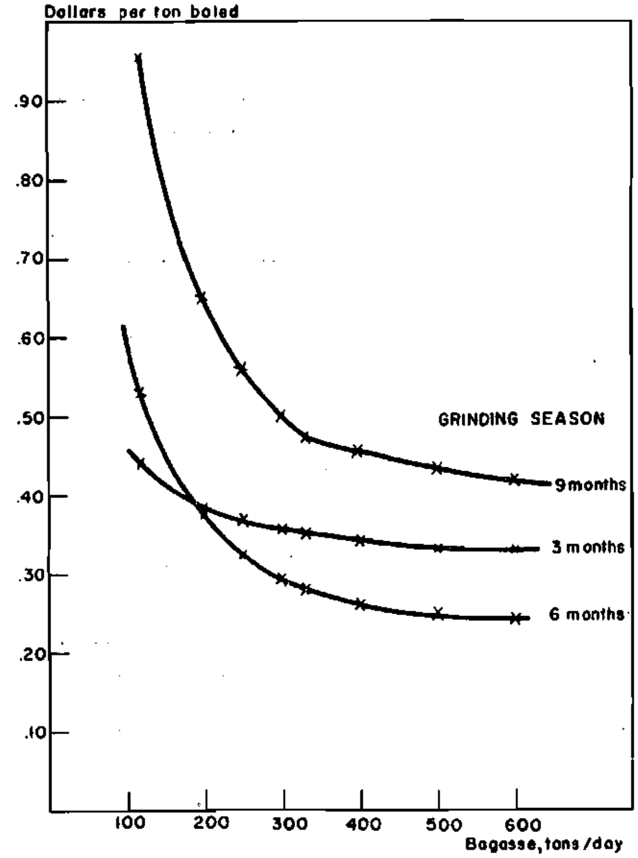


Chart VI

CAPITAL COST : EQUIPMENT

(Case B. Fresh bagasse during grinding season)



Labour for bagasse handling

Using the data for equipment requirements given above, personnel requirements may be estimated as follows:

1. *Baling and piling operation*

	Baling rate, tons/d						
	55	*110*	*166*	*331*	*662*	*994*	*1,325*
	Man-shifts per day						
Chief handler	1	1	1	1	1	1	1
Mechanics	3	3	3	3	3	3	3
Baler feeders	3	3	3	3	3	6	6
Wire tiers	3	3	3	6	12	18	24
Bale loaders	3	3	3	6	12	18	24
Tractor drivers	1	2	3	6	12	15	21
Hoist operators	1	2	2	3	6	9	12
Bale pilers	2	4	4	6	12	18	24
Clean-up men	3	3	3	3	3	3	3
TOTAL, MAN-SHIFTS/D	20	24	25	37	64	91	118
TOTAL, MAN-HRS/D	160	192	200	296	512	728	944

2. *Unpiling and bale breaking*

	Unpiling rate, tons/d			
	110	*221*	*331*	*662*
Hoist operators	1	2	3	6
Tractor drivers	2	4	6	12
Bale loaders	2	4	6	12
Breaker feeders	3	6	9	18
Clean-up man	3	3	3	3
TOTAL, MAN-SHIFTS/D	11	19	27	51
TOTAL, MAN-HRS/D	88	152	216	408

Chart VII

LABOUR REQUIREMENTS
(Baling and unpiling)

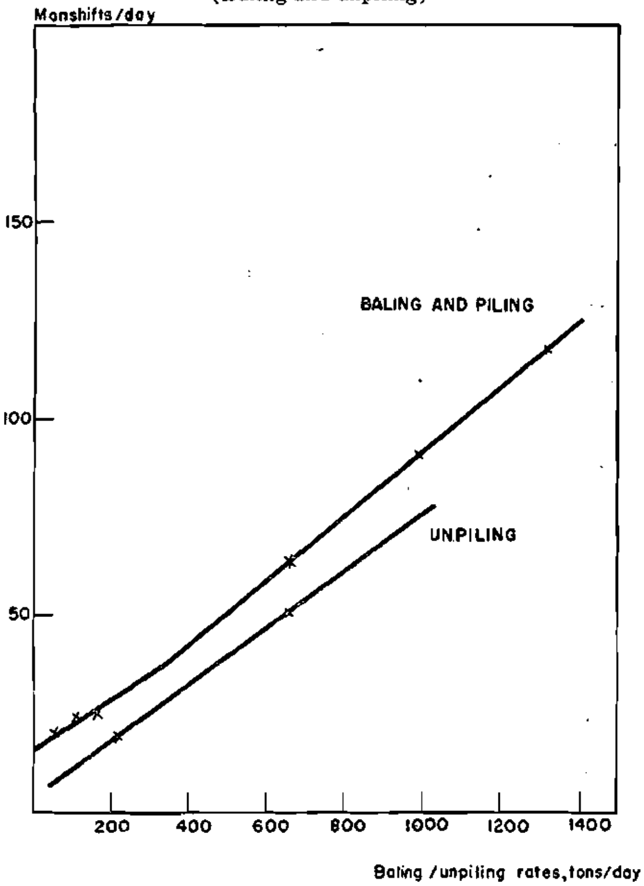
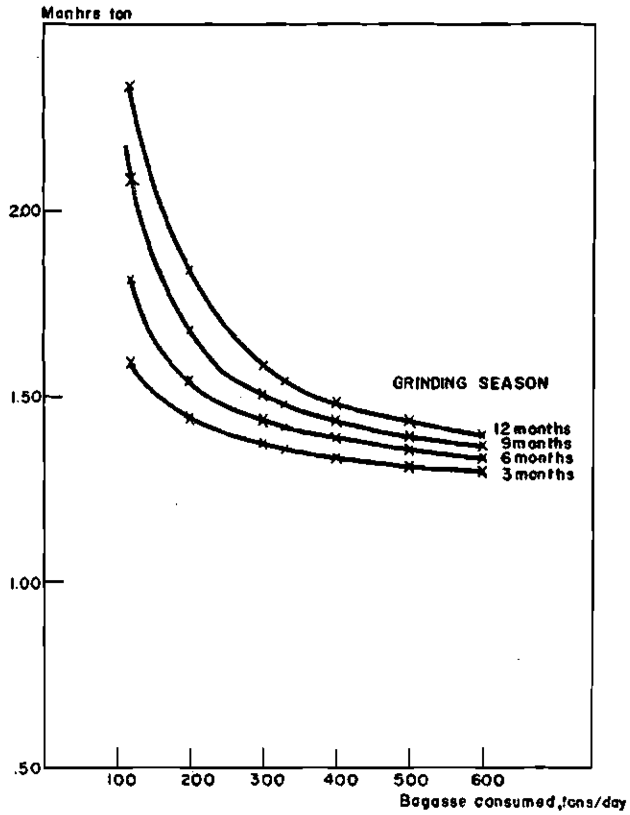


Chart VIII

MAN/HRS PER TON BALED OR CONSUMED
(Case A. Baled bagasse only)



The labour requirements, shown graphically in chart VII, approximate to linear functions of the baling and unpiling rates. These functions are calculated below, using the following symbols:

n = grinding season, months
X = bagasse consumption rate = unpiling rate, tons/day
Xp = bagasse piling rate
H = man-hrs per day
h = man-hrs per ton

CASE A: Baled bagasse only

$$Xp = \frac{12}{n} \cdot X$$

1. Piling operation
   (*a*) Baling rates less than 330 tons/day
   $$H = (16 + 0.0635\ Xp)\ 8 = 128 + 0.508\ Xp$$
   $$h = \frac{128}{Xp} + 0.508 = \frac{10.7 \cdot n}{X} + 0.508$$
   per ton baled or consumed
   (*b*) Baling rates more than 330 tons/day
   $$H = (10 + 0.0815\ Xp)\ 8 = 80 + 0.652\ Xp$$
   $$h = \frac{80}{Xp} + 0.652 = \frac{6.67}{X} n + 0.652$$ per ton baled or consumed
2. Unpiling operation
   $$H = (3 + 0.0715\ X)\ 8 = 24 + 0.572\ X$$
   $$h = \frac{24}{X} + 0.572$$ per ton baled or consumed

CASE B: Fresh bagasse during grinding season

$$Xp = \frac{12-n}{n} \cdot X$$

1. Piling operation
   (*a*) Baling rates less than 330 tons/day
   $$H = 128 + 0.508\ Xp$$
   $$h = \frac{128}{Xp} + 0.508 = \frac{128 \cdot n}{(12-n) \cdot X} + 0.508$$ per ton *baled*
   $$\text{and } h = \frac{n \cdot 128}{12\ X} + \frac{12-n}{12} \cdot 0.508$$
   $$= \frac{10.7\ n}{X} + \frac{12-n}{12} \cdot 0.508$$ per ton *consumed*
   (*b*) Baling rates more than 330 tons/day
   $$H = 80 + 0.652\ Xp$$
   $$h = \frac{80\ n}{(12-n)\ X} + 0.652$$ per ton *baled*
   $$\text{and } = \frac{6.67\ n}{X} + \frac{12-n}{12} \cdot 0.652$$ per ton *consumed*
2. Unpiling operation
   $$H = 24 + 0.572\ X$$
   $$h = \frac{24}{X} + 0.572$$ per ton unpiled or *baled*
   $$h = \frac{12-n}{12} \left\{ \frac{24}{X} + 0.572 \right\}$$ per ton *consumed*

The labour requirements for the combined operations are thus the following:

	Baling rates less than 330 tons/d	*Baling rates more than 330 tons/d*
CASE A: man-hrs per ton baled or consumed	$\frac{10.7n+24}{X}+1.080$	$\frac{6.67n+24}{X}+1.224$
CASE B: man-hrs per ton *baled*	$\frac{12}{12-n}\left\{\frac{8.67n+24}{X}\right\}+1.080$	$\frac{12}{12-n}\left\{\frac{4.67n+24}{X}\right\}+1.224$
man-hrs per ton *consumed*	$\frac{8.67n+24}{X}+\frac{12-n}{12}\cdot 1.080$	$\frac{4.67n+24}{X}+\frac{12-n}{12}\ 1.224$

Using these equations, the labour requirements for different grinding seasons and sizes of operation may be calculated. The results are set out in the tables below and are presented graphically in charts VIII, IX and X.

Chart IX

MAN/HRS PER TON CONSUMED

(Case B. Fresh bagasse during grinding season)

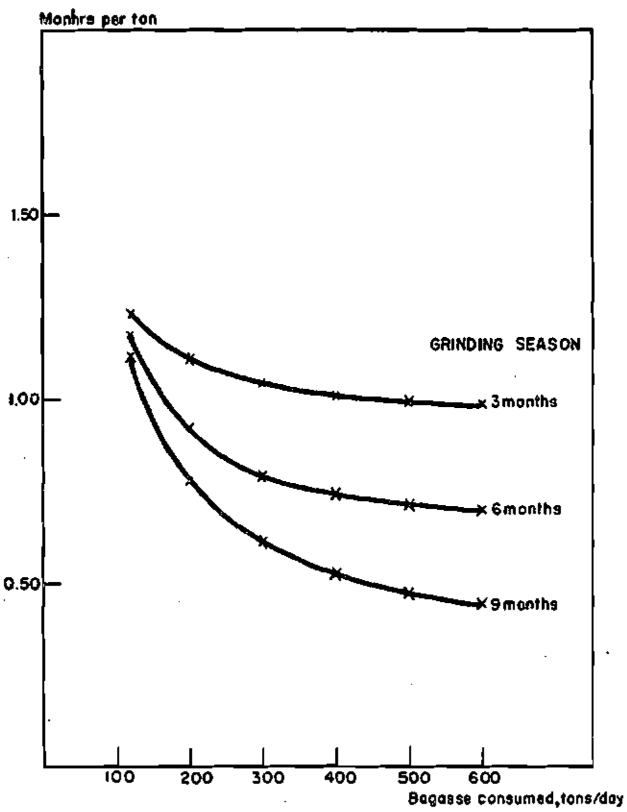
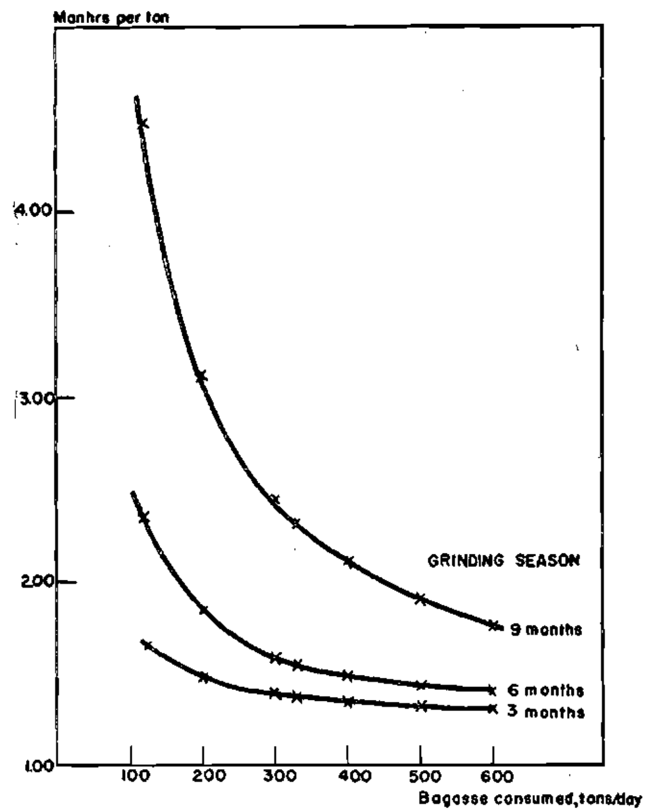


Chart X

MAN/HRS PER TON BALED

(Case B. Fresh bagasse during grinding season)



CASE A: Baled bagasse only

Consumption rate, tons/d	120	200	300	330	400	500	600
			Man-hrs per ton baled or consumed				
Grinding season, months: 3	1.591	1.444	1.371	1.356	1.334	1.312	1.297
6	1.813	1.544	1.437	1.418	1.384	1.352	1.331
9	2.080	1.680	1.504	1.479	1.434	1.392	1.364
12	2.347	1.840	1.587	1.541	1.484	1.432	1.397
CASE B: Fresh bagasse during grinding season							
			Man-hrs per ton baled				
Grinding season, months: 3	1.646	1.477	1.393	1.377	1.351	1.325	1.308
6	2.347	1.840	1.587	1.540	1.484	1.432	1.397
9	4.480	3.120	2.440	2.317	2.100	1.897	1.760
CASE B:							
			Man-hrs per ton consumed				
Grinding season, month s: 3	1.235	1.108	1.045	1.033	1.013	0.994	0.985
6	1.173	0.920	0.793	0.770	0.742	0.716	0.699
9	1.120	0.780	0.610	0.579	0.525	0.477	0.440

Cost of baling station buildings

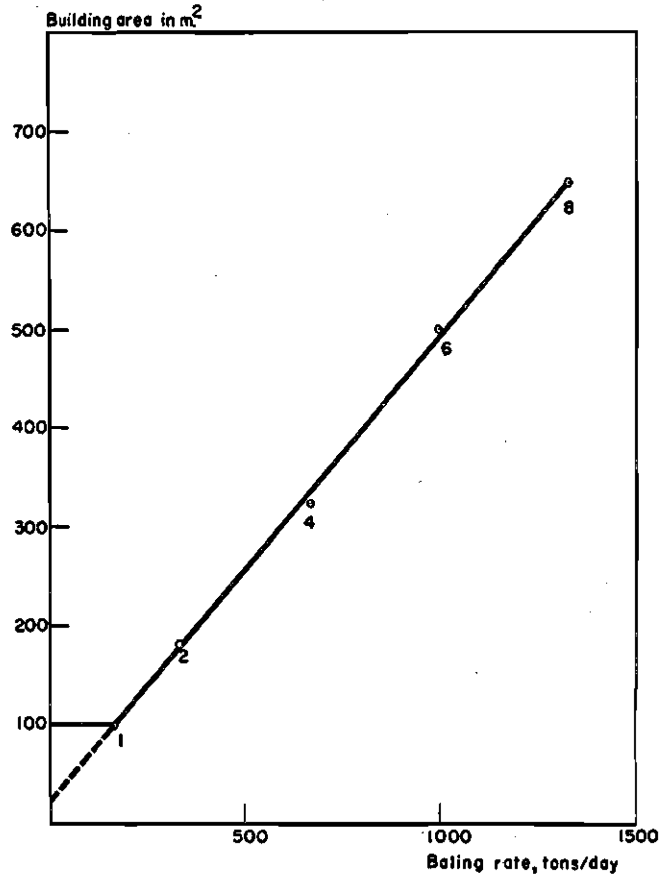
The building area required may be estimated as follows[6]:

No. of balers	*Baling capacity tons/d*	*Building area m²*
1	165	10 x 10 = 100
2	331	10 x 18 = 180
4	662	18 x 18 = 324
6	994	18 x 18 + 10 x 18 = 504
8	1.325	2 (18 x 18) = 648

(over-all building height is 9 metres)

Chart XI

BUILDING AREA, BALING STATION



The building area (A) is approximately a straight line function of the baling capacity (see chart XI).

$A = 22 + 0.473\ X_p$ with a minimum area of 100 for a baling capacity of 165 tons/day.

If construction cost per sq.m. is Z_a, the total investment is: $Y = Z_a\ (22 + 0.473\ X_p)$ and the annual cost Z, assuming 5 per cent depreciation; 5 per cent spares, maintenance and insurance, and 4 per cent average interest.

$$Z = \frac{14}{100} Z_a\ (22 + 0.473\ X_p)$$

CASE A: Baled bagasse only

$$X_p = \frac{12}{n} \cdot X \text{ where } X = \text{bagasse consumption rate}$$

and n = grinding season, months

Cost per ton consumed (or baled): $z = \frac{1}{300X} \cdot \frac{14}{100} Z_a \left(22 + .473 \frac{12}{n} X\right)$

$$= Z_a \left\{\frac{1.03}{X} + \frac{0.265}{n}\right\} \frac{1}{100} \text{ \$ per ton}$$

[6] See *Preservation, Handling and Storing of Bagasse,* paper 5.5.

CASE B: Fresh bagasse during grinding season

$$X_p = \left\{\frac{12-n}{n}\right\} \cdot X$$

$$z = Z_a\left\{\frac{1.03}{X} + \frac{0.265}{n} - 0.022\right\}\frac{1}{100} \text{ dollars per ton } \textit{consumed}$$

$$\text{and } z = \frac{12}{12-n} Z_a\left\{\frac{1.03}{X} + \frac{0.265}{n} - 0.022\right\}\frac{1}{100} \text{ dollars per ton } \textit{baled}$$

In both cases *A* and *B* the cost per ton *consumed* for baling rates less than 165 tons/d is:

$$z = 0.0467 \cdot \frac{Z_a}{X}$$

Using these equations, it is possible to establish the cost factor (f) by which the general construction cost per m² must be multiplied in order to arrive at the capital cost of baling station buildings per ton of bagasse baled or consumed for different baling and consumption rates or different lengths of grinding season. These cost factors for the several sets of conditions are tabulated below:

CASE A: Baled bagasse only

Bagasse consumption tons/d	*Cost factor—f. 100—per ton consumed or baled*						
	120	*200*	*300*	*330*	*400*	*500*	*600*
Grinding season, months: 3...	0.097	0.093	0.091	0.091	0.091	0.090	0.090
months: 6...	0.053	0.049	0.047	0.047	0.047	0.046	0.046
months: 9...	0.039	0.034	0.032	0.032	0.032	0.031	0.031
months: 12...	0.039	0.027	0.025	0.025	0.025	0.024	0.024

CASE B: Fresh bagasse during grinding season

Bagasse consumption tons/d	*Cost factor—f. 100—per ton consumed*						
	120	*200*	*300*	*330*	*400*	*500*	*600*
months: 3...	0.075	0.071	0.069	0.069	0.069	0.068	0.068
months: 6...	0.039	0.027	0.025	0.025	0.025	0.024	0.024
months: 9...	0.039	0.023	0.016	0.014	0.012	0.009	0.009
Bagasse consumption tons/d	*Cost factor—f. 100—per ton baled*						
	120	*200*	*300*	*330*	*400*	*500*	*600*
months: 3...	0.100	0.095	0.092	0.092	0.092	0.091	0.091
months: 6...	0.078	0.054	0.050	0.050	0.050	0.048	0.048
months: 9...	0.156	0.092	0.064	0.056	0.048	0.036	0.036

Storage area

(*a*) Quantity of bagasse stored

CASE A: Baled bagasse only

When operating on baled bagasse only it is important that the bales have a uniform dryness It is therefore estimated that the minimum quantity of bagasse in storage should not be less than two months supply to secure a complete drying.

Hence, $Q \min = X \cdot 25 \cdot 2$ (X = consumption rate)

and $Q \max = 2X \cdot 25 + n \cdot 25\,(X_p - X)$ (X_p = baling rate)

$$= 2X \cdot 25 + n \cdot 25\left\{\frac{12}{n}X - X\right\} \quad (n = \text{grinding season})$$

$$= X \cdot 25\,(14-n)$$

and average quantity in storage over the whole year:

$$Q\,av = 2X \cdot 25 + \frac{n \cdot 25\,(X_b - X)25}{Z} = \frac{}{2}X(16-n)$$

CASE B: Fresh bagasse during grinding Season

As uniform dryness is not so important the minimum quantity in storage is estimated equal to one month's supply.

$$Q\ min = X \cdot 25$$

$$Q\ max = X \cdot 25 + n \cdot 25\,(X_b - X)$$

$$= X \cdot 25 + n \cdot 25\left\{\frac{12-n}{n} \cdot X - X\right\}$$

$$= X \cdot 25\,(13-n)$$

$$Q\ av = X \cdot 25 + \frac{n \cdot 25\,(X_b - X)}{2}$$

$$= \frac{25}{2} X\,(14-n)$$

(b) Storage area and costs

A standard stack of bagasse bales contains about 12,000 bales (approx. 1,350 tons of fresh bagasse) and covers a net area of 37 x 20 metres. Allowing for free space between the stacks for fire protection and railroad access, the gross area for each stack will be approximately 46 x 32 or about 1,500 m². This gives a necessary storage area of

$$A = \frac{1,350}{1,500} = 0.9 \text{ sq. m./ton}$$

Storage area required is therefore:

CASE A: $A = Q\ max \cdot 0.9 = 23.5X\,(14-n)m^2$ and

CASE B: $A = Q\ max \cdot 0.9 = 23.5X\,(13-n)m^2$

It is estimated that one square metre of the field will require 0.25 man/hrs for levelling and gravelling and that one cubic metre of gravel is sufficient to cover an area of 20 m².

If labour cost is Z dollars per man/hour and the cost of gravel Z_2 dollars per m³, the cost of constructing one sq. m. of storage area is

$$\text{Unit cost} = 0.25 \cdot Z^1 + 0.05\,Z_2 = U$$

The cost of construction is therefore:

CASE A: $Y_1 = 23.5\,X\,(14-n)\,U$ and

CASE B: $Y_2 = 23.5\,X\,(13-n)\,U$ dollars

The annual costs—with 5 per cent depreciation, 5 per cent maintenance and 4 per cent average interest—are:

CASE A: $Z_1 = 3.3\,X\,(14-n)\,U$ and

CASE B: $Z_2 = 3.3\,X\,(13-n)\,U$ dollars and the costs per ton of bagasse

CASE A: $z_1 = 0.011\,(14-n)\,U$ dollars per ton *consumed* or *baled*

CASE B: $z_2 = 0.011\,(13-n)\,U$ dollars per ton *consumed*

CASE B: $z_3 = \frac{12}{12-n} \cdot 0.011\,(13-n)\,U$ dollars per ton *baled*

The factors—f—by which to multiple the unit construction cost to find the capital cost of storage construction per ton of bagasse are listed below for different grinding seasons. (Note that the cost per ton is independent of size of operation.)

	Grinding season, months			
	3	*6*	*9*	*12*
CASE A: Cost factor f_1 per ton consumed or baled.......	0.121	0.088	0.055	0.022
CASE B: Cost factor f_2 per ton consumed...............	0.110	0.077	0.044	
CASE B: Cost factor f_3 per ton baled....................	0.147	0.154	0.176	

These results are shown graphically in chart XII.

Insurance and interest on capital—stored bagasse

Insurance is calculated at 1.5 per cent and interest on capital at 8 per cent; i.e., a total capital cost of 9.5 per cent.

Average quantity stored (see above).

CASE A: $Q_a = 12.5\,X\,(16-n)$

CASE B: $Q_a = 12.5\,X\,(14-n)$

Chart XII

Cost Factor – for storage site

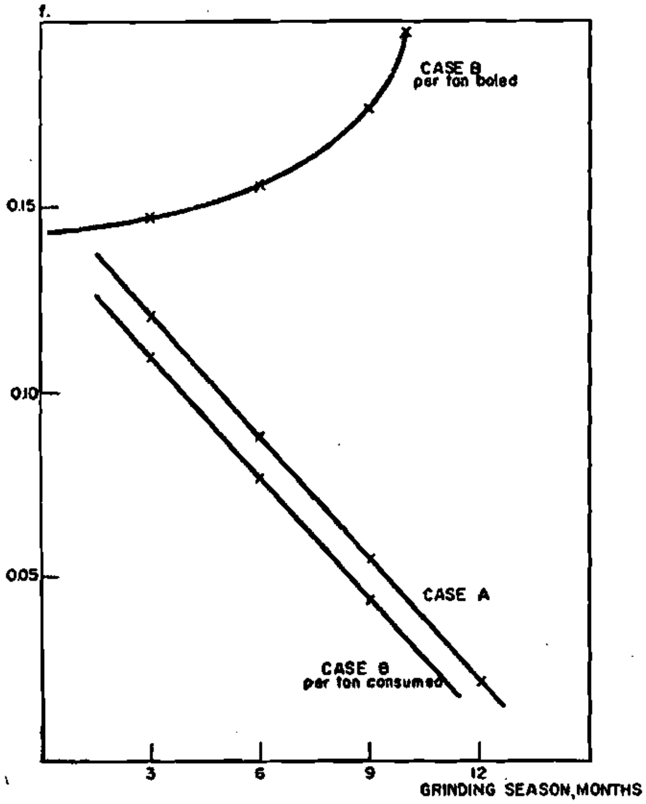
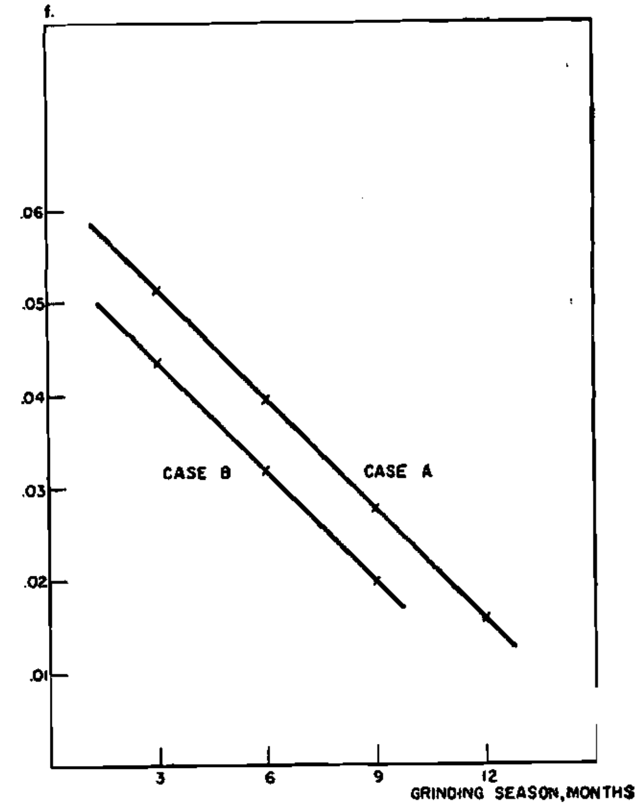


Chart XIII

Cost factor–insurance and interest on stored bagasse



Assuming that the value of *baled* bagasse is Z_b dollars per ton, the annual costs for insurance and interest are:

CASE A: $12.5 \times (16-n) \cdot Z_b \cdot \frac{9.5}{100}$

CASE B: $12.5 \times (14-n) \cdot Z_b \cdot \frac{9.5}{100}$

and the cost per ton consumed:

CASE A: $0.00396\ (16-n) \cdot Z_b$ and

CASE B: $0.00396\ (14-n) \cdot Z_b$

The cost factors—f—by which to multiply the bagasse value per ton (*baled*) in order to arrive at the cost of insurance and interest on stored bagasse per ton *consumed* are listed below for different grinding seasons.

	Grinding season, months			
	3	*6*	*9*	*12*
CASE A: cost factor f_1..........	0.0515	0.0396	0.0277	0.0158
CASE B: cost factor f_2..........	0.0435	0.0316	0.0197	..

These results are presented graphically in chart XIII.

The substitution cost of bagasse in the six countries surveyed

Each of the elements of cost that go to make up the total "substitution" cost of bagasse has now been analysed in turn. The analysis has been carried out in general terms, providing for the two alternative modes of operation (solely on baled bagasse —*Case A*—and on fresh and baled bagasse in the grinding and non-grinding seasons respectively—*Case B*) and for different lengths of grinding season. Certain factors have been assumed to be independent of locality, e.g., cost of baling wire, interest and insurance rates, gravel per m^2, etc. Certain other factors, e.g., cost of fuel oil, labour, building costs, etc., may be expected to vary considerably from country to country and even from site to site. To arrive at an estimate of the substitution cost of bagasse in a given country, therefore, it is necessary to draw on the general conclusions established above and to insert the appropriate local costs. This has been done for the six countries specially surveyed (Argentina, Brazil, Cuba, Mexico, Peru and Venezuela) in the tables below. Table VII—7 compares bagasse costs in the six countries for three different mill sizes and for both modes of operation.

Table VII—1

ARGENTINA

State of Tucumán; grinding season, 6 months

	CASE A *Baled bagasse only* *Pulp mill capacity, tons/d*			CASE B *Fresh bagasse during grinding season* *Pulp mill capacity, tons/d*					
	20	*50*	*100*	*20*		*50*		*100*	
				a	b	a	b	a	b
Fuel replacement value [c]	5.20	5.20	5.20	5.20	5.20	5.20	5.20	5.20	5.20
Baling wire	0.29	0.29	0.29	0.15	0.29	0.15	0.29	0.15	0.29
Boiler conversion cost	0.18	0.12	0.10	0.18	0.18	0.12	0.12	0.10	0.10
Capital cost of baling station [d]	0.02	0.02	0.02	0.02	0.04	0.01	0.02	0.01	0.02
Capital cost of storage site [e]	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.02	0.03
Capital cost of equipment	0.38	0.23	0.20	0.27	0.53	0.15	0.29	0.12	0.24
Labour [f]	1.90	1.51	1.40	1.23	2.47	0.83	1.66	0.74	1.47
	7.99	7.39	7.23	7.07	8.74	6.48	7.61	6.34	7.35
Insurance and interest, stored bagasse	0.32	0.29	0.29	0.28		0.27		0.23	
TOTAL COST, DOLLARS PER TON CONSUMED	8.31	7.68	7.52	7.35		6.72		6.57	

[a] Per ton consumed.
[b] Per ton baled.
[c] Fuel oil, $31.20 per ton.
[d] Building cost, $45 per m².
[e] Labour, $0.48 per man/hr. Gravel, $1.92 per m³.
[f] Labour, $1.05 per man/hr.

Table VII—2

BRAZIL

State of São Paulo; grinding season, 6 months

	CASE A *Baled bagasse only* *Pulp mill capacity, tons/d*			CASE B *Fresh bagasse during grinding season* *Pulp mill capacity, tons/d*					
	20	*50*	*100*	*20*		*50*		*100*	
				a	b	a	b	a	b
Fuel replacement value [c]	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Baling wire	0.29	0.29	0.29	0.15	0.29	0.15	0.29	0.15	0.29
Boiler conversion cost	0.18	0.12	0.10	0.18	0.18	0.12	0.12	0.10	0.10
Capital cost of baling station [d]	0.04	0.04	0.04	0.03	0.06	0.02	0.04	0.02	0.04
Capital cost of storage site [e]	0.03	0.03	0.03	0.03	0.06	0.03	0.06	0.03	0.06
Capital cost of equipment	0.38	0.23	0.20	0.27	0.53	0.15	0.29	0.12	0.24
Labour [f]	0.82	0.65	0.60	0.53	1.05	0.36	0.71	0.31	0.63
	7.74	7.36	7.26	7.19	8.17	6.83	7.51	6.73	7.36
Insurance and interest, stored bagasse	0.31	0.29	0.29	0.26		0.24		0.23	
TOTAL COST, DOLLARS PER TON CONSUMED	8.05	7.65	7.55	7.45		7.07		6.96	

[a] Per ton consumed.
[b] Per ton baled.
[c] Fuel oil, $36.00 per ton.
[d] Building cost, $78.12 per m².
[e] Labour $0.31 per man/hr. Gravel, $6.25 per m³.
[f] Labour, $0.45 per man/hr.

Table VII—3

CUBA

Grinding season, 3 months

	CASE A *Baled bagasse only* *Pulp mill capacity, tons/d*			CASE B *Fresh bagasse during grinding season* *Pulp mill capacity, tons/d*					
	20	*50*	*100*	*20*		*50*		*100*	
				a	b	a	b	a	b
Fuel replacement value [c]	3.72	3.72	3.72	3.72	3.72	3.72	3.72	3.72	3.72
Baling wire	0.29	0.29	0.29	0.21	0.29	0.21	0.29	0.21	0.29
Boiler conversion cost	0.26	0.21	0.19	0.26	0.26	0.21	0.21	0.19	0.19
Capital cost of baling station [d]	0.06	0.05	0.05	0.05	0.06	0.04	0.06	0.04	0.05
Capital cost of storage site [e]	0.06	0.06	0.06	0.05	0.07	0.05	0.07	0.05	0.07
Capital cost of equipment	0.46	0.32	0.29	0.33	0.44	0.27	0.36	0.25	0.33
Labour [f]	1.38	1.19	1.13	1.07	1.43	0.96	1.21	0.86	1.14
	6.23	5.84	5.73	5.69	6.27	5.46	5.92	5.32	5.79
Insurance and interest, stored bagasse	0.32	0.30	0.29	0.27		0.26		0.25	
TOTAL COST, DOLLARS PER TON CONSUMED	6.55	6.14	6.02	5.96		5.72		5.57	

[a] Per ton consumed.
[b] Per ton baled.
[c] Fuel oil, $22.30 per ton.
[d] Building cost, $60.00 per m².
[e] Labour, $0.75 per man/hr. Gravel, $6.00 per m³.
[f] Labour, $0.87 per man/hr.

Table VII—4 MEXICO Zone of Veracruz; grinding season, 6 months

	CASE A *Baled bagasse only* *Pulp mill capacity, tons/d*			CASE B *Fresh bagasse during grinding season* *Pulp mill capacity, tons/d*					
	20	*50*	*100*	*20*		*50*		*100*	
				a	b	a	b	a	b
Fuel replacement value [c]	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04	1.04
Baling wire	0.29	0.29	0.29	0.15	0.29	0.15	0.29	0.15	0.29
Boiler conversion cost	0.18	0.12	0.10	0.18	0.18	0.12	0.12	0.10	0.10
Capital cost of baling station [d]	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
Capital cost of storage site [e]	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Capital cost of equipment	0.38	0.23	0.20	0.27	0.53	0.15	0.29	0.12	0.24
Labour [f]	0.40	0.32	0.29	0.26	0.52	0.17	0.35	0.15	0.31
	2.31	2.02	1.94	1.92	2.59	1.65	2.11	1.58	2.00
Insurance and interest, stored bagasse	0.09	0.08	0.08	0.08		0.07		0.06	
TOTAL COST, DOLLARS PER TON CONSUMED	2.40	2.10	2.02	2.00		1.72		1.64	

[a] Per ton consumed.
[b] Per ton baled.
[c] Fuel oil, $6.24 per ton.
[d] Building cost, $23.00 per m^2.
[e] Labour, $0.10 per man hr. Gravel $1.20 per m^3.
[f] Labour, $0.22 per man/hr.

Table VII—5 PERU Grinding season, 9 months

	CASE A *Baled bagasse only* *Pulp mill capacity, tons/d*			CASE B *Fresh bagasse during grinding season* *Pulp mill capacity, tons/d*					
	20	*50*	*100*	*20*		*50*		*100*	
				a	b	a	b	a	b
Fuel replacement value [c]	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49
Baling wire	0.29	0.29	0.29	0.07	0.29	0.07	0.29	0.07	0.29
Boiler conversion cost	0.15	0.09	0.08	0.15	0.15	0.09	0.09	0.08	0.08
Capital cost of baling station [d]	0.01	0.01	0.01	0.01	0.04	—	0.02	—	0.01
Capital cost of storage site [e]	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.02
Capital cost of equipment	0.37	0.20	0.17	0.27	0.96	0.13	0.50	0.10	0.42
Labour [f]	0.21	0.15	0.14	0.11	0.45	0.06	0.27	0.04	0.18
	2.53	2.24	2.19	2.08	3.40	1.85	2.65	1.79	2.49
Insurance and interest, stored bagasse	0.07	0.06	0.06	0.07		0.05		0.05	
TOTAL COST, DOLLARS PER TON CONSUMED	2.60	2.30	2.25	2.15		1.90		1.84	

[a] Per ton consumed.
[b] Per ton baled.
[c] Fuel oil, $8.95 per ton.
[d] Building cost, $27.50 per m^2.
[e] Labour, $0.15 per/man hr. Gravel, $2.05 per m^3.
[f] Labour, $0.10 per/man hr.

Table VII—6 VENEZUELA Grinding season, 3 months

	CASE A *Baled bagasse only* *Pulp mill capacity, tons/d*			CASE B *Fresh bagasse during grinding season* *Pulp mill capacity, tons/d*					
	20	*50*	*100*	*20*		*50*		*100*	
				a	b	a	b	a	b
Fuel replacement value [c]	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59
Baling wire	0.29	0.29	0.29	0.21	0.29	0.21	0.29	0.21	0.29
Boiler conversion cost	0.26	0.21	0.19	0.26	0.26	0.21	0.21	0.19	0.19
Capital cost of baling station [d]	0.08	0.07	0.07	0.06	0.08	0.06	0.07	0.05	0.07
Capital cost of storage site [e]	0.06	0.06	0.06	0.05	0.07	0.05	0.07	0.05	0.07
Capital cost of equipment	0.46	0.32	0.29	0.33	0.44	0.27	0.36	0.25	0.33
Labour [f]	1.07	0.92	0.87	0.83	1.11	0.70	0.93	0.66	0.88
	3.81	3.46	3.36	3.33	3.84	3.09	3.52	3.00	3.42
Insurance and interest, stored bagasse	0.20	0.18	0.17	0.17		0.15		0.15	
TOTAL COST, DOLLARS PER TON CONSUMED	4.01	3.64	3.53	3.50		3.24		3.15	

[a] Per ton consumed.
[b] Per ton baled.
[c] Fuel oil, $9.55 per ton.
[d] Building cost, $80.00 per m^2.
[e] Labour, $0.45 per man/hr. Gravel, $7.00 per m^3.
[f] Labour, $0.67 per man/hr.

Table VII—7 COST OF BAGASSE IN SIX LATIN AMERICAN COUNTRIES (*Dollars per ton of fresh bagasse*)

	CASE A *Baled bagasse only*			CASE B *Fresh bagasse during grinding season*		
	20	*50*	*100*	*20*	*50*	*100*
Argentina	8.31	7.68	7.52	7.35	6.72	6.57
Brazil	8.05	7.65	7.55	7.45	7.07	6.96
Cuba	6.55	6.14	6.02	5.96	5.72	5.57
Mexico	2.40	2.10	2.02	2.00	1.72	1.64
Peru	2.60	2.30	2.25	2.15	1.90	1.84
Venezuela	4.01	3.64	3.53	3.50	3.24	3.15

Appendix VIII

Table VIII—1

Latin America: Existing bagasse pulp and paper mills

Country	Name of company	Location	Type of mill	Raw material: Procurement	Raw material: Pith separation	Fuel used	Chemicals	Process	Bleaching	Capacity	End Product
Argentina	Celulosa Argentina	1. Capitán Bermúdez, near Rosario[a]	Integrated	From independent sugar mills in Tucumán area.	Yes (dry method)	Oil	Own electrolytic plant	Caustic soda-chlorine (Celdecor)	Yes	75 tons/day	In admixture with sulphate (bleached) pulp made in same mill for light bonds, magazine & heavy book papers
		2. Tucumán	Integrated	Ditto	None	Oil		Modified soda process	None	6,000 tons/year	In admixture with waste paper and unbl. Kraft for wrapping and bagging paper
Brazil	Refinadora Paulista	Monte Alegre, near Piracicaba, State of São Paulo	Integrated	From company's own sugar mill in close proximity	Yes (dry method)	Oil and some wood (eucalyptus)	Own electrolytic plant	Caustic soda chlorine (Celdecor)	Yes	Expected soon to reach about 50 tons/day	In admixture with small quantity bl. sulphite for light bonds to heavy book paper[b]
Colombia	Cartón Colombia	Near Cali	(Details not known. The mill produces a small quantity of bagasse pulp for admixture with imported pulp in the manufacture of board).								
Mexico	Compañía industrial San Cristóbal	Ecatepec, near Mexico City	Integrated	From independent sugar mills in Zacatepec region [c]	Yes (wet method in specially designed equipment)	Oil	Caustic soda obtained by causticizing sodium carbonate brines from nearby lake waters	Mechano-chemical	None	27/30 tons/day	Wet unbleached pulp for mills in Mexico City, also bagging and wrapping papers in admixture with Mex. unbl. Krafts.
	Fábrica de Celulosa El Pilar	Ayotla,[e] very close to Mexico City	Non-integrated	From independent sugar mills [d]	Yes (dry method)	Oil	Own electrolytic plant	Caustic soda-chlorrine (Celdecor)	Yes	25 tons/day	Mill sells its output to an existing mill to produce bond type papers
Peru	W. R. Grace	Paramonga	Integrated	From company's own sugar mill in close proximity [f]			Own electrolytic plant	Modified sulphate process	None	12,000 to 15,000 tons per year	In admixture with imported pulp and waste paper for wrapping, bagging and corrugating papers
	Celulósica Papelera del Norte, S. A.	Cayaltí, near Chiclayo	Integrated	Direct from adjacent sugar mill [g]	None			([h])		3,000 tons per year	Coloured wrapping papers

[a] This mill normally operates with wheat straw and wood but uses bagasse on occasion.

[b] Also sells moist pulp to other paper makers of São Paulo.

[c] The company has paid for boiler conversion to fuel oil firing for those mills furnishing it with supplies of bagasse. It also pays for the fuel oil consumed, maintains baling stations at the sugar mills and pays for transportation of the bagasse to pulp mill site.

[d] Equipment is being installed to make a pith-molasses feed.

[e] In course of erection and nearly completed.

[f] The bagasse is used both in fresh condition from the sugar mill and/or in air dry condition, after baling and storage.

[g] The mill is designed to operate on fresh run-of-the-mill bagasse without depithing or storing it.

[h] The process used is one developed and patented by Sr. Pedro Mestres.

Table VIII—2

ARGENTINA: SUGAR MILLS OPERATING IN THE PROVINCE OF TUCUMÁN

(1953)

	Mill	Cane ground (tons)	Bagasse produced[a] (Thousand tons)
1	Aquilares	196,659	61.4
2	Amalia	214,377	61.1
3	Bella Vista	458,359	135.7
4	Concepción	780,075	227.6
5	Cruz Alta	205,263	57.9
6	La Corona	240,232	76.3
7	La Fronterita	224,557	57.1
8	La Providencia	214,136	64.3
9	La Florida	358,200	109.4
10	Lastenia	173,446	54.8
11	La Trinidad	375,210	108.9
12	Ñueva Baviera	207,350	65.7
13	Leales	204,002	61.7
14	Los Ralos	277,139	87.5
15	Marapa	231,454	68.6
16	Mercedes	222,272	70.3
17	Nuñeros	222,968	56.8
18	San Antonio	216,319	60.0
19	San José	154,486	48.6
20	San Juan	272,100	79.8
21	San Pablo	451,140	115.0
22	San Ramón	165,317	52.1
23	Santa Ana	333,575	95.9
24	Santa Barbara	158,291	49.0
25	Santa Lucía	310,190	85.8
26	Santa Rosa	181,322	57.6
27	Esperanza	165,086	49.6
	TOTAL	7,213,523	2,118.5

[a] Fifty per cent moisture content.

TABLE *VIII—3*

BRAZIL: SUGAR MILLS OPERATING IN THE STATE OF SÃO PAULO

(1953-1954)

	Mill	Cane ground (tons)	Bagasse produced[a] (tons)
1	Azucareira da Serra	41,800	10,800
2	Albertina	28,300	7,300
3	Amalia	214,100	55,200
4	Anhumas	34,600	8,900
5	Azanha	39,600	10,200
6	Barbacena	159,900	41,200
7	Barra Grande	61,600	15,900
8	Barreirinho	55,000	14,200
9	Belavista	62,600	16,100
10	Bão Vista	85,700	22,100
11	Bomfim	52,400	13,500
12	Bom Jesus	57,200	14,700
13	Bom Retiro	57,300	14,800
14	Campestre	31,900	8,200
15	Catandura	25,800	6,600
16	Chibarro	8,800	2,300
17	Costa Pinto	213,400	55,000
18	Da Barra Rhodia	—	—
19	Da Barra, S.A.	261,800	67,400
20	Da Pedra	169,800	43,700
21	Das Palmeiras	92,800	23,900
22	De Cilio	164,700	42,400
23	Diamante	68,000	17,500
24	Ester	285,700	73,600

Table VIII—3 (continued)

	Mill	Cane ground (tons)	Bagasse produced[a] (tons)
25	Furlan	29,100	7,500
26	Indiana	19,100	4,900
27	Iracema	342,000	88,100
28	Itaiquara	117,300	30,200
29	Itaquere	92,300	23,800
30	Jão	—	—
31	Junqueira	398,300	102,600
32	Lambari	24,000	6,200
33	Maluf	5,100	1,300
34	Maracai	16,800	4,300
35	Maria Isabel	25,500	6,600
36	Marrinópolis	29,300	7,500
37	Miranda	82,000	21,100
38	Modelo	99,500	25,600
39	Monte Alegre	249,600	64,300
40	N.S. Aparecida—B.C.	81,700	21,000
41	N.S. Aparecida—V.O.	123,600	31,800
42	Nova América	27,000	7,000
43	Paredão	80,700	20,800
44	Perdigão	38,600	9,900
45	Piracicaba	268,200	69,100
46	Porto Feliz	256,400	66,000
47	Rafard	232,800	60,000
48	Santa Adelaide	92,200	23,800
49	Santa Adelia	49,400	12,700
50	Santana—FSG & IR	12,800	3,300
51	Santana—LV & CIA	30,200	7,800
52	Santa Bárbara	225,900	58,200
53	Santa Carlota	—	—
54	Santa Clara	38,100	9,800
55	Santa Cruz	90,600	23,300
56	Santa Cruz, S.A.	56,600	14,600
57	Santa Elisa	120,300	31,000
58	Santa Elena	128,200	33,000
59	Santa Lidia	68,500	17,600
60	Santa Lina	30,400	7,800
61	Santa Lucía—Is	28,900	7,400
62	Santa Lucía—S.A.	86,000	22,200
63	Santa Teresinha	34,900	9,000
64	Santo Alexandre	7,200	1,900
65	Santo Antonio—AB	66,800	17,200
66	Santo Antonio, S.A.	29,100	7,500
67	São Bento	27,200	7,000
68	São Carlos	36,400	9,400
69	São Franco Ltd.	36,500	9,400
70	São Franco LBO	140,000	36,100
71	São Francisco S.A.	52,100	13,400
72	São Geraldo	82,700	21,300
73	São Gerónimo	30,200	7,800
74	São Joaq.	249,200	64,200
75	São Jorge	46,800	12,100
76	São José—IJJA	7,700	2,000
77	São José—LD	28,900	7,400
78	São José—S.N.T.	—	—
79	São José—Z.L.	72,500	18,700
80	São José DA CATCH	—	—
81	São Luiz—B.R.	30,800	7,900
82	São Luiz—S.A.	25,500	6,600
83	São Manoel	49,100	12,600
84	São Maitinho	201,200	51,800
85	São Vicente	123,400	31,800
86	Schimidt	47,600	12,300
87	Tabajara	60,200	15,500
88	Tamadupá	53,600	13,800
89	Tamoio	427,500	110,100
90	Varjao	43,900	11,300
91	Vassununga	164,000	42,200
92	Zanin	41,900	10,800
93	Guraníture	3,500	900
94	Maringá	—	—
95	Pouco Alegre	14,700	3,800
96	Santa Maria	29,300	7,500
97	Santa Rosa	18,000	4,600
98	São Domingo	1,900	500
99	Storani	—	—
	TOTAL	8,254,500	2,126,400

[a] Fifty per cent moisture content.

Table VIII-3 (concluded)

COMPARISON WITH PREVIOUS SEASON

	Cane ground (tons)	Bagasse produced (tons)
1949–50	4,196,000	1,080,900
1950–51	4,750,400	1,223,700
1951–52	5,721,200	1,473,800
1952–53	6,651,700	1,713,500

Table VIII—4

CUBA: DATA RELATING TO SEVEN SUGAR MILLS OPERATING IN PROVINCE OF CAMAGUEY (*1953*)

Mill	Cane ground (Thousand tons)	Bagasse produced[a] (Thousand tons)
1 Adelaida	332.7	83.0
2 Cunagua	546.1	136.5
3 Jarouú	881.1	220.5
4 Lugareño	425.2	106.3
5 Morón	990.6	247.7
6 Senado	394.0	98.5
7 Violeta	588.2	147.1
TOTAL	4,157.9	1,039.6

[a] 50 per cent moisture content.

Table VIII—5

ASSESSMENT OF BAGASSE SURPLUS DEFICIT SITUATION

Country	Relating to steam requirements: Ratio refined sugar produced/total sugar produced	Relating to steam requirements: Ratio litres alcohol produced/tons total sugar produced	Relating to steam generation	Remarks
Argentina[a] (Province of Tucumán)	0.45	130	(i) Practically all (99.5 per cent) of bagasse produced is burned as fuel, *plus*. (ii) 0.38 tons of wood/ton of sugar produced is burned as *additional fuel*. (iii) 0.031 tons of fuel oil/ton of sugar produced is burned as *further additional fuel*.	(i) Somewhat high average steam requirements, and no surplus of bagasse but rather a deficit. (ii) Need for additional fuels accounted for by the large proportion of sugar refined and of alcohol manufactured per ton of total sugar produced.
Brazil[b] (State of São Paulo)	0.13	173	(i) All the bagasse produced is burned as fuel. (ii) The practice of burning wood is fairly prevalent. (iii) Some mills find it necessary to purchase electric power from an outside source.	Indications point to an overall deficit of bagasse for steam raising though a lower one than that in the case of Tucumán (above).
Cuba[c]	0.10	0.97	(i) Except in the case of "mills with refinery", no additional fuels of any kind are generally required at "plain sugar mills" (save extremely small amounts of fuel oil at some mills for starting up). (ii) Some "plain sugar mills" could with their present equipment easily show small bagasse surplus, solely by taking greater care in steam usage and providing economic justification were found.	(i) Indications of a small overall bagasse surplus. (ii) Since economic justification to "save" bagasse is generally not found, mills with potential surplus find it preferable to dispose of excess bagasse in their boiler plants, which consequently are operated to act in the double capacity of bagasse-burning boilers and surplus bagasse incinerators.
Mexico	(No details were obtained regarding distribution of total sugar production—into raw and refined grades— or of alcohol manufacture. Additional fuel consumption over and above bagasse for some mills was said to be of the order of 8 to 18 kg per ton of cane ground, which is approximately equivalent to 0.08 to 0.18 tons fuel oil/ton sugar produced.)			
Peru[d]	0.23	28[e]	(No general impressions or data were obtained regarding the question of bagasse surplus, deficit, or additional fuel requirements in sugar mill operations.)	
Venezuela	(No detailed information obtained as to distribution to total sugar production (into raw and refined grades) or of alcohol manufacture. Specific data regarding a single mill that refines all the raw sugar it produces showed an additional fuel consumption of about 0.18 tons fuel oil per ton total sugar.)			

[a] From analysis of data available for all 27 individual mills which operated in the province of Tucumán during 1953.
[b] From production statistics covering a total of 99 sugar mills which were in operation in the State of São Paulo during 1953.
[c] Based on data relating to 161 mills in operation in 1952.
[d] From statistics for sugar production in 1952.
[e] 1953 ratio: $\frac{\text{litres alcohol produced}}{\text{total sugar produced}}$ (at sugar mills and elsewhere).

Table VIII—6

AVAILABILITY OF CHEMICALS, FUEL OIL, POWER AND WATER

Item	*Argentina*	*Brasil*	*Cuba*	*Mexico*	*Peru*	*Venezuela*
Alum	Available from Buenos Aires	Imported	Imported	Local supply	Imported	Imported
Caustic soda		Local supply limited. Importation necessary	Imported	Local supply limited. Importation necessary		Imported
Chlorine		Local supply limited. Importation necessary	Imported		Local excess supply. Exports to neighbouring countries	
Limestone Quicklime	Good quality from Cordoba San Juan	Abundant from Minas Gerais	Local supply	Local supply	Local supply	Abundant local supply
Salt	Good quality from salt beds in Cordoba Province	At present good quality obtainable only from distant N. E. part of country	Local supply	Good quality local supply	Local supply	Local supply
Sodium carbonate	Imported	Local supply limited. Importation necessary.	Imported	Imported	Imported	Imported
Sodium sulphate	Good quality from natural deposits in San Juan Province	Local supply limited. Importation necessary	Local supply	Imported	Imported	Imported
Sulphur		Imported	Imported	Local supply	Local supply	Imported; very small local production
Power	None available for the moment. 24,000 kw plant projected	Electrification programme under way but unlikely power available within next 5 yrs.	None available	Generally none available	Generally none available	Generally none available
Water	Good supply (rivers)	Good supply (rivers)	Problematic (probably from wells at all locations)	Probably from rivers (under ground supplies also said to be plentiful)	Great shortage. Supply problem likely to be acute	Adequate supplies at most locations (lake or river)
Fuel oil	From province of Salta (high price)	Imported (high price)	Imported (high price)	Local supply (cheap)	Local and imported (cheap)	Local supply (cheap)

Table VIII—7

COST OF CHEMICALS

(*Cost per ton*)

	Argentina[a]		Brazil[b]		Cuba 1 peso = $1		Mexico 12.5 pesos = $1		Peru 20 soles = $1		Venezuela 3.35 bolivares = $1	
	Pesos	*Dollars*	*Cruzeiros*	*Dollars*	*Pesos*	*Dollars*	*Pesos*	*Dollars*	*Soles*	*Dollars*	*Bolivares*	*Dollars*
Salt cake	400 Local, from natural deposits in San Juan	32.00	1,800 (parity) Some locally produced, small amt. imported	56.25	47 Local	47.00	690	55.20	1,660 Imported	83.00	273 Imported	81.49
Salt	185 Local	14.80	1,000 (parity) Local, from Northeast	31.25	27.50 Local	27.50	200 Local	16.00	100 Local	5.00	70 Local	20.90
Caustic soda	1,235 Local, from Celulosa Argentina, at Rosario; also imported	98.80	5,000 (parity) Conversion at parity	156.25	100 Imported; some local	100.00	1,000 Both local and imported	80.00	1,750	87.50	300 Imported	89.55
Soda ash	745 Imported	59.60	5,000 (III) Imported, some local	93.46	75 Imported	75.00	790 Local and imported	63.20	1,620 Imported	81.00	250 Imported	74.63
Limestone	65 Local	5.20	200 (parity) Local	6.25	5 Local	5.00	—	—	—	—	—	—
Quicklime	420 Local	33.60	700 (parity) Local, from Minas	21.87	30 Local	30.00	70 Local. Slaked lime at 110 pesos, also local	5.60	500	25.00	42 Local	12.54
Sulphur	1,020 Local, from Salta	81.60	3,300 (III) Imported	61.68	39 Imported	39.00	763 Local	53.00	1,700	85.00	230 Local	68.65
Alum	1,135 Local, from Buenos Aires	90.80	6,000 (III) Imported	112.15	105 Imported	105.00	650 Local	52.00	1,020	51.00	—	—
Chlorine	735 Local, from Celulosa Argentina, at Rosario	58.80	9,000 (parity) Imported; some local; Conversion at parity	281.25	355 Local	355.00	6,000 Local and imported	480.00	4,640 Local (W.R. Grace)	232.00	1,050 Imported	313.43

[a] Conversion of Argentine pesos to U. S. dollars calculated at the parity rate of 12.50 pesos per U. S. dollar. The par rate of exchange is that which appears in the *Economic Survey of Latin America, 1952*, in the note on methodology on page 33, applicable for 1950. For 1953, the par rate of exchange was multiplied by the quotient of the cost of living indices for Argentina and the United States for that year. The quotient of 12.35 thus obtained was rounded out to 12.50 to facilitate the calculations.

[b] Conversions of Brazilian cruzeiros to U. S. dollars were made at the following rates: *for imported products:* Category I (fuel oil) 24.00 cr/dollar; Category II (wood pulp for paper-making) 32.7 cr/dollar; Category III (soda ash, alum, sulphur, machinery) 53.5 cr/dollar; Category IV (salt cake) 81.6; Category V (caustic soda, chlorine) 119.8 cr/dollar. *Products manufactured locally* were converted at the parity rate of 32.00 cr/dollar. For caustic soda and chlori e conversions were made at parity rate.

Table VIII—8

Cost of fuel oil, power, labour and construction and interest on capital

	Argentina See note a, table VIII—7		*Brasil* See note b, table VIII—7		*Cuba* 1 peso = $1		*Mexico* 12.5 pesos = $1		*Peru* 20 soles = $1		*Venezuela* 3.35 bolivares = $1	
	Pesos	*Dollars*	*Cruzeiros*	*Dollars*	*Pesos*	*Dollars*	*Pesos*	*Dollars*	*Soles*	*Dollars*	*Bolivares*	*Dollars*
Fuel oil (ton)	390	31.20	860	36.00	22.30	22.30	78	6.24	179	8.95	32	9.55
	Local, controlled by Government		Imported		Imported		Local		Local, also imported		Local	
Electric power (1,000 kwh)	425	34.00	300	9.38	28	28.00	150	12.00	120	6.00	No data	
	Not enough immediately available for industrial uses. Power plant of 24,000 kw in project		None available for industrial projects. Shortage to be prolonged		None available for industrial projects. Shortage to be prolonged		No data on availability. Rates vary greatly. Figure shown is an estimated average		None available for industrial projects. Figure shown is cost of power produced at Paramonga.		None available for industrial projects	
Other fuels	102	8.16	—	—	—	—	—	—	—	—	Natural gas. Cost 1,000 m³ at 9.00 kcal at Valencia = 50 Bs.	
	Wood, price delivered at mill site, per ton.		Eucalyptus wood for fuel available. No price data available.									
Labour costs (for pulp and paper mill personnel: figures include "social benefits" of all kinds);												
per man-hour:												
(a) unskilled labour	12.35	0.99	11.15	0.35	0.75	0.75	2.50		1.93		2.25	
(b) helpers	12.83	1.03	—		—	—	2.80					
(c) operators	14.00	1.12	17.75	0.55	0.98	0.98	3.15					
	basic rate = 57%		basic rate = 93%		basic rate = 76%		Figures quoted include benefits. No data on percentage of benefits in total wages		basic rate = 65%		Figures include benefits. No data on percentage of benefits in total wages	
	benefits = 43%		benefits = 7%		benefits = 24%				benefits = 35%			
	Total 100%		Total 100%		Total 100%				Total 100%			
									Lodging provided free of cost by sugar mill			
per month:												
(a) foremen	3,325	266.00	—		240	240	1,500		4,000		No data	
(b) assistants to department heads	7,450	596.00	7,000	220	485	485	2,700					
	basic rate = 57%		basic rate = 93%		basic rate = 89%		Figures quoted include benefits. No data on percentage of benefits in total salaries		Figures quoted include benefits			
	benefits = 43%		benefits = 7%		benefits = 11%							
	100%		100%		100%							

Table VIII—8 (continued)

	Argentina See note a, table VIII—7		Brazil See note b, table VIII—7		Cuba 1 peso = $1		Mexico 12.5 pesos = $1		Peru 20 soles = $1		Venezuela 3.35 bolivares = $1	
	Pesos	*Dollars*	*Cruzeiros*	*Dollars*	*Pesos*	*Dollars*	*Pesos*	*Dollars*	*Soles*	*Dollars*	*Bolivares*	*Dollars*
Building materials:												
(a) cement (ton)	500	40.00	1,700	53.10	32	32.00	160	12.80	343	17.15	—	—
(b) crushed stone (cu. m)	24	1.92	200	6.25	6	6.00	15	1.20	41	2.05	—	—
(c) sand (cu. m)	—	—	80	2.50	—	—	15	1.20	25	1.25	—	—
(d) reinforcing bars (ton)	2,850	228.00	13,000 Local	409.00	132	132.00	1,490	119.20	2,350	117.50	—	—
(e) structural steel (ton)	3,240	259.00	11,000 (III)	205.61	220	220.00	1,800	144.00	3,800	190.00	—	—
(f) bricks (sizes as individually shown) (thousands)	300	24.00	1,000	31.25	25	25.00	130	10.40	220	11.00	—	—
	(no inform. on size)		(30 x 20 x 10 cm)		(27 x 13 x 7 cm)		(27 x 13 x 6 cm)		(24 x 12 x 7.5 cm)		—	—
(g) lumber (thousand lumber feet)	2,500	200.00	3,570	111.56	170	170.00	850	68.00	2,400	120.00	—	—
(h) estimated overall industrial construction (sq. metre)	—	—	2,500	78.12	60	60.00	295	23.00	550	27.50	—	—
Wages, construction, per hour (benefits incl.)												
(a) common labour	6	0.48	10	0.31	0.38	0.38	1.28	0.10	3.06	0.15	—	—
(b) bricklayer	6.78	0.54			0.69	0.69	2.06	0.16	3.64	0.18	—	—
(c) full bricklayer (mason)	7.66	0.61	18	0.56	1.00	1.00	2.29	0.18	5.11	0.26	—	—
(d) carpenter	7.66	0.61					3.05	0.24	5.11	0.26	—	—
Transport	*Tucumán-Buenos Aires* rail: 20 pesos/ton max. truck: 45 pesos/ton max.		Up to 200 kms outside São Paulo (average) rail: 200 Cr/ton.		No data		No data		No data			
Interest on capital (long term loans)	9–10%		10–½%		7% (*Banco de Fomento Agrícola e Industrial de Cuba*)		9–10%		10%		5–6%	

Notes: Argentina: In Argentina, the working hours are 6 per day for the pulp and paper industry. *Brazil:* Figures shown take into consideration latest minimum wage legislation, as applying to São Paulo. Wages are converted at the rate of 32 cruzeiros to the dollar. *Cuba:* Figures shown are for prevailing rates in existing paper mills. Wages and salaries in the sugar industry are higher. *Mexico:* These figures are likely to be increased soon as result of recent devaluation.

BAGASSE PULPING WITH PARTICULAR REFERENCE TO THE MECHANO-CHEMICAL PROCESS[1]

ELBERT C. LATHROP AND SAMUEL I. ARONOVSKY[2]

INTRODUCTION

Sugar-cane bagasse as a raw material has attracted the paper industry for a long time because it is annually available in large quantities as a by-product. No industrial success and, indeed, numerous industrial failures resulted from this work until thirty-three years ago, at which time the manufacture of insulating building materials from bagasse was started and proved successful. However, successful manufacture of paper from bagasse did not take place for about another eighteen years. Today, at least ten plants are producing paper and board products from bagasse. While these products are industrially acceptable in the countries in which they are being manufactured (1),[3] it is doubtful whether they would satisfy industrial standards in the United States.

Economic and technological factors have been responsible both for the failures of the past and for the differences in the quality of the products now being made. At present there are very great differences in economic conditions between countries and between the competitive situations within countries. As competition becomes more intense, quality of product plays an increasingly important role.

Much has appeared of late in the daily and technical press about new processes for pulping bagasse, new mills to be built, and particularly about making newsprint from bagasse alone. Most of the reports have, of course, some basis in fact, but the bias with which some were written and the unqualified character of many of the statements have proved very confusing. Of the extreme views held, on the one hand that bagasse is ideally suited to make almost any kind of paper, and on the other that its utility is very limited, neither is correct.

This paper presents factual information concerning the kinds of pulps and papers, from the poorest to the best, which according to present knowledge may be made from bagasse. The various pulping methods that may be used, based on industrial experience, will be described briefly. Chemical requirements, yields, and the general qualities of pulps produced by the several methods will be discussed. It is hoped that this information will prove useful in arriving at decisions that will lead to commercial successes in using bagasse in the paper and board industries.

In recent years renewed interest in the use of annual plants for paper making has resulted in extensive research by pulp and paper laboratories of a number of governments. The published researches of these institutions have cleared away many earlier misconceptions and form the basis of a rational technology. In general, pulps made from annual plants do not have the same properties as those made from pulpwoods and cannot be expected to behave exactly alike on the paper machine or to make identical papers. In some cases these pulps will make papers or boards superior to those made from wood pulps, in other cases their best use is in blends with wood pulps. Often in the latter use, papers superior to those made wholly from wood pulps may be produced.

PHYSICAL AND CHEMICAL CHARACTERISTICS OF BAGASSE

The characteristics of the fibrous elements of the cane stalk as it enters the sugar mill are described as follows: The outside of the stalk (rind) comprises a relatively tough ring. The inside consists of soft medullary tissue in the cells where the sugar is deposited. Lengthwise through this tissue run numerous fibrovascular bundles of various sizes so placed that the smallest are packed near the outside and the larger ones, less abundant, are distributed towards the centre. The rind is formed of thick-walled, elongated cells of hard or sclerenchymatous fibres. The fibrovascular bundles comprise groups of fibres and ducts. The pith, or parenchymatous cells, are short, broad, and of low resistance to penetration. These cells group around and adhere both to the fibrovascular bundles and the rind fibres. The outside of the rind often appears glassy, carries a coating of wax, and may be of a number of colours. At intervals in the length of the stalk, which vary in accordance with conditions of growth of the cane, the fibrovascular bundles send branches outwards, thereby forming a portion of dense tissue called the node. Neither the pith nor perhaps the tissue concentrated in the node is suitable for paper making (2). Fibres from cane leaves are also of little or no value in paper or board manufacture since they are so short that most are destroyed or lost during pulping and washing operations. Generally leaves and trash are removed from the cane in the field, but when mechanical harvesting of the cane is practised the bagasse will contain more trash and leaves.

It will be noted that cane is composed of three rather different elements: e.g., pith, fibrovascular bundles, and bundles of rind fibres. Browne (3) made a careful analysis of the percentage of these elements in several varieties of cane, with the following results:

Constituent	*Louisiana and Purple* %	*Java* Cheribou %	No. 36 %	No. 100 %	No. 139 %	No. 247 %
Pith	24.6	25.6	20.0	22.8	20.0	20.0
Bundles	18.6	31.5	26.5	25.4	36.0	26.1
Rind	56.7	42.9	53.5	51.8	44.0	53.9

The proportion of these elements will vary depending on a number of factors, chiefly the variety of cane. In three varieties of cane grown in Florida, for example, fibre to pith ratios as different as 1.9, 2.3 and 3.6 were recorded. Bagasse also contains a variable amount of soil and dirt, depending on the soil character and on the method of harvesting. If the leaves are burned in the field, the cane will carry many carbon particles. The proximate physical composition of five different samples of commercial bagasse from widely separate locations shows percentage of solubles, dirt, etc. ranging from 6.6 to 19.2.

[1] A very slightly shortened version of the original paper, (ST/ECLA/CONF.3/L.5.1.) which includes several additional tables setting out pulping data and results of paper tests.

[2] U.S. Department of Agriculture, Peoria, Illinois.

[3] Numbers in parentheses refer to bibliography at the end of this paper.

The moisture content of the bagasse from the cane mill may vary from 41 to 51 per cent, and often runs about 48 per cent. Sucrose remaining in the bagasse varies, depending on the conditions, from 2 to 5 per cent. Keller (4) states that the colour of bagasse will vary from a greyish-white to a very dark green. The material is non-homogeneous in size, varying from a dust that will pass a 60-mesh screen to particles around 6 inches long by 3/8 inch in cross section. Usually about 97 per cent will pass a 1-inch-square opening. The analysis on an "as produced" basis is about the following: moisture, 49 per cent; fibre and dirt, 45 per cent; soluble solids, 6 per cent.

The proximate chemical composition of samples of bagasse representative of different varieties and from different countries is given in table 1.[1] The sample of Louisiana bagasse is representative of commercially stored bagasse; the remainder of the samples were dried immediately from the sugar mill.

The fibre dimensions of sugar cane, some cereal straws, and certain pulpwoods are compared below:

	Length in μ			*Diameter in μ*			*Ratio average length to diameter*
	Average	*Maximum*	*Minimum*	*Average*	*Maximum*	*Minimum*	
Sugar cane							
Fibres	1,700	2,800	800	20.0	34.1	10.2	85:1
Parenchyma	—	840	—	—	140.0	—	—
Vessel segments	—	1,350	—	—	150.0	—	—
Wheat, rye, oat straws							
Fibres	1,480	3,120	680	13.3	23.8	6.8	111:1
Fibres with thin walls	—	2,900	800	—	34.0	—	—
Parenchyma	—	450	—	—	130.0	—	—
Vessel segments	—	1,000	—	—	60.0	—	—
Rice straw							
Fibres	1,450	3,480	650	8.5	13.5	5.1	170:1
Parenchyma	—	350	—	—	82.0	—	—
Vessel segments	—	650	—	—	40.0	—	—
White spruce	—	4,200	2,300	—	—	—	—
Jack pine	3,000	—	—	40.0	—	—	75:1
Aspen	—	1,700	800	—	46.0	20.0	37:1
Birch	—	1,600	800	—	44.0	20.0	36:1
Red gum	1,600	—	—	32.0	—	—	50:1

Paper-making possibilities of bagasse as indicated by physical and chemical properties

Thus the composition of bagasse is variable, depending on variety, soil, method of harvesting, milling, and other factors. All bagasse contains dirt and if the leaves are burned in the field, it is likely to contain carbon particles. In any case, dirt and carbon are undesirable in paper making. While a certain amount of these impurities can be tolerated in board manufacture, their presence in pulps used for high-grade papers, or those intended for bleaching, will result in extra expense for chemicals, lower yields, and pulps of poorer physical properties.

Bagasse is composed of three elements, to which must be added short leaf fibres if much leaf enters the mill with the cane. Two of these elements are fibrous, namely, the fibrovascular bundles and the rind fibres. The third element is parenchymatous tissue, or pith, a material not fibrous but composed of soft, rather unorganized tissue. The surface area of pith is vastly greater than that of an equal weight of the fibrous elements. The ratio of the three elements to each other will depend on several factors, chiefly variety of cane.

The chemical composition of different samples of bagasse varies somewhat, but this variation is less than that found in physical composition; i.e., rind, fibrovascular bundles, and pith. Canes that are more mature when harvested will have higher lignin content. Evidence accumulated in studying the chemical composition of annual plants shows that the relationships between the lignin, cellulose, and pentosan contents of straws, stalks, and cobs may be altered by plant breeding. A comparison of the chemical composition of the respective samples of pith and fibre obtained from whole bagasse samples shows that the pith contains more ash, pentosans, and 1 per cent NaOH solubles, and less cellulose than the fibre. The greater the ash content is due to the greater surface area of the pith which absorbs more dirt.

The percentage of hot-water-soluble material is greater in the whole bagasse samples than in either the fibre or pith separated from them. This is due to the fact that separation of pith and fibre was carried out by a wet process. It will be noted that the hot-water-soluble material is lower in the stored bagasse than in the other samples. During the storage period the sugars present in the fresh bagasse are destroyed by fermentation processes.

Compared with the chemical composition of the pulpwoods, fibre separated from bagasse is lower in lignin content in most cases than either the softwoods or hardwoods and contains more pentosans and more material soluble in 1 per cent NaOH. Bagasse fibre compares rather favourably in cellulose content with the pulpwoods. In chemical composition, bagasse more closely approximates to the hardwoods than the softwoods and, therefore, its paper-making properties more closely resemble those of the hardwoods.

Comparisons with wood pulps

Bagasse is easier to pulp than the hardwoods and requires less chemicals for pulping. This is due to the greater ease of penetration of chemicals into the fibrous

[1] Tables 1-11 appear before the bibliography at the end of this paper.

elements of the bagasse as compared with the dense chips of the pulpwood and also to the lower lignin content of the bagasse.

Normally, pulps made from hardwoods or from stalks and straws contain more pentosans than softwood pulps. In general, pulps which contain higher concentrations of pentosans, up to a certain maximum, have been found to beat faster and to develop greater strength than corresponding pulps containing less pentosans. On the other hand, pulps containing high percentages of pentosans tend to make denser and harder surfaced papers with lower opacity than those produced from softwood pulps. In the manufacture of glassine papers and corrugating medium, high-pentosan-containing pulps are a necessity. The use of high-pentosan pulps as blends with other pulps, particularly ground-wood or weaker pulps, produces improved paper products. Using pre-hydrolysis treatments it is possible to prepare pulps from bagasse, straws, and hardwoods that are lower in pentosan content and which, therefore, produce less dense, more opaque, and softer papers. These treatments lower pulp yields and increase costs.

A direct relationship exists between the dimensions of fibres and their paper-making properties. Tear resistence is associated with fibre length; short-fibred pulps are deficient in this property. Since strength in papers is attributed to the bonding of individual fibres, it follows that fibres with a high ratio of length-to-diameter will, other things being equal, contribute greater strength than broader fibres of the same length. "Formation" in papers is associated with fibre length and with degree of fibrillation of the pulps used. Softwood pulps, having long fibres and often fibrillated by the considerable refining required, produce less well-formed papers than shorter-fibred pulps from bagasse or hardwoods. In turn, the blending of bagasse or hardwood pulps with longer-fibred pulps will produce papers of improved formation and better suited for printing.

Bagasse and the cereal straws are composed of a number of fibrous elements which differ considerably in dimensions. The rind fibres of the cane are longer than those of the vessel segments(fibrovascular bundles) and have narrower fibre diameters. The rind fibres will therefore produce stronger papers, particularly in respect to tear resistance. While the rind fibres are shorter than those of the softwoods, they are longer than those of the hardwoods and will produce more tear-resistant papers than the latter. Cane fibres have a length-to-diameter ratio practically the same as that for softwoods and considerably more favourable than that for hardwoods.

Pith a major problem

The pith particles of the cane or of straws are very short and broad. These particles can therefore contribute little to paper making unless they can be separated and especially treated to carry out special functions, such as fillers. During pulping operations the chemicals act much more rapidly on pith than on rind or fibrovascular bundles, due first to the much larger surface of the pith and secondly to the greater ease of penetration of the chemical into it. In turn, the chemicals act more rapidly on the fibrovascular bundles than on the rind fibres, due to their greater surface area and to the fact that they contain ducts which make the penetration of the chemicals into them more rapid.

Pith therefore uses up chemical more rapidly than the fibrous elements and is more quickly softened. Pulps are handled entirely in water suspensions; they must be pumped, dewatered over wire surfaces, and defibred or refined by attrition. All of these treatments contribute to loss of the unorganized pithy material from the pulps. On the other hand, because of their greater surface areas, the pith particles absorb more dirt, which only can be removed by destruction of the pith cells. They, therefore, make the bleaching of pulps much more difficult, requiring larger amounts of bleaching agent and resulting in weaker pulps and lower yields. Finally, the drainage rate of pulps has a direct bearing on paper-machine operation. Pulps containing pith will drain much more slowly than pulps made from bagasse fibres from which pith has been separated. Since pre-hydrolysis processes are also chemical, pith will react in these processes more rapidly and to a greater extent than fibre.

Processes for pulping bagasse

The most authoritative discussion of this subject will be found in FAO Forestry and Forest Products Study No. 6 (5). That report is the result of a thorough discussion of the subject and unanimous approval of recommendations by pulp and paper specialists called together in Rome, December 3-14, 1952, by FAO. That section of the report dealing with bagasse and drawn up by the group assigned to consider non-woody fibres discusses in detail the processes recommended for commercial operation, giving chemical requirements and other pulping directions, yields, and steam, power, water labour, and bleach demands. The utility of the pulps made from bagasse by the different processes is discussed and recommendations are made for the use of these pulps alone or in blends with long-fibred pulps to produce papers commercially acceptable in world markets. That report should be studied with care by any group or company contemplating the building of new facilities for making paper or board from bagasse. In addition, attention is directed to three recent papers by Grant (6) who discusses processes for pulping bagasse and other non-woody plants.

The Peoria laboratory for a number of years has directed intensive studies to the utilization of bagasse fibre and pith. Pilot-plant facilities are available there to study all the commercial methods used for pulping bagasse, with the exception of the Celdecor process. Acid processes are not satisfactory for preparing good pulps from bagasse. Nitric acid is an exception, but since this discussion is limited to commercial processes or those that have undergone large-scale trial, no further reference will be made to the nitric acid process.

Commercial pulps are prepared from bagasse by use of the following chemicals:

(*a*) In pressure vessels:
  1. Lime alone or in combination with soda ash, caustic soda, sodium sulphite;
  2. Caustic soda;
  3. Kraft process chemicals—caustic soda and sodium sulphide or caustic soda and sulphur;
  4. Sodium sulphite with either soda ash or caustic soda as buffer.

(*b*) Celdecor process—caustic soda and chlorine.

(*c*) Mechano-chemical process:
  1. Lime or lime combinations with soda ash or caustic soda;

2. Caustic soda;
3. Kraft chemicals.

Development work of the Peoria laboratory has been directed mainly to discovering better ways of producing pulps—from non-woody plants—that will meet the rigid requirements of the United States markets. Investigations, however, have been basic and cover a wider field (7). When pulps are produced by the use of lime or combinations of other chemicals with lime, they cannot be bleached and are suitable only for the manufacture of boards or coarse papers. By the proper selection of conditions, it is possible to use any of the other pulping methods, to produce either board or coarse pulps, unbleached pulps suitable for use in wrappings and board products, or bleached pulps for use in making a wide variety of printing and other specialty papers.

The selection of a suitable process for commercial use will depend on a number of factors such as kind and quality of papers needed, volume of these products that can be sold, amount of capital available, location of the mill, kind of labour and utilities available, and other local factors. In general, the new mills will be small in comparison with new mills in the United States or Europe. In deciding on which pulping process to use, it is as well to consider the simplicity of operation and equipment and the flexibility of the setup in addition to cost factors such as capital investment and operational expenditure. However, allowance should be made for a future extension of capacity or the manufacture of higher quality merchandise as the market grows.

Pretreating methods to remove pith or to clean fibre

The dirt and pith should be removed as much as possible before pulping. A variety of ways for doing this is available. By passing the moist bagasse from the sugar mill over shaking or vibrating screens, some of the impurities are separated. This is common practise in sugar mills to obtain pith for use in filtering muds. By the use of screens with somewhat larger holes, a larger proportion of impurities can be removed.

If the bagasse has been baled and stored, a bale breaker must be used; by passing the loosened dry bagasse over vibrating screens about one-third of the pith and dirt can be removed, a practice common in pulp mills processing bagasse. Where a large excess of bagasse exists over fuel requirements, and provided the bagasse has been passed through a shredder or similar mill to loosen the pith from the fibre bundles, a system of screens with larger holes will yield about one-third of the processed material as fairly clean fibre.

The Peoria laboratory has developed three different procedures for obtaining clean fibre and high-grade pith (8). Two of these methods are applicable for use in the sugar mill, the other at the pulp mill (9). Lower-priced machinery and somewhat simpler procedures based on the principles developed are now in operation in a new mill pulping bagasse in Mexico.

The above methods are all purely mechanical. Combinations of chemical and mechanical methods are also in use. Indeed, when whole bagasse or partially screened bagasse is pulped in the presence of chemicals, a proportionately larger amount of pith than fibre is destroyed and lost by the chemical action and through washing, bleaching, and other treatments.

Another method recommended by some is pre-hydrolysis of the bagasse before the real pulping operations. This treatment destroys a certain precentage of the pith by chemical action, but more important, since the prehydrolysed mass must be washed and is very free-draining, a large amount of pith is washed out mechanically. If the process of prehydrolysis is properly conducted, a considerable percentage of the pentosans in the bagasse can be converted to sugars without too greatly degrading the cellulose. Since pulps produced from this prehydrolysed material have pentosan contents quite similar to those of softwood pulps, they produce soft papers similar to, but much weaker than, papers from wood pulps.

At Peoria, a basic study of pre-hydrolysis of bagasse has been made, directed largely to a study of methods for producing rayon pulps. Results indicate that if in the pre-hydrolysis treatment, using either acid, steam, or water under appropriate conditions, the pentosan content of the material is reduced to too low a value, the cellulose will be seriously degraded. Obviously, these treatments, since they destroy fibre and pith, lead to weak pulps in low yields. Multi-stage processes always increase costs. These facts should be borne in mind in any analysis of claims made for pulping processes.

Responses to pulping conditions are variable

For the purpose of rating the pulping characteristics of bagasse from different cane varieties and from different localities, a simple pulping procedure using elevated pressure was worked out. The conditions used and the results obtained on a number of samples of separated bagasse fibre are given in table 2. The pulping conditions were chosen so as to prepare a bleachable pulp but they are obviously not those best suited to produce a pulp of optimum qualities from any one bagasse. The results of this study illustrate the rather wide differences to be expected in yields and in the strengths of pulps obtained from different lots of bagasse. This emphasizes the facts, that bagasse is a variable raw material, and any process chosen for industrial use should be capable of simple modification so as to compensate for these variations and avoid the production of pulps of uncertain quality.

Pulping by conventional pressure processes

A comparative study was made by pulping lots of bagasse under standard conditions using the same precentage (12) of soda or kraft-type chemicals, based on oven-dry material. In this study both whole bagasse and the separated fibre from these lots were pulped. The results are given in table 3. Here, also, a variation in yields and in physical properties of the pulps derived from the different lots of bagasse is to be noted. There seems to be little choice between pulping with caustic soda or kraft-type chemicals in so far as yields or quality of pulps are concerned. The use of the latter produces a somewhat easier bleaching pulp, but this advantage may be offset by other factors, such as odour or cost of sulphur. The striking differences shown in this table are between the yields and qualities of pulps obtained from whole bagasse and from the separated fibre, respectively. In considering these results, it must be recognized that all of the samples of whole bagasse, with the exception of the stored Louisiana sample (cook No. 1001), were dry-screened before baling. They, therefore, contain only about two-thirds of the pith originally present and are representative of commercial cleaned bagasse used for pulping in most countries except Mexico and Peru.

The sodium sulphite method using soda ash as a buffer, as developed for use with straw by the Northern Utilization Research Branch, is as satisfactory for bagasse pulping as the soda or kraft methods. As in the case of pulping cereal straws by this method, yields of pulp are slightly higher than by the use of caustic soda or kraft-type chemicals, and bleach requirements are generally lower, as shown by the results in table 4. The unbleached sodium sulphite pulps are very much lighter in colour than the soda or kraft-type pulps, a distinct advantage, since they need not be bleached when used to make papers with a brightness of about 50. If caustic soda is substituted for soda ash as buffer, pulp yields will be lower, their colour darker, and the pulps will take on more and more properties of the caustic soda pulps. The same general differences in yield and quality of pulps from whole bagasse vs. bagasse fibre are obtained with other processes. The sodium sulphite method has the disadvantage that no suitable process has yet been developed for recovery of chemicals.

Celdecor Process

This is a well-known commercial continuous process for pulping using caustic soda to produce a semipulp suitable for use in corrugating medium and low-quality boards, and then completing the operation to make fine pulps by the use of wet gaseous chlorine. The process is being used in a number of countries, particularly on straw, and is used to pulp bagasse in a small mill in the Philippines and in a new mill in India (10). A mill in Monte Alegre, Brazil, has just been completed for pulping bagasse by this process. The bagasse is prepared by a dusting process which removes about one-third of the pith and dirt. The use of chlorine as a pulping, as well as a bleaching, agent tends to make a somewhat softer pulp than by other alkaline methods, except when pre-hydrolysis is used. It has not been possible at Peoria to study this method on a laboratory scale.

Mechano-Chemical Process

This process (11) was discovered at the Peoria laboratory during the development of better methods for pulping cereal straws. It has been applied to the pulping of bagasse, although because of the denser character of the bagasse fibres more chemical and a slightly longer pulping cycle are required than for most cereal straws. The process is exceedingly simple; it uses low amounts of chemicals at atmospheric pressures for pulping periods of thirty minutes to about an hour. Steam requirements have proved to be very low since a certain amount of hot black liquor is re-used for pulping. Although power requirements were slightly higher than in conventional processes a new Mexican development in the processing has lowered power requirements considerably. The process is carried out in a modification of the mechanical pulpers found now in most mills, and widely used in repulping waste papers or virgin pulp. For example when the hydrapulper is used, a larger rotor is required than is standard for pulping waste, with consequent higher power requirements. By use of the Mexican development mentioned, however, the power is less than is normally required for pulping waste papers. Since the pulpers can be made in sizes from three to twenty feet in diameter, and since the pulper may be used also for waste papers or virgin pulps, the process is suited for both very small and very large mills.

Pulping takes place through the reaction of the pulping chemicals on fibre or fibre bundle surfaces; the greater the surface area presented the more rapid the pulping action. The violent mechanical action continuously producing fresh surfaces in the presence of chemicals during pulping accounts for the very rapid rate of pulping and also for the mild pulping conditions. The long penetration period, needed for pulping wood chips under pressure, is entirely avoided. Experience has shown that the optimum conditions for producing a pulp by this process must be present at the start. If any condition, such as amount of chemical, concentration of chemical, consistency, temperature, available power, or speed of rotation of the pulping mass, is less than optimum, best results will not be obtained.

The process is now being employed commercially to pulp straw in mills in Holland, England, and Pakistan, and a new mill which will use the process is being constructed in Portugal. In Mexico a mill is producing market pulp from depithed bagasse by this process. The Mexican mill pulps at a starting consistency of 13 per cent, other mills use 10 to 12 per cent. In pulping bagasse, all screenings may be repulped. Yields of pulps made commercially will closely approach the crude yields shown in the tables. The Mexican company has carried on considerable development work, with the result that pulps with unexpected properties, such as good tear resistance, suitable for good wrapping papers, are being manufactured. The results obtained by the use of the mechano-chemical process are illustrated in the tables and will be discussed appropriately.

Corrugating medium from bagasse

The stiffness and crush resistance so necessary for high-grade corrugating medium is attributed to the high pentosan content of pulps used in its manufacture. Sugar-cane bagasse and wheat and rye straw contain higher amounts of pentosans and lesser amounts of lignin than any of the hardwoods from which standard pulps for corrugating manufacture are made at present. They, therefore, represent preferred raw materials for making corrugating medium, providing proper pulping methods are used.

Several years ago, at the request of the executives of the strawboard industry of the United States, the Northern laboratory undertook a study of pulping methods to bring about improved physical properties in corrugating medium made from wheat straw. This research (12) showed that the use of lime as a pulping chemical was responsible for the production of a softer medium, but that when caustic soda was substituted as a pulping agent the medium manufactured was stiffer and more crush resistant. When the mild pulping conditions used in the mechano-chemical process for pulping straw with caustic soda were substituted for the pressure methods conventionally used with this chemical, even higher grade pulps resulted.

Methods for producing high-grade pulps to make corrugating medium from bagasse have been extensively explored by the Peoria group. Typical results obtained are shown in table 5. It will be noted that pulping the Lockport whole bagasse with a mixture of lime and caustic soda by the mechano-chemical process produced a weak pulp as compared with pulp from the same material pulped with caustic soda alone by the conventional pressure method. When 8 per cent caustic soda was used with the mechano-chemical process, a still better pulp was obtained. When the latter conditions were employed to pulp the Lockport separated fibre, an even more acceptable pulp was obtained, as indicated particularly by the higher freeness (e.g., a pulp capable of faster running on the paper machine), and by the improved bursting and tensile strength.

The results obtained on pulping the samples of bagasse (variety F.31-436) from Clewiston, Florida, are very interesting. The samples marked "whole" had been screened before baling to remove about one-third of the pith and dirt. The lower freeness and other physical properties of the pulp made from them, as compared with the pulps from cook Nos. 1255 and 1229, using separated fibre pulped by either the pressure or the mechano-chemical process, are striking. The pulp made from the whole bagasse by cooking under pressure is freer and stronger than the same material cooked with the same amount of chemical by the mechano-chemical process. This is because the pressure cook destroys more of the pith, a fact indicated by the higher yield obtained with the mechano-chemical method. When the pulps produced by the two processes are compared, it will be observed that the pressure method gives a slightly freer pulp, but of lower bursting and tensile strength and in a slightly lower yield. When 12 per cent lime was substituted for 8 per cent caustic soda in pulping the whole Florida bagasse by the mechano-chemical method, a much weaker pulp, of lower crush resistance and freeness was produced. Both the pulps from whole bagasse were so slow draining that they would run only slowly on the paper machine. If pulps of this quality only were available, a cylinder-forming machine would be preferable to a Fourdrinier machine.

A comparison of the results obtained by pulping samples of Hawaiian bagasse (variety 8560) brings out essentially the same relationships as observed with the Florida bagasse.

It may be concluded from this work that pulps suitable for making low-grade corrugating medium can be made from whole or screened bagasse by cooking with lime, or lime and caustic soda or caustic soda alone, using either pressure or mechano-chemical methods. All these pulps will drain slowly and require the addition of waste papers or considerable washing to be run at paper-machine speeds normal for modern operations. The lime-cooked pulps will be found deficient in strength, particularly crush resistance, as compared with caustic-soda-cooked pulps. Using depithed fibre as a raw material, superior pulps are produced by the use of caustic soda with any of the pulping methods. The mechano-chemical process in general produces pulps as strong or stronger, and in higher yields.

Semi-commercial production of shipping containers from Florida and Hawaiian bagasse

A contract was made by the United States Government with the New York State College of Forestry, Syracuse, New York, under the Research and Marketing Act, to undertake the manufacture of shipping containers using bagasse as a raw material. It was decided to use the mechano-chemical process to produce both corrugating and liner-board pulps. Tonnage lots of both Florida and Hawaiian bagasse were secured. A portion of the Florida whole bagasse was depithed at Syracuse, using the Hydrapulper method developed by the Northern laboratory. The Hawaiian Sugar Planters' Association used the same method in their Hawaiian pilot plant and shipped both whole and depithed bagasse to Syracuse.

The lots of bagasse were pulped at Syracuse in an 8-foot hydrapulper which was somewhat deficient in rotor speed and in power. The results of the physical tests on some of the representative pulps so produced are given in table 6. Pulp made from the whole Florida bagasse was so slow draining that it would not run either on the Fourdrinier or the cylinder wet end of the paper machine. The pulp also contained grit. Only by rewashing the pulp, after suitable dilution, by passage twice over a decker could the pulp be made free enough to run and produce satisfactory board. The physical properties of this pulp given in table 6 are representative of the washed pulp and are very similar to the properties obtained by pulping depithed Florida fibre under similar conditions. The whole bagasse actually was thus depithed by a combination of chemical and mechanical methods. The corrugating pulps from whole bagasse and from separated fibre were produced by using 12 per cent caustic soda on the basis of oven-dry material. The liner-board pulps were made from separated fibre with 16 per cent caustic. It will be observed that the pulps obtained by cooking with the higher percentage of chemical are somewhat freer and stronger.

In this connexion it is interesting to compare the results obtained commercially in Mexico by pulping with 12 per cent caustic in a 10-foot hydrapulper, using Mexican bagasse (separated) fibre.

In making the corrugating medium at Syracuse, 85 per cent bagasse pulp and 15 per cent waste corrugating were used as the furnish, excepting in one case (HFCX) when 100 per cent Hawaiian corrugating pulp was used. Liner boards from both Florida and Hawaiian fibre were made from a mixture of 50 per cent bagasse and 50 per cent virgin kraft wood pulp, and in two cases with Florida bagasse, 25 per cent and 75 per cent kraft pulp, respectively. As a control on machine operation, corrugating medium was made from 85 per cent commercial semi-chemical hardwood pulp and 15 per cent waste corrugating, and liner board from 100 per cent virgin kraft wood pulp. The physical properties of the boards made are given in table 9. The various corrugating media and liner boards were combined into 200-pound-test container board in a commercial box plant. An examination of the physical properties of the various combinations showed the superior strength of the combinations using corrugating medium from bagasse, as compared with medium made from semi-chemical hardwood pulp or commercial corrugating medium. One combination had a remarkable crush resistance of 88; this board is actually too stiff to be practical for use in ordinary shipping container manufacture.

Three sizes of containers were manufactured commercially from these combinations. The containers were subjected to laboratory tests and to commercial shipping tests. Results (see table 9) were satisfactory in all cases, showing that corrugating medium made from depithed bagasse by the mechano-chemical process would meet or surpass the highest present commercial standards. The liner boards made from 50 per cent or more bagasse were not the equal in quality to 100 per cent kraft liner board, but they would meet most of the less exacting world industrial requirements. Except for tear resistance, the liner board containing 25 per cent bagasse and 75 per cent virgin kraft, compares favourably with the properties of 100 per cent kraft liner.

Fine pulps from bagasse for unbleached or bleached papers

Unbleached or bleached pulps suitable for use in printing and other fine papers can be made from either whole or partly screened bagasse or, better, from pith-free fibre. The effects of pith in increasing chemical costs, in producing slow draining, weak pulps, and in causing difficulties in bleaching have already been discussed. As higher grades of pulp are required, these difficulties will, of course, become more acute. For obtaining fine pulps from bagasse, the chemicals, caustic soda, kraft, or neutral sulphite, may be used with the conventional pressure processes. The amounts of chemicals required will increase as higher quality pulps are produced. The Celdecor and mechano-chemical processes also produce fine pulp, using more chemical than for preparing pulps for corrugating media or liner boards. Some of the pulps produced by these various methods may be bleached to a brightness of about 70 by a one-stage process. Depending on the amount of pith, dirt, and lignin present, others will not easily produce bright pulps except by use of multi-stage bleaching processes. To obtain a brightness of 80 to 83, the conventional three-stage bleaching process generally will be found satisfactory with pulps made from depithed fibre. The pulps produced by the three-stage process are stronger and require less chlorine than when bleached to the same brightness by the one-stage process. Pulps containing high amounts of dirt and pith require larger amounts of chlorine for bleaching, which tends to produce weaker pulps in lower yields. In some cases it appears impossible to obtain pulps of high brightness by starting with low-grade, dirty bagasse. Satisfactory pulps for fine papers cannot be made by the use of lime or mixtures of lime with caustic chemicals.

Fine pulps from depithed fibre

In order to obtain a comparison between pulping depithed fibre under pressure and by the mechano-chemical process, tests were made using kraft-type chemicals and caustic soda.

The data, given in table 7, show that in general the crude yields of pulp obtained by the mechano-chemical process are higher than those obtained by the pressure process, as is also often the case with respect to screened yields. It must be noted that the results shown in this table may be somewhat misleading, as compared with results obtained in commercial practice, since in commercial practice the screenings obtained in one cook would be returned to the succeeding cook for repulping. On the other hand, the lignin contents of the pressure-cooked pulps are lower in all cases as are also the chlorine requirements for bleaching in one stage to 70 brightness. The relation between the other physical characteristics of the pulps made by the different methods is somewhat indeterminate, depending on the particular sample of bagasse which was pulped.

This table also contains data on pulping of Hawaiian bagasse under pressure, using kraft-type chemicals in increasing concentrations. It will be noted that the first two cooks, using 8 and 10 per cent kraft-type chemicals, were not satisfactory as indicated by the low yields of screened pulps. With 12 and 14 per cent kraft chemical, the crude yields decreased and the screened yields increased; the lignin content of the pulps and the chlorine requirements for bleaching both decreased. The pulp produced with 14 per cent kraft chemical was best from the standpoint of physical properties. Pulping of the Hawaiian bagasse was more difficult than for the other samples of bagasse studied and the pulp produced was not as strong.

Referring to the effect of screenings, table 10 presents some interesting data. In preparing a rather large lot of mechano-chemical pulp for bleaching and manufacturing into paper in a co-operative study at the Forest Products Laboratory, Madison, Wisconsin, fourteen cooks (1062-1075) were made of Florida bagasse. In making the composite lot, the screenings from each cook were returned to the succeeding cooks but in the first cook, No. 1062, screenings were not repulped. It will be noted that the composite lot and the pulp from the first cook agree in freeness, bursting and tensile strength, but the composite is superior in tear and fold resistance. When the latter lot was bleached at the Forest Products Laboratory, the pulp was found to be lower in freeness but superior in other physical properties to the unbleached pulp.

In order to determine directly the effect of repulping screenings, cook 1139 was carried out without repulping the screenings. The screenings were repulped in cooks 1140-1141. The pulp prepared from the screenings had higher freeness, the same Mullen and tensile strength properties, considerably higher tear resistance and somewhat lower double fold. The screenings come largely from the dense rind fibres of the bagasse which are somewhat difficult to penetrate. It has long been known that the rind fibres contain fibre elements of a longer dimension than the fibres from the fibro-vascular bundles, an effect which shows up clearly in the higher tear resistance of the pulp from screenings.

The properties of another composite pulp made from bagasse fibre in the 8-foot hydrapulper at the New York State College of Forestry, in which the screenings were returned to the succeeding cooks, are shown in this table. Properties of the bleached pulp produced from it in a three-stage process at one of the plants of the St. Regis Paper Company are also given. It will be noted that the unbleached pulp was similar in properties to the unbleached pulp used at the Forest Products Laboratory. The New York State College of Forestry pulp had higher physical strength properties after bleaching.

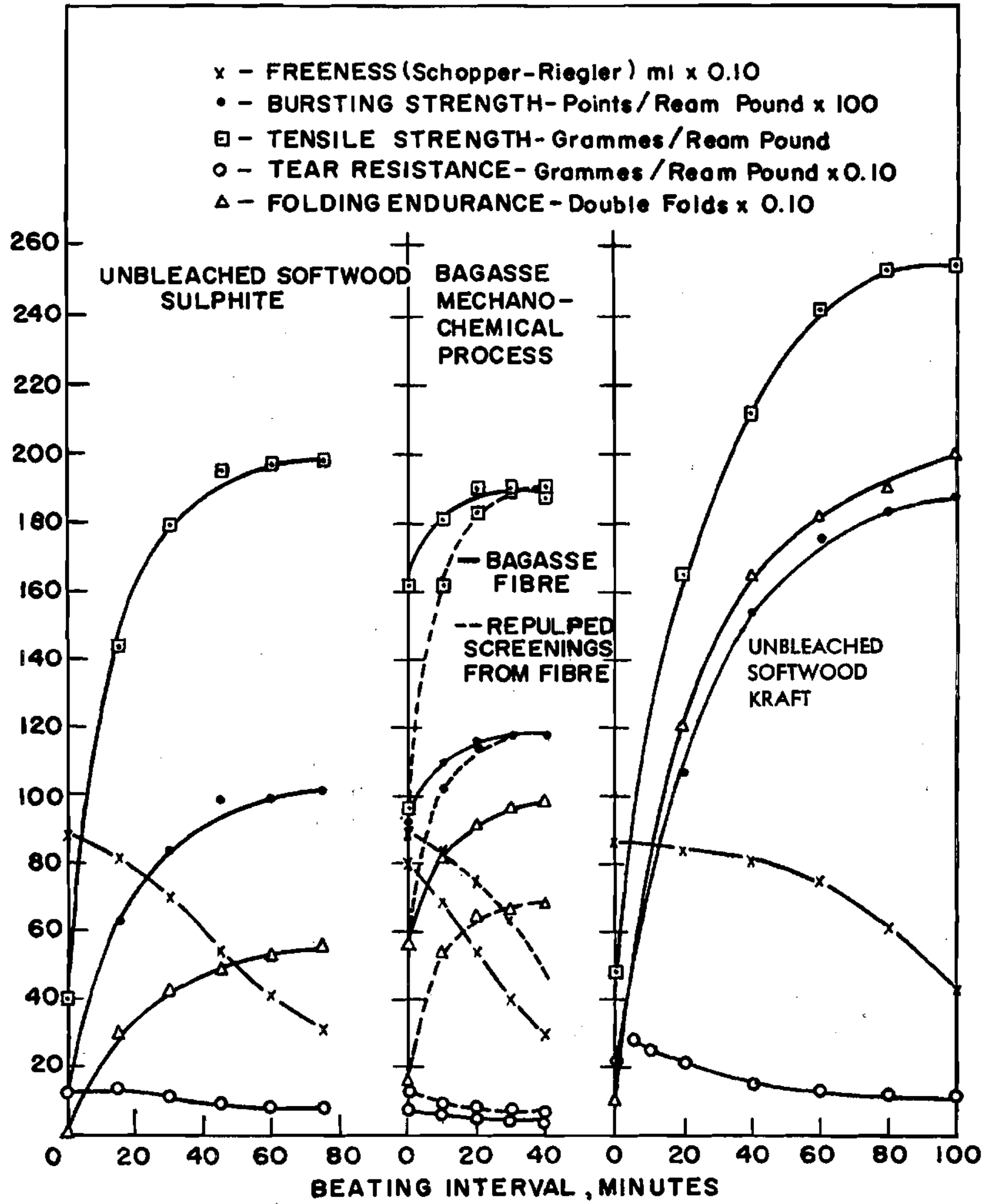
A study carried out, using increasing amounts of chemicals in pulping depithed fibre by the mechano-chemical process, showed that there is little decrease in yield or increase in physical properties of pulps after the optimum amount of chemical has been used.

When pressure pulping is used pulp yields are lower and a smaller amount of screenings is obtained, which appears to be due to a better penetration of the rind fibres and probably to greater destruction of the fibro-vascular bundle fibres. By increasing the severity of the pressure cooking conditions, the yield of pulp is further decreased. On the other hand, with the mild conditions of the mechano-chemical process, it is more difficult to penetrate rind fibres, but less destruction to the fibro-vascular bundle fibres results. The over-all yields of screened pulps are not only higher in the latter process, but by repulping the screenings a still larger yield of pulp will be obtained as compared with pressure cooking methods. While pressure cooking reduces the amount of chlorine required for bleaching, it is evident that extremely high-grade unbleached and bleached pulps can be made from depithed bagasse fibre by the mechano-chemical process.

Figure 1 illustrates the strength characteristics of unbleached depithed fibre bagasse pulp produced by the mechano-chemical process as compared with those of unbleached commercial softwood sulphite and commercial softwood kraft pulps. The bagasse pulp is superior to the unbleached sulphite pulp in all of its properties excepting tear resistance but is not as strong as the kraft wood pulp. Pulps made from the better grades of wheat straw (13) by the mechano-chemical process compare closely in physical properties with pulps made from depithed bagasse.

Figure 1

COMPARISON OF STRENGTH DATA ON MECHANO-CHEMICAL UNBLEACHED PULPS FROM DEPITHED BAGASSE FIBRE AND REPULPED SCREENINGS WITH COMMERCIAL UNBLEACHED SOFTWOOD PULPS



Fine papers from bagasse

Wrapping and bag papers

The composite pulp referred to in table 10, cooks 1062 to 1075, was blended with commercial kraft wood pulp to produce wrapping and bag papers on the paper machine of the Forest Products Laboratory. The wrapping paper was made from a blend of 50 per cent bagasse pulp and 50 per cent kraft pulp, both unbleached, and as a control this grade of paper was also made from 100 per cent kraft wood pulp. The bag paper was made from a blend of 25 per cent bagasse pulp and 75 per cent kraft wood pulp and a control run of 100 per cent kraft wood pulp was also made. It will be noted from the data in table 11 that, with the exception of tear resistance, the wrapping and bag papers made with bagasse have somewhat better strength characteristics than those made from 100 per cent kraft wood pulp. The table also includes tests made on wrapping and bag papers produced in Peru from mixtures of bagasse pulp, kraft pulp, and waste. The Philippine company producing paper from bagasse reports tests made on handsheets from blends of Celdecor bagasse pulp and American kraft wood pulp. In this case also the use of mixtures of bagasse pulp and kraft wood pulp gave wrapping papers superior to those made from 100 per cent wood pulp, excepting in tear resistance. This same phenomenon has been observed in bags and wrappings made from blends of mechano-chemical wheat straw (13) pulp and graft softwood commercial pulps. Wheat straw pulps produced by the neutral sulphite process in Italy are frequently blended with kraft wood pulps in order to produce better papers for wrapping and bags.

The reason for this apparent paradox is that the fibres of the straw and bagasse pulps greatly improve the formation of papers made from the blends, so that the kraft fibres contribute a higher proportion of their inherent strength to the papers so made.

This finding is of great commercial importance because it indicates the possibility of manufacturing very high-quality bag and wrapping papers by the use of properly prepared blends of bagasse pulps and wood pulps. This could lower the import requirements of kraft wood pulps in countries where long-fibred pulpwoods are not available. Pulps from such fibres as abaca, sisal, hemp, ramie, and flax can be added to the shorter-fibred bagasse pulps to produce papers of extremely high tear resistance (14).

Newsprint

Much of the discussion of the use of bagasse for making newsprint has appeared in the lay press and is the cause of a great deal of confusion, which arises largely from the definition of the word "newsprint".

It has been demonstrated numerous times that a paper can be made from 100 per cent bagasse pulp which will run on fairly high-speed printing presses such as are used by newspaper publishers (15). If sufficient filler and opacifying material are added to the bagasse pulp, the show-through and ink penetration of the paper will be satisfactory, but it will not have the appearance or feel generally associated with newsprint. Newsprint as known in most countries consists of a blend of 75 to 85 per cent mechanical pulp, and 15 to 25 per cent chemical pulp. When Northern spruce or hemlock groundwood is used, the chemical pulp fraction is nearly always spruce or hemlock sulphite. Using Southern pine groundwood, the chemical pulp fraction is usually semi-bleached sulphate and with eucalypt groundwood fully bleached sulphate. The properties of ink absorption, high opacity, and softness of standard newsprint are to be attributed almost entirely to the mechanical pulp. In general, the printing quality of newsprint improves as the amount of chemical pulp is reduced.

From the commercial standpoint, the question of using 100 per cent bagasse pulp for the manufacture of newsprint, magazines, or other types of low-quality printing papers will depend on whether the publishers in any particular country will accept this type of product in lieu of a product composed largely of mechanical pulp. If mechanical pulp is entirely unavailable, then there should be no question of the publisher's attitude. On the other hand, from a long-term view mechanical pulp may be produced at a lower cost than any chemical pulp. Thus it might be that for a time a country, being deficient in mechanical pulp, would use paper made entirely from bagasse pulp until papers based on a larger percentage of groundwood became available. History shows that newspaper publishers constantly demand lower-priced and better newsprint, which will result from lower-priced, or available mechanical pulps.

There seems to be no doubt that the chemical wood pulps such as unbleached sulphite or bleached sulphate, at present used in the manufacture of newsprint in various countries, may be replaced by bleached bagasse or bleached straw pulps. Indeed, there is reason to believe that, because of the high tensile strength of bleached pulps made by the mechano-chemical process from bagasse and straw, some of the weaker groundwoods such as those from eucalypt or Southern pines would be converted into higher grade printing papers than are made at present.

Tests have been carried out with the manufacture of newsprint from mixtures of bagasse and mechanical wood pulps on the paper machines both at the Forest Products Laboratory at Madison and the New York State College of Forestry. The properties of the bleached bagasse pulps used in making these papers are reported in table 10. The proportions of bagasse and mechanical pulps employed and the characteristics of the papers made are given in table 8. The papers from these blends meet the printing and physical standards for newsprint in the United States. The formation of the papers made with bagasse pulp is better than the formation obtained with the all-wood pulp furnish, because of the action of the fine bagasse fibres in improving formation. Improvements in formation of newsprint improve printing qualities, particularly of half tones. Tests in an effort to produce a somewhat stiffer newsprint from Southern pine groundwood showed that addition of 15 to 20 per cent bleached bagasse pulp to a furnish of 80 per cent mechanical pulp and 20 per cent bleached sulphate wood pulp produced a sheet comparable to Canadian newsprint.

The physical properties of newsprint made in Peru and in India from blends of bagasse and other fibres are also shown in table 8. In addition the properties of three of the "newsprint" papers made by the United States National Bureau of Standards (16) from 100 per cent bagasse are included. Paper No. 1 of the Bureau of Standards' group was judged to be best from the standpoint of printing, softness, and opacity. This paper had a very high ash content, the opacity having been brought up by the use of titanium dioxide. An analysis of the results would indicate that, had equal amounts of filler and titanium dioxide been used in making the other two papers, equal opacity and printability would probably have been obtained. Finally, this table also gives the properties of commercial newsprint used in the United States.

Writing and other fine papers from bagasse

Part of the lot of pulp bleached at the Forest Products Laboratory, cooks 1062-1075, table 10, was also used for the manufacture of bond, magazine-book, and printing papers on the Forest Products Laboratory paper machine. The bond and magazine-book papers made with blends of bagasse pulp compared favourably with the same grade of papers made entirely from wood pulps, and showed improvements in formation.

Because of the information now available on the commercial use of bagasse pulps and because of the very great similarity of pulps produced from depithed bagasse and from straw, it is entirely safe to conclude that a very wide field is open for the use of unbleached and bleached bagasse pulps, particularly those made from depithed fibre, for the manufacture of fine and specialty papers. Tabb (17) has recently given a very good summary of the properties of straw pulps and how they may be used as blends with other pulps to produce fine and specialty papers.

Because of the character of pulp from bagasse fibre, its addition in rather small percentages, e.g., in the neighbourhood of 20 to 30 per cent, to almost any other pulp with which it may be blended will be found to improve the formation characteristics of the papers manufactured. Improvement in formation makes better papers for printing and also for waxing. The high-pentosan content of pulps made from bagasse makes their beating or refining possible in much less time and at lower cost than is possible with wood pulps. Experience shows, however, that it is desirable to beat these pulps. Best results are not obtained by using unbeaten unbleached or bleached bagasse pulps as blends with other pulps. The high-pentosan content of these pulps also is responsible for their tendency to form denser papers, which points to their use in bringing about a better handle in many kinds of papers, such as bank, bond, writing of all sorts, and account books. Pulps of this sort are useful in producing a hard surface on tag papers and in closing the surface of papers used for coating or for lithography.

Mechano-chemical bagasse pulps are suited for making glassine, and glassine papers are made from straw pulps of similar characteristics in Italy and Germany.

If it becomes necessary to make papers using bagasse alone, their lack of opacity and tendency to be dense may be overcome by the addition of well-known mineral fillers. The fine fibres of the bagasse pulp result in a higher retention of fillers, and generally the cost of mineral filler is below the cost of bleached pulp. The softness of papers made from 100 per cent bagasse pulp can also be controlled to a considerable extent by the addition of fillers.

Table 1 PROXIMATE ANALYSIS OF VARIOUS TYPES OF BAGASSE *(All values except moisture on oven-dry basis)*

NURB No.	Material	Moisture	Ash	Lignin	Pentosans*	Extractives in: Hot water	Extractives in: Alcohol benzene	Extractives in: 1% NaOH	Cross and Bevan cellulose: C and B cellulose: Ash free	Cross and Bevan cellulose: C and B cellulose: Pentosans in	Cross and Bevan cellulose: Alpha as run: Ash free	Cross and Bevan cellulose: Alpha as run: Pentosans in	Cross and Bevan cellulose: Alpha-basis original—ash and pentosan free
		(per cent)											
1267	Louisiana whole bagasse—stored (Lockport—1941)...	4.1	2.9	21.3	29.4	4.0	1.7	32.9	58.4	29.3	67.2	6.1	36.8
1267	Louisiana bagasse fibre—stored (Lockport—1941).........	6.8	2.0	20.7	30.0	2.4	1.6	28.4	61.4	31.7	70.0	10.0	38.7
1267	Louisiana bagasse pith—stored (Lockport—1941).........	12.2	4.6	21.3	29.9	3.1	1.7	36.1	54.6	30.3	62.8	5.7	32.3
1740	Louisiana whole bagasse—fresh (Houma—1941)...........	4.9	2.4	18.9	30.0	8.8	6.0	35.9	53.3	27.9	67.3	7.0	33.4
1740	Louisiana bagasse fibre—fresh (Houma—1941)...........	9.7	2.2	19.9	32.5	3.4	2.0	30.5	59.0	29.6	67.7	8.1	36.7
1740	Louisiana bagasse pith—fresh (Houma—1941)...........	8.7	6.3	18.0	30.7	3.4	2.9	36.2	52.5	28.7	62.4	6.6	30.6
7892	Florida whole bagasse—fresh-dry screened (Clewiston—1948)..................	7.3	2.2	18.1	27.9	11.2	10.8	39.9	52.0	26.9	68.0	4.7	33.7
7892	Florida bagasse fibre—fresh (Clewiston—1948).........	7.2	2.0	19.1	30.9	4.5	2.6	31.2	60.4	29.0	67.2	4.5	38.8
7892	Florida bagasse pith—fresh (Clewiston—1948).........	8.9	3.4	18.2	31.4	4.6	2.5	35.0	53.9	26.2	63.4	4.0	32.8
9940	Florida whole bagasse—variety Cl. 41-223 (Clewiston—1952)	8.6	1.0	18.2	26.6	15.1	7.0	40.7	48.0	28.1	66.9	4.7	30.6
9941	Florida whole bagasse—variety F. 31-436 (Clewiston—1952)	10.1	1.6	16.4	27.4	15.5	6.4	43.2	48.8	32.7	66.5	5.3	30.8
9942	Florida whole bagasse—variety F. 31-962 (Clewiston—1952)	10.5	2.2	18.6	28.7	9.8	8.0	40.0	49.0	26.5	67.7	5.2	31.5
9992	Hawaiian whole bagasse—variety 8560 (1952)...........	13.2	5.4	21.3	27.7	5.7	3.2	33.9	50.2	27.4	69.6	8.8	31.8
9992	Hawaiian bagasse fibre—variety 8560 (1952)...........	5.6	2.0	21.1	30.7	2.4	3.6	28.8	56.0	28.8	73.4	10.4	38.3
9992	Hawaiian bagasse pith—variety 8560 (1952)...........	7.1	3.3	20.0	33.0	1.5	2.1	30.8	53.5	29.7	62.7	6.7	31.5
9333	Hawaiian whole bagasse (Laupahoehoe Sugar Co.).......	8.0	1.9	22.5	31.2	3.4	2.1	31.4	55.4	27.7	72.5	8.3	34.3
9573	Hawaiian whole bagasse—variety 1933 (Ewa Plantation)..	7.7	2.6	19.3	31.3	4.0	3.6	31.3	55.0	33.4	62.6	8.2	31.6
9851	Hawaiian whole bagasse—variety 1933 (Oahu Sugar Co.).	7.9	3.3	20.1	31.0	2.7	3.4	32.0	52.0	32.4	65.7	7.4	31.7
10081	Puerto Rican whole bagasse (Aguirre 1951, 1952).......	7.5	3.9	18.1	29.6	8.0	5.4	27.3	50.9	31.1	63.7	7.0	30.1
10081	Puerto Rican bagasse fibre (Aguirre 1951, 1952).......	11.5	1.2	19.8	31.6	1.4	2.7	27.3	59.9	30.4	67.2	5.7	40.2
10081	Puerto Rican bagasse pith (Aguirre 1951, 1952).......	4.9	3.2	18.8	31.9	2.8	2.9	30.3	53.9	30.3	60.4	6.4	32.6
10564	Mexican bagasse pith (San Cristobal, 1953)...........	6.2	4.9	22.4	29.9	7.6	2.3	40.1	46.0	25.5	61.3	5.5	26.6
10566	Philippine whole bagasse (Negros Island, 1952).........	10.2	2.3	22.3	31.8	2.8	3.0	31.3	56.8	30.6	70.2	12.5	34.9
10566	Philippine bagasse fibre (Negros Island, 1952)..............	5.3	1.2	21.8	31.2	1.9	2.1	26.8	62.9	31.9	72.0	9.1	41.2
10566	Philippine bagasse pith (Negros Island, 1952).............	3.3	2.6	22.5	33.2	3.6	2.7	36.2	55.4	32.2	66.8	5.7	34.9

* Pentosans = furfurol × factor 0.8.

Analysis by Northern Utilization Research Branch

Table 2

COMPARATIVE PULPING CHARACTERISTICS OF SEPARATED BAGASSE FIBRES FROM VARIOUS SOURCES

(Pulping conditions: Chemicals = 8.7% NaOH + 4.3% Na_2S; Liquids-to-solids ratio 7:1; Time = 1 hr. at 170° C.; Bleached 70 brightness Hunter. Tests basis weight 47 lb, 25 x 40–500. TAPPI methods used.

Material Year—Variety	Pulp yields[a] Crude	Pulp yields[a] Screened .008" cut plate	Chemical analysis[b] Ash	Chemical analysis[b] Lignin	Chemical analysis[b] Pentosans[c]	Bleaching Chlorine consumption single[b]	Bleaching Bleach yield[a]	Initial freeness S.-R. (ml)	Strength characteristics 500 ml S.-R. Bursting strength (pts/ream-lb x 100)	Tensile strength (g/ream-lb)	Tearing resistance (g/ream-lb. x 100)	Folding endurance (Schopper)	Density (g/cc)
			(per cent)										
Louisiana													
Lockport, stored 1941 Mixed	63.0	58.9	1.02	2.7	33.5	5.65	56.2	855	97	176	49	430	0.90
Terrebonne, stored 1948 Mixed	62.8	59.0	1.3	2.9	34.3	6.8	55.0	860	104	190	55	645	0.92
Houme, fresh 1941 Mixed	63.0	55.2	1.2	2.8	33.4	7.0	52.1	845	100	179	54	570	0.91
Reserve, fresh 1949 Mixed	63.8	58.8	1.3	3.7	34.2	7.6	54.8	865	100	188	57	620	0.91
Florida													
Clewiston, fresh 1948 Probably F. 31-436	64.4	58.6	1.6	4.0	33.9	10.2	53.8	815	124	214	48	1000	0.96
Clewiston, fresh 1952 Cl. 41-223	63.9	56.8	1.3	4.4	33.6	12.8	57.5	820	118	199	50	800	0.94
Clewiston, fresh 1952 F. 31-962	61.6	55.6	1.5	4.1	31.8	9.6	52.8	835	98	170	57	640	0.88
Clewiston, fresh 1953 F. 31-436	61.8	57.8	1.4	3.4	33.6	7.3	52.9	835	126	206	64	880	0.89
Hawaii													
Laupahoehoe, fresh 1950 Mixed	62.8	56.0	1.4	3.9	32.8	10.1	53.2	835	90	162	58	405	0.86
Oahu, fresh 1951 1933	62.4	56.0	2.2	3.2	34.0	7.3[d]	51.8	845	97	164	60	580	0.86
Puerto Rico													
Aguirre, fresh 1952 Mixed	58.6	49.2	1.4	4.0	33.3	12.2	45.8	835	102	182	48	615	0.89

[a] Basis oven-dry raw material.
[b] Basis oven-dry screened pulp.
[c] Pentosans = furfurol × factor 0.8.
[d] Brightness 65.

Table 3

DATA ON PULPING BAGASSE BY THE SODA AND BY THE KRAFT PRESSURE METHODS

Cook No.	Material W = Whole F = Fibre Year—Variety	Cooking conditions: Chemical[a] (per cent)	Cooking conditions: Time (hr)	Cooking conditions: Temperature (°C)	Pulp yields[a]: Crude (per cent)	Pulp yields[a]: Screened (per cent)	Chemical analysis[b]: Ash (per cent)	Chemical analysis[b]: Lignin (per cent)	Chemical analysis[b]: Pentosans[c] (per cent)	Bleaching: Chlorine consumption single[b] (per cent)	Bleaching: Brightness Hunter	Bleaching: Bleach yield[a]	Initial freeness S.-R. (ml)	Strength characteristics 500 ml S.-R.: Basis weight 25x40–500 (lb)	Bursting strength (pts/ream-lb x 100)	Tensile strength (g/ream-lb)	Tearing resistance (g/ream-lb x 100)	Folding endurance (Schopper)	Density (g/cc)
	Louisiana																		
1001	Terrebonne W Stored 1948 Mixed	12 NaOH	2	170	61	46	4.5	4.2	33	13	70	43	830	46	82	162	70	230	0.79
1002	Terrebonne F Stored 1948 Mixed	12 NaOH	2	170	62	59	1.3	2.6	32	5.4	70	57	840	46	102	184	78	660	0.90
997[d]	Reserve W (screened) Fresh 1949 Mixed	12 Kraft	2	170	59	50	1.8	5.5	34	15.1	70	46	840	46	85	168	76	420	0.80
998	Reserve F Fresh 1949 Mixed	12 Kraft	2	170	63	57	1.1	4.0	34	8.6	70	55	855	46	96	173	83	740	0.67
	Hawaii																		
1135	Laupahoehoe F Fresh 1950 Mixed	12 NaOH	2	170	62	54	1.1	5.0	31	15.1	70	50	860	47	82	162	68	300	0.79
1149	Laupahoehoe F Fresh 1950 Mixed	12 Kraft	2	170	64	55	1.0	4.4	32	13.0	70	—	850	47	84	165	62	350	0.81
	Florida																		
1076	Clewiston F Fresh 1951 Mixed	12 NaOH	2	170	69	61	1.5	5.6	34	26	70	50	805	47	110	190	55	980	0.84
1078	Clewiston F Fresh 1951 Mixed	12 Kraft	2	170	66	61	1.3	4.5	34	14.4	70	57	790	46	115	194	60	1120	0.90
908[d]	Clewiston W Fresh 1948 Mixed	12 Kraft	2	170	62	52	0.9	4.5	32	12	70	49	850	46	69	152	51	160	—
909	Clewiston F Fresh 1948 Mixed	12 Kraft	3	170	66	61	1.6	3.6	33	9.0	70	57	790	46	115	196	51	970	—

[a] Basis oven-dry raw material.
[b] Basis oven-dry screened pulp.
[c] Pentosans = furfurol × factor 0.8.
[d] Samples 998 and 908 dry-screened to remove pith.

Table 4

DATA ON PULPING BAGASSE BY THE NEUTRAL SULPHITE METHOD

Cook No.	Material W = Whole F = Fibre Year—Variety	Cooking conditions: Chemical[a] (per cent)	Time (hr)	Temperature (°C)	Pulp yields[a]: Crude	Screened	Chemical analysis[b]: Ash	Lignin	Pentosans[c] (per cent)	Bleaching: Chlorine consumption single[b]	Brightness Hunter	Bleach yield[a]	Initial freeness S.-R. (ml)	Strength characteristics 500 ml S.-R.: Basis weight 25x40–500 (lb)	Bursting strength (pts/ream-lb x 100)	Tensile strength (g/ream-lb)	Tearing resistance (g/ream-lb x 100)	Folding endurance (Schopper)	Density (g/cc)
	Louisiana																		
923	Lockport F Stored 1941 Mixed	8 Na_2SO_3, 3 Na_2CO_3	2	170	68	60	1.2	5.6	30	12.7	70	56	840	47	90	167	38	220	—
926	Lockport F Stored 1941 Mixed	10 Na_2SO_3, 3 Na_2CO_3	2	170	66	59	1.0	3.4	32	5.9	70	55	840	47	95	180	66	390	—
922	Lockport F Stored 1941 Mixed	12 Na_2SO_3, 4 Na_2CO_3	2	170	64	61	1.4	2.8	32	3.4	70	60	840	47	90	178	44	590	—
	Florida																		
925[d]	Clewiston F Fresh 1948 Mixed	10 Na_2SO_3, 3 Na_2CO_3	2	170	68	57	1.4	3.7	32	9.0	70	49	800	46	121	204	64	1150	—
1077[d]	Clewiston F Fresh 1951 Mixed	10 Na_2SO_3, 3 Na_2CO_3	2	170	67	62	0.9	5.3	30	16.0	70	56	780	47	113	188	63	920	0.87
920[d]	Clewiston F Fresh 1948 Mixed	15 Na_2SO_3, 5 Na_2CO_3	2	170	65	55	—	2.2	33	3.2	70	53	810	46	122	198	53	980	—
	Louisiana																		
1258[d]	New Iberia W Fresh 1951 Mixed	13 Na_2SO_3, 4 Na_2CO_3	2	170	63	54	2.2	2.4	34	6.3	70	52	820	47	83	157	50	160	0.84
1260[d]	New Iberia F Fresh 1951 Mixed	13 Na_2SO_3, 4 Na_2CO_3	2	170	66	58	1.0	2.0	35	5.3	70	56	850	46	101	171	58	410	0.88

[a] Basis oven-dry raw material.
[b] Basis oven-dry screened pulp.
[c] Pentosans = furfurol × factor 0.8.
[d] Samples 925, 1077, 920, 1258, and 1260 dry-screened to remove pith.

Table 5

Data on the pulping of bagasse to produce corrugating medium

Cook No.	Material W = Whole F = Fibre Year	Variety	Cooking conditions: Chemical[a] (per cent)	Time (hr)	Temperature (°C)	Pulp yields[b] (per cent): Crude	Washed	Initial freeness S.-R. (ml)	Strength characteristics 500 ml S.-R.: Basis weight 25 x 40–500 (lb)	Bursting strength (pts/ream-lb x 100)	Tensile strength (g/ream-lb)	Tearing resistance (g/ream-lb x 100)	Riehle ring crush (lb)	Flat crush (lb/sq. in)	Density (g/cc)
	Louisiana														
911	Lockport W 1941	Stored Mixed	5 NaOH 3 CaO	1	98	—	—	510	120	20	45	—	20	—	—
902	Lockport W 1941	Stored Mixed	6 NaOH	5	140	73	71	690	116	50	114	63	34	—	0.68
980	Lockport W 1941	Stored Mixed	8 NaOH	1	98	78	73	660	118	72	139	66	38	—	0.73
978	Lockport F 1941	Stored Mixed	8 NaOH	1	98	80	78	750	114	79	152	64	39	—	0.82
	Florida														
1187	Clewiston W 1953	Fresh F. 31–436	8 NaOH	5	140	61	59	685	118	83	166	62	42	—	0.78
1228	Clewiston W 1953	Fresh F. 31–436	8 NaOH	1	98	70	68	480	116	58 (400 ml)	112 (400 ml)	110 (400 ml)	34 (400 ml)	58 (400 ml)	0.60
1255	Clewiston F 1953	Fresh F. 31–436	8 NaOH	5	140	71	69	770	120	89	144	66	45	—	0.80
1229	Clewiston F 1953	Fresh F. 31–436	8 NaOH	1	98	73	71	680	118	96	173	66	45	76	0.82
1410	Clewiston W 1953	Fresh F. 31–436	12 CaO	1¾	99	—	—	560	117	72	130	70	28	—	0.76
	Hawaii														
1245	Oahu W 1951	Fresh 8560	10 NaOH	1	99	68	66	510	121	76 (400 ml)	131 (400 ml)	76 (400 ml)	36 (400 ml)	64 (400 ml)	0.69
1239	Oahu F 1951	Fresh 8560	10 NaOH	1	99	75	72	730	117	83	146	86	37	66	0.74
1256	Oahu F 1951	Fresh 8560	10 NaOH	5	140	68	67	855	117	90	142	112	40	—	0.80

[a] Basis oven-dry raw material.

Table 6

DATA ON LARGE-SCALE PULPING OF BAGASSE BY THE MECHANO-CHEMICAL PROCESS TO MAKE CORRUGATING MEDIUM PULPS[a]

Material W = Whole F = Fibre		Cooking conditions			Pulp yields[b]		Chemical analysis[c]			Initial freeness S.-R. (ml)	Strength characteristics 500 ml S.-R.				
Year—Variety		Chemical[b] (per cent)	Time (hr)	Temperature (°C)	Crude (per cent)	Screened (per cent)	Ash (per cent)	Lignin (per cent)	Pentosans[d] (per cent)		Basis weight 25x40–500 (lb)	Bursting strength (pts/ream-lb x 100)	Tensile strength (g./ream-lb)	Tearing resistance (g./ream-lb x 100)	Riehle ring crush (lb)
Florida															
Clewiston W 1952	Fresh F. 31–436	12 NaOH 8-ft. hydrapulper	1.5	99	Pulp passed over decker to remove pith and dirt		0.66	7.4	34	710	119	96	163	78	36
Clewiston F 1952	Fresh F. 31–436	16 NaOH 8-ft. hydrapulper	1.2	99	—	—	0.60	7.8	34	820	118	111	182	80	35
Hawaii															
Oahu F 1952	Fresh 8560	12 NaOH 8-ft. hydrapulper	2.0	99	—	—	1.03	11.7	33	845	119	90	161	86	34
Oahu F 1952	Fresh 8560	16 NaOH 8-ft. hydrapulper	1.5	99	—	—	—	—	—	865	120	94	164	94	36
Mexican															
F 1952	Stores Mixed	12 NaOH 10-ft. hyrapulper	1.0	94	—	—	1.1	8.4	38	700	118	88	162	62	39
Commercial semi-chemical corrugating pulp		—	—	—	—	—	1.5	14.9	22	605	118	83	148	79	31
Commercial southern kraft liner pulp		—	—	—	—	—	1.0	7.1	13	890	116	133	192	197	31

[a] Carried out by The New York College of Forestry at Syracuse. [b] Basis oven-dry raw material. [c] Basis oven-dry screened pulp. [d] Pentosans = furfurol × factor 0.8.

Table

COMPARISON OF RESULTS OF PULPING BAGASSE FIBRE BY CONVENTIONAL PRESSURE

	Material		*Cooking conditions*			*Pulp yields*[b]	
Cook No.	*Variety*	*Method*	*Chemical*[a] *(per cent)*	*Time (hr)*	*Temperature °C*	*Crude*	*Screened*
1249	Florida, variety F. 31-436, CD. 9941	Pres.	13 kraft	1	170	61.9	55.8
1232		*M-C*	14 NaOH	1	99	69.6	65.0
998	Louisiana, CD. 8953	Pres.	12 kraft	2	170	63.3	56.6
985		*M-C*	15 NaOH	¾	98	72.1	55.4
1417–1418	Puerto Rican, CD. 10081	Pres.	13 kraft	1	170	58.6	49.2
1363		*M-C*	16 kraft	¾	99	69.2	58.1
1397–1423	Florida, variety F. 31-436, CD. 10366	Pres.	13 kraft	1	170	62.0	57.8
1394		*M-C*	14 NaOH	¾	99	69.3	61.1
909	Florida, CD. 7892	Pres.	12 kraft	2	170	66.0	60.6
921		*M-C*	15 kraft	¾	99	71.4	58.0
1147	Hawaiian, CD. 9333	Pres.	8 kraft	2	170	70.1	36.5
1148			10 kraft	2	170	66.9	44.3
1149			12 kraft	2	170	64.0	55.2
1150			14 kraft	2	170	61.4	56.4

[a] Basis oven-dry raw material.
[b] Basis oven-dry screened pulp.

Table

NEWSPRINT PAPERS MADE FROM

		Furnish			
		Bagasse	*Wood sulphite*	*Groundwood*	*Other*
Place made	*Run No.*	*(per cent)*			
USDA—FPL Madison, Wisconsin	MR-3652	30	—	7 spruce-aspen	—
	MR-3654	30	—	70 spruce-tupelo	—
	MR-3653	—	20	80	—
New York State College of Forestry, Syracuse, N. Y.	MR-9	30	—	70	—
	MR-8	—	20	80	—
Peru		80	10	—	10 waste
India		70	—	—	30 bamboo
U. S. Dept. of Commerce, National Bureau of Standards, Washington, D. C.	1	100	—	—	—
	2	100	—	—	—
	3	100	—	—	—
Commercial news	—	—	30	7	—

7

METHODS AND THE MECHANO-CHEMICAL PROCESS TO PRODUCE FINE PAPER PULPS

Chemical analysis [b]: Ash (Per cent)	Lignin (Per cent)	Pentosans [c] (Per cent)	Bleaching: Chlorine consumption single [b]	Brightness Hunter	Initial freeness S.-R. (ml)	Strength characteristics 500 ml S.-R.: Basis weight 25 x 40-500 (lb)	Bursting strength (pts/ream. lb x 100)	Tensile strength (g/ream-lb)	Tearing resistance (g/ream-lb x 100)	Folding endurance (Schopper)	Density (g/cc)
1.3	3.2	32.0	8.7	70	810	47	115	186	60	680	0.89
1.2	5.9	34.0	12.0 [d]	70	850	47	121	193	59	910	0.89
1.1	4.0	34.5	8.6	70	855	47	96	173	83	740	0.87
1.4	6.1	31.7	—	—	810	46	90	166	82	380	0.83
1.4	4.0	33.3	12.2	70	835	47	102	182	48	615	0.89
1.3	6.5	33.6	14.3	70	790	46	93	173	64	480	0.83
1.4	3.4	33.6	7.3	70	835	47	126	206	64	880	0.90
1.0	6.0	32.9	12.6	70	780	46	105	174	63	660	0.87
1.6	3.6	33	9.0	70	790	46	115	196	51	970	0·96
—	5.1	36	12.5	70	780	46	106	188	44	980	0.66
1.6	9.3	31.3	25.4 [d]	70	830	47	70.5	151	52	150	0.80
1.2	6.9	31.5	13.0 [d]	70	840	47	79.5	162	59	270	0.80
1.0	4.4	31.8	6.4 [d]	70	850	47	84.5	165	62	350	0.81
1.0	2.6	32.9	3.4 [d]	70	850	47	88.5	154	62	480	0.84

[c] Pentosans = furfurol × factor 0.8.
[d] Three-stage bleach.

8

BLEACHED BAGASSE IN WHOLE OR PART

Basis—weight 25 x 40–500 (lb)	Basis—weight 24 x 36–500 (lb)	Bursting strength (lb. sq. in.)	Tensile strength k-15 mm width MD	Tensile strength CD	Tearing resistance Elmendorf MD	Tearing resistance Elmendorf CD	Folding endurance MD	Folding endurance CD	Density (g/cc)	Caliper (.001 in)	Opacity contract ratios (Per cent)	Ash (Per cent)
39.5	34.1	12.7	3.9	2.2	25.6	28.8	8	3	0.53	4.1	—	—
30.0	25.9	9.1	3.2	1.7	22.4	25.6	3	1	0.40	4.1	—	—
39.9	34.5	11.2	3.9	2.0	28.8	33.3	6	3	0.49	4.5	—	—
39.6	34.2	9.5	3.1	2.1	16.0	17.3	3	2	0.58	3.8	(85 Brt.) 97	8.0
39.0	33.7	8.0	2.5	1.8	19.8	20.5	2	3	0.55	3.9	97	5.4
42.0	36.3	15.4	4.1	2.3	22.7	25.6	19	8	0.72	3.2	—	—
45.0	38.9	12.6	3.8	2.9	32.0	37.0	10	8	0.77	3.2	—	1.2
41.4	35.8	11.0	3.9	2.1	29.0	43.0	13	7	—	3.2	(MgO) 92	13.2
38.4	33.4	8.0	3.0	1.8	19.0	18.0	7	5	—	2.9	78	5.4
49.5	42.8	13.5	4.1	3.0	25.0	24.0	12	11	—	4.1	82	14.9
37.6	32.5	7.0	2.4	1.2	19.0	23.0	5	1	—	3.5	90	0.24

Table 9

PHYSICAL PROPERTIES OF CORRUGATING MEDIUM AND LINER BOARDS MADE UNDER U.S. DEPARTMENT OF AGRICULTURE RMA CONTRACT WITH NEW YORK STATE COLLEGE OF FORESTRY, 1952

				Strength characteristics 500 ml S.-R.									
		Components in per cent		Basis weight		Bursting strength	Tensile strength		Tearing resistance		Riehle ring crush		
				1,000 sq. ft.	25x40-500		With	Across	With	Across	With	Across	
Designation	Kind of board	Bagasse	Other	(lb.)		pts./ream-lb x 100)	(g/ream-lb)		(g/ream-lb x 100)		(lb.)		Caliper (.001 in)
FFC	Corrugating	85 Florida fibre 1952 F. 31-436	15 waste corrugating	29.7	118	71	143	102	98	105	31	22	8.3
HFC	Corrugating	85 Hawaiian fibre 1952 8560	15 waste corrugating	33.1	106	74	104	115	165	95	32	24	8.8
HFCX	Corrugating	100 Hawaiian fibre 1952 8560	None	33.1	115	68	170	104	91	96	39	31	9.8
CC	Corrugating	85 commercial semi-chemical pulp	15 waste corrugating	30.3	105	70	168	99	92	111	35	24	9.2
GC	Commercial corrugating	—	—	41.3	143	53	143	33	127	199	32	18	11.0
FFL	Liner	50 Florida fibre 1952 F. 31-436	50 virgin southern kraft	42.7	148	88	188	91	166	218	40	29	11.0
FFLX	Liner	100 Florida fibre 1952 F. 31-436	None	41.3	143	85	167	110	90	94	40	36	9.8
FFLY	Liner	25 Florida fibre 1952 F. 31-436	75 virgin southern kraft	37.0	129	97	189	92	195	191		27	9.6
HFL	Liner	50 Hawaiian fibre 1952 8560	50 virgin southern kraft	44.7	155	81	164	94	170	221	54	40	12.7
CL	Liner	—	100 virgin southern kraft	39.7	138	100	191	80	212	272	39	26	10.6
GL	Commercial kraft liner	—	—	43.0	149	88	158	86	262	313	32	26	13.2

Table 10

DATA ON LARGE-SCALE PRODUCTION OF FINE BLEACHED AND UNBLEACHED PULPS FROM BAGASSE FIBRE BY THE MECHANO-CHEMICAL PROCESS

Cook No.	Material: Year — Variety	Cooking conditions: Chemical[a] (per cent)	Time (min).	Chemical analysis[b]: Ash (per cent)	Lignin (per cent)	Pentosans[c] (°C)	Brightness Hunter (per cent)	Initial freeness S.-R. (ml)	Strength characteristics 500 ml S.-R.: Bursting strength (pts/ream-lb x 100)	Tensile strength (g/ream-lb)	Tearing resistance (g/ream-lb x 100)	Folding endurance (Schopper)	Density (g/cc)
1062	Clewiston, Florida Separated fibre 1950–51 Mixed	15 NaOH	60	—	—	—	—	750	116	192	48	980	—
1062–1075	Composite bleached at Forest Products Laboratory	15 NaOH	60	1.3	5.7	33	—	730	115	186	56	1060	0.89
1062–1075	After bleaching 3 stage at FPL	11 chlorine	—	0.6	0.3	34	81	700	121	190	58	1120	0.97
1139	Clewiston, Florida Separated fibre 1950–51 Mixed	15 NaOH	50	—	—	—	—	800	116	192	56	930	—
1140–1141	Screenings from Cook No. 1139 Cooked separately	10 NaOH	45	—	—	—	—	890	116	192	66	700	—
New York College of Forestry	Clewiston, Florida Separated fibre 1952 F. 31-436	16 NaOH, 8-ft hydrapulper	60	1.4	6.1	32	—	840	115	184	56	805	0.89
New York College of Forestry	After bleaching 3 stage at St. Regis Paper Co.	13 chlorine	—	0.2	1.4	33	80	770	126	207	59	1480	0.92

[a] Basis oven-dry raw material.
[b] Basis oven-dry screened pulp.
[c] Pentosans = furfurol × factor 0.8.

Table 11

KRAFT BAG AND WRAPPING PAPERS MADE IN PART FROM UNBLEACHED BAGASSE PULP

Place made	Kind of paper	Run No.	Furnish: Bagasse (per cent)	Wood sulphite (per cent)	Physical characteristics: Freeness Canadian (ml)	Basis weight 25 x 40–500 (lb)	Bursting strength (pts/ream lb x 100)	Tensile strength k–15 mm width: MD	CD	Tearing resistance: MD (g)	CD (g)	Folding endurance (Schopper): MD	CD	Density (g/cc)	Caliper (.001 in)
USDA—FPL Madison, Wisconsin	Bag	MR-3643	25	75		54.0	96.7	11.9	4.5	58.9	78.1	960	400	0.75	4.0
		MR-3645	—	100		51.8	75.9	11.3	3.5	74.2	106.0	1100	140	0.70	4.1
	Wrapping	MR-3644	50	50		98.7	101.0	21.1	8.7	122.0	137.0	1200	800	0.79	6.9
		MR-3646	—	100		104.0	78.4	18.5	7.1	227.0	273.0	—	—	0.71	8.1
Peru	Bag	8P	67	28		48.0	49.0	6.2	2.9	41.4	54.0	150	27	0.62	4.3
	Wrapping	3C	55	15		107.0	42.0	10.8	6.5	111.0	140.0	—	—	0.64	9.5
Handsheets prepared from blends of American wood kraft and Celdecor bagasse pulps															
Philippine[a]			—	100	630	39.2	89.0	5.6	—	107.0	—	2970	—	0.55	3.9
			100	—	510	36.9	87.0	5.1	—	51.0	—	450	—	0.46	4.5
			50	50	520	39.2	101.0	7.1	—	53.0	—	1610	—	0.45	4.8
			75	25	460	39.8	89.0	6.3	—	47.0	—	2170	—	0.52	4.2

[a] "Paper from bagasse," *World's Paper Trade Review 134* (13), 860, Oct. 5, 1950.

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ECONOMIC AND OTHER FACTORS TO BE CONSIDERED IN THE USE OF SUGAR CANE BAGASSE AS A RAW MATERIAL FOR PULP AND PAPER MANUFACTURE[1]

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I. Introduction

The delay in utilizing sugar-cane bagasse as a raw material for the manufacture of cellulose pulps is due, to a large extent, to the belief by both the sugar and cellulose industries that it was either a waste or a low-grade by-product. This thinking led to an underestimation of the importance of economic and technological factors. Not until about thirty years ago did any industry, based on the utilization of bagasse, make a lasting success. This was the manufacture of thermal and sound insulating products from bagasse in Louisiana. Fifteen years ago the first successful manufacture of paper from bagasse was started.

The sugar industry in general uses bagasse as a fuel. Over the years improvements have been made in sugar-house operation, particularly in heat economy, so that in the manufacture of raw sugars, in well-operated houses, a surplus of bagasse up to 30 per cent or more

[1] A shortened version of the original paper, ST/ECLA/CONF.3/L.5.2.

exists. Generally this excess is burned merely to dispose of it. With the manufacture of refined sugar and/or alcohol as processes associated with the sugar mill, there is little or no surplus. The fibre content of cane varieties also governs the extent of excess over fuel requirements. In any event, a sugar company has generally been interested in a market either for excess bagasse or for all its bagasse, so as to replace it with gas or oil and obtain a small bonus besides. It has been demonstrated that gas or oil are better fuels and make for improved sugar-house operations. But sugar companies, with few exceptions, have had no interest in upgrading the bagasse, nor in the problems of handling, storing, and converting it into other products.

On the other hand, industries purchasing bagasse have had little knowledge of the problems of the sugar industry and were only interested in obtaining a stable source of raw material at as low a price as possible.

Experience in the successful utilization of bagasse, except for fuel, has shown that this loose buyer-seller interest must be strengthened by closer association. The Louisiana company first successfully using bagasse became financially interested in sugar manufacture so as to insure supply, improve quality, and lower handling and storage costs of its bagasse. When manufacture of insulating products was undertaken, first in Australia and later in Hawaii, sugar interests initiated, financed, and managed the developments. Likewise, the first successful manufacturer of paper from bagasse operated a sugar company.

Today the interest in using bagasse to make paper and board has become very real again, but it is evident that neither paper nor sugar manufacturers have a clear understanding of each other's problem and do not appreciate the full significance of the economic and technological factors under their joint control that may contribute to lasting success in both industries. Much new information is available, particularly new technical information. A full discussion may enable new ventures into bagasse utilization to be made with the least risk of failure.

II. Factors relating to bagasse production

Bagasse is the fibrous residue left after the cane is crushed and the sugars and soluble materials are extracted. It is not a uniform material. It varies both in physical and chemical properties from locality to locality, from mill to mill and from season to season. Fresh bagasse is different from stored bagasse not only in physical and chemical but also in pulping characteristics.

A. *Variations due to cane culture*

Like all agricultural crops, yield and quality of cane are dependent on cane variety as modified by local soil conditions, practices of cultivation, fertilizer application, rainfall and climatic changes. In many countries the sugar-cane plant is harvested before it reaches maturity, the growing season being 9-10 months, but in Hawaii the growing season is about 22 months. The lignin content of plants increases as they approach maturity. Hence the lignin content of Hawaiian cane varieties is generally higher than those from other localities, and Hawaiian bagasse is more difficult to pulp, largely on this account. Sugar cane is subject to many diseases and insect attack, and constant study is under way to develop better and more resistant varieties of cane.

The sugar planter desires a cane giving the highest yield of sugar per acre. Very high yields of cane and of sugar have been recorded. Verified yields of 90 to 110 tons of cane per acre have been reported from numerous countries. The per cent fibre, including pith, in cane varies from less than 10 per cent in some varieties to as much as 17 per cent in others. Large-barrelled canes contain more pith and generally less fibre than small-barrelled canes. The small-barrelled canes have an exceedingly hard rind, are generally resistant to borer attack, and mill differently than the softer canes.

The yield of cane can vary considerably from year to year. When varieties become subject to disease the situation may become disastrous. For example, in the late 1920's culture of cane in Louisiana was almost wiped out. The introduction of new P.O.J. varieties, developed by Brandies of the United States Department of Agriculture, and of improved fertilizer and cultural practises, restored the industry. To the variable factors mentioned there must be finally added that of sugar quotas.

All of these factors are related to the *quantity* of potential bagasse. Since it is clear from this discussion that numerous conditions, not always under control of the sugar planter, may cause the total or surplus bagasse to fluctuate annually in any locality, careful surveys must be made before locating paper mills to use bagasse. The past history of bagasse availability should be reviewed; and the production of the contemplated mill should be somewhat less than evident bagasse availability. In addition, plans should be made to provide ample stored bagasse to meet such contingencies as a partial crop failure, or loss of a portion of stored bagasse through fires.

B. *Variations due to cane-harvesting practices*

Harvesting practices also have some effect on the quantity of bagasse produced, but most importantly they affect *quality*.

To have efficient sugar-house operation the cane should be topped and the leaves removed before it is ground. The growing top of the cane contains a high proportion of glucose and if this part of the cane is also ground the yield of crystallizable sucrose is reduced and that of molasses increased. Leaves are generally referred to as trash, and, depending on harvesting practices, tops are sometimes included in trash. Table 1 gives an idea of the amount of tops and trash associated with cane ready for grinding.

Table 1

Approximate tonnage of waste constituents from annual sugar crop, South Africa

Constituent	*1,000 long tons*	*Per cent at moisture content produced*
Sugar cane	5,000	100.00
Trash	575	11.50
Tops	386	7.75
Bagasse	1,900	38.00
Filter cake	250	5.00
Molasses	162	3.324

Dymond (1) also states that the tops from 5 million tons[1] of cane would contain 34,800 tons[1] of sugar, which

[1] Long tons.

at a 90 per cent extraction would produce 3.76 million gallons of alcohol. He says that, as silage, the tops from a 40-ton[1] crop on one acre would provide the feed requirements of 200 mature animals. Table 2, also from Dymond (1), gives an estimate of the important fertilizer constituents of these two materials.

Table 2

HUMUS AND FERTILIZER CONSTITUENTS OF CANE TOPS AND TRASH IN TERMS OF DRY SUBSTANCE

Constituent	Trash	Tops
	Per cent	
Humus	9.23	6.92
Nitrogen	0.27	0.90
Total ash	7.29	7.46
P_2O_5	trace	2.70
K_2O	3.20	23.30

Methods of disposing of the leaves and tops varies in countries and on plantations, depending partly on the availability of cheap labour. In any case these practices influence the quality of bagasse. In many localities it is the practice to burn the leaves from the standing cane in the field. This method has long been under debate, because of possible effects on purity of the cane juices and of the reported lessened vigour of the following ratoon crop cane. Where hand labour is available at low cost, the leaves and tops are removed by hand in the field and the trash is generally added back to the soil. The shortage and high cost of hand labour mean that cane growers must rely more and more on mechanical harvesters. Machine-cut cane carries much more trash than hand-cut cane, even when the trash is burned. This means that inert fibrous material must be passed through the mills along with considerable dirt or stone. The result is more sugar lost in the bagasse and a lower purity of juice; a slower grinding rate, due both to the greater volume of fibre and to the extra time for clarifying the juice; more filter muds to handle; and increased wear and tear on equipment. It has been stated that in Louisiana where a factory grinds a mechanically harvesting cane containing 10 per cent of trash, not unusual in that location, the total losses that can be charged to trash may amount to $1.00 per short ton of cane ground (2). Because of the structure of the cane leaves, they have very little value for making any but the lowest grades of paper.

From the standpoint of economical sugar manufacture, the high content of trash in mechanically harvested and loaded cane is bad enough, but equally bad is the large proportion of soil, which creates great difficulties in the mills, fouls the juices, and imposes extra loads on clarifiers and filters. In Hawaii this dirt problem has become even more serious. A method of harvesting has been developed which consists in breaking off the cane near the ground by means of bulldozers and loading the cane, without removal of leaves or tops, into trucks for transport to the sugar mill. This has caused the development of extensive cleaning plants to remove the excessive rock, dirt and trash before grinding. In Hawaii the topping of the cane is not so important, because of its greater maturity. Evidently the interest of the sugar-mill operator is to receive or prepare cane as free from trash and dirt as possible before grinding.

As for paper or board manufacture, while a small amount of dirt in bagasse might be tolerated in low quality board, in bleached and fine papers its presence in the bagasse will be a continual source of trouble and expense. Trash lowers the quality of bagasse: leaf fibre is suitable only for low-grade board products. However, it should be observed that Singh (3), in describing a new development in India, says that "the trash, which represents 12 to 15 per cent of the total weight of the cane, is manufactured into paper and cardboard in the estates' own pulping mill".

When the leaves are burned from the cane the ends of many of the leaves where they join the stalk remain as carbonized material. In the ordinary washing and milling processes these carbonized fibres remain in the bagasse. Buds at the nodes of the cane are carbonized in the same manner and carry through into the bagasse. The presence of carbon in the bagasse, particularly when bleached pulps are to be made from it, is much more serious than the presence of dirt. Generally the dirt, where it is freely suspended, may be removed by sufficient separation treatments; but the carbon, having a density close to that of the fibre and being friable, is almost impossible to remove from the pulp.

C. *Variations due to milling practices*

A description of the characteristics of the fibrous elements of the cane stalk as it enters the mill is of interest. The outside of the stalk comprises a relatively tough rind. The inside consists of soft medullary tissue in the cells where the sugar is deposited. Lengthwise through this tissue run numerous fibrovascular bundles of various sizes so placed that the smallest are packed near the outside and the larger ones, less abundant, are distributed towards the centre. The rind is formed of thick-walled, elongated cells of sclerenchymatous fibres. The fibrovascular bundles comprise groups of fibres and ducts. The pith, or parenchymatous cells, is short, broad, and of low resistance. These cells group around and adhere both to the fibrovascular bundles and the rind fibres. The outside of the rind often appears glassy, carries a coating of wax, and may be of a number of colours.

At intervals in the length of the stalk, which vary in accordance with conditions of growth of the cane, the fibrovascular bundles send branches outwards thereby forming a portion of dense tissue called the node. Neither the pith nor the tissue concentrated in the node is suitable for paper making (4).

Extraction of juice is only possible when the cells and tissue of the cane are ruptured. This rupturing action can be advanced by shredding or using knives, but has to be completed under a compression exercised between grinding rolls. The purpose of the extracting rolls is to pass the fibre and to hold back the juice contained therein. This extraction can only be achieved in high degree when the compressed bagasse between the coacting rollers forms a juice-tight seal, so that the extracted juice cannot be re-absorbed by the bagasse which has passed the maximum pressure between the rolls. The completeness of extraction depends on the fineness of the bagasse and the quantity of juice it contains. Since the bagasse will always hold a certain amount of juice or liquor by capillarity, 100 per cent extraction is impossible to attain.

The first set of rolls after the knives, or shredder, are crushers. Even if the cane has been previously shredded, its degree of fineness produced by the crusher

[1] Long tons.

is not very great, but the quantity of juice is five or six times that of the fibre and normally a 40 to 60 per cent extraction is obtained at the crushing rolls. This relieves the work of the first set of rolls of the cane mill. All of the rolls, including the crusher rolls, are maintained under hydraulic pressure. Fresh water, called maceration water, is added to the bagasse to obtain the maximum extraction. Shredders, knives, crushers, and cane mills vary greatly in design, width and length. Such milling equipment may vary from a crusher with a cane mill of nine rolls, to a complete chain of knives, or shredders, crusher, and a cane mill of eighteen rolls. The subject of juice extraction is intricate and much attention has been devoted to the engineering problems involved.

The physical character of the cane, whether hard or soft, has a pronounced effect on the character of bagasse. It is evident that bagasse ground and extracted with the most complete milling equipment will be composed of shorter fibre bundles than the same material milled on smaller, lighter equipment. Heavy milling equipment will loosen more pith from the fibre than light milling machinery. The shredding operation will greatly assist in loosening pith and carbon particles as well as increasing extraction. Since the bagasse acts as a filter mat for the juice in the extraction process at each set of rolls, the dirt and carbon will be worked into the bagasse more thoroughly on a big mill than on a small one. Dirt on the cane consists of fine silt or powdered soil and is spread over the surface of the pith and the fibre more or less uniformly during grinding. The surface area of pith as compared to that of the fibre is greater in any sample of bagasse, so that pith will pick up and hold a proportionately larger amount of dirt and carbon particles. In some mills, muds from the filters are spread on the bagasse as it is conveyed from the cane mill. This practice must be stopped if bagasse is to be pulped. Generally some of the bagasse from the cane mill is passed over rotating or vibrating screens to separate loose pith and fine fibres which are used to assist in the more rapid settling and filtration of the juice. This practice is desirable.

The average amount of maceration water added is said to be 100 parts to 140 parts of bagasse. The moisture content of the bagasse from the cane mill may vary from a low of 41 to approximately 50 per cent, and often runs about 48 per cent.

Bagasse is only one of the products produced in the sugar house in processing cane. Table 3 gives data calculated by Martin from reports by Grayson(6) of the United States Department of Agriculture on the average composition of materials obtained in processing a ton of sugar cane in the 1948 crop.

Table 3

AVERAGE COMPOSITION OF MATERIALS OBTAINED IN PROCESSING A TON OF SUGAR CANE IN 1948 CROP

Based on recapitulation of final reports

Cane................	1 short ton	(2,000 lb.)			
				(Fibre	229 lb.
Fibre................	229 lb.	Bagasse	648 lb.	(Non-sucrose	11
				(Sucrose	19.9
Sucrose..............	191 lb.	(Raw sugar	146.2	Sucrose	140.3
less undetermined...	5.4	(Press cake	91.3	Sucrose	3.8
		(Molasses	84.0	(Sucrose	21.7
				(Invert	20.0
	185.6 lb.			(Nonsugar	23.5
		(		(Acon. Acid	2.0
Non-sucrose..........	63 lb.	(	Press cake	Wax	0.8
				Minor const.	0.5

It will be noted that bagasse comprises about one-third the weight of the cane, and slightly more than the raw sugar produced. Keller(5) says that probably 95 per cent of the bagasse produced annually is burned. There has been little incentive for most sugar mills to do more about improving quantity or the quality of the bagasse than absolutely necessary for their sugar operations.

This discussion shows that many factors may affect the quantity and quality of bagasse available at a sugar mill. Like most crops, in the culture of cane attention has been directed almost entirely to the fruit produced, sucrose, and practically none to anything excepting the nuisance value of the by-products.

III. BAGASSE AS A RAW MATERIAL

A. *Fuel value*

Only a portion of the bagasse produced is waste material, in the sense that its disposal involves an expense. Bagasse is a high bulk material, having a weight, as produced, of about 10 lb/cu.ft., and is ordinarily conveyed directly to the boilers or to the loose-storage pile, which serves as a standby for fuel when the cane mill is not operating. Bagasse is a good low-grade fuel. With present boiler design, there is generally more bagasse produced than is needed for all of the sugar house fuel requirements. If no other use is made of the surplus bagasse, it is used in the furnaces, resulting in lower efficiency, and greater expense, or it is stored in piles which are later burned. Gastrock and Lynch(7) reckon that one short ton (2,000 pounds) of bagasse, 50 per cent moisture content, has a fuel value of 6 million BTU equivalent to 6 MCF of 1,000 BTU gas, or one barrel of fuel oil (42 gallons). Dry bagasse would have twice this fuel value. In some places bagasse is baled for use as fuel after the grinding season; during storage its fuel value increases due to loss of moisture. In Java(8) briquettes were made from bagasse to supply fuel for cooking and other purposes.

The cost of fuel to replace bagasse in sugar-house operation will vary widely depending on location, and availability and cost of the fuel. Louisiana is particularly favoured with low-cost gas and oil, and this may have been one reason why it was possible to start a successful industry based on bagasse as a raw material. On the other hand, gas and oil as fuels are much to be preferred in sugar-house operation, and no sugar house that has used either of these fuels will of its own choice return to the use of bagasse for fuel.

In making economic surveys for the location of industries based on the use of bagasse, the question of fuel requirements deserves the most careful consideration.

B. *Present uses, other than as fuel*

Efforts to make valuable products from bagasse have occupied many minds for more than a century. The results of all this work are meagre indeed, and, even now, less than one million short tons of bagasse, dry basis, are used annually in the world for any purposes other than fuel at the sugar mill. Building material products are now made from bagasse in Louisiana, Hawaii, Australia, England, and, before the war, in Formosa. The technology of these operations is now well understood. Several companies are prepared to build mills for this type of manufacture, so that its establishment in still other countries depends only on solving sales and economic problems. In Louisiana and Florida, bagasse is processed into chicken litter, and mulch to replace sphagnum moss; a business that is not only proving profitable, but also shows increasing sales volume year by year. For this purpose the bagasse as it is produced is dried, using rotary driers, screened to remove as much pith, fine fibre, and dirt as possible, and baled. In some mills the moist bagasse is also screened before drying; after drying, they pass the dried material through a coarse hammer mill to loosen more pith before final screening. It is possible to operate such a plant after the grinding season by using baled, stored bagasse. The material prepared from fresh bagasse is brighter in colour, less friable, and cleaner than that made from stored bagasse. The cost of preparing the mulch and litter from fresh bagasse is lower, in spite of the cost of drying.

In making mulch and litter, a by-product of mixed pith and fine fibre is obtained. By screening this mixture, pith of a low density and relatively high absorption is obtained for use in the manufacture of dynamite. Mixtures of pith and fine fibres are used to absorb molasses intended for feeding purposes. Some sugar mills find the manufacture of mulch, litter, and feed materials so profitable that they do not seem to be greatly interested in using bagasse for paper manufacture.

Early failures to manufacture paper from bagasse can be attributed to a lack of appreciation of the technological and economic factors involved. In some cases the plants were too small for economical operation; in others the handling costs and imperfect methods of storing bagasse were at fault. In the late 1930's interest revived in the possibility of making paper from bagasse. By this time the problem of storing bagasse was solved, and methods for economical baling and handling had been developed. A better understanding of the technology of pulp manufacture had been gained in many laboratories.

At the present time, ten paper mills are known to be operating to make pulp from bagasse. Most of these mills blend the bagasse pulp with wood or bamboo pulps to make a variety of papers or boards. Three mills, in the Argentine, the Philippines, and in India, use the Celedcor process to make bleached pulp, and another is beginning operations in Brazil. Two mills in Peru use a modified kraft process, making board, and a wide variety of papers, including some newsprint for the Peru market. A mill in Formosa is making unbleached and bleached bagasse pulp by the neutral sulphite process. Two small mills in the Argentine are making board from soda-process pulp, and another in Colombia from lime-process pulp. Finally, a new mill has started in Mexico producing pulps and paper by the mechano-chemical process.

In all these mills, with the possible exception of the mills in Colombia and in Argentina, as much pith as possible is removed from the bagasse before pulping.

C. *Storage and handling*

In most countries sugar cane manufacture is seasonal. Since a paper or board mill should operate the year round, provision must be made to store fibre for somewhat more than a year to meet all contingencies.

As noted, bagasse contains about 50 per cent moisture and from 2 to 5 per cent sugar. The soil from the cane fields inoculates the bagasse with all types of microorganisms. Unless strong chemicals that prevent the growth of the organisms are intimately mixed with the bagasse at once, or unless it is immediately dried to about 15 per cent moisture content, it is impossible to prevent fermentation processes from being initiated in it. The storage of this fibre without serious loss in quality and quantity posed an extremely difficult problem.

Research by the Louisiana company starting the manufacture of insulating-board products led to a successful solution to this problem. While the methods developed have been described by Lathrop and Munroe(9) and are detailed in their U.S. patent 1,920,129, recent published discussions of storage methods have not clearly brought out the necessary principles which apply, nor some precautions which should be observed.

During the first grinding season in 1921 that the company operated, part of the bagasse was blown into loose piles and part was baled. The material in the loose piles underwent severe rotting in a period of two to three months. It was later established that a wood-destroying toadstool was largely responsible for this. The baled material was stored in uncovered piles and an examination of many bales stored for the full season showed considerable evidence of rot and some of the bales were blackened on the outside as though they had been carbonized. Previous attempts to store baled bagasse in Louisiana had resulted in fires due to spontaneous combustion. It was estimated at that time that the loss of bagasse during a season's storage was about 30 per cent, a figure which was later substantiated.

A research programme lasting about five years was required to solve the storage problem. Unfortunately, it was found that results obtained by experimenting with small piles were quite misleading. During the final year of the investigation the research department supervised storage of the entire production of one of the large sugar mills on an experimental basis. Every bale was weighed in and out of the piles. Exact labour costs were kept, and in some cases whole piles of 500 tons or more of fibre were run through the board mill to determine the effect of a particular storage procedure on the quality of manufactured product.

Due to the presence of sugar, moisture, and yeasts in the bagasse, the sugar is fermented to alcohol in the course of a few hours, and in turn in the presence of bacteria and oxygen, the alcohol is fermented to acetic acid. Both fermentations produce a great deal of heat, and large volumes of carbon dioxide are also produced by the alcoholic and other fermentations which follow the two mentioned. It was observed that if the moist bagasse was baled promptly and placed in large piles, the temperature inside the piles rose to 60°C in the course of a week or so. At the same time, the gas given off at this high temperature by the fermentations reduced the moisture content of the bales rapidly. At this temperature growth of many bacteria, fungi, and other organisms that would destroy the fibre at lower temperatures was stopped. It was found that the interior mass of bagasse took about 3 months to cool to normal air temperature. It was obvious that if the bales were piled so as to provide air channels in the pile, the moisture could escape more freely and the material would dry out faster.

When the bagasse is dried to about 20 per cent moisture content, danger of rotting is practically eliminated. There were two other reasons for piling in this fashion: One was to avoid local heating that would bring about spontaneous combustion, and the other was to prevent the action of the hot acetic acid from making the fibre unsuitable for pulping. If the bales were piled too close or if ventilation channels were clogged, due to loose bagasse, it was noted that some fibre would have a coffee-brown colour, an acid odour and taste, and would be brash and brittle and very difficult to pulp.

In locations where piles of stored bales would be subject to only a little rain, the method described would be sufficient, but in Louisiana there are many rains. Two other provisions had to be made to cope with rains. One was to place a roof over the piles. The most practical one was made from galvanized iron panels which roofed the piles like shingles. The panels were dipped in asphalt to withstand the corrosive action of the acetic acid in the vapours rising from the piles. These panels, kept properly coated with asphalt, have lasted for twenty years or more. It was found that tarpaulins, or other protective covering placed over the top of the pile and held down over the sides were not suitable since the water ran down the tarpaulin and into the pile. Furthermore, these coverings lasted only for a year or so.

It was necessary also to protect the outside bales from rotting due to wetting by rains. For this purpose, it was found that a small amount of boric acid placed in a continuous layer on the outside top edge of each bale on which the under edge of the next bale rested, as the pile was made, supplied sufficient fungicide to effectively stop the growth of destructive microorganisms. Boric acid was also spread over the top bales because of the drip of condensed moisture that took place at night from the under side of the metal roof. Piles were only erected on cleaned, slightly raised, well-drained soil. Cinders should not be used as a base. All of the precautions noted are necessary, and if properly used the loss of fibre on the dry basis during storage of 18 months should not exceed 10 per cent. Furthermore, the fibre will be uniformly free from badly rotted areas. Borax can be used instead of boric acid, and at present a product, borascu, $Na_2B_4O_7 3H_2O$, is available. More recently the use of boron compounds to preserve straw in storage has been adopted by the American strawboard industry.

Wet bagasse is hard to bale and balers built for cereal straws and such dry residues are not sufficiently strong and rugged. Several makes of balers are available, the latest model being provided with mechanisms for automatic wire tying. A single baler of this type has a capacity of about 200 tons of bagasse in twenty-four hours. In the United States, in Peru, and in Mexico the standard-size bale is 19" x 22" x 36" long and weighs wet, about 250 lb; dry 125 to 135 lb. It is noted that plants using the Celdecor process in the Philippine Islands and in India make bales 12" x 12" x 24" long containing 90 lb of wet bagasse. The making and handling of the smaller bales is more costly than that of larger bales, unless very low-cost labour eliminates the possibility of mechanical handling.

It will be found that after the bales are formed and tied they will expand in volume. In the early days of the industry this resulted in the breaking of many wire ties, with the result that much loose bagasse had to be handled from the storage piles. The solution to this problem was to obtain baling wire having a high elastic limit. After the bales have been stored for some months and have dried out, the material compacts into a rather hard mass, which requires some effort to break down to loose fibre for pulping. This can be done with hand labour using pick axes, or with bale breakers. The stored material is generally extremely dusty and is preferably treated to remove the dust before pulping. The wires, removed from bales, should be carefully collected since pieces of wire can cause many hand and foot injuries. Labourers should be given protection against bagasse dust, since there have been cases of lung injury due to exposure to it.

Baling, storing, and handling bagasse are expensive operations. Every effort must be made to eliminate unnecessary work. Experience has shown that the operations can be highly mechanized. Bagasse piles are about 66' x 100' x 25 to 30' high. The piles should be sufficiently distant from each other to prevent fire from travelling from one pile to the other. Weeds should be kept from growing near the piles, and employees must be warned against smoking while working on or near the piles. A number of fires have occurred in bagasse piles; but, so far as is known, all of these are believed to have been due to carelessness. A fire once under way in a pile of bagasse cannot easily be put out, since the material will continue to smoulder for days. The best method is to completely drench the pile with water, so that the pile can be taken down in every area to which the fire has penetrated.

Generally it is necessary to build at the sugar mill a baling station to which the loose bagasse is conveyed on a belt. The installations for the necessary baling equipment, housing, yards, switch tracks, loading cranes, and living quarters, according to Keller in Louisiana, would cost about $150 thousand for a size adequate to handle 15 thousand short tons of fibre per season. The bales, as produced, are moved into the storage yard by tramcar or truck and are lifted by a crane, using a special kind of tong or grab, in groups of six to the top of the pile being formed and are stacked in a definite pattern so that proper channels for air circulation are formed. When the piles are taken down the same tong is used to load the 6 bales on to cars for transportation to the board mill.

Keller (7) also gives the following costs for baling, storing, and placing bagasse on cars at the sugar-mill site: *Per short ton B.D. fibre.*

Purchase price of bagasse	$2.50*
Baling, stacking, and covering bagasse in field	$6.00
Loading costs and storage to railroad cars	$0.50
Total cost at sugar mill	$9.00

To this cost must be added transportation to the board mill, costs of unloading and handling into the mill. The total cost, including the 10 per cent loss of fibre during storage, will be close to $12.00 per short ton B.D. fibre.

IV. Economic use of "total bagasse"

At the present time no method exists for the economic use of "total bagasse". When the sugar mill uses the bagasse as fuel, some of the pith and fine fibre is screened out and finds good use as an aid in settling and filtration of juices, but not all of the bagasse is needed for fuel. When bagasse is baled for storage, losses in fibre occur. When the whole bagasse is used for the manufacture of insulating or hardboard products, losses of pith and fine fibre to the white water, or sewer system, amount to 10 to 15 per cent. When bagasse is used for paper or board manufacture, most companies make an effort to separate as much pith or fines and dirt as they can by dry screening. When bagasse is upgraded by processing into litter or mulch, pith and fine fibres are separated by screening operations, and some uses have been found for these. Used as special fillers in dynamite or as absorbents, particularly for molasses in feeds, are profitable. This type of upgrading approaches total-bagasse utilization most closely.

Objections to pith in paper manufacture

In pulp and paper manufacture, innumerable difficulties may be caused by broken fibres in the form of flour, ray cells, bark particles, and unorganized tissue. The difficulties that whole bagasse with its pith, dirt, carbon, and other unorganized matter can contribute to paper making are of like character. Experiments to find practical means for removing pith have been conducted for over 40 years. The real difficulties have been that there was no profitable use for the pith, once it was removed from the fibre, and no practical low-cost method had been found to prepare pith-free fibre. In addition, the whole burden of doing these things fell to the lot of the pulp or paper mill interested in using bagasse.

There is nothing mysterious in the behaviour of pith in the operations of pulp and paper making, although sometimes patent claims would make it appear otherwise. Pulping is a chemical reaction taking place on surfaces. The greater the surface exposed to the chemical, the more rapid the pulping action. It follows that pith and fine fibres will pulp more rapidly than coarse ones; they will consume chemical more rapidly, making pulping less uniform. Pulps must be agitated in chests, passed through pumps, over screens, and collected on wires. All these mechanical actions break up pith particles and increase their loss to the sewer. Since hydration of pulp is also related to surface area, pulps which contain pith hydrate more rapidly, have slower drainage, shrink more on drying, and produce harder papers than normal pulps.

If such pulps are bleached, the presence of pith causes higher bleach consumption, since the dirt which is absorbed in the pith cells can only be removed by destroying the pith; excess bleach will reduce the pulp yield and produce weaker pulp. When carbon is present it may not be possible to obtain a highly bleached pulp.

There is no truth in the contention that, if proper pulping methods are applied to whole bagasse, pith is an asset rather than a liability. Dirt is inside the pith cells when the whole bagasse goes into the cooker; to remove it the pith must be destroyed to the point that the dirt content of the pulp is not objectionable. Methods of prehydrolysis followed by washing and pulping consist essentially in using chemicals to get rid of the pith. Yields are low, chemical and operating cost high, and the pulps are weak.

It is clear that pith may perform a useful function in specialty products, as suggested by Wells and Atchison (11), but in such cases the pith should be separated from the bagasse, given the necessary treatment and blended with paper pulps in the amounts needed for the specialty boards or papers.

The presence of dirt in board pulps and in the lower grade pulps used for cheap wrapping is not so serious. What is serious is the low drainage rate of pulps containing much pith, since these demand slow paper-machine operation. While it may be thought that small mills can survive using small machines running at low speeds, the whole trend today is towards faster operation. The investment in a paper mill is high and is warranted only if the mill can operate successfully for a long time.

At the present time bleached and unbleached bagasse pulps are being made commercially from partially depithed bagasse in a number of countries. While most of the boards and papers made in this way would have difficulty in competing in world markets, they can at present fulfil definite needs in the countries in which they are produced. As the technological standards of these countries improve such operations will find it more and more difficult to survive.

On the other hand, pulps can be made from depithed bagasse that can compete in any market. By proper blending, improved board and paper products can be made in any country. These pulps will be obtained by applying the best pulping techniques to pith-free fibre. Evidently, to accomplish this, two developments are necessary: (*a*) a practical method for separating pith, and (*b*) a use for pith that will make both pith-free fibre and fibre-free pith highly desirable, profitable raw materials.

Methods used to separate pith[1]

All of the commercial methods used for mechanically separating pith depend on dry screening. Such methods will remove only about one-third of the pith from either stored baled bagasse or artificially dried material. The remaining pith is firmly embedded in rind fibres or covers fibrovascular bundles. Some of this pith is loosened if the material is passed through hammer, or like mills, but this action breaks up a good deal of fibre, and a mixture of about half pith and half small fibres is removed on screening. Less severe hammer milling loosens less pith and breaks up less fibre.

At one sugar mill, where an excess of bagasse for fuel

*Fuel value plus slight bonus, based on gas at 16.66 cents per million BTU.

[1] The processes mentioned are protected by patents or patent applications. See also P. M. Horton and A. G. Keller, U.S. patent 2,650,176, August 5, 1953.

exists, enough bagasse is mechanically treated to produce the fibre requirements of the associated paper mill; the cleaned fibre is baled and the remainder is used for fuel. In this case the quality of the pith does not matter and since the excess fibre cannot be used for fuel it is obtained at low cost. A method of this sort is not widely applicable.

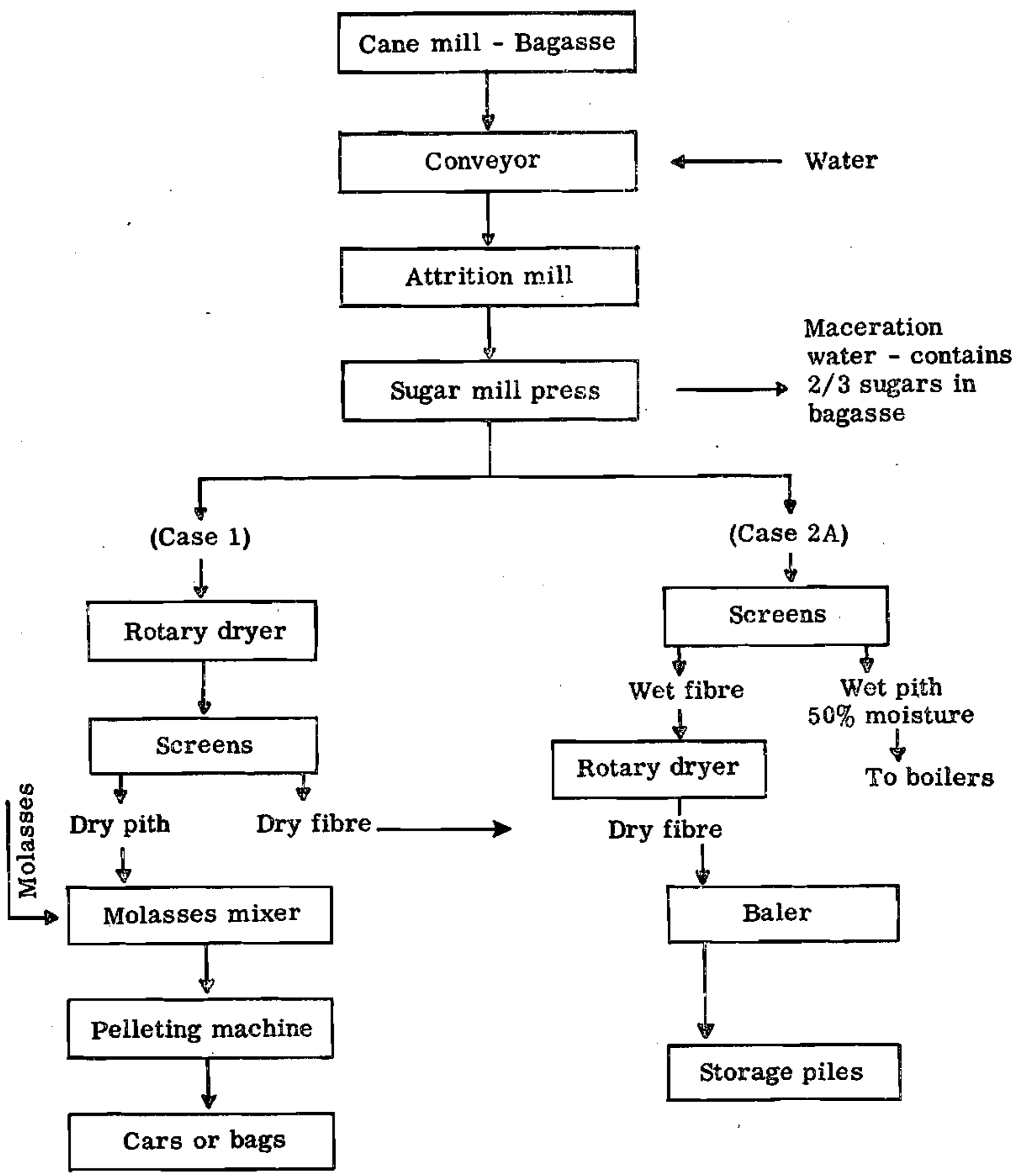
It is generally recognized now that to obtain a separation into pith and fibre, both of high quality, the material must be processed in a wet state to loosen the pith.

Two machines have been found that will loosen the pith without cutting the fibre. The first of these is the hydrapulper which is best suited for the separation process starting with baled, dry bagasse. The second is the single-disk attrition mill, best suited for treating wet bagasse directly from the cane mill. Methods based on both machines have been operated on large pilot-plant scales and cost estimates have been made.

From the standpoint of low costs and of utilization of pith, separation is best carried out at the sugar mill. In doing so it is possible to recover about two-thirds of the sugar left in the bagasse; the bagasse is upgraded into clean fibre and pith, so that these products may be used to their best advantages. The process uses no new machinery and since every step of the operation is well known no serious problems should exist in installing it. (Flowsheet, figure I.)

Figure I

FLOWSHEET OF ATTRITION MILL METHOD FOR SEPARATING WET BAGASSE AT THE SUGAR HOUSE INTO PITH-FREE FIBRE AND PITH



In its first step the process consists in treating the bagasse from the cane mill, on a conveyor at 50 per cent moisture content, with about an equal weight of water. The mass is then passed through a single-disk attrition mill, of the type used for grinding feed, using a special plate and a wide opening between the fixed and rotating plates. Such a 36-inch mill has a capacity of 100 short tons bagasse, O.D. per 24 hours, and a power consumption of 1 hp per daily ton. Water does not drain from the material as it comes from the attrition mill. It is conveyed through a sugar press of three rolls, such as is used in the cane mill, whereupon the added water is now extracted. Its volume represents about two thirds of the water used in maceration; it contains two thirds of the sugar left in the bagasse; and it is returned to the cane mill as a part of the maceration water. Depending on the disposition to be made of pith or of fibre, the mass may be either dried and screened, or may be screened moist and then either the pith or fibre dried as desired.

The method which consists first of drying the mass and then screening it is to be preferred, if the pith is to be obtained in dry form. In this case the material from the sugar press is conveyed to a rotary drier and dried to about 15 to 20 per cent moisture content. Since most of the sugar has been extracted from the material it will dry with less caramelization and loss than is now being obtained in sugar houses drying bagasse. Since the pith has now been loosened from the fibre it is possible to make a good separation of pith and fibre by screening. For this purpose a set of three vibrating screens supplied with plates having round holes of selected diameter is used. The pith fraction passes all three screens, while the materials collected on the screens are combined to make up the fibre fraction. The fibre may now be baled, and sold for paper making, litter, mulch, or other purposes. This dry fibre, if kept protected from rains, will not undergo fermentation, or rotting; so that a saving of at least 10 per cent fibre is assured as compared with purchasing wet bagasse. Furthermore, stronger pulps can be made from this dried, fresh fibre (11).

The pith is clean and of excellent absorptive capacity. It is available to mix with blackstrap molasses as each is co-ordinately produced at the sugar house; and the mixture may be pelleted or otherwise packaged for use as feed.

If it is desired to obtain only dry fibre and to burn the pith, the material from the sugar press may be screened directly over the same screens as used for the dried material. The screen capacities will be somewhat lower. Pith with a moisture content of 50 per cent may be used as powdered fuel, along with oil or gas, or other fuel. The fibre is dried in a rotary drier and baled. It is also possible to bale the screened fibre in the wet state and burn the pith. Whether such wet-baled, separated fibre will store according to present methods without large losses due to rotting would have to be determined. It is possible that not enough sugar would be left in the fibre to induce the fermentation processes.

Estimates of the cost of obtaining dried, baled fibre and dried, pelleted pith by this method are given in table 4.

It will be noted that a fuel value of $2.50 per short ton of bagasse O.D. and a cost of $2.50 per ton for baling the fibre or for pelleting the pith is assumed. The costs of $12.45 per ton for fibre baled and stored and $8.29 for pelleted pith represent mill cost and do not include

Table 4

ESTIMATED OPERATING EXPENSE TO SEPARATE WHOLE BAGASSE INTO PITH-FREE FIBRE AND PITH. CASE 1—WHOLE BAGASSE DRIED BEFORE SCREENING, FIBRE BALED; PITH MIXED WITH MOLASSES AND PELLETED. YIELD 21.6% PITH, 68.4% FIBRE, 10% DIRT AND LOSS.

(Fuel value bagasse $2.50 per O.D. ton. Estimate based on O.D. short ton)

	Dollars
Fuel and power	1.08
Labour, supervision, maintenance, supplies	1.406
Fixed charges	1.481
TOTAL	3.967
Credit for sugars recovered	1.000
	2.967
Cost/O.D. ton fibre or pith 90% yield	3.296
Fuel value/O.D. ton pith or fibre	2.500
Cost/O.D. ton baling fibre, or pelleting pith	2.500
Cost/O.D. ton baled fibre or pelleted pith	8.296
Cost stacking, covering piles, loading (Keller)	4.000
Cost stored pith-free fibre/O.D. ton	12.296
Cost pelleted pith/O.D. ton	8.296

profit, or administrative and sales expense. For this method to be practical both fibre and pith would have to be marketed.

Table 5

ESTIMATED OPERATING EXPENSE TO SEPARATE WHOLE BAGASSE INTO PITH-FREE FIBRE AND PITH. CASE 2A—FIBRE DRIED AND BALED AFTER WET SCREENING; PITH BURNED WET AS FUEL. FUEL VALUE $2.50 PER O.D. TON. YIELD 21.6% PITH, 68.4% FIBRE, 10% DIRT AND LOSS

(Estimate based on O.D. short ton)

	Dollars
Fuel and power	0.631
Labour supervision, maintenance, supplies	1.336
Fixed charges	1.342
TOTAL	3.309
Credit for sugars recovered/O.D. ton bagasse	1.000
Net operating expense/O.D. ton	2.309
Cost/O.D. ton fibre or pith 90% yield	2.565
Net cost separating pith/O.D. ton fibre	
Cost separation/O.D. ton $0.89	0.890
	3.455
Fuel value/O.D. ton fibre	2.500
Cost baling/O.D. ton fibre	2.500
Cost stacking, covering piles, loading (Keller)	4.000
	12.455

Table 5 gives cost estimates for method 2A. In this operation the wet bagasse from the sugar press is screened, the wet pith is sent to the boilers for fuel, and the fibre is dried in a rotary drier, baled and stored. It will be noted that in all these cost estimates the figure used by Keller for baling, piling, covering, and loading of $6.50 less $2.50 for baling costs is used to estimate storage and piling costs. The cost of $12.40 for pith-free fibre by method case 2A is slightly higher than when both fibre and pith are baled and pelleted. However, in case 2A pith does not have to be marketed.

When it is necessary to prepare pith-free fibre from stored bagasse another method is required. Obviously passage of the dry bagasse through the attrition mill would result in severely cut fibre. This treatment would probably be worse than hammer milling. In selecting a wet process of separation it must be recognized that dry stored bagasse is difficult to wet. The best method for wetting bagasse is treatment in the hydrapulper. This method is used commercially on a large scale. Whole bales are added to the hydrapulper continuously and the wetted fibre, which is maintained at low consistency, is drawn off continuously through the extraction plate of the pulper.

When bagasse at high consistency is treated batchwise in the hydrapulper the internal friction produced in the circulating mass loosens the pith during a period of fifteen to twenty-five minutes. About five minutes of this time is required for wetting the material. The pulper is supplied with an extraction plate having holes 3/8 inch in diameter. At the end of the treating period the draw-off valve is opened and water is added for about two minutes to the hydrapulper at the same rate it is being drawn off. This washes out the pith, leaving the clean fibre ready for pulping. The pith contains coarse fibres which may be removed by passage over a Jonnson screen having 0.075-inch holes. The fibre is used for pulping and the pith may be collected over a decker, and de-watered to 40 per cent dry in a screw press. It can be dried in a rotary or flash drier. The pith and fine fibre after pressing may be used as powdered fuel. The flow-sheet of this operation is given in figure II.

Table 6

ESTIMATED COST PER O.D. TON OF SEPARATING BALED BAGASSE INTO PITH-FREE FIBRE AND PITH. FIBRE TO BE PULPED WET, PITH TO BE BURNED WET. COST BALED BAGASSE $9.00 STORED PLUS 10% STORAGE LOSS—TOTAL $9.90. YIELD 21.6% PITH, 68.4% FIBRE, 10% DIRT AND LOSS

(*Estimate based on O.D. short ton*)

	Dollars
Raw material cost	9.90
Power and water	0.70
Labour, supervision, maintenance, supplies	1.45
Fixed charges	1.57
TOTAL	13.62
Net operating cost/O.D. ton fibre and pith 90% yield	15.13
Net operating cost/O.D. ton fibre based on yield of 68.4% with pith of no value	19.91
Credit fuel value pith/O.D. ton fibre at $2.50/ton	0.79
Net cost wet fibre for pulping/O.D. ton	19.12

Estimates of the costs of separation by the hydrapulper method are given in table 6. In this case also the pith is burned. The whole stored bagasse is charged into process at $9.00/O.D. ton plus a 10 per cent storage loss or at a total of $9.90/O.D. ton. The costs of separation are higher by this process than by other methods of separation as will be noted from the cost comparisons given below.

Table 7

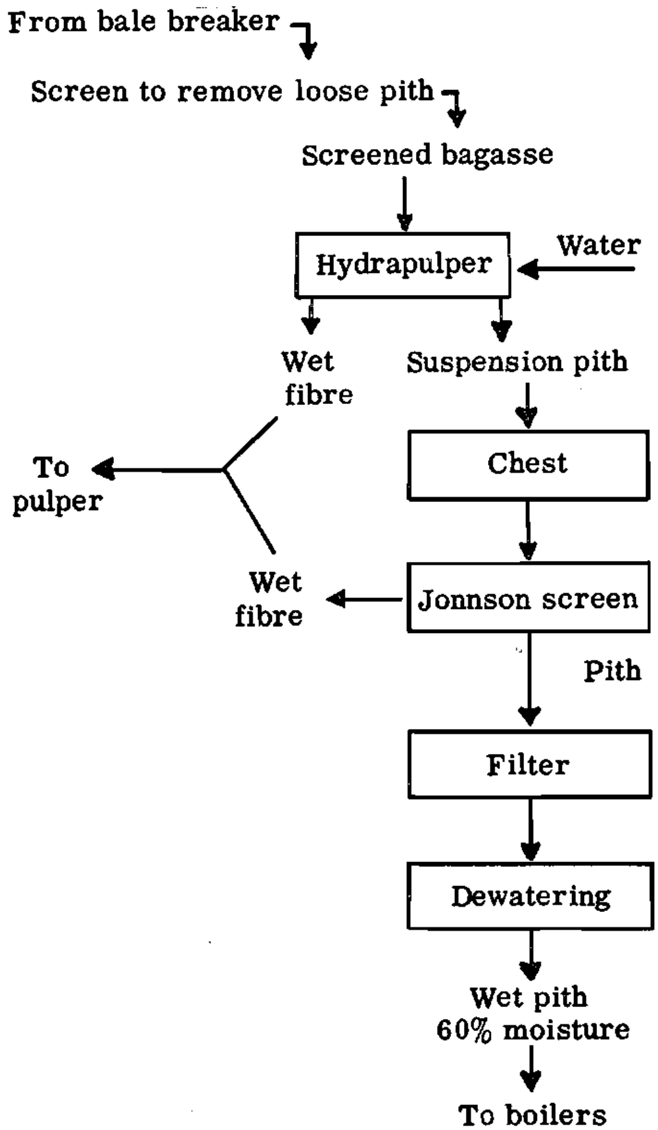
ESTIMATED COST[a] PER O. D. TON OF PREPARING, STORING, LOADING AND COVERING BALED FIBRE AND FOR PELLETING PITH OR SEPARATING STORED BAGASSE. BASED ON COST/O.D. TON

	Whole bagasse (Keller)	*Case 1 Dry fibre baled dry pith pelleted*	*Case 2A Dry fibre baled wet pith burned as fuel*	*Case 2B Dry pith pelleted wet fibre burned as fuel*	*Case 2C Wet fibre baled wet pith burned as fuel*	*Hydrapulper wet fibre pulped wet pith burned as fuel*
Fibre	$9.00	12.215	12.445	Fuel	11.476	19.12
Pith	$9.00	8.296	Fuel	13.866	Fuel	Fuel

[a]All references are to dollars.

Figure II

FLOWSHEET OF HYDRAPUPLER METHOD FOR SEPARATING STORED BAGASSE AT PULP MILL INTO PITH-FREE FIBRE AND PITH



In making the various estimates, costs of buildings have not been included. The differences in the fixed charges shown in tables Nos. 4, 5 and 6 are due, respectively, to differences in capital costs and overhead. Costs of the present methods of commercial screening of bagasse are not now available. It is believed, on the same cost basis for labour, overhead, etc., that screened, baled, stored bagasse will cost about the same as dried, baled, stored fibre (case 1 or 2A).

Table 8

COMPARISON OF COSTS[a] OF PULPS IN TERMS OF RAW FIBRE BASED ON COSTS OF BAGASSE—PITH-FREE FIBRE—CASE 1 $12.215/O.D. TON; HYDRAPULPER, $19.12/O.D. TON; AND STORED BAGASSE (10% STORAGE LOSS) $9.90/O.D. TON

	Pith-free fibre			*Whole bagasse*	
		Cost/O.D. ton pulp			
	Yield	*Case 2A*	*Hydrapulper*	*Yield*	*Cost/ton O.D. pulp*
Bleached 80 brightness	48	25.43	39.83	37	26.73
Unbleached	60	20.35	31.87	48	20.61
Corrugating	75	16.25	25.49	65	15.25

[a]All references are to dollars.

It has been pointed out that higher yields of much stronger and freer pulps can be obtained from pith-free fibre than from unscreened stored material. In table 8 an estimate is given of the cost of pith-free fibre and whole bagasse required to produce a ton of pulp of three different kinds, based on average pulp yields. These figures do not take into account the larger amount of chemical required for pulping the whole bagasse and, in addition, the greater amount of power, labour, etc., required because of slower washing, screening, and slower paper-machine operation. These data show that the costs of fibre (case 2A) and whole bagasse required to produce a ton of these pulps are practically the same, excepting for corrugating pulp. A recent large pilot-plant run to produce corrugating pulp from whole bagasse showed that it was so slow draining that it would not run on the paper machine, and only after passing the pulp over deckers to remove about 8.5 per cent material, consisting of fines, could a satisfactory corrugating medium be made from it. On the other hand, a corrugating medium was easily made from the depithed fibre that was superior to commercial medium. These data suggest that with present methods of separation pith-free fibre can compete costwise with whole bagasse. From the pith-free fibre a high quality product will be obtained, instead of a low or fair grade product from whole bagasse.

A more recent process for depithing bagasse, either moist as it comes from the sugarcane mill or dry from bales, has been perfected by the Mexican Company now using the mechano-chemical process for pulping. The machine used in this process is of high capacity, relatively inexpensive to build, uses very little power, and requires little maintenance. Costs of depithing by this process will be lower than any of the above estimates.

The magnitude of the costs will change depending on fuel prices and the relative proportion of pith to fibre in the particular bagasse. As more pith is removed by mechanical treatment the costs of chemicals will be reduced, and the quality of the pulp will improve. The optimum for both quality and for low chemical costs per ton of pulp will only be obtained by using pith-free fibre.

Uses for pith

The cost analyses show that pith-free fibre can be prepared best at the sugar mill during the grinding season. If an excess of bagasse for fuel exists, pith can replace some of the fibre used for fuel, with a lowering of cost of $2.50 per ton of fibre. If a better market than fuel can be found for pith then the sugar mill is in a position to benefit still further.

It has already been indicated that such a market exists in using pith as an absorbent for molasses to prepare cattle feed(12). The Northern Regional Research Laboratory has continued to investigate this subject, with the result that a method for determining the absorption capacity of pith or other feed ingredients has been reported(13). It was found that the absorption capacity of commercially separated pith is two-thirds to one-half that of wet separated pith, while the capacity of common feed ingredients is from one-third to one-half of the same value. A mixture of 30 per cent wet separated pith and 70 per cent 80°-Brix molasses will not cake in a humid climate on standing, while a mixture of this same proportion of molasses with commercially screened pith will cake. Both mixtures can be pelleted.

Blackstrap molasses and bagasse are the major by-products of sugar-cane manufacture, and each is produced in almost the same amount when cane is ground for sugar extraction. While bagasse always has had a use as fuel, there have been times when blackstrap molasses in some areas had no use. The price of molasses always has been pegged to that of alcohol, and has hence experienced very wide fluctuations(14). With the increased manufacture of synthetic alcohol and the closing down in the fall of 1953 of the synthetic rubber plants using alcohol, the future for molasses in this market is not bright. From the standpoint of the sugar industry it is extremely important to divorce the molasses market and molasses prices from the effects of conditions in the alcohol market. The latest report of the United States Department of Agriculture on the molasses situation(14) suggests that the conditions for this are the brightest in history.

It has been repeatedly emphasized that the highest price market for molasses is in feeds. The use of molasses in feeding in the United States has steadily increased since 1945. At the present time a large number of the authorities on animal feeding are investigating the use of roughages, molasses, urea or ammonium salts and necessary feed supplements for the fattening, finishing, and feeding of cattle. For example, very large tonnages of ground corncobs are being used in such rations. Much study is being devoted to the digestive action of rumen bacteria in making it possible for the animal to gain energy from the carbohydrates, cellulose and pentosans, of low-grade roughages. Molasses is evidently an important ingredient in promoting this action. New information suggests that it is desirable to absorb the molasses on a finely divided carrier so that it will not pass too quickly from the rumen. This prevents scouring which often takes place when liquid molasses is fed, and also seems to assist in producing more energy from the roughage. One-third of the protein requirements of the animal may be supplied in such feed by urea, or ammonium salts. Molasses may be ammoniated and urea can be dissolved in the molasses. The other feed ingredients such as minerals, vitamins and antibiotics, are available in the chemical markets, but the remainder of the protein requirement must be supplied from vegetable sources, generally oilseed meals.

Market surveys have indicated that there is a tremendous potential for molasses as feed in the United States, estimated at nearly a billion gallons per year. Merchandising of liquid molasses to the small feeder, or farmer, particularly in the northern states, is difficult. Molasses in some dry form is desired.

Numerous efforts have been made in the tropics to feed molasses mixed with screened bagasse. Two main conditions were probably responsible for failures. First, the type of cattle that could withstand the tropical climate were not desirable for meat. It would appear that the new breeds of cattle produced in Texas and Florida could be used in the tropics satisfactorily. Secondly, while there is an excess of carbohydrates in most tropical countries, protein that can be used for feed is not plentiful. Since now at least one-third of the protein requirement can be supplied with urea or ammonia, protein requirements for feeding in the tropics are less severe. Instead of shipping copra to America or Europe for extraction of oil, for example, its extraction in the tropics would provide a source of protein.

Cattle, finished by lot feeding or carried through the winter on rations consisting of roughages containing molasses, produce better meat than grass-fed cattle. There seems to be a general belief that a protein diet based on meat is preferable to one based on vegetable proteins.

In some countries, where alcohol production is under government monopoly, and sugar production cannot be expanded because of lack of markets, another approach to the production of pith-free fibre is possible. Sugar cane might be grown and ground as at present, but the juice instead of being converted to sugar would be fermented directly to alcohol. This operation would require much less fuel. In this case the pith used as fuel could release even more fibre. The slops from the alcohol plant could be fermented to methane gas, which can be used efficiently in diesel engines to produce power directly. If such integrated operations proved to be sound economically, fibre for the paper industry could be provided at extremely low cost.

However, in considering the close integration of a sugar and pulp and paper mill a word of warning is necessary. The paper mill, if it is to make bleached paper, should not burn bagasse or pith for fuel, because of the almost certain contamination of the bleached pulp with carbon particles. If the paper mill is to be located near a sugar mill, it should be so located as to avoid the same hazard.

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SAVING OF BAGASSE FOR PAPER MAKING—THERMAL CONSIDERATIONS

Cellulose Development Corporation Ltd. and John Thompson Water Tube Boilers Ltd., together with certain sugar producers and sugar equipment manufacturers (England)

Introduction

Whilst the use of bagasse for making board of various types and also coarse wrapping papers has been fairly well known for some time, it is only since just before the War that the production of bleached pulp from bagasse for fine paper making has been commercially established. Recent improvements in pulping techniques have made possible a significant increase in the commercial production of paper and board from bagasse, and certain sugar mills have themselves taken the initiative in this profitable development.

At the same time it is frequently maintained by sugar mills that they have little or no bagasse surplus to their steam-raising requirements to release for paper making, and that substitution by other fuels might well be uneconomical.

Before considering how more bagasse might be released it is necessary to determine what are the minimum annual requirements of bagasse to operate a pulp mill economically. For this purpose, a minimum capacity of 20 metric tons[1] pulp per day is assumed, although there are special cases where a lower output of only 15 tons bleached pulp may be economically justified. This in turn may represent from 60 to 95 per cent of the corresponding finished paper and board output because of the admixture of other pulps, according to the type of end-product required.

The purpose of this Paper is to suggest means whereby, where little or no surplus bagasse now exists, such minimum quantities may be liberated without using an alternative fuel; release of bagasse by substitution is also considered.

Pulp output is usually designated in air-dry (a.d.) tons, i.e., tons with 90 per cent bone-dry or oven-dry (o.d.) cellulose, and 10 per cent water. The annual bagasse requirements will depend on the yield of pulp from the prepared raw material given by the pulping process and also on the number of days worked per annum. Allowance must be made for the amount of pith (from nil to 30 per cent) which may be removed prior to pulping (and may be used as fuel), according to the quality of paper and board produced.

The days worked may be assumed as six days per week for semi-pulp and "continuously" (13½ days per fortnight) for bleached pulp production because such a mill would probably produce its own caustic and chlorine from an electrolytic plant which normally runs continuously. An annual "shut" of 14 days may be assumed in each case. This gives the table following (table 1).

Table 1

AMOUNT OF BAGASSE REQUIRED PER YEAR TO PRODUCE 20 TONS OF AIR-DRY PULP PER 24 HOURS

Type of pulp	*Yield of a.d. pulp % bone-dry bagasse*	*Tons o.d. raw bagasse per 24 hrs*	*Working days p.a.*	*Tons of bagasse per year*	
				o.d.	*45% moist*
Semipulp for corrugating paper, boards, etc....	say 65	31	300	9,300	17,000
Semipulp for wrappers, sack papers, etc......	say 55	36	300	10,800	20,000
Bleached pulp for fine papers (e.g., printing and writing).........	say 39	52	340	17,700	32,000

Mr. P. Honig, Chairman of the International Society of Sugar Cane Technologists (ISOCATE) in 1950, has stated that it has been found possible for a raw sugar mill to provide its factory power and steam from only 8 per cent fibre on cane.

It is understood that this represents a very efficient operation and the figure is an optimum, as will be shown later. Nevertheless, as the amount of fibre on cane may vary between 11 and 17 per cent, the amount of surplus bagasse therefore theoretically available in a raw sugar mill may vary from 3 to 9 per cent. If an average figure of 13 per cent is taken, it means a surplus of 5 per cent fibre on cane.

Clearly therefore the choice of a cane with a higher fibre content will increase the surplus of bagasse available. It is equally clear that such a policy of developing a high fibre yield would only be carried out if sugar production is to be restricted and there is an attractive price offered for bagasse.

Where refining is carried out on site for sale locally (plantation white sugar, as in Brazil), the normal steam consumption will then be greater by 10 per cent or even more—possibly up to 20 per cent. A few modern refined sugar mills may still have a surplus of bagasse available for pulp manufacture.

However, the greater part of sugar is produced as "raw" sugar and exported for refining elsewhere, and the steam requirements of such raw sugar mills may be roughly set out as follows (table 2).

Table 2

RAW SUGAR MILL STEAM REQUIREMENTS

	Steam per ton cane (p.t.c.)
Case I, completely unelectrified, direct action steam-driven pumps..........................	600–700 kg
Case II, modern, with a turbo-generator supplying current for all small machines, particularly pumps; steam carefully used..................	500–600 kg
Case III, with quintuple effect, steam bleeding from the evaporators, thermocompression or evaporation under pressure, with high pressure steam, superheated................................	400–500 kg

Steam raising with bagasse

A normal evaporation ratio with bagasse—certainly not below the average—is that for a low pressure, small, superheat type installation. 2.6 kg of steam are evaporated per kg of moist bagasse, consisting of approximately 45 per cent moisture and 55 per cent solid matter, or, expressed in relation to the dry *fibre*, the evaporation is approximately 5 kg of steam per kg of fibre.

The proportion of fibre in sugar cane varies as has been already mentioned, but if it is again taken at an average of 13 per cent (130 kg per ton of cane) the steam production if all the bagasse is burned at the evaporation rate quoted would be 5 x 130=650 kg per ton of cane.

If only 8 per cent of fibre on cane were burnt, as suggested above, or just over 60 per cent of the total of 13 per cent available, the total steam raised would be only 400 kg approximately. It is evident therefore that to run a raw sugar mill burning only 8 per cent of the weight of cane crushed, the steam usage would have to be *most* economical, and would assume first class supervision and everything in first class working order. In such an ideal case, the remainder of the bagasse, amounting to nearly 40 per cent, would be available as surplus.

In many older installations, due to inefficient boiler plant and furnaces, the water evaporation rate of moist bagasse is no more than 1.9 with bagasse containing 45 per cent of moisture as before or 3.65 in relation to the dry fibre. This corresponds to 475 kg of steam per ton of cane if all the bagasse is burned, whereas the consumption in such a mill (see table 2 above) may be in the range of 600 to 700 kg steam per ton of cane. Such mills have to use supplementary fuel to supply their full steam requirements.

[1] Whilst metric tons and the metric system generally will be used throughout, the English and American punctuation will be used to indicate decimals, i.e. 1.0=one decimal nought, and 1,000=one thousand.

Thus the situation which has to be considered is that the economies of raw sugar mills vary so much that whilst some may possibly have up to 40 per cent bagasse surplus to their fuel requirements, others may need to use supplementary fuel.

Mills in the former category may well be able to provide sufficient bagasse to supply a paper mill, and are in fact glad to do so since the surplus bagasse is an embarrassment to them and disposal represents a problem and/or expense. (An example is the sugar mill associated with Cia de Celulosa de Filipinas, fifteen tons-a-day bagasse fine paper mill in the Philippines.)

Similarly, mills having a balanced fuel requirement at their designed capacity commonly find that when this capacity is raised with the same milling plant, as is often done, they accumulate surplus bagasse without any other changes being made.

The percentage surplus bagasse in a sugar mill is given by

$$\text{Surplus} = \frac{\text{Total bagasse produced} - \text{bagasse burned}}{\text{Total bagasse produced}}$$

The quantities of cane to be crushed per annum to liberate sufficient bagasse for paper making (as shown in table 1) are given below for representative precentage surpluses (table 3).

Table 3

MINIMUM WEIGHT (APPROX.) OF CANE TO BE CRUSHED P.A. TO PROVIDE SUFFICIENT SURPLUS BAGASSE FOR PAPER MAKING, I.E., FOR A PULP MILL OF 20 TONS PER DAY OUTPUT

Assumed average fibre content on cane: 13%

Type of pulp	*Surplus* 10%	20%	30%
For corrugating paper, boards, etc.	715,000	355,000	240,000
For wrappers and sack papers	830,000	415,000	280,000
For fine papers	1,360,000	680,000	455,000

Despite these promising-looking figures, it very often happens that a sugar mill has little or no surplus bagasse. This is not surprising since, as already mentioned, to have a surplus of bagasse without a special use for it is to incur a serious disposal problem. Therefore there is normally no incentive towards high thermal efficiency in sugar mill design, provided the steam consumption is less than the quantity of steam produced by burning the bagasse. Thus it has been quite logical frequently to provide the simplest boilers and the simplest steam system.

This being the case, it may be quite easy to find means of making substantial improvements to the thermal efficiency in order to create a surplus of bagasse for pulp making.

The two lines of approach are:

I. Economizing and eliminating waste in the actual utilization of steam;

II. Improving the efficiency of steam generation.

These are taken in turn as follows:

I. Economies in the utilization of steam in the sugar factory

1. *Steam for power*

The over-all steam requirements in a raw sugar factory have been shown in table 2 to vary widely between 70 per cent on cane to less than 50 per cent in a modern, highly integrated mill. That part of the steam required for power naturally varies considerably according to whether the mills are driven by Corliss engine, direct steam turbine or electrically through a turbo-generator; the remaining machines can also be driven either by steam or electrically.

Whatever the combination, it will be found that the mills are generally designed so that there is always a margin—which may be considerable—between the steam which passes through the prime movers and the total required for process heating. For a proper balance it is generally recognized that only three-quarters at most of the steam produced in a sugar mill passes through the power units; the remaining 25 per cent is supplied as process steam direct from the boilers. Hence the important conclusion:

> So long as all the exhaust steam from the turbines and engines is used for process heating, their efficiency is of relatively small importance.

It is not the inefficiency of the small engines and duplex pumps which adversely affects the steam economy, but the heavy loss if their exhaust steam is not used for process heating, and also the loss through many steam pipes which remain unlagged. The losses here may be considerable, and an important step to economy is to electrify these machines, augmenting or installing the requisite turbo-generators, and to lag where necessary.

The electric driving of the crushing mills is similarly of no interest from the point of view of steam economy unless the boiler pressure is raised sufficiently high to allow the turbine to be designed with back-pressure exhaust steam discharged at, say, 135°C—140°C (2 to 3 kg/cm^2 gauge). With steam at this temperature, pressure evaporation of the juices is possible and instead of the latent heat of the steam from the last effect being discarded because of its low temperature (say 50°C), the last effect could discharge its vapour at 105°C. At this temperature the vapour can be used for juice preheating or in the vacuum pans.

This, however, would involve a major reconstruction in the sugar mill and may be considered for new projects where it may offer a valuable economy. It has to be borne in mind also that high temperatures for any length of time do not normally suit cane sugar juice, although there is not the same objection for beet juice.

The installed first cost of electrically-driven mills is high and it is questionable, now that the direct turbine-driven mills have proved successful, whether the electric drive mill will be much built in the future. On the other hand, the steam turbine drive as compared with the Corliss engine drive may not only be more efficient (it can operate at higher steam pressures, superheated) but it needs less space, is probably cheaper in upkeep, and most important, gives oil-free back pressure steam for juice heaters, evaporators and vacuum pans.

From the foregoing, it is clear that it is in process steam requirements where effective economies must be made if bagasse is to be saved.

2. *Process steam*

If the steam requirements for juice heating, evaporating, and boiling are all supplied direct from the low-pressure steam chest, the following approximate quantities apply (table 4).

Table 4

PROCESS STEAM REQUIRED BY SECTIONS

		Kg steam per ton cane
Juice heating:	1,000 kg juice heating from 30° to 105°C, sp. ht. 0.93 = 70,000 kcal............	120
Evaporation:	1,000 kg juice evaporated from 12 to 60 Brix = 800 kg water evaporated; in quadruple effect, steam required.....	200
Vacuum pans:	200 kg syrup evaporated from 60 to 96 Brix x 1.5 to include dilution........	110
Miscellaneous and lines,	including centrifugals, say............	100
	TOTAL	530

These requirements will only be met in part by back pressure exhaust steam—say, about half in the case of mills which are not wholly steam driven.

As mentioned above, evaporation under pressure, so enabling the steam to be at a particular pressure from the last effect, and used for juice heating or the vacuum pans, might save about 20 per cent of the total steam, but this is probably not generally satisfactory to cane sugar usage.

Economies relating to evaporation

Bleeding of steam from the evaporators. For at least much of the juice heating, it is possible to obtain steam which has served in evaporators working at normal pressures by bleeding off steam between the effects.

For various reasons, the fall in pressure from about 1.5—2.0 kg/cm² absolute (equivalent to 112°C at least) in the first effect, to 0.160 kg/cm² absolute in the last effect (53°C) is best divided more or less equally between the effects.

Under this condition, it is found that the evaporating capacity of each effect per unit of heating area is smaller than in the preceding one. There exists, therefore, the possibility of evaporating each effect near its maximum capacity, and dividing the evaporated steam so that the subsequent effect receives what it can utilize, the surplus being bled off and used for juice heating. The amount bled off from, say, the third effect will already have evaporated three times its own weight of water; that bled from the second effect twice its own weight, etc. The large amount of steam from the last effect is unfortunately usually too cold to be worth using unless the evaporation is under pressure.

An example of the saving which may be effected by bleeding off steam in this way is given below (table 5).

In order to evaporate 800 kg of water in quadruple effect without steam bleeding the steam consumption would be 800 ÷ 4 = 200, so that if 125 kg were needed for juice heating, the total steam would then be 325 kg required for these two purposes. With bleed-off under the above conditions, the steam for juice heating would be provided by the evaporators, the steam consumption of which, however, would be increased to 267 kg per T.C. The maximum saving would be then 325 − 267 = 58 kg. In relation to the total steam consumption for process heating this would be a saving of about 11 per cent (58 ÷ 530).

Table 5

STEAM BLEEDING FROM MULTIPLE EFFECTS

	Kg steam supplied per T.C.	*Kg steam evaporated per T.C.*	*Kg vapour bled off per T.C.*	*Temperature of vapour °C*
Back-pressure steam supplied to 1st effect at 1.5 − 2.0 kg/cm² abs.......	267			112
1st effect......		267	47	103
2nd effect......		220	49	93
3rd effect......		171	29	80
4th effect......		142	0	55
		800	125	

It would of course be necessary to heat the juices in a series of heat exchangers, the lowest pressure steam being used for the cold juice.

Number of Effects. Theoretically, the steam consumed in the first effect is given by the evaporation divided by the number of effects. In practice, for 3 or 4 effects this is approximately true because the losses due to radiation, etc., are more or less compensated by the auto-evaporation of the juice which enters each effect at a higher temperature than the vapour in that effect.

However, the losses mount very rapidly with the number of effects, so that in a quintuple effect the total loss will be at least $(5 \times L_1) + (4 \times L_2) + (3 \times L_3) + (2 \times L_4) + (1 \times L_5)$, where L_1 = loss in the first effect, L_2 = loss in the second, etc. In practice, it will be higher than this indicates.

Some illustrative figures for losses in evaporation are given below (table 6).

Table 6

EVAPORATOR LOSSES AS PER CENT STEAM SUPPLIED TO FIRST EFFECT

	Partly lagged	*Well lagged*
2x effect..............................	0.46	0.26
3x effect..............................	2.07	1.05
4x effect..............................	5.00	2.70

With this progression it is found that whilst the losses are reasonable (say 5 per cent) with quadruple effects, five effects are only interesting for mills crushing more than 100 tons of cane per hour, and sextuple effects are rarely found, being only suitable for very large installations.

An increase from three to four effects would reduce the steam required for the first effect from about 270 kg per ton cane to about 200, and as such is an important economy. (It may be noted that the installation of an additional effect unfortunately does not increase the amount of water which can be evaporated.)

Circulation of condensate in evaporators. The passage of condensate from the first to the last effects so that the condensate gives flash steam on arrival at the next effect at lower pressure can effect a saving of 5.4 per cent of the steam used for evaporation, or say 10 kg P.T.C., and this practice is widely used. On the other hand, some heat is lost in the boiler feed-water thereby, and it may then be advantageous to use an economizer.

The most common way is when the condensate from the first effect, pure and at little below the exhaust temperature, is passed straight to the hot well or boiler feed tank. The condensate from the second vessel onwards is flashed as described above; the economy in this case is of the order of only 2 per cent.

Thermocompressors. In principle, the thermocompressor offers an additional and interesting method of steam economy.

The principle is similar technically to that of a heat pump, but instead of using a mechanical pump (or turbo-compressor) to bring the low pressure and cool steam to a useful pressure and temperature, the compression is effected with an injector. This is simpler and less costly than a turbo-compressor, though less efficient.

In practice, one or more injectors may draw vapour from the first effect, compress it, and return it, together with the exhaust steam from the engines, into the calandria of the first effect. High pressure steam is required for this. Much of the high pressure steam which normally is reduced in pressure by a reducing valve, and which augments the supply of exhaust steam when inadequate, may be added via the thermocompressor. It thus does useful work which, when decompressed in a reducing valve, it does not.

It is found that 1 kg of live steam at 23 kg/cm^2 passed through the injector will withdraw about 2 kg of vapour at 1.033 kg/cm^2 absolute and inject 3 kg of steam at 1.375 kg/cm^2 absolute into the calandria. This re-use of vapour must not of course be carried to the point where the existing exhaust steam is not all used.

The steam supplied to the first effect evaporator will be q kg of high-pressure live steam + q_1 kg of exhaust + ϕq kg of compressed recycled vapour ("ϕ" is the ratio of entrainment of the injector, which as mentioned = ± 2). This will evaporate $q + q_1 + \phi q$ kg of water in the first effect, and of this $q + q_1$ will pass to the second effect, and ϕq will be recycled. In the second, third and fourth, etc., effects, $q + q_1$ will proceed to evaporate the same weight of water in each effect. The total evaporation will then be, for quadruple effect, given by: Evaporation = $4(q + q_1) + \phi q$ for a steam consumption of $q + q_1$.

To evaporate this amount of water in quadruple effect without the thermocompressor, the steam consumption would be one quarter of the amount of water evaporated and would therefore be $q + q_1 + (\phi q \div 4)$. Therefore compared with this, the thermocompressor saves $\phi q \div 4$ kg of steam.

In order to see how this affects the total steam consumption, it may be supposed that the evaporators consume 200 kg of low-pressure steam per ton cane without the use of a thermocompressor, and that this LP steam comprises 100 kg exhaust and 100 kg reduced-pressure live steam. If a thermocompressor is installed, and it uses 80 kg of high-pressure steam as motive steam, then the saving will be $\phi q \div 4 = (2 \times 80) \div 4$ (say), = 40 kg steam/ton of cane.

The disadvantages of the steam are that it requires a fairly high degree of technical control and its efficiency is said to depend on a steady load which will not be given in a sugar factory where the demand for heat at the vacuum pan station constantly varies. It may be for these reasons that so far the device has never become popular.

Effect of imbibition water. It is obvious that a reduction in the amount of imbibition water which is sprayed onto the cane during crushing will reduce the amount of steam which is required for evaporation. However, the amount of sugar extracted will also be reduced, and it is therefore necessary to strike a balance, which will depend on the relative values of the bagasse saved and the sugar lost.

It is worth remarking that the use of more imbibition water does not necessarily affect the moisture in bagasse; whilst certain installations may be found with bagasse discharged at 50 per cent or even 55 per cent, there is no need for this in a correctly designed mill and the effect on the fuel efficiency is very harmful, as will be shown later.

The proportion by weight of water added per part of fibre in cane is the ratio of imbibition (called z, say). Taking as example values of z equal to 1.0, 1.5 and 2.5, this will represent (where the cane contains 13 per cent fibre), 130, 200 and 330 kg of water per ton of cane respectively.

Taking $z = 1.5$ as a basis of comparison, there are 70 kg less water to be evaporated P.T.C. when $z = 1.0$, and 130 kg more when $z = 2.5$. If in a quadruple effect evaporator 1 kg of steam evaporates 4 kg of water, then when $z = 1.0$, the steam required will be 17.5 kg less than when $z = 1.5$, and when $z = 2.5$, the steam required will be 32.5 kg (say 32) more, per ton cane.

However, the improvement in the extraction of sugar rises rapidly between $z = 0$ and $z = 2$, but slowly thereafter, and we may estimate that the extraction would vary more or less in the ratio of 90.0 : 92.1 : 93.7 for $z = 1.0$, 1.5 and 2.5 respectively.

Evidently, if $z > 1.5$ (about 20 per cent water on cane), careful consideration should be given to reducing the imbibition water if it is desired to save bagasse because its value for paper making may exceed the extra sugar extracted by using more water.

In considering these economies in the evaporator section it should be borne in mind that in practice in many factories the evaporation capacity tends to lag behind the increases in output achieved by other parts of the mill; this naturally tends to hinder steam economy (and hence bagasse economy) in this department.

Effect of alcohol production on steam consumption in a raw-sugar mill

Those factories which produce alcohol from their final molasses require more steam per ton of cane than those which do not. If from one ton of cane, 40 kg of final molasses are obtained, which in turn produce 12 litres of alcohol, about 60 kg of steam will be required for distillation—say 70 kg total extra per ton cane.

Generally speaking, the supply of molasses exceeds the requirements for alcohol production in a given area. When the production of alcohol is more than a means of utilizing the molasses, but is on a large scale (as it is in certain sugar-producing countries which wish to restrict the import of petrol), juice may be sent directly to the fermentation with no treatment other than clarification in the cold. Under these conditions, considerable steam economies can be made, because for that part of the juice going to fermentation, steam for juice preheating, evaporation and cooking is eliminated.

Mariller, in his "Distillerie Agricole et Industrielle", points out that 100 kg of invert sugar (glucose) will theoretically produce 61 litres of alcohol; in practice, say, 57.

The juices contain predominantly sucrose, and 100 kg of sucrose will produce 105 kg invert sugar. If, as before, 5 kg steam are required per litre of alcohol, then the steam consumption for distillation of alcohol will be 5 x 57 x

$\frac{105}{100}$ = 300 kg of steam per 100 kg of sucrose.

It has been shown already that to produce raw sugar from 400 up to 600 and even more kg of steam are required per ton of cane; if the cane yields 12 per cent of sugar, between 330 and 500 kg of steam per 100 kg of sucrose (sugar) are required.

Comparing this with the figure above, it is evident that a substantial steam (and hence bagasse) economy can be made by producing alcohol instead of sugar. The problem is rather complex for full consideration here because of other factors arising, such as the effect on economy of steam usage if the evaporators are run below capacity, etc.

Insulation

It is unnecessary to point out the importance of good insulation as a considerable proportion of the total heat may be lost by poor lagging. This remark applies, of course, throughout the factory, including the return condensate lines in which a drop in temperature of 6°C represents 1 per cent loss in steam. It is also useful to have a reserve of hot condensate in a lagged tank to avoid using cold fresh water when there is a sudden increase in the steam demand. In such circumstances, steam accumulators will help, as will modern hearth-type furnaces which contain a relatively large reserve of bagasse actually in the combustion chamber.

II. Improved efficiency of steam generation

Bagasse as fuel

Whilst the moisture content of bagasse varies quite widely (it has been known as low as 39 per cent and may even be as high as 55 per cent), a representative sample of bagasse may be considered to consist of:

	Per cent		*Per cent*
Dry material	52	carbon	45
		hydrogen	6
		oxygen	46
		ash	3
Soluble matter (Brix)	3	sucrose, glucose, fructose.	
Water	45		
	100		

The gross calorific value of the dry material and soluble matter together (i.e., oven-dry bagasse) is generally taken as approximately 4,600 kcal/kg. With 45 per cent moisture, the gross or higher calorific value falls to 2,530 kcal/kg. If the moisture content were to be as high as 55 per cent, the gross calorific value would be 2,070 kcal/kg.

The low average efficiency[2] of bagasse-fired boilers is due to the large amount of heat absorbed as latent heat in vaporizing the moisture already in the bagasse as fired, as well as the moisture formed by the combustion process itself. This latent heat could only be recovered if the products of combustion were all cooled down again to the original temperature of the bagasse. This is clearly impossible in any industrial furnace, and so the loss of heat "up the chimney" due to this cause can only be reduced by decreasing the moisture content of the bagasse as fired.

The high moisture content of the bagasse as fuel is also associated with the comparatively high temperature of the flue gases as discharged into the chimney which have been common. Therefore a means of improving the heat recovered from the combustion process is to absorb more heat from the flue gases and reduce the exit gas temperature. These two aspects of boiler efficiency can be considered in turn.

Effect of moisture in bagasse on boiler efficiency. Figure 1 illustrates the effect on efficiency of reducing the moisture content of bagasse as fired on both hearth-type and stepped-grate-type furnaces with constant exit gas temperature. The difference in the efficiency curves between the two types is principally due to the better combustion efficiency of the hearth-type furnace, with its lower unburnt loss combined with better air control which enables higher proportions of CO_2 to be obtained and consequently somewhat lower gas losses. In both types, a significant increase in efficiency follows the reduction in moisture content of the bagasse.

By firing the bagasse relatively dry instead of wet, a substantial saving is achieved for the same steam production. This is illustrated as follows:

Assuming an existing plant is burning bagasse of 45 per cent moisture with hearth-type furnaces, and the exit gas temperature is 320°C, the efficiency would be of the order of 61.6 per cent, and the amount of fuel burned, is, say "X" tons per hour for the required steam production. If by some external means the moisture content as fired can be reduced to 12 per cent, then the corresponding efficiency would be 72.3 per cent, and in this case only 0.533X tons of bagasse of 12 per cent moisture would be required, this being equivalent to 0.852X tons of original bagasse of 45 per cent moisture. In other words, a saving of 14.8 per cent of original bagasse would be effected, this percentage being the same whether the comparison is made on dry or wet bagasse.

It is essential that the saving in bagasse is assessed on the basis of a given steam production and not by a direct comparison of the increased efficiencies.

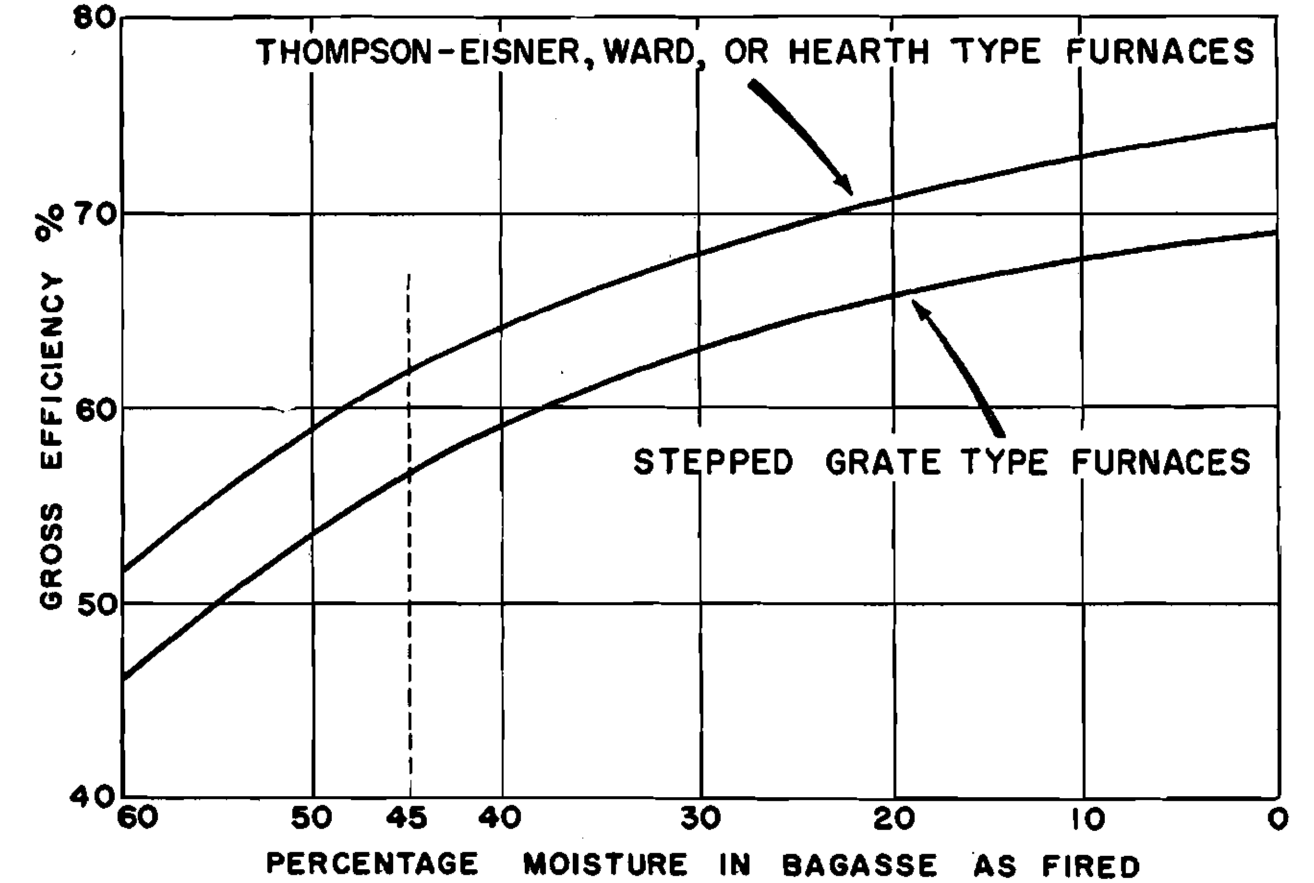
[2] The efficiency of boilers is taken here to be given by

$$\text{Efficiency} = \frac{\text{heat usefully employed in steam-raising per kg of bagasse}}{\text{gross or higher C.V. per kg of bagasse.}}$$

It is not proposed to use the lower, or net calorific value, in view of the divergence in values which can be obtained by the slightly different interpretations placed on this value in various countries. While, however, the gross efficiency and the gross calorific value have been used throughout in the following comments, a similar comparison of the boiler efficiencies can be made on the net calorific value. The divergence between the values is, of course, progressively less as the moisture content is reduced.

Figure 1

Efficiency curves for boiler plant (with assumed exit gas of 320° C)



A similar comparison may be made at the same moisture contents for the stepped-grate-type furnaces, the efficiencies being 56.6 per cent for 45 per cent moisture and 67.2 per cent for 12 per cent moisture and a saving in bagasse of 15.8 per cent is thereby achieved.

Effect of temperature of flue gases on boiler efficiency. Where economy of bagasse has not been important, bagasse-fired boilers have generally not been fitted with economizers or air pre-heaters and the temperature of the exit gases has been somewhat high—usually in the neighbourhood of 320°C (the basis for figure 1).

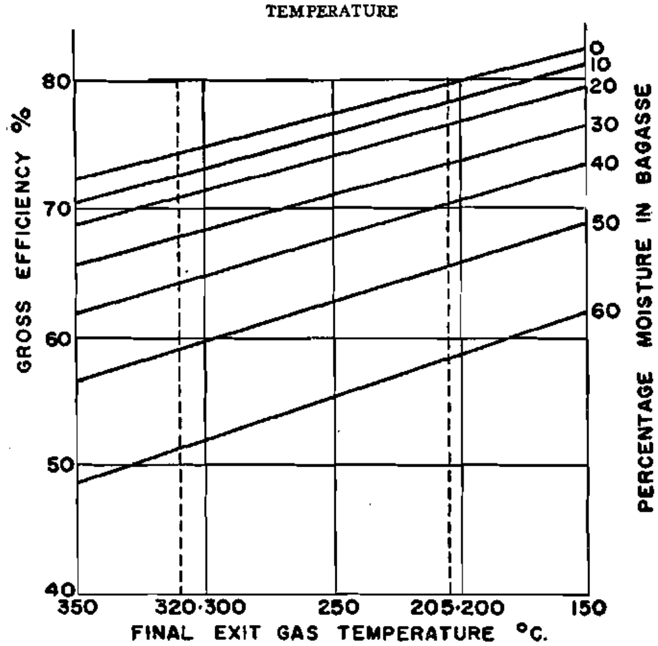
Figure 2 illustrates the relation for various moisture percentages in the bagasse between efficiency and final exit gas temperature for a typical boiler fitted with a hearth-type furnace; the gas loss is based on reasonable operating conditions, namely, some 45 per cent excess air, i.e., 14 per cent CO_2 in the combustion chamber.

Considering a plant operating with 45 per cent moisture and an exit gas temperature of 320°C, the efficiency, as previously remarked, would be 61.6 per cent and "X" tons of bagasse would have to be burned for the required steam production. If now by some external means the exit gas temperature is reduced to 205°C (which is approximately the minimum temperature we would recommend for gases with this percentage of moisture) the efficiency would be increased to 68 per cent and 0.906X tons of bagasse would be burned for the same steam production. Therefore a saving in bagasse of 9.4 per cent would be achieved.

Effect of moisture and exit gas temperature reduction together. If the same plant is next considered operating

Figure 2

Relationship between efficiency and final exit gas temperature



at a moisture content in the bagasse of 12 per cent, and a final exit gas temperature of 320°C, the efficiency would be 72.3 per cent and 0.533X tons of 12 per cent moisture bagasse would be required for the same steam production, compared with 0.625X tons of 12 per cent moisture bagasse available (i.e., X tons at 45 per cent moisture).

Assuming that on this particular plant additional heat recovery surface is added to reduce the gas temperature to 150°C (which temperature would, of course, be entirely satisfactory with the lower percentage moisture of the exit gases), the efficiency would be increased to 81.2 per cent and only 0.475X tons of 12 per cent moisture bagasse (0.760X tons at 45 per cent moisture) would require to be burned for the same steam production.

From the above specific example it will be realized that a combined saving of bagasse of 24.0 per cent has been effected by the joint features of lower moisture in the bagasse as fired and lower exit gas temperature. Again, at the risk of reiteration, we would point out that this saving of bagasse applies regardless of the basis of comparison, i.e., dry bagasse, 12 per cent moisture bagasse, 45 per cent moisture bagasse, etc.

Naturally, if the initial percentage of moisture was higher than the 45 per cent used in the example, the percentage saving in bagasse would be greater; by using the two graphs shown, the saving which can be achieved in any particular case may be readily assessed.

Thus if practice could follow theory fully, the foregoing shows that about one quarter of the bagasse burned can be liberated for paper making by (1) fitting an economizer and/or air pre-heater, and (2) by drying the 45 per cent wet bagasse before burning to a normal air-dry state (say, 12 per cent moisture)—as may be done by baling and storing and allowing to dry out naturally in stacks over a period of several months.

In practice, however, certain important considerations arise, which are referred to later.

Economizers and air pre-heaters. The reduction of the temperature of the combustion gases from the boiler to the chimney may take place in either an economizer or air pre-heater or both, depending on the economy which can be effected by the two sections of heat recovery equipment. For example, in the case of economizers, in order that steaming should not take place in the economizer, it is preferable to ensure that the outlet temperature from the economizer is some 40°C below the saturation temperature of the boiler water. As, in general, the feed water temperature in a sugar factory is of the order of 90°C and can easily be maintained at 105°C (condensate return tank under pressure), the heat recovery which may be effected in an economizer, particularly a low-pressure installation, is somewhat restricted. Economizers will therefore be found to be more valuable when used in conjunction with high- or higher-pressure boilers.

With air pre-heaters, depending on the type of hearth furnace employed, there is a limit to the extent of air pre-heating considered advisable; while the upper limit was formerly considered as about 200°C, with modern plants 250°C is quite suitable.

Air pre-heating, therefore, may be advised as the first economy in conventional sugar mills equipped with low-pressure boilers.

To obtain the fullest advantage of air pre-heating hearth-type furnaces should be employed, as the forced draught fans which are in any case necessary with air-heaters are similarly necessary with hearth-type furnaces; their use with stepped-grate furnaces is attended in some cases with operational difficulties. These difficulties are not experienced with the hearth-type furnaces, and the air pre-heat assists not only in the drying of the bagasse, but also in the general combustion conditions.

Thus, although there is the factor of increased furnace maintenance costs to be considered when operating at higher temperature, there is no reason why a saving of some 10 per cent bagasse in round figures may not be achieved by the addition of an air-heater to a hearth-type furnace.

If a stepped-grate type of furnace is at present in use, a rather higher percentage improvement, say up to 15 per cent, may be realized by the incorporation of an air-heater and also the adaptation of the grate to a modern hearth-type design, an alteration which need not be elaborate or expensive.

Bagasse and alternative fuels

It is relevant here to consider the average calorific value of bagasse as compared with alternative fuels, bearing in mind the different average efficiency with which they are generally burned.

The amount of bagasse which may be liberated by burning an alternative fuel can be calculated approximately from the last column. It will be realized that in actual fact probably less of an alternative fuel will be required than is indicated by the calorific value and the efficiency; this is in general due to the fact that most alternative fuels are more convenient to burn than bagasse. With fuel oil, for example, it is relatively easy to adjust the quantity of fuel to match the steam demand and, as this is likely to be subject to sudden fluctuations, a measure of economy can be achieved with such a readily controllable fuel. On modern bagasse-fired installations with self-feeding furnaces of the Thompson-Eisner type and with automatic boiler pressure control, however, it should be noted that the rate of combustion of the bagasse can be readily controlled in relation to the steam required.

The table below shows that 8,000 ÷ 1,390 = 5.7 tons of 45 per cent wet bagasse burned at 55 per cent effi-

Table 7

LIBERATION OF BAGASSE BY BURNING ALTERNATIVE FLUES

	Gross calorific value (CV) kcal/kg	*Typical approx. boiler efficiency (e)*	*Heating value kcal/kg (CV x e) 100*
Poor coal (e.g., Bihar, India)	5,600	75	4,200
Average coal	6,700	78	5,200
Fuel oil	10,000	80	8,000
Moist bagasse (45% water)	2,530	55 (stepped-grate)	1,390
		60 (hearth-type)	1,520
Air-dry bagasse (12% water)	4,050	80 (hearth-type with air-heater and/or economizer).	3,240

ciency are liberated by substituting one ton of the more conveniently manipulated fuel oil burned at 80 per cent efficiency.

If the cost of fuel oil is assumed to be $25 per ton, then since 5.7 tons of 45 per cent wet bagasse equals 3.14 tons of oven-dry fibre, the cost of liberation by alternative fuel is $25 ÷ 3.14 = $8 per ton of o.d. fibre. To this must be added the cost of baling, stacking and unstacking the bagasse in order to allow it to dry out to an air-dry condition of, say, 12 per cent moisture. For calculating purposes this may be taken as an average of $6 per o.d. ton,[3] making a total cost of $14 per o.d. ton in all (the total cost to the paper mill of bagasse obtained in this way) if the sugar mill is not to lose money over the substitution.

If the bagasse is burned in an air-dry condition in a hearth-type furnace, then the table shows that 8,000 ÷ 3,240 = 2.47 a.d. tons will do the work of 1 ton of fuel oil at 80 per cent efficiency; this represents 2.17 tons of o.d. fibre. By comparison with the heating value of wet bagasse fired on a stepped grate at 55 per cent efficiency, the saving of o.d. bagasse fibre is 3.14 − 2.17 = 0.97 tons or approximately 31 per cent.

Taking the cost of baling, stacking, etc., as before at $6 per o.d. ton means that the cost of supplying the sugar-mill furnaces with 2.17 o.d. tons of bagasse in the form of air-dry bagasse will be $13—say $14, if the cost of breaking down the bales for feeding to the furnace is included. This will do the work of a ton of oil at $25, but whereas the straight substitution by oil liberates 3.14 o.d. tons of bagasse for paper making as shown above, the corresponding amount of bagasse released by burning a.d. bagasse is only 0.97 o.d. tons. Thus the fuel replacement cost of liberating one o.d. ton of bagasse by burning a.d. baled bagasse is $14 ÷ 0.97 = $14.5 per ton, compared with $8 with fuel oil substitution. Adding the cost of baling at $6 per ton as before, the total cost to the paper mill of the baled bagasse is $20.5 per o.d. ton — 50 per cent higher cost than for baled bagasse obtained by direct oil substitution.

When account is taken of the ease of handling fuel oil compared with the tremendous if not impracticable task of baling over three times the amount of bagasse which is to be released for paper making, it is obvious that the burning of dried bagasse after baling, although attractive in principle because of the much higher boiler efficiency, is not to be considered practically.

Thus it can be said from the foregoing that the maximum efficiency (and hence economy in bagasse) can be achieved by delivering the bagasse as dry as possible from the sugar mill, and by installing a modern hearth-type furnace with air pre-heater and/or economizer.[4]

The question of using alternative fuels in the sugar mill may also be linked with the supply of fuel for steam and power generation in the proposed bagasse pulp mill. The pulp mill will generally be close to the source of bagasse, and the whole question therefore of the availability of substitute fuels for the sugar mills assumes a different aspect.

It should be stressed that the value of the bagasse to the paper maker may well exceed that of providing the alternative fuel, and this point needs to be fully examined when assessing the possibilities of a bagasse pulp and paper scheme.

[3] This figure is the mean between $4.55 o.d. ton of fibre for the Philippines and $7.15 per o.d. metric ton equivalent in Louisiana, U.S.A.—the latter figure being computed by Prof. Keller (*Paper Trade Journal*, 2.5.52).

[4] On initial installation, the cost of a Thompson-Eisner hearth-type grate is little different from that of a stepped grate—slightly cheaper, if the latter is equipped with forced draught. A conversion costs initially the same as putting in another stepped grate. If the necessary fan equipment is available and the boiler front is suitably shaped, the over-all cost is not a great deal more than a major brickwork renewal and overhaul. The effect of such conversions in a number of mills in British Guiana, for instance, has been approximately to double the evaporation rate of the boilers.

SAVING OF BAGASSE BY IMPROVED BOILER-HOUSE OPERATIONS[1]

G. Ranwez

This study aims at showing how to improve the efficiency of steam generating installations in the sugar mills, so that fuel consumption can be reduced. This not only eliminates the need for using wood or oil as a supplementary fuel, it also frees bagasse for the paper industry.

Table 1 below compares four installations:

I. A typical installation in a sugar mill having boilers equipped with the type of furnace that is still most commonly used for bagasse burning, such as the stepped- or horizontal-grate furnace.

II. The same boiler and furnace, but equipped with heat recovery units such as an air heater or economizer, or both, depending on local conditions.

III. The same boiler with the recovery units indicated in case II, but with the addition of a modern bagasse-burning unit consisting of dumping grates, feeders, injectors and turbulence equipment.

IV. The boiler mentioned in case III completed by the installation of water jackets in the furnace.

These installations are discussed in turn.

Case I

The typical installation selected consists of a water tube boiler with a heating surface of approximately 500 m², 15 tons per hour of steam at 12 kg per square centimetre—270°C.

The standard combustion equipment is the stepped- or horizontal-grate furnace, which requires a pre-furnace, the front of which projects beyond the front of the boiler, and which consists principally of one or, if possible, more sections of the furnace itself to facilitate regular cleaning. A grate operating by natural draught is

[1] A shortened version of the original paper, ST/ECLA/CONF.3/L.5.4.

Table 1

OPERATION, EFFICIENCY AND PRODUCTION OF A 500 M² BOILER

(12 kg/cm²—270°C—15 t/h)

	Basic equipment case I	*Equipped with recovery units case II*	*With scattered feeding and recovery units case III*	*With water jackets case IV*
Temp. exit gases°C	350	200	200	200
CO^2 in gases (per cent)	8.5	8.5	15	15
Efficiency (per cent)	57	73.5	82	82
Daily evaporation (t.)	324	324	360	400
Bagasse (t/day)	150	142	136	151
Fuel-wood (t/day)	22	—	—	—
T. steam/t. fuel	1.88	2.27	2.64	2.64
Personnel: $\frac{\text{man hours}}{\text{t. steam}}$	0.26	0.18	0.034	0.031

placed in each one of these sections; the distribution of the combustion air depends on the manner in which the fuel has been distributed, in most cases arbitrary.

The extraction of ashes and the cleaning of the sections takes place periodically (approximately every eight hours) and the corresponding section ceases to function during the operation. During cleaning, the boiler pressure drops, so that operation practically ceases for a period of 30 to 45 minutes.

Specific evaporation (steam production in kg for each kg of fuel consumed) is 1.88. Fifteen per cent of wood is required as additional fuel.

Labour requirements are one stoker for each boiler and a gang of six operators to attend to the cleaning of four boilers. Adding the manp-power required to handle the fuelwood, the total figure becomes 0.26 man-hours per ton of steam produced.

CASE II

In this case, the specific evaporation, 2.27 kg of steam per kg of fuel, already represents a considerable reduction in the amount of fuel required per ton of steam as compared with case I.

The installation of recovery units eliminates the need both for additional fuelwood and for the labour required for its handling. A small surplus of bagasse becomes available, which can be used as raw material in some other industry.

The saving in fuelwood costs permits amortization of the recovery unit over a period of approximately 120 working days.

CASE III

In this instance the boiler is equipped, in addition to the recovery unit, with a bagasse-consuming unit of modern design, with a scattered feed, e.g., made up of a variable speed feeder, a mechanical rotary distributor, and dumping grates with the draught forced through the grates. Equipment is included also for reinjecting into the furnace the ashes deposited in the channels of the boiler, and for producing turbulence in the furnace by air currents, permitting a more complete combustion of the bagasse.

The outstanding characteristics of this system are continuity and uniformity in feeding and burning.

In an average furnace the bagasse is distributed irregularly and the cleaning out of the ash receptacle is a long and costly process, during which the operators are exposed to high temperatures while strong currents of cold air enter the furnace.

In the new equipment part of the fuel is placed in a thin uniform layer over the grate, cooled by the secondary air currents. The grate is cleaned from the outside by a simple lever motion lasting only a few seconds, which does not cool the furnace.

Maintenance costs are low and the units can easily be adapted to completely automatic combustion controls; this is not possible with any degree of efficiency using the old systems.

Daily output increases to 360 tons, with lower fuel consumption. For equal daily evaporation, the application of these modern units permits a daily saving of thirty tons of bagasse as compared with case I, in addition to the having in fuelwood.

Labour requirements fall to 0.034 man-hours per ton of steam, with a corresponding reduction in the cost of steam.

This saving is the result of the unit being operated at a more rational and uniform speed. The elimination of the cleaning periods means that the installation pays for itself in less than 150 working days out of fuelwood savings alone.

This calculation does not take into consideration the reduction in labour cost, nor the potential sales value of the bagasse released.

CASE IV

The addition of water jackets increases the heating surface. Output may be considered the same as in case III, but the evaporation capacity of the unit rises to some 400 tons per day, permitting a reduction in the number of operating units and in personnel.

The protection of the furnace's refractories by the water tubes prolongs their life and substantially reduces conservation costs.

CONCLUSIONS

Thus existing installations can be improved considerably at a fairly low cost. These improvements can be amortized in a very short time.

Considerable quantities of bagasse can be released for the paper industry. Rationalization of fuel in the sugar-mills would permit substantial savings of wood or fuel-oil.

These economies arise from modifications in the present system of bagasse-burning, rationalization which can be carried out simply, cheaply and without going beyond the resources of local industry. The discussion has not touched on bagasse savings which would arise from conversion of the boilers to burning other fuels; this would require heavier investment and perhaps the import of expensive equipment.

PURCHASING, HANDLING AND STORING OF BAGASSE[1]

A. Watson Chapman

The Celotex Corporation began its operations in the collecting of bagasse fibre in the Louisiana sugar-cane growing area during the season of 1920-1921. In the thirty-three annual grinding seasons since that time the Corporation has continued and expanded its activities in this field and has developed standard operating procedures and techniques to handle the large volume of material which must be baled and stored within a period of approximately seventy-five sugar-mill operating days. It is the purpose of this paper to describe these current operating procedures and to point out some of the difficulties that were encountered during their development, with the hope that it will be of assistance to others who are interested in the use of this fibre as a raw material.

It might be well to point out that the Celotex Corporation examined a great many types of fibres and agricultural residues before making the decision to use bagasse as the raw material for the manufacture of rigid insulating fibreboard. As is usually the case in making such a decision, there were both advantages and disadvantages in the use of this material. Among the advantages are the facts that bagasse is:

(1) A long, tough and strong fibre;

(2) Naturally resistant to decay;

(3) Of high purity;

(4) An annual crop;

(5) Hauled from the fields to the sugar factories and is thus available in quantity at specific locations which are already accessible to some means of transportation; and

(6) A (bulky) by-product of the sugar cane industry and as such, one which must be disposed of or used up.[2]

Among the disadvantages of bagasse are:

(1) The high moisture content of the fibre as it comes from the sugar mills;

(2) The handling of huge volumes in a relatively short working period;

(3) The problem of storing and preserving it under uniform conditions;

(4) The necessity for employing a large volume of labour to handle baling and storing activities during a short period of the year;

(5) The problem of finding and supplying an available and economical replacement fuel;

(6) The necessity for removing and handling the fibre as quickly as it is produced by the sugar factory; and

(7) The fact that sugar factories are usually located in rural areas which means that transportation to an industrial plant may result in relatively high transportation costs, especially considering the bulk of material which has to be moved.

These disadvantages have all had an effect upon the development of the company's operating procedures.

Purchasing

So far as the Corporation is concerned, the purchasing of bagasse is normally handled on a contract basis with the individual sugar mill. Such contracts provide for the buying of oil, or gas, or other substitute fuels to replace at least the fuel vaue of the bagasse. Allowance for the heating value of the bagasse is based on the actual average cost to the sugar house for the fuel oil purchased, and delivered each year, and consumed during the grinding season of the same year in the production of steam in the sugar-house furnaces. If some fuel other than oil is used, the heating value of this substitute fuel is taken into account in determining the equivalent price based on the current price of fuel oil.

There is usually a penalty clause in the contract whereby the Corporation has to take care of any costs incurred if the sugar mill is forced to shut down its operation because of some breakdown at the baling station. The reason for this is obvious, when it is remembered that the grinding season is of such short duration; every hour counts and the sugar mill operates twenty-four hours a day, seven days a week once grinding starts, except for an occational short stop to permit clean-ups.

Since both the amount of bagasse required for the Celotex Corporation's activities and the tonnage of cane grown are bound to fluctuate somewhat from year to year, the contract contains an optional clause whereby the Corporation must notify the sugar mill well in advance of its intentions with respect to any changes in quantity to be purchased at that particular factory during the next grinding season. At some locations the company may take all or none of the bagasse produced during a particular grinding season. At other locations, the sugar mill may be equipped so as to burn part of its bagasse and the percentage of the bagasse taken by the Corporation may thus vary from one season to the next.

Usually arrangements are made to obtain the steam and electricity required by Celotex for its baling operations from the adjacent sugar factory, and this may form part of the purchase contract or it may involve a separate agreement. Similarly, there may be a separate

[1] Originally issued as ST/ECLA/CONF.3/L.5.5.

[2] Its major value to the sugar industry is, of course, that of being a cheap but rather low grade fuel.

agreement covering the rental of the land required for the baling station and storage field.

In order to determine the weight of moisture-free fibre which has been delivered to the Corporation, it is necessary for both Celotex and the sugar mill to run certain control tests and exchange information obtained. These include determination of the total weight of bagasse delivered to the baling station, the moisture content of the material both as it leaves the factory and as it reaches the balers, and the percentage of soluble solids which are left in the bagasse itself. A new factor has entered this picture in recent years which is usually identified as "cane trash". When the Celotex Corporation started its activities in the gathering of bagasse and set up a specification, the cutting of cane was entirely a hand operation. As each stalk was cut it was topped and the leaves stripped off by the cane cutter with his cane knife. With the introduction of mechanical harvesters and the cutting of larger and larger volumes each year by these machines, the arrival of cane at the sugar factory with the leaves still attached became more and more of a problem, especially in the earlier part of the grinding season while the leaves were still green. The presence of these leaves cut down the grinding capacity of the sugar mill and increased the bulk of material handled at the baling station—with coresponding increases in storage and transportation costs—without any corresponding increase in the quantity of good fibre obtained. The measurement of the amount of trash from cane delivered to the sugar mill is now a standard procedure and deductions are made when it exceeds an agreed-on maximum.

Handling of bagasse

The handling of bagasse requires installation of a baling station on land adjacent to the sugar mill. When the first crop was handled in 1920 at the one factory from which material was collected that particular year, a blowing system was installed which conveyed the bagasse through a pipeline into a field where it was allowed to build up in loose piles, the intention being to bale the bagasse after the grinding season was over. It was quickly realized that this system was a mistake. There were numerous breakdowns of the blowing system and it was, of course, inefficient first of all to pile the bagasse and then to take it down again to be handled through the balers. Secondly, it was discovered that there were no standard balers on the market which handled this material satisfactorily. They all produced bales in which the fibre was compacted tightly on one side and loose on the other. Thus it was necessary to design an extra heavy baler and this design, with modification and improvements, has been operating successfully even since.

A modern baling station covers an area of about 18 x 18 metres with a height of about 9 metres or so, depending upon the arrangement of the equipment within the station and the height at which the bagasse feed comes into the area. A railroad track runs inside the baling station along one wall and the balers are elevated above the floor so that they discharge to a platform which is above the floor level of the small railroad cars on which the bales are placed for transportation to the storage field. The bagasse is moved from the discharge end of the sugar mill to the baling station by means of slat conveyors, or belt conveyors, or a combination of the two. It enters the baling station near the roof and discharges into a cross conveyor which moves the fibrous material past discharge gates leading down to the hoppers of the balers underneath. These discharge gates are adjustable so that the fibre input can be split up between two or more balers as circumstances require. At the end of the cross conveyor there is a pick-up conveyor which takes care of any bagasse that has failed to drop into one of the discharge chutes and conveys it back again to the head of the discharge conveyor.

The first type of bagasse chutes leading from the overhead conveyor into the hopper of the baler were simply inclined troughs. These were open on the top side and a man with a rake was stationed at each one to rake the material down and thus keep the hopper full of material at all times. These have been changed to vertical completely enclosed chutes fitted with counterweighted trap doors. The trap doors serve to hold back the bagasse momentarily so that when they open, a full charge is dropped into the baler for the next stroke of the baling ram.

The number of balers installed at a station depends upon the amount of material to be handled and also the speed at which the particular model of baler can be operated. Usually three or four balers are installed, one being intended to serve as a spare in case of a breakdown, or to handle any sudden surge of material which may come either from the sugar factory or from cleanup of broken bales. The first balers used were the block type in which a sudden block was inserted into the hopper at intervals to govern the length of the bales. These blocks had channels in them through which wire could be fed by hand, and the loose ends tied on either side of the discharge press on the baler. The expansion of the bale as it left the press tightened these wires around the bale. The block press has been replaced by the semi-automatic baler in which mechanical needles force the wires through the fibrous mass and cut the wires to the proper length so that the ends may be tied together by hand. These balers turn out about one bale every forty-five seconds. The latest baler designed involves much heavier construction and although as yet this has not been put into wide use, there is every indication that it will be able to produce the same size bale at approximately twice the speed, thus cutting down the number of balers required per installation.

The bales are about 46 x 56 x 81 cm (18" x 22" x 32") in size and are held together by two wires which circle the bale in the long direction. A bale weighs about 115 kg and since it usually contains from 40 to 50 per cent moisture as made, this represents rather more than 55 kg of moisture-free fibre. If the bale is made much larger than this, it becomes difficult for one man to move it into place. On the other hand, if a bale is made much smaller, then the amount of wire used per ton of usable fibre is increased as well as the amount of "loose" which is produced when the bales are broken apart as they come out of the baler. This loose material drops down into a chute which reintroduces it into the discharge conveyor with the entering bagasse. The bales are rolled into position on the small flat cars or placed in position by small hoists. Any bales broken in handling have the wires stripped from them and the bagasse fed back into a conveyor so that it can be reintroduced into the discharge conveyor at the top of the baling station.

One method of checking the weight of bagasse produced is to weigh all the loaded flat cars on a track scale as they leave the baling station headed for the storage field. The empty cars and any loose material which has fallen off and remained on the car platforms are then re-weighed when they come back from the field and the difference represents the weight of bagasse which has been sent to the storage area. A recent innovation has been introduced of automatic weighing equipment inserted in the conveyor system between the sugar factory and the baling station. This gives a record of the weight of material which has passed over the belt. In either case, moisture samples have to be taken to correct the weight of bagasse to the moisture-free condition.

In the baling station itself a standard crew per shift would consist of a mechanic in charge of operation of the balers, a man checking the flow of bagasse to all the balers, a clean-up man handling loose bagasse, and, for each baler, a wire tier and a man handling the bales between the baler and the railroad cars.

Storage of bagasse

The size of the storage field depends on the amount of material to be stored at the particular station. For a factory which grinds 2,000 tons of cane per day, space for thirty-six stacks would allow handling the normal season's output. Where the land area available permits, it is customary to make the storage field rectangular in shape and to erect the stacks in parallel rows with the long dimension of the stack in the same direction as the long dimension of the storage field. The standard stack is 38 metres long by 21 m wide by 9.5 m high (120′ x 66′ x 30′) and would contain about 600 tons of dry fibre or approximately 12,000 bales.

The stacks have to be spaced to provide for both fire protection and railroad access. The normal arrangement of a field, rectangular in shape and designed for 36 stacks, would be to have the stacks in four parallel rows. There would be a space of 9.5 m between the edge of the field and the first row of stacks and each stack in that row would be separated from its neighbour by a 9.5 m (30′) space. Between this row and the next parallel row, a 15.7 m (50′) space would be set aside to permit laying a railroad track down between these two rows of stacks. In like fashion, there would be a 9.5 m gap between the second and third rows of stacks, a 15.7 m (50′) gap between the third and fourth rows and a 9.5 m space between the fourth row and other edge of the storage field. Thus, this storage yard would require an area of approximately 140 x 470 m (450′ x 1,500′).

In preparing a storage field the area on which the stacks are to be located should be crowned and drainage ditches provided on either side so that any ground water resulting from rain will drain away from the stacks.

The bales when they reach the pile area are picked up off the small railroad cars by a hoist using a special design grab which lifts six bales at one time. As these are swung into position and set down, special spacer bars on the outside of the grab automatically leave a ventilation duct between this particular group of bales and those which have been previously placed in position. The provision of ventilation ducts in these stacks is of extreme importance so that the heat of fermentation may be removed and the material dried out as rapidly as possible. Powdered boric acid is sprinkled over all the outside bales and also over all the bales on the top of the stack to reduce mould growth and to act as a preservative where rain water might enter. The top tiers of the stack are arranged in a gable effect and after the heat of fermentation has been dissipated the piles are covered with metal panels like huge shingles. These are fastened by driving large spikes down into the bales, and the ends which project like eaves over the sides of the stack are secured with cables and spikes. Wicks are placed on these cables so that any rain water running down them will be deflected from entering the pile itself.

When the time comes to start shipment from any particular pile into the board plant itself, the roof panels are removed and the stack is taken down using a hoist and grab. The railroad company provides either gondolas or boxcars whose roofs have been removed and which are earmarked for this special service.

Naturally some field losses occur in the handling of the material. These include, for example, loose material, which cannot be picked up economically, muddy bales from the bottom tier if improper drainage has occurred in the storage field, and a few localized burnt spots or areas in which ventilation has not been sufficient to prevent deterioration of fibre strength through acid fermentation. However, considering the huge volume of material handled, field losses are remarkably small.

One aspect of these field operations which has not been included above is connected with the labour problem. In order to secure the necessary amount of labour for such a short period of each year it is necessary for the Corporation to bring in personnel from a considerable distance. This involves transportation costs and the provision of both board and room facilities.

It also means, in most of the locations where baling operations are conducted, that it is necessary to provide boarding houses for the seasonal transient labour. This need for a hotel and restaurant service at some fifteen different locations for a period of about three months of each year is no small problem in itself.

The fact that these baling-station operations must be carried on at a multitude of places demands a large investment in buildings and equipment. A modern baling station with its buildings, balers, conveyors, storage fields, hoists, railroad tracks and railroad equipment, track scales, etc., calls for an investment of approximately a quarter of a million dollars. In addition to the operations carried on at each individual sugar-mill location, there has to be a central supply warehouse with mechanics available twenty-four hours a day to take care of emergencies. Maintenance and repair work is also required throughout the year even though the stations may not be operating the whole time. It is as well, therefore, to keep these facts in mind whenever the statement is heard that bagasse is a "cheap" fibre. It is a good, economic fibre, yes, but it is not cheap.

FACTORS INFLUENCING THE SELECTION OF PROCESSES AND CHOICE OF EQUIPMENT FOR BAGASSE PULP MANUFACTURE[1]

JOSEPH E. ATCHISON

I. INTRODUCTION

This paper gives an outline of the most important individual processes available for the production of pulp from bagasse, some comments on the highly important depithing operation which should precede any of these operations, and a discussion of the many technical and economic factors which need to be considered in selecting the proper process for any proposed mill. It then deals with some of the factors which should be considered in selecting the type and source of equipment which will be necessary after the proper process has been chosen.

II. THE NEED FOR CARRYING OUT A THOROUGH TECHNICAL AND ECONOMIC SURVEY FOR EACH PROJECT

As the first step in the development of any project for the production of pulp from bagasse it is essential that a complete technical and economic survey is carried out by personnel who are competent in this field. A survey made by people whose entire experience in the pulping field has been with wood is of little value; the problems inherent in pulping bagasse and in constructing and operating a pulp mill based on this raw material are entirely different from the problems connected with wood. In fact, one of the prime reasons for the failure of scores of bagasse pulp and paper mills has been a lack of understanding of the nature of the raw material, combined with attempts to handle it as pulpwood is handled.

The choice of process and equipment, as well as the decision whether a project is feasible at all, involves a consideration of many complex, inter-related technical and economic factors which can be properly treated and analysed only by highly experienced personnel.

The survey must be thorough in every respect and must be specifically applicable to the exact location in which the mill is to be constructed. It is folly to base the development of a project on data obtained from and conditions existing in other countries, or even in other mill locations in the same country.

The survey should be impartial and should clearly indicate the choice of process and equipment which best fit the situation after all factors have been considered, giving sound reasons for this choice. The report should also show clearly the economic prospects for the mill and the possibilities for carrying out a profitable operation on a competitive basis. Under no circumstances should it recommend construction of a mill where there is the slightest doubt of profitable operation over a long-term period.

III. THE IMPORTANCE OF DEPITHING THE BAGASSE BEFORE PULPING

Whether or not sugar cane bagasse should be depithed before pulping has been a subject of controversy ever since the prospects of using this raw material for the production of pulp were first considered. This problem, as well as various methods for carrying out the depithing operation, is discussed in other papers, notably that by Dr. E. C. Lathrop,[2] who has done such important work in the whole field of pulping agricultural residues and who has developed many processes for separation of the pith from the bagasse fibre itself.

In the literature on pith separation, at least three views may be distinguished. The first holds that whole bagasse can be used without pith separation, thus obtaining a high yield of usable product. This view disregards the quality of the product and the tremendous difficulties which ensue in paper mill operations when the pith is left in the pulp. This view is held mainly, although not entirely, by men whose chief experience has been in the field of pulping wood. Many of them, after years of work with bagasse in which they have experienced many difficulties, have finally come to the conclusion that separation of pith from the fibre is necesary after all. However, many mills have been built on this basis over the course of years and in almost all cases have failed because of a tendency to arrive at definite conclusions before carrying out sufficient preliminary work. Many failures could have been avoided, and much valuable time and money saved, had thorough use been made of all the literature describing previous work. The literature of the past fifty years offers a tremendous storehouse of information on bagasse which clearly indicates the need for depithing bagasse before attempting to use the fibre for pulp.

Another view, while recognizing the difficulties involved in handling pith, makes an attempt either to remove it in the cooking process or to carry out this operation in such a way as to change the character of the pith and render it usable as a filler in the final product. These processes are usually complicated and involve at least two stages of pulping, which, of course, considerably increases the cost, thus rendering the processes of doubtful economic value. Furthermore, in spite of the claims of both these groups of workers that the pith goes through the process and is usable in the final product, in actual fact a large proportion of the pith is lost in the pulping process, in washing the pulp, in the refining process and in all subsequent processes carried out in the paper mill. When the pith is left in the bagasse, a considerable proportion of it is always dissolved in the pulping operation because of its large surface area and ability to absorb the cooking chemicals even more readily than the fibres. When the cooking liquor is washed out of the pulp, and if the washing is good, additional pith is eliminated with the wash liquor.

When the pulp is subsequently run through pumps, over knotters, through centrifugal separators, over screens, over thickeners, and into stock chests with agitators, every step of the way involves the mechanical action of one fibre against another. Later, when the pulp is broken up in the paper mill, it is again subjected to violent agitation, pumped in slush form through refiners

[1] A slightly shortened version of the original paper, ST/ECLA/CONF.3/L.5.6.

[2] See Paper 5.2, *Economic and other factors to be considered in the use of sugar cane bagasse as a raw material for pulp and paper manufacture.*

and into more chests with more agitation. Inevitably, more pith is knocked loose from the fibres and into the water suspension and much of it is thus eliminated from the system and lost completely.

Even so, the remaining pith always causes trouble throughout the paper mill operations and constant care must be exercised to prevent these ill effects. Thus, materials such as diatomaceous earth and other fillers of high absorption capacity must be added to prevent the pith from clogging up the wires, sticking to the presses, clogging up the felts and otherwise hindering the operation of the paper machine.

Thus, in spite of all efforts, only a low yield of paper is obtained, while many of the difficulties inherent in pulping bagasse with the pith present are still experienced.

The third view, to which the author wholeheartedly subscribes, advocates that all pith separation be carried out by mechanical means preliminary to the pulping operation. It further advocates that after this separation both pith and fibre be given any further treatment separately and be used for purposes specifically suited to each.

This group of workers has found that, because of the nature and condition of the pith and the accompanying extraneous substances which exist in the bagasse at the time of leaving the sugar mill, pith is detrimental in every way to the production of high quality pulp.

The pithy material, if allowed to remain in the bagasse during the pulping or digestion process, is attacked much more easily by the chemicals than is the fibre; its digestion therefore consumes much more chemicals yet yields little chemical pulp.

Furthermore, since the pith contains a high proportion of the residual sugars and other water soluble materials remaining with the bagasse, these materials also react with the chemicals, thus further increasing the chemical consumption. A considerable proportion of the pith is dissolved during the digestion process and thus a low yield results in comparison with the total rate charged to the digester. In addition, when the bagasse is subjected to strong alkali or other chemicals in the digestion process while the pith is still present, some of this pith, along with the absorbed extraneous materials associated with it, tends to swell and become gelatinous in character, so that it causes great difficulties throughout the converting process. This gelatinous material tends to clog up the wires on the paper machine, excessively decreases the drainage rate of the pulp on the paper machine wire, sticks to the press rolls, slows up the felts, and decreases the drying rate of the paper. It also makes the paper brittle, greatly decreases its strength properties and gives rise to dirty and shiny spots. In general it renders the pulp unsuitable for conversion into high grade products.

Furthermore, because of the absorbed dirt and colloidal soil, the pith contains a high proportion of the ash content of the bagasse. Therefore, if the pith has not been separated before digestion, when an attempt is made to bleach the bagasse pulp an excessive amount of bleach is required and even then it is almost impossible to obtain a high brightness without dirt spots.

Thus for production of high quality pulp from bagasse fibre, separation of the pith from the fibre is necessary before digestion. However, if the pith is removed and discarded, the yield of pulp from bagasse is in some cases too low to permit economic operation. Over the past fifty years, many investigators have advocated separation of the pith from the fibrous elements of bagasse, but only a few have attempted to put such a process into commercial operation, because there was no economic use for the pith. The consequence has been that many mills, because they sought a high yield by leaving the pith cells with the fibre throughout the pulping, bleaching and paper-making operation, have failed in their attempts to produce a salable paper from bagasse. Operations proved inefficient and costly and the final product was of poor quality and not acceptable on the market.

However, as a result of intensive efforts made over the past few years, excellent methods have now been developed for the separation of pith from bagasse fibre and highly profitable uses have been developed for the pith fraction. Therefore, provided other factors are favourable, there need be no fear of this problem in constructing new bagasse pulp mills in the future.

Two important pieces of work in this field clearly point out the need for separation of pith from fibre. In 1948, Dr. Arthur G. Keller, Professor of Chemical Engineering at the Louisiana State University, studied the fractionation of pith which had been separated from Louisiana bagasse. The pith was in the dry state and fractionation was carried out by means of sieves of various mesh sizes. The results of this work, which are shown in table 1, point conclusively to one of the sources of difficulty in the attempt to leave the pith in bagasse when producing pulp: this is the high ash content, which varies from 7 to almost 40 per cent. It is obvious, then, that one would experience great difficulties especially in attempting to bleach a pulp containing the pith. These results also indicate that the finest particles of pith

Table 1

RESULTS OF PITH FRACTIONATION WORK CARRIED OUT BY DR. ARTHUR G. KELLER OF LOUISIANA STATE UNIVERSITY IN 1948

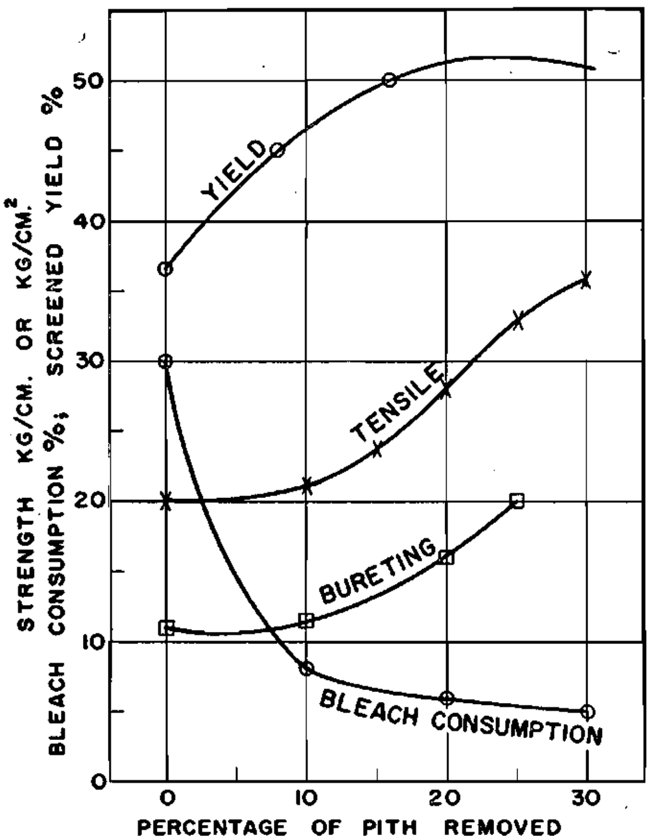
Fraction retained	*Percentage of total pith*	*Percentage of ash content*
SAMPLE 1–11/4/48		
On bottom pan	8.5	35.22 ash
On 80 mesh screen	6.5	21.39 ash
On 60 mesh screen	74.0	13.00 ash
On 20 mesh screen	10.5	7.69 ash
On 14 mesh screen	None	—
TOTAL	99.5	
SAMPLE 2–11/5/48		
On bottom pan	8.0	34.88 ash
On 80 mesh screen	4.5	22.90 ash
On 60 mesh screen	74.5	11.40 ash
On 20 mesh screen	12.5	8.01 ash
On 14 mesh screen	None	—
TOTAL	99.5	
SAMPLE 3–11/9/48		
On bottom pan	16.0	39.20 ash
On 80 mesh screen	9.0	22.80 ash
On 60 mesh screen	69.0	9.90 ash
On 20 mesh screen	5.0	6.88 ash
On 14 mesh screen	None	
TOTAL	99.0	

contain the greatest proportion of the absorbed colloidal soil and other extraneous materials and that for some grades of paper a partial separation of pith might prove to be adequate. This has been proved true in commercial practice, and techniques have been developed for carrying out such a partial separation.

Another valuable piece of work on these lines was carried out by the Taiwan Pulp and Paper Corporation in Formosa. The effect of leaving varying proportions of the pith in bagasse going to the pulp mill was studied; the results are shown graphically in figure 1.

Figure 1

Effect of pith content of pulping and bleaching bagasse as determined by the Taiwan Pulp and Paper Corporation



This again seems to point out conclusively the disadvantages of leaving the pith in the bagasse, if high quality products are to be produced economically. The percentage of pith removed is based on the total content of pith (amounting to approximately 30 per cent of the whole bagasse). Thus 30 per cent removal means complete removal, 10 per cent means removal of one-third and 20 per cent means removal of two-thirds of the total pith.

The strength of the pulp continues to increase until all the pith is removed, while there is a sharp increase in strength when the last 50 per cent of the pith is removed. This is very important if strong papers are to be produced and indicates that complete pith removal is necessary or at least desirable for such grades.

As regards screened yield of pulp, a yield of 50 per cent is reached after about half the pith is removed and the yield increases very little as additional pith is removed. However, this figure shows that when using whole bagasse a yield of only about 37 per cent is obtained as against 50 per cent with partial or whole pith removal. Thus removal of a considerable amount of pith before pulping does not alter the final yield based on the weight of the original bagasse.

The results in bleaching are particularly significant, showing that when whole bagasse is used, bleach requirements are exorbitant, total chlorine amounting to 30 per cent based on the weight of the pulp. With removal of pith, bleach requirements decrease rapidly, falling as low as 5 per cent chlorine when all the pith is removed.

Thus, the findings of research workers all over the world confirm that pith separation before pulping is one of the keys to the successful use of bagasse as a raw material for pulp. It therefore plays a major role in the choice of processes and equipment for manufacture of bagasse pulp.

IV. Conventional pulping methods used for pulping wood which, without modifications, are not applicable to pulping bagasse

In choosing a process and the equipment for a bagasse pulp mill, it should be emphasized that, without considerable modifications, the methods used for pulping wood are not applicable to bagasse. One of the reasons for this fact has been described in detail in the previous section on depithing. There are other important reasons.

Bagasse is very bulky compared with the compact structure of wood. Therefore, if conventional digesters are used, the capacity per digester is small and due allowance for this factor must be made in furnishing a sufficient number of digesters to obtain the desired pulp production. In addition, proper methods must be chosen to ensure good packing in the digester so that the maximum amount of bagasse fibre can be charged per cubic foot of digester space. The weight of bagasse fibre per cubic foot of digester space can vary greatly, depending upon the method of treating the bagasse fibre before it goes to the digester and also upon the method of packing.

Furthermore, because of the highly absorbent nature of bagasse, digesters with liquor circulation systems are usually impracticable. While liquor ratios of 4.5 to 1 or 5 to 1 are common in wood pulp mills with circulating systems, in order to get good liquor circulation with bagasse, liquor ratios of 10 to 1 or 12 to 1 (that is, the ratio of the weight of the liquor to the dry weight of the bagasse) must be used in order to ensure satisfactory circulation and good heat transfer necessary for uniform cooking. This necessitates a high steam consumption to heat the excess liquor, and even then the nature of the fibre favours channelling of the liquor as it passes down through the digester, which again results in a non-uniform cook. In fact, stationary vertical digesters of the type now commonly used in modern wood pulp mills are highly unsuitable for bagasse pulping. Instead, digesters of the rotating type are essential if pressure digestion is to be used. These may be either of the globe rotary type or the vertical tumbling type. The latter has the advantage of allowing the digester charge to be blown from the digester without lowering the pressure to zero and then removing the lid and dumping, which is time consuming. By means of a rotating action the bagasse, liquor and steam are mixed thoroughly, thus resulting in good heat transfer and uniformity of cooking even at liquor ratios of 4.5 to 1 or 5 to 1.

The chemical concentration used in cooking is another important factor in which great differences exist between pulping wood and pulping bagasse. The procedures necessary when pulping wood, because of its compact structure and the difficulty of penetrating the wood cells completely, are far too drastic for handling bagasse. On the other hand, bagasse fibres, because of their open nature, are far more susceptible to chemical action. Therefore a much lower concentration of chemicals is sufficient. In fact the drastic conditions normally applied to wood, when used in bagasse pulping, result in severe damage to the cellulose.

Besides the differences in physical structure, the proportions of the various chemical constituents found in wood and bagasse also differ greatly. While they contain approximately the same amount of holo-cellulose or total carbohydrate fraction, woods generally contain more alpha-cellulose, while bagasse contains more hemi-cellulose. Therefore, to make bagasse pulps competitive with wood pulps, it is necessary to produce them in such a manner that a considerable portion of the hemi-cellulose is retained, thus ensuring larger yields than are obtainable when standard wood pulp techniques are applied to this new material.

These facts again point to the need, when new bagasse pulp mills are being projected, for taking advantage of the services of companies experienced in this particular field.

V. Review of the most important processes available for pulping bagasse

General comments

During the past 100 years various investigators all over the world have used almost every conceivable method for the experimental production of pulp and paper from bagasse fibre. From a technical standpoint, it has been found that the soda, sulphate and monosulphite processes, or any modification of these well-known methods, can be used to produce a satisfactory pulp. By using a standard three-stage bleaching process a good quality bleached pulp can be produced.

Since straw pulp has been produced and used successfully in many countries of the world, the processes used commercially for pulping straw must also be given full consideration when choosing a process for pulping bagasse. Once the pith is removed from bagasse, the clean fibre constitutes a raw material which can be handled in much the same manner as straw and which in many respects is far superior to straw for production of high quality pulp and paper products.

The acid pulping processes seem to be the only commonly used methods that are not adaptable to pulping either straw or bagasse. Pulps produced by the acid processes make relatively weak and brittle paper and paperboard products. It is true that two-stage processes, such as the nitric acid process and those involving a prehydrolysis procedure, followed by an alkaline cook, have produced satisfactory pulps from bagasse, but the yields are invariably low and the costs higher than with a one-stage process. Therefore the practical value of such two-stage procedures is rather doubtful, and at the present time they seem definitely uneconomic for producing paper-grade pulp.

The alkaline processes, the neutral monosulphite process and their various modifications are already in use in different parts of the world, and good quality pulps are being produced by these means from both straw and bagasse. When using these processes in the conventional manner, with rotating pressure digesters, it has been found that the alkaline processes give somewhat stronger pulps, whereas the monosulphite process gives a weaker pulp but of a higher yield and of a somewhat lighter colour before bleaching. Thus the ideal process would be one which results in both high yield and strong pulp, combining the advantages of the conventional alkaline processes and the neutral monosulphite process. From the results of some of the newer methods, it can be seen that excellent progress has been made towards attaining this ideal.

In this paper no attempt is made to describe all the processes and modifications which have been proposed in the past for pulping bagasse. Attention is concentrated on those methods which appear to warrant most consideration: the conventional soda process, using pressure digesters, the conventional or modifications of the sulphate or Kraft process using pressure digesters, the neutral monosulphite process using pressure digesters, the continuous caustic soda chlorine or Celdecor process and the new mechano-chemical or Peoria process, using either a soda or sulphate pulping method. The last two are both carried out at atmospheric pressure, but the processes are entirely different in character, as are the characteristics of the pulps they produce.

It should be mentioned that the pressure digestion processes—either soda or sulphate—might also be carried out in continuous digesters, some of which have achieved a certain amount of success in wood pulping, especially in semi-chemical pulping. These continuous pressure digestion methods for pulping bagasse have not been included in this report, because they are not at the present time in wide use commercially for this purpose.

In the pages which follow, the principal features of these five commonly used processes are given in order to facilitate comparison.

1. *The soda process using pressure digesters*

The conventional soda process using either rotary globe digesters or tumbling type pressure digesters, is in wide use in many parts of the world for the pulping of agricultural residues. The amount of chemical used depends very much on whether a recovery system is employed. When such a system is used, the chemical concentration may be as high as 24 per cent, based on the dry weight of the bagasse being pulped. With this high concentration of chemical, a short cook at relatively low pressures may be used and since approximately 80 to 90 per cent of the chemical utilized may be recovered, the chemical cost remains low. On the other hand, when a chemical recovery system is not used, every effort is made to employ a very low concentration of chemical (about 14 to 16 per cent when producing a bleachable pulp) so that the over-all chemical cost may still be kept at a low level.

When cooking depithed bagasse by the conventional soda process, the maximum yield which may be expected is about 53 to 55 per cent of unbleached pulp or an over-all yield of about 48 to 50 per cent of bleached pulp. This might be obtained by cooking for two hours at a maximum temperature of 170°C when using approximately 15 per cent caustic soda based on the dry weight of depithed bagasse.

When preparing a high yield pulp—such as coarse board pulp—by the soda process, chemical requirements are about 7 to 9 per cent of caustic soda under the same cooking conditions as above. In this case a very good quality board pulp suitable for corrugating medium and other rough grades of board or for filler pulp and cylinder board can be produced in yields of 70 to 75 per cent.

The principal disadvantage of the conventional soda process, as well as of the other conventional pressure digestion processes, is the high initial investment necessary for pressure digesters and the auxiliary processing equipment. This results partly from the fact that bagasse is very bulky and thus requires high digester capacity per ton of pulp produced. Furthermore the yield is somewhat low and the over-all cooking cycle is long. Owing to the low yield, the chemical cost per ton of pulp is comparatively high unless a chemical recovery system is used. In this case, of course, the investment cost would again be very large and might not be justifiable for a small mill.

In recent years many mills have modified the conventional soda process by adding small amounts of sulphur or sodium sulphide. In this way they gain some of the benefits of the sulphate process which is described below. Thus, as a result of these modifications, the two processes are really approaching each other.

2. *The sulphate or kraft process using pressure digesters*

The sulphate or kraft process has come into prominence in the past thirty years and has almost replaced the soda process for the production of alkaline pulp from coniferous woods. It has also permitted great headway in the pulping of hardwoods when using conventional pressure digesters. The details of the process are similar to those of the soda process save that the loss of soda in the recovery system is made up by the addition of salt cake (sodium sulphate) instead of soda ash or caustic soda. The actual sulphate cooking liquor contains caustic soda and sodium sulphide. The presence of the sodium sulphide results in a milder action, giving a slightly increased yield of pulp, which is more easily bleachable than that prepared by the soda process.

The conventional sulphate process has approximately the same disadvantages as the conventional soda process. Initial investment cost is very high and in this case it is absolutely essential to have a recovery system, in order to reduce the sodium sulphate (or salt cake) to sodium sulphide. In the normal sulphate process the recovery furnace serves as a reducing furnace and the make-up sulphate is reduced to sodium sulphide in the reducing atmosphere of this furnace.

The conventional sulphate process has one other great disadvantage. This is the fact that it is attended by a most persistent, penetrating, disagreeable odour, due to the organic sulphur compounds formed in the reaction under high pressure.

When using this process for the production of a bleachable pulp from depithed bagasse, the chemical consumption amounts to about 14 to 16 per cent total chemicals (sodium hydroxide plus the sodium sulphide) based on the dry weight of depithed bagasse. With this chemical concentration, a cook of two hours at 170°C is sufficient to produce a high quality bleachable pulp. The unbleached yield is about 53 to 55 per cent and the bleached yield about 48 to 50 per cent of the weight of depithed bagasse. In carrying out the bleaching process, the chlorine requirements are about 8 to 9 per cent of the dry weight of the bleached pulp.

For the production of a coarse pulp suitable for board, the total chemical requirements would amount to approximately 7 to 9 per cent of the dry weight of depithed bagasse and the resulting yield would be about 75 per cent.

In spite of the above-mentioned disadvantages, the sulphate process has been used very successfully for the production of high quality bleached pulp from agricultural residues.

In areas where the cost of sodium sulphate (salt cake) is low, this process, or some modifications of it, has some advantages. One of the modifications particularly applicable to pulping agricultural residues involves a decrease in the amount of sodium sulphide as compared with wood pulping.

In normal pulp mills using coniferous woods, the commonly used percentage of sodium sulphide is 33⅓ per cent of the total chemical. In contrast, when pulping agricultural residues, some investigators have found that a ratio of 12 to 15 per cent of sodium sulphide is beneficial.

Another modification, of course, is the new mechano-chemical process, in which the same chemical concentrations as mentioned above are used, but higher yields result. It should perhaps be pointed out here that, if either the soda or sulphate process is to be used in any form, the mechano-chemical process involving the use of hydrapulpers instead of pressure digesters has some very definite advantages. This process is described later.

3. *The monosulphite or neutral sulphite process*

The sodium monosulphite or neutral sulphite process has become widely used in the United States for the production of semi-chemical pulp from hardwoods. This process has also been used extensively in Italy and Germany for the production of straw pulp, and is at the present time being used in Formosa for the production of bagasse pulp. The principal cooking agent consists of sodium sulphite which is buffered with sodium carbonate, sodium bicarbonate or caustic soda during the cooking operation. Since sodium sulphite is a mild cooking agent, it is necessary to use comparatively high pressures of about 100 pounds per square inch.

From a purely technical standpoint, the monosulphite process might be considered as one of the most suitable of all the conventional processes that use pressure digesters for the production of pulp from agricultural residues, including bagasse. However, when economic factors are considered, especially the cost of chemicals, the use of this process may not prove feasible at all in certain areas.

The unbleached pulp produced by this process, in yields of 55 to 58 per cent of the dry weight of depithed bagasse, is not so strong as the pulp produced by the conventional soda or sulphate processes. However, the yields are higher and the pulp is somewhat lighter than that produced by the alkaline processes. Thus the process is more suitable for the production of bleached pulp, semi-bleached pulp or light coloured unbleached pulp where high strength qualities are not so important. For high strength unbleached or bleached pulp the alkaline processes or modifications of them are usually more suitable than the monosulphite process.

When employing this process, the most favourable cooking conditions involve the use of about 12 to 14 per cent sodium monosulphite and 3 to 4 per cent sodium carbonate based on the dry weight of depithed bagasse. With this concentration of chemicals a cook of two hours' duration at 170°C results in a very easily bleachable pulp of high yield.

For the production of a coarse pulp suitable for board, the total chemical requirements would amount to about 6 to 8 per cent sodium sulphite and about 3 per cent sodium carbonate, based on the weight of the depithed bagasse.

The monosulphite process is operated without a chemical recovery system. Therefore its economic success depends very much upon the cost of soda ash and sulphur in the countries where it is to be used. In the United States, where the cost of these chemicals is extremely low, the production cost renders this process economically feasible without a recovery system, even in small mills with a capacity of twenty-five tons per day. In many areas, however, the high cost of soda ash and sulphur or sodium sulphite makes the cost of production prohibitive. Furthermore, the monosulphite process has the same disadvantage as the conventional soda and sulphate processes have, in that pressure digesters are necessary.

4. *The Celdecor or soda-chlorine process*

The Celdecor or Pomilio process is another method in rather wide use all over the world for pulping agricultural residues. This is really a modification of the soda process, in which a mild caustic soda cook at atmospheric pressure is followed by a drastic chlorination stage which continues the cooking process. The chlorination is followed by a caustic soda extraction process, in which a comparatively high concentration of caustic soda is used; this in turn is followed by a hypochlorite stage or stages to complete the bleaching.

The Pomilio process was originally designed to enable the products of an electrolytic plant to be used in approximately the ratio in which they came from the cells. This made it attractive to countries which had no established chemical industry but possessed plentiful supplies of salt and low cost power, because the only raw material required, other than fibre, was common salt, about 0.5 tons of salt being required per ton of bleached pulp product. The pulping and bleaching chemicals consisted of the caustic soda and chlorine, which were used without modification as they came from the electrolytic cells. Since this resulted in the use of a high proportion of chlorine in the over-all process of cooking and bleaching, the Pomilio process has become known as a caustic soda-chlorine process. When operated in this manner, with such an extremely high ratio of chlorine, the original Pomilio process was never very successful. The resulting pulp was extremely brittle and not of very high quality. However, in the course of the development of this process the Cellulose Development Corporation in the United Kingdom has made changes which have resulted in many improvements. They have found that better results are obtained by increasing the amount of caustic soda in the first stage of the cooking process, thus abandoning the idea of using the products of an electrolytic plant in the exact ratio in which they come from the cells. However, a relatively mild caustic soda cook is still employed, followed by a somewhat greater proportion of chlorine than is used in the normal soda, sulphate or monosulphite processes for producing bleached pulp. The Celdecor process has both advantages and disadvantages over the conventional methods using pressure digesters. One reported disadvantage is that the pulp tends to be somewhat brittle owing to the high consumption of chlorine, and therefore has relatively low folding or bending resistance. Another is the relatively high chemical consumption as compared to the conventional pressure digestion methods. If, for example, the total amount of caustic soda is added to the total amount of chlorine used for production of a bleached pulp, the Celdecor process requires considerably more chemical than the conventional processes. On the other hand, it has the great advantage of operation at atmospheric pressure and that the first investment cost is lower than when using digesters as in the conventional digestion processes.

A yield of 45 per cent, based on depithed bagasse, may be expected when using the Celdecor process for the production of bleached pulp. When producing coarse grades of pulp for board, yields of 65 to 75 per cent may be expected.

5. *The mechano-chemical or Peoria process, using either soda or sulphate chemicals*

The new revolutionary mechano-chemical process developed by Dr. Lathrop and Dr. Aronovsky of the Northern Utilization Research Branch in Peoria, Ill., appears to have some very definite advantages over the conventional processes for pulping bagasse. This process was discovered while attempting to arrive at the ideal process for pulping agricultural residues. This method gives both a high yield and excellent strength characteristics, thus combining the good points of the conventional alkaline processes with the advantages of the neutral monosulphite process.

In this process either caustic soda or a combination of caustic soda and sodium sulphide, as in the sulphate process, may be used. The pulping is carried out at atmospheric pressure and at a low temperature of about 100°C. During the cooking process the fibre is agitated in a hydrapulper. The rapid pulping rate made possible by this process is attributed to the impact action of the impeller of the hydrapulper in forcing or pumping the chemical liquor into and out of the bagasse. The bagasse and chemical are circulated at a rate sufficiently high to develop and maintain a good vortex in the unit, resulting in rapidly repeated impact of the bagasse particles by the impeller vanes. As a result of the mechanical action between the liquor and the fibre, the chemical acts very rapidly and therefore a relatively low concentration may be used to obtain a high quality pulp in a short period of time.

When using the same amount of chemicals, based on the dry weight of depithed bagasse, the mechano-chemical process requires a cooking period of only about one hour at 100°C as compared with about two hours at 170°C in conventional pressure digesters. Furthermore, the yields of mechano-chemical kraft and soda bagasse pulps exceed by 6 to 8 per cent those obtained from cooking by the conventional methods involving pressure digestion. The alkaline pulps obtained by this process are considerably stronger than pulps obtained by the neutral sulphite process and actually approach the strength of softwood kraft pulp in all characteristics except tear resistance. When using this method for the production of bleachable pulp, chemical requirements amount to 14 to 16 per cent of the weight of the depithed bagasse. For a coarse grade of board pulp, requirements are about 7 to 9 per cent.

When using the mechano-chemical process to obtain bleachable pulps from depithed bagasse, the average unbleached yields amount to almost 60 per cent of the dry weight of the original material. Bleached yields have been reported as consistently above 50 per cent of the original depithed bagasse. When using the process for the production of a board grade of pulp, it is quite possible to obtain yields of 75 per cent and over.

Any of the above-mentioned processes may be used to produce a satisfactory pulp for certain purposes. The choice depends on a complex of technical and economic factors applicable to the specific location of the mill and the particular type of product to be manufactured. These factors are discussed below.

However, for purposes of comparison figures 2 and 3 of this paper show simple flow diagrams for both the pressure digestion method and the mechano-chemical method. In the case of the pressure digestion method, the same equipment might be used for either of the alkaline processes or for the monosulphite process. In the case of the mechano-chemical process either soda or sulphate cooking may be used. The systems illustrated are considered workable, though naturally many modifications might be made to the arrangements shown in the diagrams.

VI. Technical and economic factors to be considered in the choice of process and equipment

General comments

The technical and economic factors which must be considered in selecting the proper process and equipment for any bagasse pulp mill project are so interrelated that one can hardly be discussed without reference to others. These factors include:

1. Initial cost of equipment for each process, or the capital required for a mill of given size;
2. The relative availability and cost of chemicals necessary for each process in the specific area;
3. The availability and cost of fuel delivered to the plant site;
4. The availability and cost of purchased power;
5. The availability and cost of labour in the area;
6. The availability and cost of an adequate water supply;
7. Means available and cost of effluent disposal;
8. The cost of bagasse delivered to the pulp mill site;
9. The grade of pulp, paper or paperboard which is to be manufactured.

Each of these factors is discussed below in relation to the choice of process and equipment.

1. *Initial cost of equipment for each process, or the capital required for a mill of given size*

Though preoccupation with low equipment cost is understandable in these days of limited capital availability, it is a great mistake to place too much emphasis on low initial cost.

The initial cost of equipment must be placed in its proper perspective and analysed from the standpoint of maintenance costs, life expectation, operational costs and the prospects of trouble-free operation. Experience has shown conclusively that cheap equipment may cost more in breakdowns and idle time in one year of operation than the best equipment available. In pulp mill operations, even one day's idle time, resulting from failure of one piece of equipment, may destroy the entire continuity of the operation and cause considerable expense. On the other hand, better equipment—although initially more expensive—may give years of trouble-free and satisfactory service without the need of constant and costly replacements and high maintenance costs.

Thus, when the initial cost of equipment is extremely low, the operational costs or production costs per ton of pulp almost invariably prove to be high over the years. This fact has led almost all progressive pulp and paper companies throughout the world to adopt a policy, in choosing equipment and processes, based on quality and long-term results rather than on price.

This point is emphasized because some machinery suppliers have a tendency in their selling techniques to place low initial cost above all other factors. In fact, the writer has seen some price quotations which were so low as to be almost unbelievable in the light of present-day machinery manufacturing costs. In some cases these quotations, on further analysis, were found not only to be offering very cheap, low quality equipment, but were excluding many items of equipment necessary for efficient mill operation. Therefore, when comparing and analysing competitive quotations for processes and equipment, one must be certain either that all necessary equipment is included or that any "missing items", which would have to be supplied locally, are listed in full. Otherwise one might be faced with prohibitive and unexpected local costs which would render the project entirely unsound from an economic standpoint.

2. *The relative availability and cost of chemicals necessary for each process in the specific area*

The relative availability and cost of the various chemicals in the specific area in which the mill is to be located has a very important bearing on both the choice of pulping process and the equipment to be supplied.

For example, in areas where the costs of soda ash and sulphur are low, the monosulphite process might be very favourably considered. In other areas, where cost of these chemicals is high and since no recovery system accompanies this process, its use may be entirely prohibited for this reason alone.

Where salt cake is readily available at reasonable cost, the sulphate process—either with pressure digesters or by use of the mechano-chemical process—might be expected to merit favourable consideration. Where salt cake is not available cheaply, this process might seem to be precluded. However, since a chemical recovery system is almost always used in conjunction with the sulphate

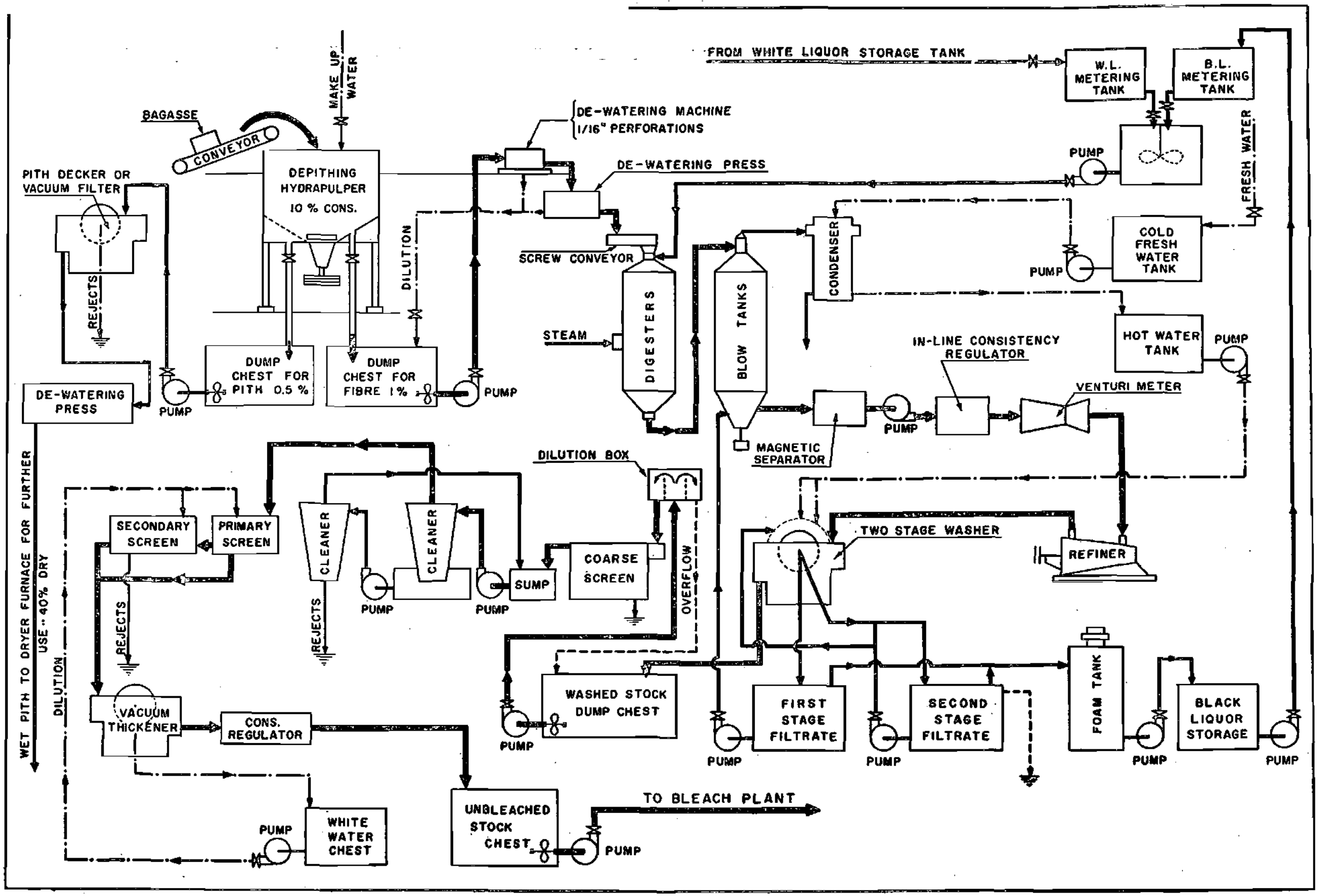


Figure 2

OUTLINE OF PROCESS FOR PULPING BAGASSE IN PRESSURE DIGESTERS

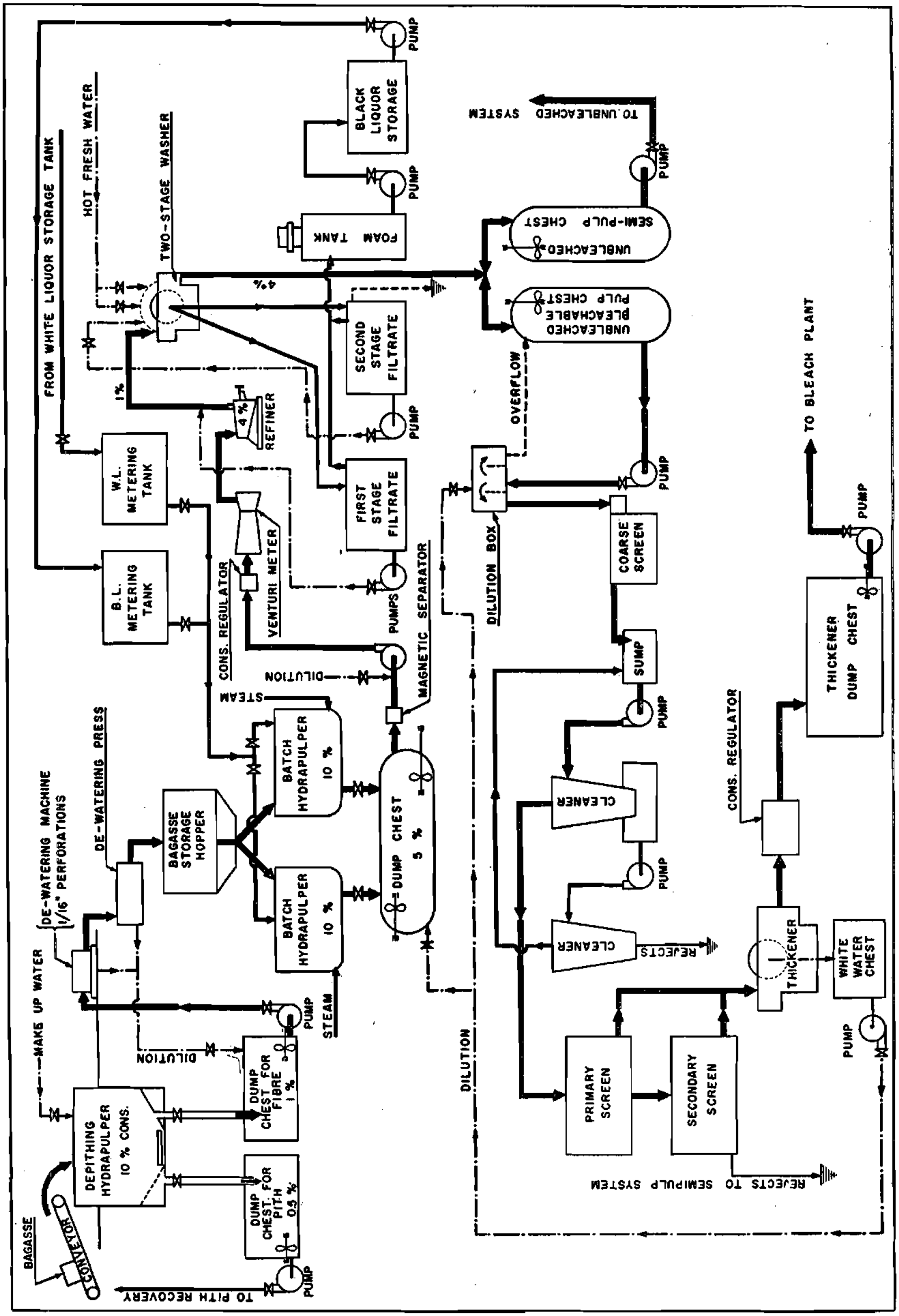


Figure 3

OUTLINE OF PROCESS FOR PULPING BAGASSE BY THE MECHANO-CHEMICAL PROCESS

process, its use might prove to be the proper choice, even though the cost of salt cake is relatively high. In reaching a decision, the investment cost necessary for the recovery system and the cost of the make-up salt cake have to be weighed against the total cost of production when using other processes not requiring a chemical recovery system.

In areas which have a well-developed chemical industry, with caustic soda or soda ash readily available, the soda process or any of its modifications might prove to be most favourable. It would then be necessary to make a careful study as to whether a soda recovery system would be justified.

In the matter of bleaching, the cost of chlorine may determine whether an electrolytic plant should be integrated with the pulp mill, and, if so, this factor may have a decided influence on the choice of pulping process.

In areas where all the chemicals necessary for any of the processes are available, the choice of process might be more complicated since it would then be necessary to consider all the commonly used processes. The choice of process might then be determined by entirely different factors, with little importance attached to the relative cost of chemicals.

In other areas, where no chemical industry has been developed and where the cost of all pulping and bleaching chemicals is high, it might be necessary to include both an electrolytic plant and a chemical recovery plant in order to ensure economic operation. In this case, by building an electrolytic plant of proper size, it would be possible to carry out the mill operation in such a manner that the chlorine necessary in the bleach plant and the make-up caustic soda needed in the pulp mill could be so balanced as to consume the entire output of the electrolytic plant. This, of course, might dictate the use of the soda process or some modification of this process, such as the mechano-chemical process.

In other cases, where the cost of salt cake is low and the cost of chlorine high, an electrolytic plant might still be necessary for the chlorine requirements of the bleach plant. It might then be advantageous to market the excess caustic soda from the electrolytic plant and to use salt cake as make-up chemical for the sulphate process or any of its modifications. This method of operation might be particularly applicable in areas where salt cake is produced as a by-product chemical, such as occurs in some rayon mills. In this case, the by-product sodium sulphate from existing chemical plants might be exchanged for caustic soda from the pulp mill electrolytic plant at a very favourable rate.

When one of the alkaline processes is to be used, the cost of lime must also be considered and this factor may determine whether the construction of a lime kiln, along with the pulp mill recovery plant, would be justified.

Many other examples could be given of the part which the relative cost of chemicals might play in choice of process and equipment. In any case, the need for thorough study by experienced personnel before the final decision is made is clear. The chemical cost factor alone may often dictate the choice of one particular process or eliminate certain processes from consideration.

3. *The availability and cost of fuel delivered to the plant site*

If bagasse is to be used as a raw material, its cost to the pulp mill may be determined almost entirely by the cost of replacement fuel for the sugar mill. If the replacement fuel cost is too high, the use of bagasse may be entirely precluded.

Some processes require more steam and power than others, so that high fuel costs may favour that process with the lowest steam and power requirements. On the other hand, if fuel costs are low, this factor may play little part in the choice of process.

The cost of fuel may also determine whether the mill should have its own power plant or merely a low-pressure steam plant to supply the necessary steam requirements. It may determine whether a waste heat boiler should be included in the chemical recovery system or whether an electrolytic plant could be operated economically. It may also have some bearing on the cost of operating a lime kiln and other items of equipment which need to be considered.

4. *The availability and cost of purchased power*

The availability and cost of purchased power can play a very important part in choice of process and equipment. Low-cost hydro-electric power might eliminate the need to include a power plant with the pulp mill or might indicate the desirability of having a power plant integrated with the steam plant for the pulp mill requirements alone, using purchased power only for the electrolytic plant.

In contrast, high cost of purchased power might make the construction of complete power facilities absolutely essential. This condition, combined with high fuel cost, may dictate the choice of both process and equipment, so as to keep the power consumption to an absolute minimum. It may even result in the use of manual labour rather than mechanical handling equipment commonly used in most modern pulp mill operations.

5. *The availability and cost of labour in the area*

Where labour rates are high, and fuel and power rates moderate, each process will be analysed to determine which requires the least labour. Equipment would be chosen with this fact in mind, and every effort will be made to control the operation of the plant by automatic and mechanical means. All material-handling systems would be designed with every possible labour-saving device and power would be substituted for labour throughout the plant. Maximum use might also be made of instrumentation to reduce manual labour still further.

In contrast, where labour rates are low but fuel and power costs high, the reverse procedure will be necessary. A process with high labour demands and low power cost might then be chosen and all equipment selected with this situation in mind.

6. *Cost and availability of an adequate water supply*

Even though when proper re-use of water is practised almost all the processes might be considered as requiring approximately the same amount of total make-up water, the degree of purity of the water might affect one process more than another. Therefore, if costs of water purification are high, this factor could play some part in the choice of process. In addition, it may also affect the choice of grades of pulp to be manufactured and might place definite limitations on pulp grades that can be produced economically in a given area.

Thus, either the quantity of water available, or its chemical composition, might affect the choice of process, the choice of equipment or the type of product to be manufactured.

7. *Means and cost of effluent disposal*

Regardless of the process used, some good means must be available for the disposal of effluent. Since the effluent disposal problem is greater when certain processes and certain modifications of processes are used, this factor sometimes plays an important part in choice of process and equipment.

If the means of waste disposal are limited and the costs are high, then the use of a process with a chemical recovery system might be dictated, in order to keep the effluent to an absolute minimum. For the same reason it would be absolutely essential to have a lime kiln, so that waste lime would not be a problem.

However, if for example the mill is to be located on a large river, and stream pollution is not a serious problem, then this factor may assume minor importance. It must nevertheless be investigated from every angle, considering the long-term viewpoint as well as the present circumstances, before the final decision as to process is made for any given mill operation.

8. *Cost of bagasse delivered to the pulp mill site*

The cost of bagasse, though in a given location independent of the process used, must be considered carefully because the yield of pulp produced by the different processes varies considerably. Thus the cost of the bagasse may play a far more important part in over-all production cost for some processes than others.

Where the cost of bagasse is high, this factor may weigh heavily toward choice of that process giving the highest pulp yield. Where bagasse costs are low, however, and surplus bagasse is readily available, this factor is likely to be greatly overshadowed by the many other factors which need to be taken into consideration.

9. *The grade of pulp, paper or paperboard which is to be manufactured*

The grade of pulp and the grades of paper and paperboard into which the pulp is to be converted have a very distinct effect on the choice of process. The pulp from each of the processes mentioned possesses its own characteristics which are different from those of pulp produced by the other methods. In some cases these differences are striking and must be understood completely if the correct choice of process is to be made for the end-product or products contemplated.

For example, one process may result in a soft bulky pulp of high opacity which would be excellent for printing or book papers but completely unsuitable for papers such as glassine or for papers requiring high strength. Another pulp might have just the right qualities for certain thin papers but because of brittleness or lack of folding endurance might be completely unsuitable for heavier papers or folding grades of board where folding endurance plays a part. One process might result in a perfect pulp for glassine paper but because of lack of opacity this same pulp might give completely unsatisfactory results if used for book papers.

In certain cases, where an unbleached pulp of relatively high brightness without bleaching is necessary for an end-product not requiring high strength, the monosulphite process might prove to be a perfect choice. On the other hand, if unbleached products of high strength and folding endurance were desired and colour were of minor importance, the mechano-chemical process might be indicated.

Where a variety of grades of paper and paperboard are to be produced, each requiring pulp of special but different characteristics, it becomes necessary to choose a process and select equipment offering the maximum degree of flexibility, so that, by varying the conditions properly, the correct grades of pulp can be produced as desired. This particular situation is indeed a common one and it requires the most careful study on the part of experts in the field of pulping agricultural residues. For a specialty mill of this type, the choice of a process and installation of equipment not possessing this high degree of flexibility for producing grades of pulp with quite different characteristics could easily and rapidly result in failure.

To sum up, the choice of process and equipment for any bagasse pulp mill depends upon a great many interrelated technical and economic factors, all of which must be given careful consideration for each particular mill location before any final decision is made. In comparing the various processes and equipment offered for any project, it is as well to remember the following words of warning:

(*a*) Beware of processes involving extremely low cost equipment, because they may prove to be inferior, result in failures in operation and in excessively high operational cost;

(*b*) Beware of claims of excessively high yields, because the resulting pulp may be of extremely low quality;

(*c*) Beware of processes claiming to produce high quality pulp in high yields and at low cost without removal of pith;

(*d*) Beware of processes or proposals which show costs of production far below those of reputable competitors, because such great differences simply do not exist;

(*e*) Beware of depending upon complete strangers to the field of bagasse pulping;

(*f*) Beware of secret processes, because these are usually not secret at all but merely re-hashed schemes which add nothing to improving the quality of the product or reducing the cost of production as compared with the well-known processes—about which there are no secrets.

EXPERIENCE IN INDUSTRIAL BAGASSE PULPING[1]

CELLULOSE DEVELOPMENT CORPORATION (ENGLAND)

I. BACKGROUND

The first proposed process for pulping bagasse is said to date back to the year 1838, whilst the first commercial attempt to use bagasse for paper stock has been attributed to France in the year 1844. In recent years, owing to the steeply rising world demand for pulp, attention has been focussed increasingly on the possibilities of bagasse for paper making, particularly newsprint. World pulp

[1] A slightly shortened version of the original paper, ST/ECLA/CONF.3/L.5.7.

production rose from an estimated total of 8.3 million tons in 1913 to 36.3 million tons in 1952. Taking into consideration only the last twenty-five years, annual production/consumption of wood pulp has risen from an average of 13.6 million tons in 1925-27 to 36 million tons in 1950-52. It may be noted that pulpwood absorbed in the production of pulp during 1952 amounted to no less than 20 per cent of the world's total cut of industrial wood, and 95 per cent came from softwoods (conifers).

This rapid development in the world's pulp industry has taken place largely in regions with high consumption of paper and board, viz: North America and Europe, where 90 per cent of the world's pulp industry is at present located. If Oceania (Australia, New Zealand, etc.), which also enjoys a high level of paper consumption, is added the total population of these regions may be reckoned at about 600 million; their consumption may well increase in the future. This total of 600 million, however, compares with an estimated 1,800 million for the remaining regions of the world which at present have low per capita consumption figures. In so far as these latter are able to raise their standard of living and industrial development, it seems certain that they will also raise their consumption of paper and board.

Apart from the question of whether these countries will be able to rely on the traditional producing regions for their future supplies of wood pulp there is also the problem of finding the necessary foreign exchange. Hence many countries have a considerable incentive to produce their own supplies.

These factors explain in part the great effort being made to develop new sources of fibrous raw material, and the great interest currently being taken in the possibilities of pulping broadleaved species of timber and agricultural residues. Sugar-cane bagasse meets the required qualifications of a good raw material for pulping more nearly than any other crop fibre. Up to just before World War II, however, the only successful commercial ventures in a long series of attempts to pulp bagasse were a few wallboard mills, an insulating board being the most successful product.

Certainly Latin America has known its share of expensive failures. About 1939, however, three very interesting but apparently independent developments took place in different parts of the world. In Peru, the W. R. Grace Company, using bagasse as the principal raw material, began operating the country's largest paper mill. This mill has continued to operate successfully and profitably, making a wide range of papers and boards, including newsprint. It does not produce bleached bagasse pulp on a commercial scale, but it has made a very significant contribution by demonstrating the successful use of bagasse, with substantial additions of long-fibred wood pulp, in the manufacture of multi-wall sack papers. The process is reported to be a slight modification of the batch-type soda process, with a small amount of sulphur included with the caustic soda, so giving some of the advantages of the sulphate process.

Also in 1939, the Tatu mill, near Taichung in Formosa, began to produce bleached pulp from bagasse, following extensive experimental and pilot plant work by the Japanese who were then in possession of the island. A year later, a larger plant was started up at Hsinying, Tainan. Both these mills in Formosa used the acid magnesium-based sulphite process, this fitting in rather well from an economic point of view with magnesite coming from Manchuria and sulphur from Taipei. The process did not produce a high quality bleached pulp, although until the mills were put out of action by Allied bombing it was exported in quantity to Japan, China and South Pacific countries to help the wartime shortage of pulp. Since the war, bagasse pulping has not been resumed at the Tatu mill, while at Hsinying the acid sulphite process has been abandoned in favour of neutral sodium sulphite. Although first in the field with the commercial production of *bleached* pulp from bagasse, the Taiwan mills cannot be said to have provided a satisfactory answer to the problem. This has been achieved, however, through the third development which took place about this time.

Following five years of work by the Cía. General de Tabacos de Filipinas and the Central Azucarera de Bais, in February 1941, Cía de Celulosa de Filipinas started up their 15 tons-per-day bleached bagasse pulp and fine paper mill using the continuous caustic soda-chlorine process, known today as the Celdecor-Pomilio process. This mill ran successfully from the beginning, producing some 1,500 tons of bank and bond papers from bagasse (with the addition of no more than 10 per cent of imported wood pulp) which it sold to the Philippine Government. After some months, mill operations were put to an end by the Japanese invasion and it was not possible to re-start until April, 1949. Since then, the mill has continued to operate successfully, and in 1953 produced its highest output so far of just over 5,000 tons of banks and bonds, with another 1,000 tons of high grade chipboard made with similar bleached bagasse pulp.

This mill can claim to have made history, therefore, by being the first bagasse mill to produce bleached pulp for fine paper making successfully and economically without changing its basic process. It produces its own chemicals on site from the electrolysis of common salt, and there is a small surplus of chlorine which is absorbed by a local hydrochloric acid plant.

By mid-1954, there were further mills producing bleached pulp from bagasse in India (Rohtas Industries Ltd., Dalmianagar, Bihar) and in Brazil (Fábrica de Cellulose e Papel "Piracicaba", Monte Alegre, São Paulo State); these also are Celdecor-Pomilio process mills. In addition, Celulosa Argentina S.A., the oldest-established and largest of the mills based on the Pomilio process, is capable of pulping bagasse and has in fact done so, though its primary raw material is cereal straw. Thus in mid-1954 four mills were producing bleached pulp from bagasse, three of which used the Celdecor-Pomilio process. Two other bleached pulp mills, however, are ready to start up—one in Louisiana, U.S.A., using a process developed by the Valite Corporation, and the other a Celdecor-Pomilio process mill in Mexico.

Apart from the above, there are mills producing unbleached semi-pulp for coarse papers and boards in Argentina, Colombia, Mexico and Peru (in addition to the Grace mill), whilst South Africa has two such plants. Altogether there are now about a dozen pulp and paper mills actually operating on bagasse in various parts of the world apart from others due to start up, and it may be truly said that bagasse has "arrived" as far as the paper maker is concerned.

II. Availability of bagasse

The sugar and the fibre content of cane vary widely but each amounts to approximately 13 per cent on cane.

Therefore the amount of bagasse produced by vacuum pan mills (on a dry weight basis) corresponds roughly with the tonnage of raw sugar made. Where relatively poor agricultural methods are employed, or where the sugar content of the cane is low for climatic or other reasons, there would be rather more dry bagasse than sugar, so that the world average ratio is taken to be slightly more than 1:1.

World cane-sugar production in 1953/54 has been estimated at 25,250,000 metric tons. Deducting about 3,500,000 tons for Indian "gur" (sugar not processed in centrifugal factories) gives a total of 21,750,000 tons of sugar, equivalent to, say, 22,500,000 tons of bagasse fibre on a dry basis. This is a huge potential supply, of which rather more than half is concentrated in North and South America and the Caribbean. However, bagasse is normally used for process steam and power generation by the sugar mills, and in many cases the sugar mill's thermal system is designed to consume as much of the bagasse as possible to avoid the nuisance and expense of finding other methods of disposal.

Although opinions vary as to the amounts of surplus bagasse available, the Celdecor Company's own experience in various parts of the world has been that where there is not already an acknowledged surplus, it is often possible to suggest means of liberating sufficient bagasse for a pulp mill of economic size. A combination of improved boiler efficiency and more efficient steam usage can often enable a raw sugar mill to liberate between one-third and one-quarter of its bagasse for pulping.

Such a sugar mill may then be able to support a pulp and paper mill with surplus bagasse alone, as is the case at the Bais Central in the Philippines, which provides all the bagasse for a 15-tons-per-day pulp mill. Alternatively, surplus bagasse from two or three mills may be collected for one pulp mill, as is done in Formosa (though in this instance pulverized coal is burned in addition).

If 20 tons per 24 hours of air-dry pulp is considered to be the minimum economic size of a pulp mill, then the minimum quantities of bagasse (at 45 per cent moisture content) may be estimated as follows:

Semi-pulp for corrugating papers, boards, etc.	17,000 tons
Semi-pulp for wrappers, sack papers, etc.	20,000 tons
Bleached pulp for fine papers (printing, writing, etc.	32,000 tons

If these quantities cannot be achieved by economies alone, then substitution of bagasse by other fuels may be considered. The following table shows the relative quantities required, taking into account gross calorific value and the normal efficiency of combustion:

	Comparative quantities of fuel for the same amount of steam
1. Fresh bagasse (45 per cent moist)	1.0 (stepped grate)
2. Poor coal	.33
3. Average coal	.27
4. Fuel oil	.175

III. Baling and storage

Cost of unbaled bagasse

The cost to the mill of bagasse in its wet unbaled form varies from nil (or a negative value taking into account any saving due to eliminating the burning of the surplus in an incinerator) to the cost of the substitute fuel.

Frequently the cost of bagasse may be expected to lie between the two, since the supply to the mill will probably consist partly of surplus and partly of bagasse for which an alternative fuel has to be found.

In general, the change to an alternative fuel is an advantage. Apart from increased boiler efficiency, alternative fuels are more manageable than bagasse, permitting economies in the matching of fuel to steam demand.

Cost of baling and storage

The cost of baling bagasse at the sugar mill, storing it until dried out, and then delivering it to the pulp mill has to be added to this negative, nil or replacement cost of the raw bagasse.

In the United States in 1950 the cost of baling, stacking, covering in the fields for drying out, and unstacking onto trucks, was assessed at the equivalent of $7.15 per ton of bone-dry fibre. In India and the Philippines, where wages are lower, the figure would probably be nearer $6 (at 12 per cent moisture content). This cost has to be added to the cost (if any) of the raw wet bagasse. Three high-pressure balers with a capacity of about 4,000 bales of wet bagasse per twenty-four hours (say 150-160 tons), each operated by a team of three men per shift in the crushing season, are usually sufficient to cover the year-round supplies needed by a 24-ton-per-day bleached bagasse pulp mill.

Tying. Where bagasse has to be transported considerable distances, highly compressed bales are called for, and wire, preferably well galvanized, is used for tying. Sometimes it is not easy to buy suitable wire because of currency restrictions, and advantage may be taken of long fibrous materials which often grow in or near sugar-producing regions, sisal, jute, abaca, etc., or even grass or straw ropes.

Stacking. Cases of fire in stacks of baled bagasse are rare. Stacking with air spaces between the bales is usual, to create favourable conditions for drying out. In Formosa bales are stacked in this way; in a mill in India, on the other hand, the bales are tightly packed with no spacing, yet the bales remain a good colour—a fair indication that overheating has not occurred. The possibility of fire from accidental causes—sparks from locomotives, cigarettes, etc.—is much reduced when the bales are tightly packed; a possible fire is then confined to the exterior of the stack.

It is impossible to generalize on the question of covering the stacks, since it depends on the relative cost of bagasse and roofing material, as well as on climatic conditions. In Formosa, matting is laid on the bagasse; in the Philippines, a semi-permanent structure of scaffolding thatched with palm is used, whilst in India permanent coverings of asbestos cement on steel trusses are employed. In some areas, the amount of bagasse lost in uncovered stacks may not warrant the cost of covering.

IV. Pulping bagasse

Pith separation. One of the causes of difficulties in the past in pulping bagasse has been the high pith content of the material, which may amount to 40 per cent of the whole. Bagasse fibres themselves, although usually from 1 to 1.5 mm in length (as against 3 to 4 mm for pine or spruce), are strong and pliable and have good felting properties. The pith cells however are very short and possess few felting properties. Moreover, the pith definitely reduces the drainage rate on the paper machine, leads to sticking at the press rolls and generally reduces the rate at which the paper can be made; in addition it impairs bleaching and the general appearance of the pulp, and adds to the consumption of chemicals.

On the other hand, if it were possible to remove all the pith, the yield of pulp—even assuming 50 per cent yield on the depithed material, which may be reached in commercial practice—would be reduced to the rather low figure of 30 per cent on the original dry weight of material. Nevertheless, for bleached pulp for fine paper making, some depithing is essential—usually something over 20 per cent.

Unbleached bagasse pulp for corrugating and other coarse products has been made without any depithing at all; nevertheless, it is recommended that some pith be removed even for the lowest grade of coarse papers although not necessarily for board. The improvement in paper machine operation and quality of the product amply compensates for the reduced yield.

An important point is the use to which the separated pith can be put. Various uses have been developed; mixing with molasses to make stock feed is a well-known example. The pith can also be burned in the mill boiler furnaces, since its calorific value is only a little less than that of whole bagasse.

Two general methods for pith separation have been developed—the wet and the dry method. In the wet method, the bagasse is vigorously agitated whilst suspended in water so as to rub the pith from the fibre; the pith is then screened out. The latter process may be rendered difficult by the fact that the bagasse and pith emerge saturated with water and may have to be repressed.

In the dry method, the bales of dried bagasse are fed to a special disintegrator followed by other devices, enabling the pith to be separated by sieving and air-blowing. This has the advantage that the pith is obtained in an air-dry condition and can be blown directly to the pulp mill furnaces.

Pulping processes. There seems to be no call for special processes for bagasse; once depithed, it reacts somewhat similarly to cereal straws, and in very general terms it may be said that a process satisfactory for straw should be satisfactory for bagasse, though bagasse is a little more limited in its tolerance. On the one hand, the rind of the sugar cane is harder to digest than most cereal straws. On the other hand, the processing conditions must not be so drastic as to fragment the large quantity of cellular material present in bagasse. The sulphate process has successfully produced bleached pulp from straw and it would seem likely that it may be applied equally to bagasse.

A laboratory investigation into seven different methods of producing easy bleaching bagasse pulp with the minimum consumption of chemicals showed that the sulphate, Pomilio and sodium monosulphite processes were the most suitable. The figures adduced, however, flattered the yield of the last-named, since pulp produced by the monosulphite process frequently contains up to 10 per cent ash.

For a mill to be able to make its own chemicals and thus be independent of outside sources of supply is an important consideration, especially in countries lacking a large chemical industry. This advantage is open to a Celdecor-Pomilio bagasse mill because it uses caustic soda and chlorine not only in the proportions but in the condition in which they are discharged from the cells.

It should be noted, moreover, that an electrolytic plant producing some excess chemicals may be the jumping-off point for creating a healthy subsidiary industry. This has been fully demonstrated in Argentina by Celulosa Argentina which provides alkalis, chlorine, hypochlorites, chlorates, hydrogen, ammonia and fertilizers, chlorinated organics, etc.

To sum up, it is scarcely possible or desirable to lay down that one process is always better than another; so much depends on local circumstances, availability of caustic soda, sulphur, common salt, disposal of effluent, the possibility of being able to pulp wood or bamboo in the same plant, etc. There is also always a risk in setting up the first commercial plant based only on a laboratory or even pilot plant technique, as has been shown by experience in the past.

This has been demonstrated in the case of dissolving pulp production, where there have been costly failures in attempting to make rayon pulp from bagasse; the yield is low and the product may not be satisfactory. Though dissolving pulp can be made from straw and bagasse, further laboratory and pilot plant research is still needed.

Newsprint. A somewhat similar situation exists with regard to newsprint. The Cellulose Development Corporation has made newsprint with a high proportion of bagasse which has been successfully used to print special editions of newspapers. The problem is that straw and bagasse, which must be pulped chemically, are fundamentally handicapped when it comes to manufacturing a product comparable with standard newsprint, containing about 85 per cent mechanical groundwood pulp. Naturally a chemical process with a yield in the region of 50 per cent is almost bound to be more costly than a mechanical one, where the yield exceeds 90 per cent. In other respects, notably opacity and ink absorption, bagasse and straw also compare unfavourably with mechanical groundwood for newsprint.

It is considered that it may be economical to combine the production of some newsprint with that of other papers and boards in a multi-purpose mill and under special circumstances, involving such factors as heavy freight from the normal newsprint sources, high import tariffs, lack of foreign currency, or other reasons of national self-sufficiency. In general, however, bagasse is recommended for pulping for those grades of paper and board up to the highest where success has already been achieved; for newsprint and rayon pulp production bagasse is not naturally suited.

V. Uses and production of bagasse pulp

As has been the case with straw, the applications for which bagasse pulp may be found suitable are likely to extend with actual usage. The properties of bagasse pulp, however, limit the range of papers which can be made without incorporating other fibres with bagasse fibres, which are of moderate strength and fairly hard.

In the white range the most successful are writing papers (where up to 90 per cent bagasse can readily be used), and in the brown range corrugating paper. For most printing papers it is desirable to add rather more than 10 per cent of other fibres to impart softness. For sack papers and strong wrappers, long fibres must be added to impart tearing strength.

Blended with other pulps, bagasse has a wide range of uses. Like straw and esparto, bagasse possesses certain distinct qualities which make it a definite asset in its own right for a paper-making furnish and not merely as a substtute for another fibre. For example, the relative shortness may be put to good advantage in making fine papers from bleached pulp; it imparts good appearance and strength, which can only be obtained with wood pulp by considerable beating or shortening of the fibres. The good sheet-forming characteristics are utilized by mixing bagasse pulp with wood pulp, thus reducing the amount of beating required for the latter. The small fibres give a firm sheet of paper, particularly suitable for writing papers.

Advantage of this property has been taken in the Philippines plant, whose products manage to hold their own in the domestic market against competition from the big American mills. Situated beside a sugar mill, it produces good papers containing not less than 90 per cent of bagasse pulp, the balance being woodpulp or repulped waste papers of good quality—"ledgers". These bagasse papers have a good white colour and are more than sufficiently strong. They are clean and remarkably—though not entirely—free from those surface imperfections which are caused by occasional clusters of unresolved fibres. These may be found as slightly shiny places on the surface of the paper.

These unresolved fibre bundles are very well-known to every manufacturer of agricultural residue pulps, and a great deal of importance attaches to their successful elimination. They arise from the heterogeneous structure of the gramineae, to which family the cereal straws, sugar cane and bamboo belong. The growing points—nodes, buds and heads—contain parts which are more difficult to pulp than the rest of the plant.

There are three main approaches to this problem. One is to cook or chemically treat the whole raw material sufficiently to break down the hard parts; this may result in the remainder being overcooked. Another is to screen out the harder parts and dispose of them in a low quality paper. The third method is to cook correctly for the main mass of the raw material, and then to screen out the hard parts and subject them to further chemical treatment. This last is the practice in Celdecor-Pomilio process mills, except where the previous possibility exists of mixing the rejects in other papers.

The mill in India, the second Celdecor-Pomilio process plant to be built exclusively for bleached bagasse pulp production, came up against difficulties not previously experienced arising from the unexpected introduction locally of tough varieties of cane. Various modifications succeeded in overcoming these difficulties and this mill is now obtaining results superior to those of the successful Philippines plant.

The next Celdecor bagasse plant to start up was the Ngoye mill which began in 1953 in Natal, South Africa. This mill is partly owned by a neighbouring sugar mill which supplies the bagasse. It uses part of the Celdecor-Pomilio continuous process and produces an unbleached semi-pulp, for paper made on a Fourdrinier machine with one vat. The product is a rigid corrugating medium which has found a ready sale with converters in the Union; this mill's capacity is to be doubled.

Another Celdecor-Pomilio bleached bagasse pulp mill has been erected in Brazil at one of the sugar mills in the State of São Paulo belonging to the Morganti's Refinadora Paulista. It was expected that late in 1954 a 40 tons-a-day new American paper machine of modern design would be installed. This is the first mill in the Americas designed to make fine paper based on bagasse, and it is significant that the initiative has been taken not by a paper mill but by a sugar company.

A further bleached bagasse pulp plant which will purchase its bagasse from neighbouring sugar mills and sell its pulp to an existing paper mill was due to start up late in 1954 in Mexico, not far from the capital.

VI. Conclusion

Whilst much clearly remains to be done in this field, a fairly wide variety of bagasse papers and boards are now being produced in a dozen commercial full scale mills around the world without anything particularly novel—and certainly not secret—in the way of pulping techniques or processes.

A further big advance may be expected as soon as there is a regular production of first-class bagasse pulp on the market, enabling its qualities to be more widely known and tested. There seems to be no reason to doubt that bagasse can play a significant part in equipping the nations of the world with the paper they need.

INDUSTRIAL EXPERIENCE IN BAGASSE PULP MANUFACTURE IN ARGENTINA[1]

Research Laboratory of Celulosa Argentina, S.A.

I. Introduction

For the study of the manufacture of paper from bagasse the Research Laboratory of Celulosa Argentina, S.A. set up a small pilot plant at the paper factory at Tucumán. Bagasse was obtained from sugar mills some few kilometres away.

Bagasse leaves the sugar mill with a 50 per cent moisture and a 2 per cent sugar content. Baled and piled in stacks of from 400 to 500 tons, fermentation soon takes place, producing gases which, combined with the increase in temperature resulting from fermentation, bring about a rapid lowering of the moisture content of the bagasse and a loss in weight of about 10 per cent.

To facilitate the escape of the gases, moisture and acids, spaces are left between bales at intervals. If well

[1] A short version of the original paper (ST/ECLA/CONF.3/L.5.8), which includes 22 tables setting out in detail the results of all the tests referred to herein.

protected by a layer of straw or reeds against the rain, stacks of bagasse will keep for a year or more.

The storage of bagasse in stacks not only reduces the moisture content from 50 to 20 or 24 per cent, but leaves the pith material in such a condition that a simple beating is sufficient to remove it, thus avoiding the need for the complicated installations required to remove pith from fresh bagasse.

At one time 20 per cent of the pith was eliminated from the dry bagasse at Tucumán. Later this was reduced to 10 per cent. However, no appreciable difference was noted in the pulp obtained. It was therefore decided to experiment with the manufacture of pulp from whole bagasse, without any pith removal. Dark soda pulps are today being manufactured at Tucumán from whole bagasse and blended with sulphate pulp for kraft-type paper.

II. Influence of pith in the manufacture of pulp from bagasse

Some mills have special installations in which the bales of bagasse are split and then shredded and broken up in hammer mills or by other means to remove the pith from the fibre, the percentage removed varying from mill to mill.

The composition of bagasse depends on its country of origin and on the physical and chemical characteristics of the soils on which the cane is grown. An average sample taken at the Tucumán factory showed the following composition: Moisture (determined by drying at 105°C)—10.00 per cent; solubles in 1 per cent NaOH—31.88 per cent; solubles in hot water—5.30 per cent; alcohol-benzene extraction—2.75 per cent; lignin (with H_2SO_4)—22.40 per cent; pentosans—25.55 per cent; and ash—1.98 per cent.

At the laboratory of Celulosa Argentina S.A., pith and short fibres were screened out and processed separately. Bleached pulp yields were 50 per cent from the bagasse without pith and 20 per cent from the dry pith. This argues, assuming the dry bagasse at Tucumán to contain 85 per cent fibrous material and 15 per cent pith and short fibres, a yield of 45.5 kg of bleached pulp (42.5 plus 3) from 100 kg of dry whole bagasse. Yield from 100 kg of depithed bagasse (equivalent to about 120 kg of dry whole bagasse) is about 50 kg of bleached pulp.

Tests were next conducted to verify that whole bagasse would yield a bleached pulp whose physical and chemical characteristics were not inferior to that made from depithed bagasse. For the former, whole bagasse, two alternative cooks were studied, simple and two-stage digestions.

These tests confirmed the yields—50 to 52 per cent for depithed, 45 per cent for whole bagasse. Differences in caustic soda consumption were not great—from 24 per cent for depithed to 27 per cent for whole bagasse. Pulp from whole bagasse was not inferior to that from depithed bagasse in initial freeness or in wet strength.

III. Manufacture of neutral sodium sulphite bagasse pulps

Laboratory tests showed that, to obtain good quality chemical pulps, easily manufactured on an industrial scale, a suitable method is the neutral sodium sulphite process, using sodium sulphite solutions maintained in a buffered state through the addition of sodium hydroxide so that they remain within the neutral or weak alkaline pH zones. This limits the destruction of the cellulose, and the greater part of the hemi-cellulose fraction is incorporated into the final product. Lignin removal is complete, and it is possible with well cooked pulp to obtain final bleached yields of from 52 to 56 per cent in terms of whole bagasse.

Subsequently three kinds of digestion were tried on an industrial scale at the Tucumán factory. The pulps resulting, their yields and uses are set out below:

Pulp	*Yield (in terms of whole bagasse) (per cent)*	*Use*
High-yield unbleached pulp.....	73	Second quality printing papers, in blends with mechanical and fully bleached sulphite pulps
Semi-pulps..................	65 (if simply refined) 62 (if semi-bleached)	White coloured papers and coloured wrappings, mixed with other pulps and first-class waste paper
Easily bleached pulp..........	54 to 56	40 to 60 per cent for white, writing and printing paper; 100 per cent for glassine paper

IV. Manufacture of pulp from bagasse by the caustic soda process

Laboratory tests were also carried out on the production of pulp from whole bagasse by the caustic soda process. The purpose was to plan industrial scale production in the Company's installations, on the basis of beating or refining, and continuous digestion in towers with a solution of caustic soda at 120°C for four hours. The tests showed that good pulp may be obtained from whole bagasse by treating it with from 12 to 14 per cent caustic soda under these conditions. This pulp has better strength properties than those obtained from the neutral sodium sulphite process, but the latter gives pulps which are also satisfactory and with higher yields.

These and the preceding tests and industrial experience lead to certain general conclusions. The selection of the process depends a good deal on the type of pulp desired, and in some cases on the installations and the facilities at the plant in which bagasse is to be utilized.

Celulosa Argentina's experience fully confirms S. I. Aronovsky's statement: that "to make special kinds of paper experience has shown that much better results can be obtained by mixing two or more pulps than by only using one type. Each fibre used in the mixture will contribute in giving the paper a characteristic or characteristics which could not as easily be obtained, or as well, from only one type of fibre. It is very well known that sulphate and sulphite coniferous pulps have high tearing and breaking strength, while mechanical pulps and pulps from short-fibred woods give good formation, softness, smoothness and opacity to paper".

Thus bagasse fibre, like the fibres from wheat straw, sudan grass, bamboo and eucalypt, represent an abundant and complementary source of raw materials; they yield pulps which can impart a number of beneficial properties to paper and can make it possible to effect a more rational utilization of long-fibred, coniferous pulps.

V. Newsprint from bagasse

Laboratory tests followed by industrial scale production at the installations of Celulosa Argentina have confirmed that it is possible to make newsprint from bagasse. Indeed, this has never been doubted by technicians who for many years have manufactured all kinds of papers from bagasse. The basic problem in manufacturing newsprint from bagasse is economic, not technical.

Bagasse pulp for newsprint was prepared in the laboratory by applying to whole bagasse a neutral sodium sulphite process. After passing through a Jordan refiner the pulp was divided into two groups, the first for direct bleaching with calcium hypochlorite, the second for chlorine treatment followed by an alkaline wash before calcium hypochlorite bleaching. Yields in terms of whole bagasse were similar, as was total chlorine consumption.

Mechanical pulp was added to correct for opacity, and loading agents added in a proportion which does not change very much the strength of the paper. The strength of bagasse pulp does not require the addition of long-fibred sulphite pulp. A series of newsprint papers made in the laboratory from 75 per cent bleached bagasse pulp and 25 per cent mechanical pulp, plus various types of loading agents, showed good strength properties and adequate opacity.

Production was later carried out on an industrial scale, using 70 per cent bleached bagasse pulp and 30 per cent mechanical pulp (manufactured from popuar-willow at Zarate), with 10 to 15 per cent kaolin. Without previous preparation of the machines, satisfactory newsprints—glazed (for rotogravure) and unglazed—were run off at 200 metres per minute.

INDUSTRIAL EXPERIENCE IN BAGASSE PULP AND PAPER MANUFACTURE IN PARAMONGA, PERU[1]

José Correa S.

I. Background

In 1939 the sugar-producing firm of W. R. Grace set up a paper mill using bagasse as a raw material at Paramonga, an industrial town situated on the coast of Peru, 200 Km north of Lima, the capital. Paramonga has a population of about 10,000 inhabitants, of whom 1,500 work in the sugar plantations and 1,300 in the industrial plants. The total area of sugar cane under cultivation is 4,000 hectares, which produces a yield of 160 tons of sugar cane per hectare for each crop. The yield of bagasse, which is the fibrous residue of the sugar cane once it has been processed, is approximately 30 per cent of the weight of the sugar cane.

The climatic conditions permit constant cultivation of sugar cane so that the sugar mills can operate throughout the year. Thus the consumption of bagasse by the paper mill is continuous, and there is no need to store very large quantities of the raw material at one time.

Production began in 1939 with one machine with a capacity of 7,500 tons per year, another machine was added in 1944, and a third to be installed shortly will bring the capacity up to 30,000 tons a year. Production of paper and board for 1953 was 17,000 tons and will be 19,000 for 1954.

II. Industrial experience

Since 1939 many different types of paper have been produced. The bagasse that was formerly merely used as fuel for the sugar mill boilers, or mixed with molasses as food for cattle, is now being converted into bags for foodstuffs, cigarette paper, corrugated cardboard boxes, copy paper, newsprint, blue paper for wrapping cotton-wool, "kraft" and "sulphite" types of paper for wrapping purposes, and coloured cardboards.

The total percentage of bagasse employed in the manufacture of paper has increased steadily; whereas in 1940, bagasse represented 21 per cent of the total pulp utilized at Paramonga, today it averages 70 per cent. Certain types of paper, such as the "sulphite" type for wrapping, newsprint and printing paper in general are manufactured with 100 per cent semi-bleached and/or bleached bagasse pulp. The greater part of the mill's output is absorbed by the Peruvian market, though small quantities of all types of paper, excluding newsprint, are exported to Bolivia, Colombia and Ecuador.

III. Chemical process employed

The Paramonga process consists, firstly, of milling and screening the bagasse to remove the pith, digesting the fibrous part that remains for the specific time required to produce different types of pulp, and, finally, refining the pulp to the degree most appropriate for the manufacture of the qualities of paper desired.

At one time up to six or eight different types of pulp were produced, but the plant has now become standardized to produce four types, including semi-bleached pulp. Future plans include the use of completely bleached bagasse pulp.

On receipt of the bagasse from the sugar mill a mechanical system of pith separation is used to separate up to 35 per cent before the usable fibre is packed into bales for storage. This part of the operation is carried out only during the cane-grinding season.

After the bagasse has been stored in bales for several months, the process is continued by standard methods

[1] A slightly shortened version of the original paper, ST/ECLA/CONF.3/L.5.9.

in rotary digesters, blow tanks, vacuum washers, screens and thickeners. The fibre is digested by means of a modified soda process; the quantity of chemicals used varies according to the type of pulp being manufactured. For coarse papers, such as corrugating medium, an unbleached type of pulp is produced. For better quality papers, semi-bleached pulp is produced. At the present time bleaching is carried out by the standard single stage process using hypochlorite.

For beating and refining the pulp, standard equipment is again used (Hollander and conical refiners), but care has to be taken in these operations in order to attain the proper degree of refining which, combining to best advantage the important factors of strength and freeness, permits the manufacture of strong papers with minimum sacrifice in the speed of the machine.

There are two paper machines at Paramonga; one has two kinds of forming equipment which are used alternately ("Fourdrinier" and cylinders, i.e., for the manufacture of paper and board respectively) and has a net trim of 254 cm. The other machine, for the manufacture of light weight papers, has a net trim of 183 cm, and a Yankee dryer. The speed of the large machine varies from 24 m per minute for boards to 230 m per minute when producing paper for sacks and for wrapping purposes. The machine for light weight paper operates at a maximum speed of 183 m per minute. Bagasse pulps usually retain water longer than wood-fibre pulps, so that unless they are carefully handled maximum speeds cannot be reached. Speeds are regulated in accordance with the composition of the fibres in order to obtain economical operations, so that in Paramonga it is generally drying capacity that limits speed.

IV. Conclusion

Paper made from bagasse, which was looked on with some scepticism at first, is now well accepted. Multi-wall paper sacks have proved preferable to the cotton sacks formerly used for sugar exports from Peru. Tests on crush resistance carried out on board made from bagasse showed that it was superior to that made from woodpulp, and that corrugated cardboard containers made from bagasse also have a greater crush resistance than those made with other pulps.

Furthermore, research activities carried out at Paramonga over the last eighteen months have led to important results which are now being tested in a pilot plant. In the near future modifications will be adopted in the main plant which will make possible the economic production of any quality of paper with 100 per cent bagasse pulp.

TWENTY-FIVE YEARS OF ARGENTINE INDUSTRIAL EXPERIENCE IN THE PULPING OF STRAW AND CANES[1]

Juan Di Felippo

I. The development of Celulosa Argentina

The electrolytic process for the production of alkali, after early successes, found its expansion hindered by lack of adequate outlets for chlorine and chlorine derivatives, though it was the simple, simultaneous production of alkali and chlorine that had given it its first impetus. The problem arose in many parts of the world of finding a use for electrolytic chlorine. One solution was the treatment of agricultural residues with moist chlorine gas to manufacture chemical and semi-chemical pulps. The chlorine gas process, however, in spite of its advantages, was slow in becoming standard industrial practice, since it called for the co-ordination of three complex branches of chemistry: electrolytic production of chlorine, pulp manufacture, and paper manufacture.

Early attempts on the laboratory and semi-industrial scale led to the adoption of the process, in 1919, by the Electroquímica Pomilio concern at Naples. Slow operations, with heavy losses of chemical reagents and steam, in the pilot plant led to complete redesign and reconstruction under the direction of Ing. Umberto Pomilio. Late in 1926 tests began on continuous chlorination, and these tests continued on a semi-industrial scale until the problems attached thereto were solved. In 1928, Ing. Pomilio went to Rosario (Argentina) at the invitation of the Chamber of Commerce to study the installation of a mill manufacturing paper from agricultural residues, making use of the continuous chlorination process with chlorine gas produced directly in the electrolytic chamber.

Argentina was a natural choice since it had a high consumption of paper per head, mostly imported; there was no domestic pulp production; and about 20 million tons of agricultural residues (wheat, linseed and maize straw) were being burnt yearly. Ing. Pomilio, after examining costs of baling and storing straw, the costs of salt, energy, fuel, labour and transport, and market prices for paper, reported favourably. Celulosa Argentina S.A. was founded and, in February 1929, construction started at Juan Ortiz, on the Paraná river, fifteen kilometres from Rosario.

In the early months of 1932 the new mill was producing monthly 314 tons of pulp and 439 tons of printing and writing paper, while ancillary operations gave a monthly output of 54 tons of hydrochloric acid, 82 tons of caustic soda for concentration and 115 tons of refined table salt.

Good quality salt was available from Quilino (Córdoba province) and N. Levalle (Buenos Aires province). Plentiful supplies of wheat straw were available, the province of Santa Fé, in which the factory is located, being one of the principal centres of wheat production. In the early days experiments were carried out both on the laboratory and industrial scale with flax straw and maize stalks. The measures necessary to counter the uneven action of the chemical reagents on the external fibres and on the short internal fibres and pith led to low

[1] The original paper (ST/ECLA/CONF.3/L.5.10), of which this is a shortened version, contains 19 pages of tables and 7 charts illustrating the experiments conducted in the Research Laboratory of Celulosa Argentina S.A.

yield and high cost. It was decided to use neither at the Juan Ortiz plant, since ample supplies of wheat straw were available.

In nearly twenty-five years of operation, the installations of the Juan Ortiz plant have been constantly improved and expanded, and output of all commodities has considerably increased. Today the plant covers an area of 2 million square metres, as compared with 125,000 square metres when operations began. The boiler room has been twice radically transformed. The electrolytic installation now contains 500 cells, as against twenty-eight in 1932. Moreover, since 1940, efforts on the part of the Company to improve the original "Giordano-Pomilio" electrolyzers, especially with regard to energy yield, have led to the production by the Sindacato Cellulosa Pomilio of the "C.A.S.A." circular electrolyzer; these are now installed at Juan Ortiz and have been adopted in various parts of the world. Today the electrolytic installation at Juan Ortiz can manufacture daily forty-five tons of caustic soda and forty tons of chlorine gas with a daily input of 130 to 150 tons of salt.

Pulp output has risen to seventy-five daily tons of wheat pulp and about forty daily tons of bleached pulp from Castilla cane, bamboo, eucalypt or pine.

During this period a small continuous cooking tower for wheat straw was developed, which later was modified to two continuous towers for the cooking of 160 tons daily of wheat straw, fed under pressure, making work at higher temperatures possible.

At the same time, fixed vertical digesters were installed, with and without circulation of the cooking liquid, to heat bamboo, eucalypt and different varieties of pine. Cooking these woods under pressure with a sulphate process required the installation of a complete plant for the recovery of black liquors, producing about thirty tons of white liquor ($NaOH$ plus Na_2S) and twelve tons of steam hourly. At present the black liquor from the cooking of wheat straw is also recovered, and part of the white liquor is recirculated, permitting the cooking of wheat straw with sulphate. The effect of the silica content of this black liquor on the evaporators has been offset by precipitating it with lime in a new installation.

In this section, two complete Kamyr bleaching equipments have been installed. Each installation, one for forty tons of wod pulp, the other for seventy-five tons of wheat straw pulp, consists of two chlorination towers, two alkali washing stages and one bleaching tower with calcium hypochlorite.

The original paper machine, installed in 1930, produced twenty to twenty-five tons of paper daily. A second machine, with an average daily output of seventy tons of white, good-quality paper, has been added, while a third machine, to produce thirty daily tons of white and coloured paper, is now being installed.

The papers produced—white papers for printing, writing, posters, envelopes, drawing, etc.—vary in composition from 60 up to 85 or 90 per cent wheat straw; they have found ready acceptance on the Argentine market.

The water purification plant has been expanded and now consists of two Dorr flocculators which can give 3,000 to 4,000 cubic metres hourly. Present water consumption is approximately 3,000 cubic metres hourly, pumped directly from the Paraná river.

Two diagrams at the end of this paper show the processes used for the production of wheat straw pulp at Juan Ortiz in 1931-35, when operations began, and today.

Studies undertaken at the research laboratory

Because of the complex problems involved in the manufacture of bleached cellulose from very different raw materials, consisting mainly of stems and leaves, in a continuous installation, each raw material has to be studied to determine optimum cooking and bleaching conditions.

The Research Laboratory of Celulosa Argentina has paid special attention to the preliminary study in the laboratory of raw materials to be used later on an industrial scale.

The laboratory manufacture of pulps in a closed container where temperatures, pressures and amounts of raw materials and reagents are recorded differs considerably from industrial manufacture, in constant quantities and qualities, in a tower in which the plant matter and the solution flow at different speeds, with areas of maximum and minimum contact with the solution and the temperature.

The problems are further complicated when the pulp must be manufactured from both stems and leaves or when the same continuous installation has to be used for wheat and rice straw, sudan grass, Castilla cane or bagasse with cooking variables which have been previously determined. Only close collaboration between the laboratory and the plant has made it possible to use the same installation to treat different plant materials.

The following pages give an account of some of the laboratory tests carried out, namely, on cooking conditions for wheat straw, on two-stage cooking of wheat straw to eliminate silica from the residual liquor, and on the pulping of Castilla (*Arundo donax*).

Effect of cooking conditions in soda and sulphate cooks of wheat straw

The first series of tests was carried out on an average sample of straw from Santa Fé province—in a 500 ml digester. The time taken to reach maximum temperature was 1¼ hours and time of exposure at maximum temperature 5½ hours. Both sulphate and soda cooks were carried out, with maximum cooking temperatures of 100, 115, 130, 135 and 160°C in each case. In all these cooks the dry straw/solution ratio was 1:3. The quantity of active alkali or caustic soda in the cook was from 8 to 14 per cent of the dry straw. The caustic soda cooks were then repeated with straw/solution ratios of 1:4, 1:5, 1:6 and 1:7, instead of 1:3, other conditions being kept constant.

For each of the pulps obtained, after washing and grinding in a "Turmix", calculations were made of yield, permanganate number, lignin, ash and viscosity.

The degree of cooking undoubtedly influenced the yields, and the dissolution of lignins and hemi-celluloses. Between 100° and 160°C the pulp yields decrease, owing to the increase action of the alkali on the lignins, on the hemi-cellulose and ultimately on the cellulose itself.

With a weak alkali solution, yield remains constant for cooks up to 130°C, thereafter decreasing owing to dissolution of the cellulose. Amounts of alkali above 11 per cent react on the lignin at lower temperatures, with a consequent decrease in yield. Higher temperatures do not substantially diminish yield, since dissolution of the hemi-cellulose is offset by reprecipitation of lignin owing to the lowered pH of the solution. Yield may even increase. When alkali is excessive, the lowering of pH and consequent reprecipitation of lignin is prevented, and pulp yields drop.

For a given amount of alkali, the permanganate number drops as cooking temperature rises, reaching a minimum and thereafter rising. The greater the amount of alkali, the lower the minimum permanganate number and the greater the temperature at which this minimum is recorded. These minimum points indicate the temperature necessary for complete alkali consumption.

Generally speaking, the increase in the cooking ratio facilitates the dissolution of non-cellulose matter, with a subsequent decrease in yields. When the ratio is increased at a constant rate of active alkali, the dilution results in a lessened attack on the encrustants, especially in low temperature cooks, and the permanganate numbers are higher. At higher temperatures, the influence of the increase of liquids predominates, because the cooks are more homogeneous and the pulps have a lower permanganate number, and less lignins and ash.

These tests were next repeated in revolving digesters of 18 litres' capacity. For each cook 1,500 grammes of straw were used, maximum temperatures being attained in 1 hour and held for 5½ hours. Variable factors were temperature (110, 130 and 150°C), the cooking ratio of straw to solution (1:3, 1:4 and 1:5) and the percentage active alkali to dry straw (9, 11 and 13 per cent).

Again cooked pulp yields dropped in relation to increases in the amount of alkali, the temperature and the cooking ratio. Again lignin reprecipitation was evident at the higher temperature.

Bleached pulp yields at 110°C and 130°C, with 9 and 11 per cent active alkali, showed little difference. Yield at 150°C was slightly lower, much lower if the higher percentage of lignin is taken into account. Careful examination of the data suggested 120°C as the ideal temperature for cooking wheat straw with 9 to 13 per cent alkali in relation to the dry straw.

Two-stage cooking of wheat straw to eliminate silica (SiO_2) from the residual liquor

The laboratory studied the problem of recovering waste liquor, which has a high dissolved silica content. The problem was partly solved by two-stage cooking. Moreover, this solution led to a more complete cook, the easily eliminated compounds being dissolved in the first stage while in the second stage, with a new soda solution, the more difficult parts (lignins) were directly attacked.

A series of tests was made on an average wheat straw sample, with 4.6 per cent silica content, to determine the time, temperature and amount of soda required for the dissolution of ash and silica in the residual liquor.

At 20°C, the lowest in the series of tests, there is minimum solubility of silica, i.e., least SiO_2 in the residual liquor, whatever the percentage of soda. This is not, of course, a practical temperature since, besides keeping silica dissolution to a minimum, the cook must ensure that the maximum of starches, fats, pectines and hemi-cellulose in the straw be attacked. The data pointed to the advisability of two-stage cooking, using, for the first stage or pre-cook, less than 5 per cent NaOH for 30 minutes at 90 to 100°C. The second stage consists of a longer cook, at higher temperature, with a higher percentage NaOH. The residual liquor from the second stage is recovered for use in the pre-cook.

Two series of tests on two-stage sulphate cooks were then carried out, cooking conditions being the same as for the soda cooks, namely, 30 minutes at 100°C for the pre-cook and three hours at 115 to 120°C in the second stage. In the first series, 4 and 5 per cent active alkali were used for the two stages, and in the second series 4 and 7 per cent. Black liquor from the first stage was removed for treatment in the recovery section, while cooking liquors from the second stage, after dilution, were re-used for further pre-cooks; in all cases they showed a low silica content.

Practical experience of the difficulties encountered (deposition of insoluble matter in the tubes, with consequent halts of the evaporation plant for cleaning) had at one time led to the conclusion that it was not worth while to attempt to recover residual liquors.

On the hypothesis that recovery requires the removal of silica, tests were made with gypsum, dolomitic lime and quicklime to precipitate the silica in the form of insoluble silicates. These tests led to the conclusion that purification with quicklime is the most suitable process for treating the black liquor; 15 to 30 minutes at 50°C or 100°C give the best silica elimination without excessive installation costs and NaOH losses.

This treatment makes possible the recovery of wheat liquors, and hence enables straw to be cooked by the sulphate process, giving a better quality pulp output. In the Capitan Bermudez installation all the black liquor from the treatment of wheat straw is now being recovered by this method.

Pulp from "Castilla" or common cane (Arundo donax)

(a) *Botanical characteristics: cultivation and reproduction*

Common cane *(Arundo donax)* has a thick tuberous rhizome, covered externally by abundant long, shiny white hairs. Similar hairs are also found on the outer side of the sheaths of the first leaves. The stem, growing to three or four m in height, ends in a great panicle whose numerous branches and twigs form a thick cluster.

It is quite common in Mediterranean Europe, North Africa, the Canary Islands, Syria, etc. In the Mediterranean countries—as in South America—it is extensively cultivated. In Italy it grows on the plains and on the lower slopes of the mountains all along the peninsula. On moist soils, along rivers, in the mountains, near the sea, etc., *Arundo donax* often forms small thick woods, very much like the perennial grass woods of tropical countries. The method generally used for the reproduction of common cane is that of subdividing the rhizomes. The characteristics of the species are thus conserved because the reproductive organ is an integral part of the mother plant. The plants will be more vigirous and better developed when well-formed or medium-size rhizomes are used, as they feed directly on the sap contained in the rhizome. Plantations generally use rhizomes weighing 500 to 1,000 g, and the very small ones, weighing under 100 g, are discarded.

The soil for cane plantations must be soft, well fertilized and moist. In general cane gives a very good yield in any kind of soil which is deep, sandy or not very compact, containing mineral elements, some humus and moisture. Excessively sandy soil is quite unsuitable.

This cane also grows very well on plains which are rich in lime, potash and organic matter in an advanced stage of decay, while recently fertilized, acid or lime-deficient soils are the least suitable.

In Italy, where this cane is much cultivated and used, there are plantations which give an average yield per hectare of 11.5 tons of green cane.

The plant, after cutting and storing, still retains some leaves in the knots, and also the stem, which is covered by a sheath that is difficult to remove.

The problem is how to obtain resistant and good-quality pulp from such heterogeneous raw material. As no system has been invented to remove the leaves and still less the sheaths of the stem, the stems have to be used with the sheaths and a small proportion of dry leaves.

This complicates cooking with caustic soda. The parts soluble in alkali give the cooked stocks a jelly-like consistency which makes washing difficult. The leaves and sheaths produce very short or fine fibres which are lost in washing and straining, with a consequent loss in bleached pulp yield.

A number of tests were carried out in the Celulosa Argentina laboratories to determine quality, yields and costs of bleached pulp which could be obtained from the stems, the leaves and the stems with leaves.

(*b*) *Laboratory tests*

Pulp from stripped stalks (without sheaths or leaves). An average cane sample was taken from stocks which had been kept in storage for some months. The stalks were strong and rigid, with an average diameter of 15 to 20 mm and covered for the most part with the dry sheath.

The leaves and sheaths were removed by hand and the stalks cut into small pieces about the size of wood chips. Five cooks were made. Bleached pulp yields were between 40.7 to 45 per cent, and for the bleached pulps breaking length ran from 6300 to 6800 m, and the tear factor (Elmendorff) between 25 and 40.

Pulp from canes with sheaths and leaves. The same average samples were used, without removal of the sheaths and leaves. Three cooks were made. The bleached pulp yields were between 34.0 and 35.5 per cent; and for the bleached pulps breaking length ran from 6,250 to 7,000 m, and the tear factor (Elmendorff) between 30 and 35.

Pulp from the leaves. The hand-picked leaves from the stalks were cut into 50 mm pieces and one cook was made. The bleached pulp showed a yield of 26.1 per cent; the breaking length was 2,800 m, and the tear factor (Elmendorff) was 16.

Conclusions

The analysis of the stalk, sheath and leaves shows that the stalk is the part of the plant which can give the better pulp in greater amounts.

The ideal solution would be to utilize only the stalk, the leaves being used as fertilizer. Unfortunately this is not possible as no machine has been found to cut the plant and strip it of its leaves in one operation.

It is possible, however, to crush and ventilate the cane to remove the leaves and sheaths. Thus better yields, and a better quality pulp can be obtained at lower cost. Laboratory tests show that 40 to 42 per cent bleached pulp is obtained from stripped stalks, as against 35 to 36 per-cent from stalks with leaves.

The mixture of stalks and leaves is also undesirable because cooking is not uniform. The cooked pulp is difficult to press and wash and the loss of fine fibres is relatively high.

Pulp from common cane does not have very long fibres, but a mixture of fibres of different lengths which, when mixed with long wood fibres, can produce a good white paper with normal strength characteristics.

(*c*) *Neutral sodium sulphite process.* This process, used with advantage for farm waste (especially wheat, rice, rye straws and bagasse), can also be applied to common cane. As this raw material is much more compact and woody than wheat straw, the respective amounts of sodium sulphite and caustic soda needed for normal cooking are very much higher and the yields improve in comparison with the other common processes.

Ten tests were made with different cooking times and reagent concentrations at a constant temperature of 170°C. The raw material consisted of a stock of canes in a good state of preservation which had been planted in September 1948, cut the following year and sent to storage in January 1950. Most of the leaves had fallen off.

The bleached pulp yield varied between 43.8 and 49.1 per cent; and for the bleached pulps the breaking length ran from 6,000 to 9,500 m, and the tear factor (Elmendorff) between 17 and 32.

The tests showed that higher yields were obtainable with the neutral sulphite process than with the sulphate process. In general, strengths were greater when the pulps were well cooked and lower when it was necessary to use greater amounts of chlorine and soda to obtain satisfactory bleaching.

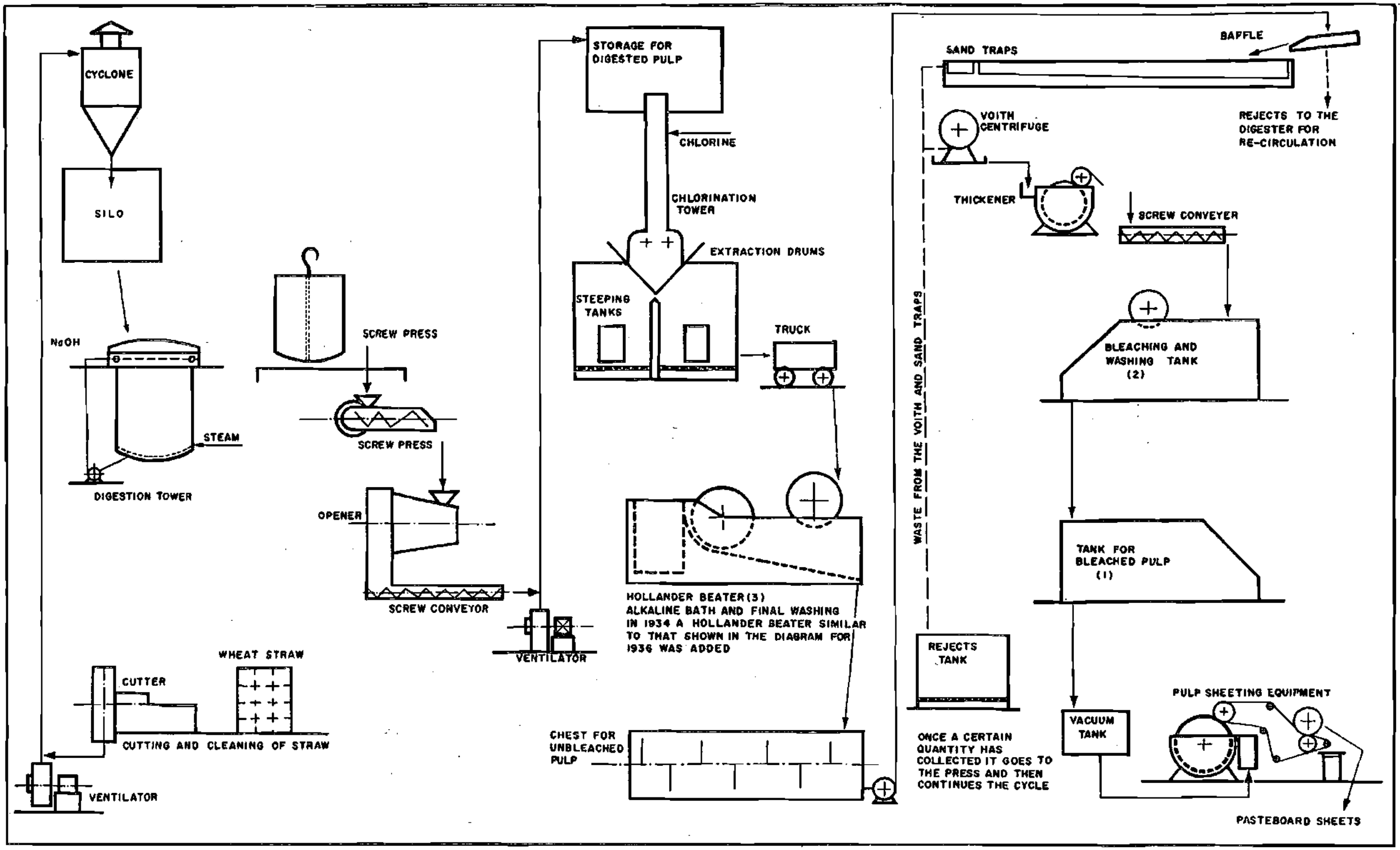


Diagram 1

DIAGRAM FOR THE PRODUCTION OF PULP FROM WHEAT STRAW EMPLOYED FROM 1931-35

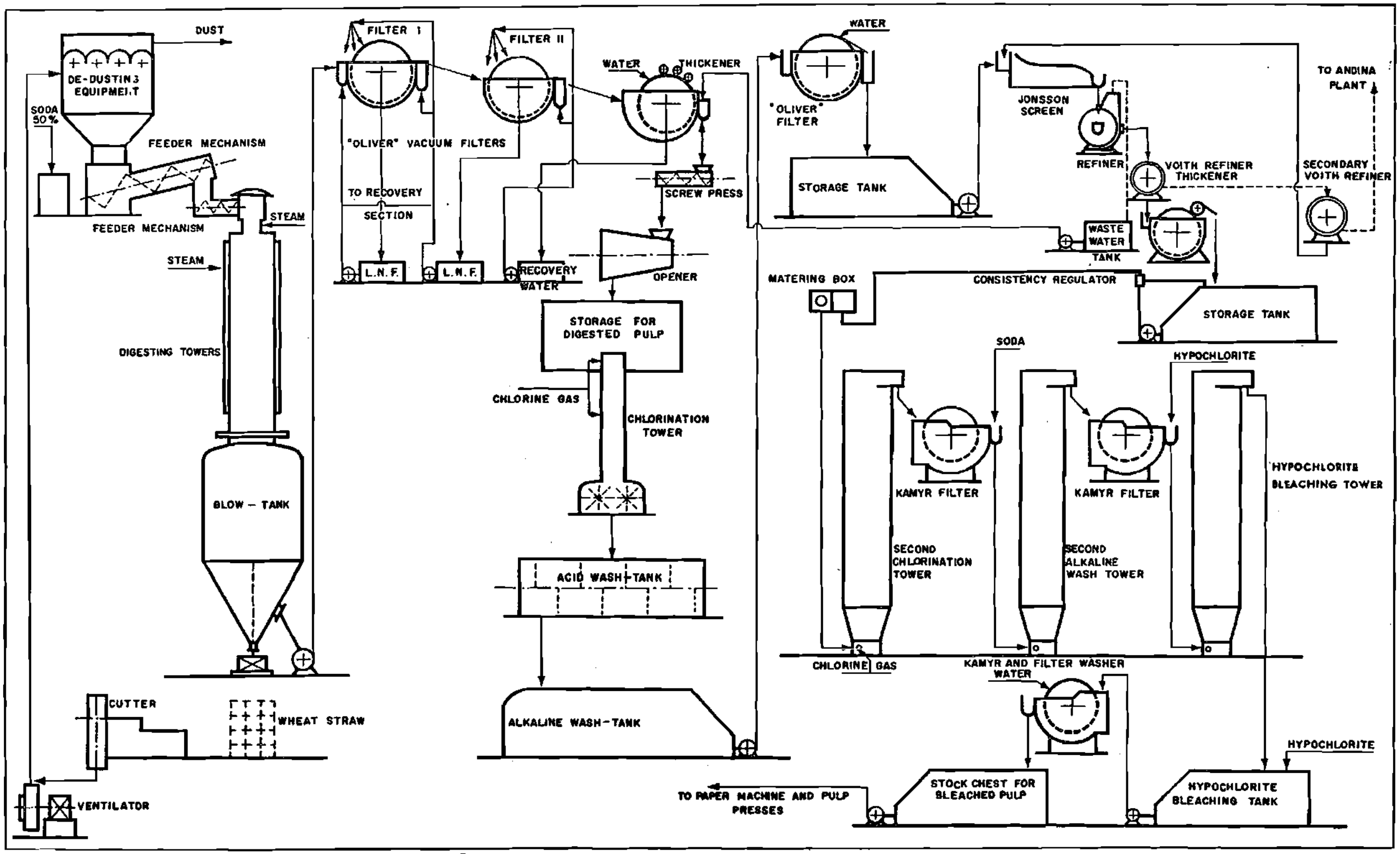


Diagram 2

DIAGRAM FOR THE PRODUCTION OF PULP FROM WHEAT STRAW EMPLOYED IN 1953-54

INDUSTRIAL EXPERIENCE IN BAGASSE PULP MANUFACTURE AT PIRACICABA[1]

LINO MORGANTI

I. INSTALLATION OF THE PAPER MILL

Recent developments in the use of sugar-cane bagasse as a raw material for the manufacture of paper induced the sugar-refining enterprise Refinadora Paulista S.A. to install a pulp and paper mill utilizing bagasse at the Monte Alegre sugar mill, Piracicaba, in the State of São Paulo.

The Monte Alegre sugar mill was chosen for the following reasons: its situation in the centre of the State of São Paulo, with easy access to the capital, and the fact that it is served by the Sorocabana and Companhia Paulista railways; the high density of population in the region; its position on the river Piracicaba, which has a large volume of water; and, finally, the availability of electric power. An abundant supply of bagasse existed and it was possible to install a mill with a production capacity of up to 30,000 tons of pulp.

It was decided to adopt the soda-chlorine method (also known by the name of its inventor, Umberto Pomilio) since it permits the production of high-grade writing and printing papers, containing 80, 90 and even 100 per cent of bagasse pulp.

The mill was begun in the summer of 1951; actual production of paper began in October 1953 and has suffered no interruptions.

II. DESCRIPTION OF THE PLANT

The installation, which was planned by the Cellulose Development Corporation (England) and by the Sindacato Cellulosa Pomilio (Italy), consists of the following sections:

Extraction of pulp: This operation is continuous. The bagasse received from the sugar mill in bales weighing 15 kg is treated in the following manner: the bales are opened and the bagasse is cleaned (a very important operation when a high quality paper is required and one, moreover, which results in a saving in chemical reagents), the fibre is then separated from the pith—the part of bagasse that does not produce pulp and can be used as fuel in the mill.

The bagasse, when opened and cleaned, is forced into a cyclone by a fan. After separation in the cyclone the fibre drops into a tank where it is mixed with the digesting agent; it continues to the digesting tower where it is cooked by indirect steam, removed by a continuous extractor, and pumped into the wash tank where it is washed twice and pressed to separate all the substances that have been dissolved. Between the two wash tanks there is a conical refiner for treating the digested pulp. It is then transferred to a special apparatus where it undergoes treatment enabling the chlorine gas in the chlorination tower to penetrate the fibre suspension evenly. At this point the chlorine reacts with the lignin. Once chlorinated, the bagasse is washed with pure water in a rotary filter to separate the hydrochloric acid that forms during chlorination, and then treated with a weak solution of caustic soda to transform the organic chlorine derivatives, formed during the previous stage, into easily soluble sodium salts. The pulp finally passes through rotary screens to separate out incompletely pulped material.

The bleaching of bagasse pulp consists of a pre-treatment with chlorine followed by an alkaline wash. The actual bleaching cycle with calcium hypochlorite takes place in two towers, each of which is followed by a filter, permitting bleaching in two stages with a minimum amount of hypochlorite. After the latter treatment, the pulp is ready to be transferred directly to the paper mill or to the wet-lap machines.

Paper production: The paper section of the mill consists of two continuous machines, one made in Brazil by Cavallari and the other, now being installed, made in the United States by Bagley and Sewall.[2]

Water supply: This section consists of an installation with an actual capacity of 500 m^3 per hour, for the pumping and filtration of water taken directly from the Piracicaba river. It consists of a large flocculator and a battery of sand filters.

Steam production: The steam required for digesting the bagasse and drying the paper in the continuous machine is produced by a boiler with a heating surface of 500 m^2, which can supply up to 12,000 kg of steam per hour at a pressure of 17.5 ats and a temperature of 250°C. The fuel employed at the present time is eucalypt wood, together with bagasse pith that has been separated during the bagasse-cleaning process.

Electric power: This is supplied by a 60,000-volt line from the Companhia Paulista de Force e Luz, and is transformed to 450-volt current for the mill line by an intermediate 11,000-volt transformer.

III. BAGASSE

In a year's experience the greatest difficulty so far encountered has concerned the bagasse supply. Baling and storing this material to await natural drying has proved extremely costly because of (*a*) high labour costs for baling, stacking and unstacking; (*b*) electric power for baling; (*c*) wire cost, and (*d*) losses in transport and storage. A study has therefore been made of the possibilities of drying the bagasse before it leaves the sugar mill, at the same time removing the maximum quantity of pith, and conveying it to the pulp mill in dry form. This would limit the need for storage to the 6 months non-grinding season and reduce the weight of bagasse to be transported by 60 per cent while the lower volume of bagasse to be stored should reduce fire risk.

For these reasons it has been decided to install bagasse dryers in the sugar mill during the next period of operations.

In due course the thermal section of the sugar mill will be completely converted to fuel-oil burning, leading to

[1] A shortened version of the original paper, ST/ECLA/CONF.3/L.5.12.

[2] The original paper gives particulars of the machine wires, Fourdrinier and Dryer sections of these two machines, as well as of pulp preparation and finishing equipment, and of the auxiliary electrolytic section.

many economies in the fuel system and at the same time freeing more bagasse for pulping.

IV. Pulp production

Experience at the Monte Alegre plant suggests that it is only possible to obtain a satisfactory product and efficient functioning of the installation by using dry bagasse with a minimum amount of pith, not only for the production of high quality white paper, but also for semi-chemical pulp used in corrugating medium. Failure to eliminate pith leads to higher chemical consumption, more impurities, difficulties on the paper machine, and a lower quality product; thus the claimed advantage of higher yield is fictitious. Moreover, tests have shown that if wet bagasse is stored for three months—an insufficient period to allow thorough fermentation and natural drying of the material—pith elimination falls from 18 to 12 per cent with a consequent increase of 9 to 13 per cent in soda consumption.

Bleaching came up to expectations, and the decision of the mill planners to distribute the "chemical work" between chlorine and hypochlorite proved to be successful.

The yield and consumption of reagents in the production of air-dry bleached pulp were as follows: yield in relation to clean bagasse (without pith), 50 to 52 per cent; total consumption of caustic soda, 20 to 22 per cent; total consumption of chlorine, 17.5 to 19.5 per cent.[3] Consumption of reagents is on the basis of the air-dry weight of the bagasse pulp.

[3] Average consumption of chlorine in the actual bleaching was as follows: as chlorine, 1.5 to 2 per cent; as hypochlorite, 1 to 2.5 per cent.

V. Paper production

During the first stage of operations in the mill, production was limited to paper for corrugating medium (from 100 per cent bagasse semi-pulp) with a substance of 120 to 230 g/m^2. This proved immediately successful on the domestic market.

The following types of high-quality papers have since been produced:

First-grade white printing and writing paper ranging from 48 to 90 g/m^2;

White pasteboards from 100 to 200 g/m^2;

Unsized paper for cyclostyle from 62 to 74 g/m^2.

These papers contain varying percentages of unbleached sulphite pulp which was mixed with unbleached bagasse pulp and introduced into the final stock before bleaching.

After some early resistance on the part of the market due to the novelty of the product, within six months after production began these papers were accepted without reservation, especially for the production of exercise books.

Surplus wet pulp that could not be absorbed by the paper machine at the time found a ready sale.

As soon as the Bagley & Sewall machine is in operation it will be possible to produce up to 15,000 tons of high-quality paper annually. Demand continues to rise and the future of bagasse papers from the Piracicaba mill seems assured.

THE ALKALINE PULPING OF BAGASSE FOR HIGH STRENGTH PAPERS AND DISSOLVING PULPS[1]

William J. Nolan

Introduction

The problem of processing sugar cane waste for the paper industry is very complex. In addition to the usual investigation of the pulping variables of the cellulosic raw material, the researcher has to contend with variations in the raw materials due to geographical location and to differences in methods of harvesting and processing the cane. Finally there is the problem of the actual physical separation of the pith cells from the fibrous cellulose prior to pulping.

The following pages give a short account of research carried out at the University of Florida on three aspects of bagasse pulping problems:

(*a*) Separation of pith from fibre;

(*b*) High purity pulps for dissolving purposes; and

(*c*) High strength pulps.

All the research was conducted on Florida cane, grown near Clewiston, Florida.

[1] A shortened version of the original paper (ST/ECLA/CONF.3/L.5.13), which includes six tables and six charts setting out the results of the tests conducted, together with a photograph of the experimental machine built for depithing.

I. Separation of pith from fibre

Two types of bagasse were used in this study. The first material was prepared in the laboratory from freshly cut cane, transported overnight to the laboratory. The cane was chopped into lengths about 2 inches long and fed to a Jackson and Church 015 rotapulper, where the material was torn apart into individual fibres of about the same length as the cut cane. The shredded material was fed to a Jackson and Church ZM screw press, where the sugar juices were removed, resulting in a pressed cake of 40 per cent fibre.

The pulp was passed twice more through the rotapulper and repressed to 40 per cent fibre. A countercurrent washing system enabled 98 per cent of the sugar to be extracted with a minimum of water dilution. From the standpoint of bagasse utilization, this counter-current extraction process approached the ideal for preparation of fibre. The three passes through the rotapulper, due to the intense rubbing action involved, separated practically all the pith which had been attached to the cellulose fibres. The fibres were very long, almost two inches in length, with very little fibre breakage. But though the bonds between pith and fibre had been broken, the two components were still intimately mixed.

The second form of bagasse studied was dry baled bagasse, which had been dried in a fire drier and was marketed as chicken litter. The material was quite dark in colour and contained a large amount of dirt, carbon, and what appeared to be traces of carmelized sugar.

The dry bagasse was soaked overnight in hot water to restore the original flexibility of the fibres. The soaked bagasse was drained of excess moisture, then submitted to two or three passes through the rotapulper. It was found that this treatment broke the bonds between pith and fibre, just as in the case of fresh bagasse. However, the resultant fibres were much shorter than when fresh cane was used—the fibre mixture varying from two inches to less than ¼ inch in length. Fibres were much darker in colour than those from the fresh cane.

A rough estimate of power consumption was made for the rotapulper treatment. The bagasse can be processed in this manner for about 0.75 kilowatt days per ton per pass and the machine, when equipped with a 100 HP motor, should handle 75 to 100 tons of bagasse per day.

Pith separation was first attempted on a flat slotted screen (0.46 mm slots), the pith-fibre mixture being fed to the screen at 0.5 and 1.0 per cent consistency. About 60 per cent of the material was retained on the screen, 40 per cent passing through the slots. The retained material was mainly fibre, but yet contained that part of the pith larger in diameter than .018 inch; it could not be considered as having been satisfactorily depithed. At the same time the pith fraction—that part passing through the screen—contained, in addition to pith, short broken fibres amounting perhaps to 50 per cent of the total weight.

To obtain a fibre fraction sufficiently pith-free to warrant pulping research, the fibre fraction was dried to 5 to 10 per cent moisture and passed over a Day Ro-ball shaking screen using 14-mesh window screen wire as a separation medium. Though the long fibres were retained, and though most of the loose pith passed through the screen, unfortunately the very short fibres were carried through also. In fact, about 10 to 15 per cent of the material fed to the screen was passed through. Thus, while the over-all process did yield a supply of very clean fibre for pulping experiments, it would not be commercially practicable.

The depithing problem was analysed, taking into account all the properties of the pith-fibre mixture, and a machine was designed to take advantage of these properties as far as possible. First, a high proportion of the pith is always larger in diameter than the cross-section of most of the fibre. Second, if allowed to flow freely in water, part of the pith will come to the surface rather than pass through a screen because of the air held in some of the pith cells. Therefore a machine must be designed in which the fibres are held flat on the screen, the screen openings being made large enough to permit passage of the largest particle of pith with no passage of fibre. Sufficient water has to flow through the material so that the tendency of the pith to cling to the fibre will be overcome. The velocity of the water must be such that the buoyant pith will be carried along with the stream. The amount of water on the screen must be kept low enough so that there is no tendency for the fibres to orient themselves so that they can flow, edgewise, through the large screen openings.

An experimental machine was designed to these principles, with a continuous belt, 30 cm (12″) wide, made of 14-mesh screen wire, stretched between 20 cm (8″) dia. rolls, set about 1.5 m (5′) between centres. The peripheral speed of this belt can be varied between 0.9 and 4.5 m (3′ and 15′) per minute. Two deckle straps, made from rubber strips 2.5 x 2.5 cm (1″ x 1″) in cross-section, ride on the top of the screen and are stretched between 20 cm (8″) guide rolls, 1.22 metres (4′) between centres. A galvanized trough fits tightly under the wire to catch the material passing through the wire. A 38 mm (1½″) pipe is welded into the bottom of this trough, and eight 6.3 mm (¼″) nozzles supply water in the form of flat spray to the screen surface.

In operation, a mixture of wet pith and fibre, after two or three passes through the rotapulper, is fed to the screen belt, just ahead of the sprays. The discharge valve under the trough is adjusted so that there is a water layer about 12 mm (½″) deep on the screen surface, contained by the deckle straps. The mixture of pith and fibre is spread out evenly on the wire and travels through the sprays, which wash the pith through the wire, leaving the fibres on the screen surface. The washed fibre is picked off the end of the belt, and pith is collected in the galvanized can.

The effective washing area of the machine is very small. The distance between the inner edges of the deckle straps is 23.8 cm (9⅜″), while the length of screen over which the sprays operate is 40 cm (16″). Two passes result in a very clean separation which is not improved by a third pass over the machine. The longest fibres were about 6.3 cm (2½″) long. Fibre recovery should amount to 70 to 80 per cent of the original bagasse. On a continuous screen belt with an effective width of 7.5 m (25′) and a washing length of 16 m (53′) it should be possible to process 100 tons of clean fibre per day. Belt speed should be about 38 m (126′) per minute.

Between 250 and 420 litres of water will be used per kilogramme of fibre; the water can be used repeatedly, after passage over a side-hill screen for pith removal. The principal cost of operation should be the power cost for pumping.

II. Pulping of bagasse fibre for high purity pulps

Three types of bagasse fibre were pulped: one from the laboratory extraction of fresh cane, followed by wet and dry screening; the second obtained by soaking dry, baled bagasse in hot water, passing it twice through the rotapulper followed by wet and dry screening; the third from dry bagasse, soaked and refined in the same manner as the second, but thereupon separated by two passes over the washing screen.

All pulps were cooked at constant concentration of chemical, simulating continuous operation. All cooks were carried out at high concentration, 80 to 125 g Na_2O per l. The tests showed that bagasse fibre is ideally suited, by its natural degree of subdivision and consequently high surface area, for rapid continuous cooking. Pulps containing 95 to 96 per cent alphacellulose can be obtained in 5 min cooking time at surprisingly low steam pressure, 5.6 kg/cm² (80 psig). Pentosan content is satisfactorily low, comparing with spruce sulphite, a standard source of dissolving pulps.

It is probable that pulps with a degree of polymerization of 1000 to 1100, unbleached, would be most suitable for dissolving purposes. The conditions chosen as best suited for dissolving purposes were 80 g per litre, 25 per cent sulphidity, 8.8 kg/cm² (125 psig) steam pressure, and 10 minutes cooking time. A screened yield of 45 per cent of the depithed fibre can be expected under these conditions.

It was found that these pulps cannot be bleached to a G.E. brightness of over 72, regardless of the quantity or type of bleaching agent used, unless the pulp is first extracted with dilute acid. It was found that the pulps cooked without sulphide were somewhat brighter than those using sulphide but these pulps were not bleached. Nor were bleaching experiments conducted on any of the fresh bagasse pulps; it is not known, therefore, whether the poor colour was due to processing the bagasse before baling.

The effect of acid extraction on final brightness of the bleached pulp was clearly shown. The unextracted pulp attained a final G.E. brightness of only 68.1 even though considerable excess of chlorine had been employed. After extraction, the pulp was bleached to a G.E. brightness of 84—a very satisfactory figure.

The D.P. of the bleached pulp (880) is at about the correct value for proper xanthation. Its pentosan content (2.0 per cent) is satisfactorily low for dissolving purposes. Although this pulp has not yet been tested for the production of rayon, its analysis indicates that it should be a satisfactory raw material in this field.

III. Pulping of bagasse fibre for high strength pulps

The same equipment was used for these experiments as for the previous cooking of high purity pulps. Since high pentosan is desirable in paper-making grades, low initial concentration of cooking liquor was used and low liquor-bagasse ratios were employed to insure decreasing concentration during the cook. Constant steam pressure was used in all cooks.

Yields of pulp from the depithed bagasse were very high, being in the range of 60 to 63 per cent. This increase over the yield of dissolving grades is primarily due to the conservation of pentosan in the pulp. Bagasse which did not have pith removed before cooking gave a much lower yield, caused by degradation of pith cellulose, which presents much greater surface for reaction than does the fibre cellulose. The average chemical consumption amounted to 0.236 g Na_2O per g of bagasse dissolved.

Several pulps were hydrated in the Niagara beater and hand sheets were prepared for physical testing. All methods followed the standard set up by TAPPI. Sheets were tested for double folds, tensile strength (breaking length), bursting strength and tear strength.

Compared with a high grade of unbleached pine kraft pulp, the bagasse pulps were found to be definitely superior in burst, tensile and double folds. In tensile strength the bagasse is about 20 per cent stronger than the maximum strength of the kraft pulp. In burst it is 10 per cent stronger.

Tearing strength, however, is less than half that of pine kraft. This is to be expected, as the fibre length of bagasse is in the order of 1.0 mm compared with 2.5 to 3.0 mm for pine.

The most interesting feature of the strength of bagasse pulp in burst, tensile and folding strength lies, not in the very high values for maximum strength after beating, but in the very high strength of the pulps before beating. Most wood pulps, before beating, are low in burst and tensile strength and their folding endurance is negligible. On the other hand, bagasse pulps are very strong before beating and reach their maximum strength after very little time in the beater.

These high unbeaten strengths are probably due mainly to the very high pentosan content of the pulps. Pentosan content of 23 to 24 per cent can easily be realized in bagasse pulps, in contrast to about 18 per cent in hardwood pulps. Pine kraft usually contains 8 to 9 per cent pentosan. The commercial significance of this high pentosan content lies in the very low power costs which will be involved in refining bagasse pulps ahead of the paper machine.

Further research on the production of paper-making grades may quite possibly result in pulps of somewhat higher strength, particularly in tearing strength.

It is apparent that bagasse will produce pulps of higher quality, strengthwise, than can be expected from hardwoods. It can also be used wherever kraft is used, if the tear strength is not important. It is not recommended for use in newsprint except as a substitute for the sulphite component.

VI. Presentation of papers on selected technical matters

MODERN TRENDS IN LAYOUT AND DESIGN OF PULP AND PAPER MILLS[1]

A. M. Hurter

I. Introduction

The past decade has witnessed the introduction and rapid growth of the semi-chemical pulping processes, high yield pulping, the consolidated and standardization of the multi-stage bleaching processes, the use of chlorine dioaxide for pulp bleaching, the introduction of chemi-groundwood and improved methods of pulping agricultural residues. However, apart from these developments there has been little change in the basic technology and processes of pulp and paper manufacture and there is no indication that this situation will change in the near future.

The big change in the industry has been rather in the more careful application of the standard and established processes and equipment to effect improved control and man-power and waste reduction. In other words, the biggest changes in the industry and present trends have been and are more a matter of careful engineering than a matter of the introduction of any revolutionary development of the research laboratories.

This change, automation, man-power and waste reduction, has come about so gradually that it has, to a large extent, passed unnoticed. The reason for this is simple. As mentioned, with a few exceptions, no basically new process or art is involved, nor has there been any radical change in processing equipment. Modern pulp and paper equipment, while in many cases greatly improved, remains essentially the same as equipment available a decade ago. Indeed, in many cases the modernization of equipment has consisted merely of quite unnecessary "streamlining" to improve the appearance. It is quite possible, therefore, with very minor modifications, to design an essentially modern pulp and paper mill using equipment available a decade ago. The opposite is equally true—it is also quite possible to design an obsolete mill today using modern equipment and technology.

How, then, has this change to better control and man-power and waste reduction come about? It has come about gradually by product specialization, the introduction of product control systems, the application of automatic control systems and effective materials handling, and through well-engineered mill layouts and mill integration.

The first of these factors, product specialization, is simple. It is not difficult to see that a mill producing only one, or a very small number of products, will be more efficient and have a lower unit production cost than a mill producing a wide variety of products, all other factors being equal, and for this reason there has been a pronounced trend towards product specialization.

However, product specialization is not always possible in a limited market, and for reasons that will be discussed more fully later, specialization in only one product is not desirable if a high-grade product is to be produced at reasonable cost. A careful analysis of production costs of various grades, together with a more careful analysis of customer requirements can, however, greatly improve the efficiency of a mill producing a wide variety of products. One fine paper mill we know of, operating in a limited market, greatly reduced the variety of papers produced without loss of sales volume by such an analysis. They found that the production costs of some grades were higher than economical due to the additional cost of lost time on grade changes, and that in many cases the customer had no real reason for requesting a particular grade other than precedent. It was found that in many cases the customer was quite willing to accept an alternative grade if it met his actual needs, particularly if he could obtain the new grade at a lower price.

The second factor, product control systems, is somewhat less obvious. Quality control, testing procedures and statistical control methods form a subject in themselves and are beyond the scope of this paper.

The primary reason for product control systems is quality uniformity, but there is also the secondary purpose that the customer shall not necessarily receive the highest quality that is technically feasible, but only the quality commensurate with his needs, production costs, the price received and market conditions. Worded in this manner, this may sound somewhat strange. It is a fact, however, that many mills do produce a much higher quality product than is required by the end use, the competitive position and even the customer's desires. We know of a pulp mill whose management pride themselves on the excellence of their product. It is excellent pulp—far better than competitive brands at the same price—but the excellence is due to a very drastic wood-cleaning operation which results in a direct loss of 15 per cent of their raw material. The chief reason that they continue to maintain such an operation is that they lack, among other things, a product control system and cannot control uniformity of product except by such severe wood-cleaning methods.

As mentioned, product specialization and product control systems are a subject in themselves. We have mentioned them briefly because they are factors affecting man-power and waste and they are important factors. However, in our opinion the chief factors that have influenced the modern trends in layout and design of pulp and paper mills are—automation, materials handling, mill layouts and mill integration. The effect of these latter factors form this paper.

[1] A slightly shortened version of the original paper (ST/ECLA/CONF. 3/L.6.1) which contained twelve diagrams and eleven photographs illustrating the author's explanations.

II. Automatic control

The trend towards automatic control and instrumentation is not peculiar to the pulp and paper industry. Indeed, it is a growing feature of almost all industries. The general trend to automation has been termed "The Second Industrial Revolution" and many articles and papers have been written on the subject of automatic factories, automatic control and servo-mechanisms. Even novels have appeared outlining the social impact of automation of production.

In the pulp and paper industry the factors that lead to the introduction of automatic control systems are many. The more obvious ones are better control of quality and material and reduction of waste. The shortage of labour during the war and the high post-war cost of labour focused attention on the man-power reduction possible by automatic control. Also the sheer growth in physical size of many pulp and paper mills and the need for co-ordinating a large series of unit operations has, in many cases, made manual operation impractical.

The growing trend toward automation is also closely tied in with process equipment development and design. Batch process operations have large equipment and space requirements which greatly increase the capital cost of a mill, hence continuous processing with much smaller equipment and space requirements are favoured. At the same time, automatic control systems which improve quality control and reduce labour requirements are more easily applied to continuous processing systems while conversely the design of most continuous process equipment is based on the maintenance of constant material and energy balances which requires automatic control.

Automatic control and continuous processing are thus closely linked and have arisen from both operating and capital cost considerations. Which has led to which is difficult to say, but we believe that no one will deny that automatic control has shaped and affected the design and process of modern pulp and paper mills to a very great extent.

In addition to controlling operations at, or near, optimum efficiency, automatic control systems generally provide a record of their operations. This has provided a source of data and information on plant operation and troubles such as was never previously available. This source of information has proved invaluable to research staffs and plant management who are constantly seeking to improve the plant efficiency and to detect the source of trouble, though some regard the records furnished by automatic control instruments as a mixed blessing. The sheer volume of record charts that must be collected and changed, analysed and filed each day in a modern mill is rather overwhelming. It would appear that pulp and paper mill personnel having been without very complete records of operation for so many years are now determined to record everything possible. In time, as equipment and technology improves, the number of recording control instruments will probably decrease and only the more important process variables will be recorded. There is also a trend toward multipen instruments which will record several process variables on one chart. This should help in reducing the volume of charts and at the same time facilitate the analysis and comparison of interdependent variables.

Automatic control in pulp and paper mills is still far from complete automation. Indeed, automatic control is at present, in most cases, confined to individual process stages and there is little interlinking of successive operations. However, much has been accomplished.

The latest development in automatic and remote control panels is the graphic panel. On such panels a flowsheet of the process stage is painted on the panel, or formed from strips and plastic silhouettes. The remote control valve switches and the control instruments are mounted on the panel at the correct positions relative to the flowsheet. Usually the instruments are of a miniature type for space reasons.

Such graphic panels have the advantage that it is instantly apparent what points in the system are being controlled by the various control instruments and switches, and the chances of error are therefore reduced. They are also of great assistance in training new personnel and in starting up a new process or mill.

We expect the trend will continue and that as the equipment and technology for continuous processing improves, the degree of interlocking of control systems for various process stages will steadily increase with a still further reduction of man-power. At the same time, stock chests which are at present required to equalize flow and quality between stages will gradually disappear.

At present most of the instruments used for automatic control are of the pneumatic type. They have the merit of being relatively simple—their handicap is a limited transmission distance. Electronic instruments, which do not have this limitation, are gradually making their appearance though there is some hesitation to their adoption among mill personnel. These instruments are definitely not so easy to repair.

At this point one may well say, "Ah, repairs! Automation may be very well in Canada and the U.S.A. where proximity to suppliers makes repairs a simple matter. What about countries remote from instrument suppliers such as South America? In any case labour saving is not so important here—labour is cheaper."

In answer to the latter quite common remark it should be pointed out that automation not only decreases the man-power required but also decreases the operating skill required. To learn to cook pulp by manual control to a consistenly reasonably uniform quality requires years of experience. With automatic control almost anyone can obtain good results in less than two weeks. Thus, if a mill is to be built in a remote area where little, if any, skilled labour is available, in the first place automatic control reduces the number of men that have to be trained; and secondly, the training period can be greatly reduced. The mill can thus begin to produce at a much earlier date and the gain in production will more than offset the cost of the instruments.

With regard to the second remark, it is perfectly true that automatic control instruments require maintenance and any control system is only effective as long as it is properly serviced. It is at this stage that most difficulties occur. If the mill is located at a considerable distance from instrument suppliers and does not have a man trained in instrument work they may as well forget about automation completely. Any money spent on instrumentation would be wasted.

However, most of the instrument companies have excellent training programmes to train mill personnel in the application, care and repair of control instruments.

It is thus possible to have personnel trained to service properly any instruments purchased.

The size and type of mill also have a large influence on this matter. A large mill using instrumentation extensively, or even a small mill producing only one or a small number of products which permit extensive automatic control, can afford to maintain a trained instrument mechanic or engineer.

On the other hand, mills producing a wide range for products largely on a batch basis and which can therefore utilize only a limited amount of automatic control, generally cannot afford the instrument maintenance required.

The big mistake mills make is that they purchase a few instruments, so few that having a man trained and assigned to maintaining them is not warranted. As a result these instruments soon become useless from lack of maintenance. We would suggest that in areas remote from instrument suppliers automation is a question of all or nothing.

If we were to design a large mill for South America, or a small mill producing one or a small number of products such as a pulp mill, or a newsprint mill, we would recommend complete instrumentation wherever possible.

For a paper mill producing a wide variety of papers and having a batch preparation system we would recommend no instrumentation beyond very simple mechanical servo-mechanisms.

III. Materials handling

Materials handling, that is, the effective economic handling of raw materials, materials in process and finished product, has received a great amount of attention in the past few years. It is a major consideration in modern mill design and is one of the pronounced differences between older and modern mills. As generally used, the term "materials handling" in the pulp and paper industry applies primarily to the handling of raw materials, or finished products. However, although the bulk of the "handling" of materials in the processing stages of pulp and paper mills is by pump and piping, some very interesting "materials handling" problems do arise in the processing stages.

The handling of raw materials and finished product is a simple matter of economics—of how to handle the material at the lowest possible unit cost. The high cost of labour in North America was the prime incentive for the study and application of materials handling methods and techniques. The high cost of labour is also, incidentally, the reason that materials handling techniques are most advanced in North America.

The handling of materials in process is another matter and is due largely to the trend to continuous processing. While man-power saving is a factor, it is more a problem of providing uniform feed to processing stages, which is difficult to accomplish manually. The important consideration is that the system shall permit the desired degree of control and that it is capable of continuous trouble-free operation with very little maintenance. Cost is of secondary importance and in general the technically best solution is used.

The subject of materials handling is complex and the applications vary greatly among mills and areas. Almost each material in each area and type of mill is a subject in itself. We will, however, attempt to cover briefly some of the principal trends.

The one basic trend is towards handling of all raw materials in one shift, and in some specialized cases such as large newsprint mills this trend is being expanded to include handling of finished product. The labour saving is obvious. On a three-shift operation man-power is reduced to a third, on a four-shift operation to a quarter. Handling of all raw materials in one shift requires that the handling equipment be of sufficient capacity to deliver the total daily requirements in one shift and sufficient storage with automatic discharge to carry mill operations over the remaining shifts.

The handling and storage of chemicals and fuel for one-shift materials handling operation usually presents no difficulties and no great expense. The storage of wood chips is also no great problem or expense but the cost of the wood handling, barking and chipping equipment increases considerably with one-shift operation. In the case of straw pulp mills, particularly those using a cut straw operation, one-shift operation with appreciable labour saving is difficult.

The handling of wood, the most common raw material and, in the production of wood pulp, the largest by volume and the most cumbersome of the raw materials used, has naturally received the most attention. Wood handling systems vary considerably depending on the mill location, type, size and means and frequency of wood delivery.

Mills where delivery is seasonal must have sufficient wood storage to carry the mill over periods when no wood is delivered. Generally, such long term log storage is by large random block piles. While racking of wood is preferable, particularly in the case of chemical pulp mills, only mills requiring a comparatively small amount of wood storage, or mills in areas of high wood costs, can afford this method.

Racking of wood and reclaiming, whether by travelling crane, a conveyor system, or manually, is costly. Random piling by means of a stacker and reclaiming by grapple and crane is very much cheaper.

Mills in areas where wood supply is more or less continuous all year round have no great storage problems. Storage by random piling by crane, racked storage, or water storage is feasible and inexpensive.

In modern mills of north-eastern North America, wood handling by belt conveyors is the trend in larger mills. The belt conveyor is technically the best solution for handling wood in northern climates. Power and maintenance costs are low but capital costs are high.

However, if capital is expensive and the first cost of a wood handling system is of paramount importance, or if the quantities of wood handled are small, a cable conveyor system is generally used, even though it is technically inferior and the power and maintenance costs are high.

Short or steep log conveyors are usually of the chain type. It is, however, possible to carry wood on belt conveyors up inclines of up to 8 degrees if a herringbone profile type rubber belt conveyor is used. Cable conveyors can handle wood up inclines of up to about 20 degrees.

In warmer climates and where an ample supply of water is available, water flumes are used extensively in place of the belt and cable conveyors used in northern mills. For obvious reasons flaumes are used in northern mills only for the summer delivery of wood.

In all cases the critical points of any wood handling system are the transfer points between conveyors. Ideally, logs should transfer with a minimum of drop, at a speed matching the conveyor and turned in the right direction. Logs falling from a considerable height, or hitting the conveyor at too high a speed, can cause serious damage or reduce life, while logs transferring at random angles can cause log jams. The correct design of transfer points is not simple and considerable experience is required.

The conventional position of the chip bins used to be above the digesters. Today, in all modern mills the chip storage is on ground level. There are several reasons for this. The digester house dimensions restricted the practical capacity so that one-shift wood handling operation was virtually impossible. Structurally, it resulted in an expensive building—a tall slender building with all the load concentrated at the top and lastly, the chips tended to arch in such bins and discharge was far from uniform and required considerable attention.

With ground level storage there is no capacity limitation and simpler structures are possible. Two types of ground level bins are in use today, the circular silo type and the rectangular type of our patent. The silo type has the advantage of lower first cost. Our rectangular bins have the advantage that chips cannot arch but flow freely, which permits fully automatic operation and remote control by push button.

The handling of finished pulp, either dried or wet, by slitter-cutter, automatic layboy, automatic baling and weighing and the versatile fork lift truck is standard practice in almost all modern mills. In the case of paper mills, however, there is wide variation in the handling of the finished product and while lift trucks are used extensively, there is still considerable manual labour required. Larger mills are beginning to install rather elaborate conveyor systems for their finishing departments and our firm recently designed a fully automatic roll wrapping machine. This machine wraps, crimps, applies glue, puts on end bands, cuts the sheet and ejects a packaged roll in forty-five seconds, or less. In one mill one of these machines, combined with a new conveyor and storage system wraps the entire production of a 1,000 ton per day newsprint mill. This system requires only two men per shift and has resulted in a man-power saving of twenty-eight men. A second machine will be installed shortly which will permit the entire production of this mill to be handled and wrapped in one shift.

Beyond mention that materials handling is a very large factor in modern mill design, that there is a trend to one-shift operation and to ground level chip storage, there is little of a general nature that can be said regarding the trends and influence of materials handling methods and techniques in the design of modern pulp and paper mills. The applications are specific to each problem, material and mill, and the methods used vary greatly.

The important point to be kept in mind is that with the exception of the handling of material in process, materials handling is a matter of economics—that the technically neatest solution is not necessarily the best and that a good solution in one mill, is not necessarily applicable to another.

Cable conveyors, despite their shortcomings, are often a better solution than the use of the technically superior belt conveyors.

Mere mechanization is also not necessarily the mark of good materials handling. One mill we know of in Europe would have been well advised to continue their manual racking of wood. The travelling overhead crane system that they installed, while reducing man-power, yielded a very low return on the investment.

In the design of a materials handling system, there are many alternatives and the optimum development of each is not a simple matter. Considerable experience with all the various alternative methods is required in order to make the correct selection.

IV. Plant layout

One of the most important factors in the design of modern pulp and paper mills is the layout of both equipment and buildings. The effect of equipment layout on mill efficiency is not difficult to understand and is generally appreciated. The effect of the building structure and disposition of buildings on mill efficiency is less obvious and is often not fully appreciated.

Equipment layout is important and is generally given very careful consideration in the design of any modern mill. Some of the more important "rules" governing good equipment layout are:

1. Provide easy access to all equipment and make sure that the equipment can be properly installed in the first place and that any component which may have to be removed for maintenance repair or replacement can be removed or replaced without difficulty. If access is not made easy, the equipment will not be serviced properly and maintenance costs will be high. If adequate access for removal or replacement of equipment is not provided, demolition of walls or floors may be necessary at a later date and major plant shutdowns may be required.

This point would appear to be obvious, but unfortunately it is often overlooked. We have seen some mills where access was so successfully blocked off that major structural changes and removal of walls and floors were required for equipment replacement and other mills where equipment was hidden away and not serviced for years—indeed almost forgotten, until it broke down. We could give numerous examples.

Any additional space to provide easy access to equipment is a good investment. We might also mention that no matter how ample the space appears in the original layout we have yet to see a mill with too much space to spare. In the space of a very few years an ample layout has the habit of becoming crowded as auxiliary equipment and refinements are added to the original layout.

2. Provide easy access to all equipment control and adjustment points and keep distances between major control adjustment points and keep distances between major control points short. If access to equipment controls is difficult or if the operator has to walk a considerable distance to control points, the controls will not be adjusted by the operators as frequently as required

for optimum production and quality. Where necessary adequate platforms and stairways over and around equipment should be provided and in such cases as digester houses and bleach plants, which cover several stories, elevators should be available.

3. Keep piping or conveyors connecting equipment as short as possible. This not only reduces capital costs but maintenance and power costs as well. However, all valves should be conveniently located. In accessible valves or valves so located that a ladder or undue stretching or bending is required to operate them will not receive much attention. Also, pipelines and conveyors should not be too inaccessible for maintenance while at the same time proper clearances must be observed. Thus it may at times be necessary to make the interconnecting piping or conveyors somewhat longer to permit convenient location of valves, to simplify maintenance, or to maintain clearances.

4. Group similar equipment whenever possible. For example, if possible group all the pumps for one mill department on the same floor or in the same bay. Avoid duplication of operations. This not only reduces operating but also maintenance labour.

These are the principal "rules" for layout of equipment. Basically the development of a good layout involves the elimination of as many men as possible and arranging that operation and maintenance are as convenient as possible for such men as are required.

As mentioned previously the advantages of a good equipment layout are generally appreciated. The actual mill layout, however, and the disposition of the various buildings is less well appreciated and is the subject of some controversy.

On the subject of mill layout we have our own quite definite opinions and in order to illustrate the trends in modern layout, and our conclusions, a brief historical review may help to clarify the issue.

Originally most paper mills were located close to streams or rivers which in addition to supplying the process water requirements also furnished the power through water wheels. Power transmission within the mill was mechanical by gearing, shafting, belts, and pulleys. As a result, mills were crowded close to river banks and were kept as compact as possible because of the limitations of mechanical power transmission. The entire mill layout was governed to a very large extent by the location of the water wheels and the mechanical power transmission system.

The introduction of the steam engine permitted somewhat greater flexibility in mill layout. However, the layout of such mills was still subject to the limitations of mechanical power transmissions for it was quite impractical to have each piece of machinery driven by an individual steam engine. The introduction of electric motors increased the possibilities of mill layout still further though in the initial stages it was generally merely a matter of substitution of electric power for steam or water wheels—mechanical power transmission to the various machines was still used. However, even after the introduction of the steam engine and later the electric motor, many mills continued to be crowded against river banks in order to exploit water wheels and mechanical transmission to the fullest extent and this trend continued into the second decade of this century.

Such older mills, many of which are still in existence today, are characterized by their almost complete lack of flexibility in layout. The buildings are crowded together due to the limitations imposed by mechanical power transmission and some departments and processing stages are completely surrounded by other departments. Due to the crowding of equipment and departments access to equipment is difficult and there is generally little or no provision for inter-department traffic or communication.

Expansion or addition to such mills is virtually impossible without almost complete duplication of operations. Normally, on one side of the mill is the river and on the other side the department to be expanded is usually blocked off by other buildings or the yards and storage piles. Thus any expansion or addition must be carried out as a separate or duplicate operation away from the main mill complex which increases capital costs and results in a disproportionate increase in man-power. Furthermore, as such mills grow by additions or duplication of operations they become progressively less efficient. Maintenance, processing sequence, supervision and internal traffic become complex and manufacturing costs increase.

When individual electric motor drives became available for pulp and paper mills, mill layouts changed rapidly. Since the main drawback of the older layouts was lack o fspace and provision for expansion, a trend in some areas was to go to the other extreme, namely, a scattered layout in which the various mill departments such as wood room, bleach plant, digester house, recovery system, boiler house, screen room, machine room and finishing, etc., are housed in individual buildings, set far enough apart to permit practically unlimited expansion of any repartment. The various buildings were then linked by conveyors and piping and a system of roadways within the mill property provided access to the various buildings. Many new mills are still being built according to this "scattered" or "spread" layout system.

In our design work we, among others, did not follow this trend. Perhaps the prime and original reason for this was our climatic conditions. Most Canadian mills are located in areas where there is a long hard winter. A scattered layout results in a greatly increased exposed wall area. When building for our climate this increases building costs considerably, and a larger exposed wall area also means higher heating charges. Furthermore, a system of communication between scattered processing stages by means of exposed roadways is far from pleasant when the snowfall is heavy and the temperature drops to 40°F below zero or lower.

For a northern climate a compact mill layout with a minimum exposed wall area was to our mind the only practical solution. The only problem was to avoid or eliminate the disadvantages of the older crowded layouts and that was to provide for effective internal traffic and to provide for future expansion without duplication of operations. Over a period of years we developed what we term the "central corridor" layout and most of the mills designed by our firm follow this pattern.

The various mill departments are grouped according to process sequence on either side of a main traffic corridor running down the centre of the mill on the two main floors. Unrestricted expansion is provided for at both sides of the mill and it should be noted that such a layout allows for symmetrical expansion without duplication of operations and that the extension of any department becomes a part of the department and not a separate unit.

The main mill corridor provides access to every department and permits rapid movement of inter-department traffic with a minimum number of elevators. Equipment can be replaced or moved to the machine shop for maintenance or repairs with little difficulty and regardless of weather. Distances are short.

Besides providing effective internal traffic, the main mill corridor provides space for a neat, direct and accessible mill service system for steam, water, compressed air and power distribution. These lines and often ventilating ducts run down the main corridors and branch out into each department.

The "central corridor" layout proved very successful and although originally developed to meet climatic conditions other advantages became apparent. In the first place, building construction costs are lower than for a scattered layout and though this advantage is less pronounced in warmer climates where a good deal of equipment such as recausticizing tanks, blow heat recovery equipment, etc., can be located outdoors, it still represents a considerable saving. In addition to reducing the exposed wall area, a considerable number of internal partitions can also be eliminated, which further reduces building costs. Piping and conveyor costs are also lower, for distances between successive processing stages are very much shorter. At the same time power and maintenance costs are proportionally lower.

Although in warmer climates an external system of roadways for communication between isolated mill departments is feasible, few mills are located in areas where there is no rainfall and no bad weather. An internal communication system unaffected by weather is certainly to be preferred, not only for the benefit of the operators but also for the maintenance and repair crews. In bad weather it is not pleasant to shift equipment outdoors to or from the machine shop for maintenance or repair and costs rise correspondingly.

The time required for an operator to reach his working position is very much less in the case of a compact layout than in the case of a scattered layout. A compact layout also requires less operating man-power, smaller maintenance crews, and less supervisory personnel, all factors such as automatic control and materials handling being equal.

However, perhaps the most important advantage of a compact central corridor layout is the very close and rapid communication possible between the operators of various departments. The cook in the digester house need take only a few steps to see how the pulp looks on the vacuum washers. The bleach plant operator can discuss problems with the screen room operators personally and see for himself any difficulties that may have arisen. In other words, the operators are not a group of isolated individuals linked by telephone but a closely knit team aware of each others' problems. Supervision and co-ordination are greatly simplified and efficiency is improved.

Comparing the two types of modern layouts, the advantages of the scattered layout are:

1. Engineering of the mill layout is very much simpler. A scattered layout is not very difficult to develop.

2. Engineering of the mill departments is very much simpler. The equipment layouts can be made without regard or consideration of the layout of other departments and an optimum equipment layout for each department can be achieved.

3. As a result of greater simplicity of design the engineering time required is less and construction can start at an earlier date after commencement of engineering.

4. Since the mill is composed of individual buildings, construction is simpler and may be somewhat faster than in the case of a large building complex. Much, however, depends on the contractor; the difference is not so great in the case of an experienced contractor. The disadvantages are:

(*a*) The scattered layout is limited to milder climates.

(*b*) Traffic between departments is subject to weather conditions and greater distances must be traversed.

(*c*) Mill processing stages become isolated units and inter-department communications, co-ordination and supervision are not as good and labour costs are higher.

(*d*) Building costs are higher.

(*e*) Piping and conveyor costs and maintenance are higher.

(*f*) Expansion is generally non-symetric and duplication of operations may be necessary in some cases.

The advantages of the compact "central corridor" layout are:

1. Very greatly improved internal communications, co-ordination and supervision between departments.

2. Lower building costs, though this advantage is less in warmer climates.

3. Lower piping and materials handling costs.

4. Lower labour requirements.

5. Lower maintenance costs.

6. Better over-all efficiency.

The disadvantages are:

(*a*) The engineering time required is somewhat longer.

(*b*) The construction time required may be somewhat longer, though it might be mentioned that in the case of a "central corridor" type mill layout recently developed by us for a Japanese client, the mill reached full production exactly one year after construction was started.

Basically, in the scattered layout the mill is considered as a group of independent departments or components loosely linked by piping, conveyors and roadways, and each component is designed individually. In the compact layout the design concept is the mill as a whole and the mill is designed as an integrated unit of which the various departments are components which interact upon each other.

It will be appreciated that designing with the concept of the mill as a unit presents more problems than designing a series of components. Also, at times some sacrifices in the layout of a department must be made in order to achieve optimum layout of the mill as a whole.

In our opinion, since a mill is operated as a unit it should be designed as such, and although a compact unit design is more difficult to develop than a scattered individual component design, we believe the advantages inherent in the compact design will make this the principal trend in mill layout.

Mill property

Another factor which can affect mill efficiency to a very great extent is the mill site and external traffic arrangements. That any proposed mill should be located in an area having ready access to raw materials, water, labour, and means of transportation of raw materials and finished product is a matter of economics and is well understood. However, assuming that the general area in which the mill is to be located is the optimum possible from economic considerations, quite serious errors are often made in the selection of the actual mill site or property itself and it is this latter point which merits brief discussion.

The most common error is the provision of insufficient area for the mill property. Very often the mill property is of sufficient size only for immediate requirements and there is no provision for future additions to, or expansion of the mill. We know of quite a number of mills in this predicament today, and some are in the unhappy position of having residential areas of towns or villages located between mill departments or storage piles. Needless to say, under such conditions, materials handling costs both for raw materials and finished product are considerably higher. The correct procedure is to estimate the maximum possible future expansion of the mill in view of the economically accessible volume of raw materials and to size the mill property accordingly.

The second most common error is the choice of a mill site where the terrain or natural features will restrict expansion or make this costly. A particularly good example of such a case is a mill we know of in Europe. This mill owns property on two sides of a small river. On one side is a relatively large flat area. On the other side is a very narrow strip of land between a large steep hill and the river. For reasons that will probably always remain unknown, the mill was built on the narrow strip between the hill and the river. The mill has been expanded several times and each time huge volumes of the hill had to be removed and high retaining walls built. The cost was very high and the resultant layout not particularly efficient.

The third common error is the location of the mill and property in such a manner that access to transportation is only possible from one side or end of the mill. As a result there is interference between incoming shipments of raw materials and outgoing shipments of finished product, which can greatly increase materials handling costs. The mill located between the hill and the river that we mentioned previously, besides being poorly located for expansion, is also poorly located for access to transportation. Transportation connexion is by means of a single spur railway line crossing the river. Furthermore, the strip of land on which the mill is located is so narrow that every railway car must be turned on a turntable before it can be moved to the proper mill department. Since all raw material received and finished product produced must pass over this turntable and single railway spur it is not difficult to imagine the handling problems.

Ideally, the mill property should be a relatively flat piece of land free from natural obstacles, of sufficient area to permit expansion within the limitations of the raw materials economically available, and the property should be so located with respect to transportation facilities, either road, ship, or rail, that there will be no interference between incoming and outgoing shipments. It should be possible for raw materials to enter one end or side of the mill and for finished products to leave the other side or end of the mill.

The external traffic arrangements are an important factor in the design of a modern mill, and the mill property can greatly affect future expansion or additions to the mill. The best modern equipment and the best mill layout can be spoiled by poor mill property selection, even if all economic factors for the area in general are favourable. Considerable care should therefore be taken in the selection of the actual mill property.

VI. Mill structures

At this stage, before passing on to the process phases of modern mill design, a few words on mill structures and their effect on mill efficiency and flexibility should be in order.

Actually perhaps this wording should be reversed, for the shape, size, disposition and form of the structures for a pulp and paper mill are determined by the equipment arrangement and layout. In other words, the buildings and structures are primarily a housing and support for the equipment and the buildings are shaped mainly by equipment requirements and not by architectural considerations.

The structures cannot be designed until the equipment layout has been determined, and any attempt to reverse this sequence, that is, to fit equipment for a mill into buildings designed in advance or into existing buildings will not result in an efficient mill.

In the design of the structures there are two viewpoints, one, that while the shape is determined by the equipment layout, the structure is a housing and support, pure and simple, and divorced from equipment, and, the other, that the two are interrelated. As in the case of mill layout, our viewpoint is that the design should not be divorced, but that structure and equipment form a unit. Such equipment items as boiler settings, flumes, tanks and towers are in effect structural members that can and in our opinion should be incorporated in the building structure. The resultant design is neater, cleaner in appearance and requires fewer building columns than when the structures are designed as independent housing or supporting units.

Framed structures are preferable for pulp and paper mill buildings. Monolithic concrete or bearing wall structures are too difficult and expensive to alter if a change or expansion of the mill is necessary at some future date. For walls, materials such as brick, pre-cast concrete panels, metal panels or metal, wood or asbestos sheathing are suitable. The choice depends on mill location, climate, and costs. Solid concrete or cyclopean masonry should be avoided because of the cost of alterations. Floors should be concrete.

For the structural frame, steel or reinforced concrete may be used. The number of columns should be kept to an absolute minimum even if this means that the cost of the structure is increased slightly. Columns are always a source of interference and hinder access to equipment. Even if favourably located in the initial equipment layout, the columns almost invariably interfere with any proposed changes in equipment or layout.

Whether to use steel or reinforced concrete for the structural frame is largely a matter of economics. In the case of a few mill departments, however, it is decidedly preferable to use steel since a reinforced concrete frame cannot be easily altered or expanded. Screen rooms and stock preparation departments seem to be subject to rather frequent changes which may involve structural alterations. These buildings are best designed in steel frame or at least with steel trusses. The building for a single paper machine, where there is the possibility of an additional machine in future, is also best executed in steel construction. Otherwise the addition of the second machine will involve either a disproportionately large building with a duplication of the tending aisle or a row of columns which will interfere with the access to the second machine.

In the case of these small mill areas, screen room and stock preparation, where we would recommend the use of structural steel for buildings, we would also recommend that the floors should not be designed purely to carry the loads of the equipment as located initially. These departments are subject to frequent equipment relocations and the floors should be uniformly strong enough to carry the weight of the equipment no matter how or where located.

In our opinion, a good structural design for a pulp and paper mill should be as unobtrusive as possible. The number of columns should be at a minimum and placed in keeping with equipment layouts. Wherever possible, equipment should be incorporated in the structure. It is well worth while to spend a little more money and time to achieve clear, neat structures relatively free of columns. The cost of the mill structures is approximately 25 per cent of the cost of the mill and it is false economy to permit interference with the efficient operation of the equipment to effect a small saving on the cost of the buildings.

VII. Waste reduction and mill integration

Another significant trend in modern mill design is the reduction of waste. This has been accomplished in a number of ways; by process refinement to produce less waste, re-use of waste in the process, by the production of secondary grades from waste, the production of by-products, and by integration of a number of mills.

Less drastic barking and wood cleaning systems, modern chippers, rechippers and chip screening, and better knowledge of chip size ranges have greatly reduced wood losses in wood preparation.

Refining of screenings, rejects with disk refiners and extensive re-use of white water and savealls have reduced wood losses still further, while at the same time the re-use of white water also reduces water requirements and increases the system temperature.

In chemical pulp mills improvement of chemical and heat recovery systems and modified cooking practices have greatly reduced chemical and steam requirements.

Such waste reduction and re-use of waste in the main process is largely due to equipment refinement and the careful application of existing equipment. In the design of a modern mill all these refinements are almost automatically included in the original design. However, the production of secondary grades from waste which is a modification of the principle of the re-use of waste in the mill, is a very important consideration in the design of any modern mill and is sometimes overlooked or ignored.

In the manufacture of higher grades of paper and bleached pulps, extensive re-use of rejects and white water is more difficult to justify economically if quality is to be maintained at a high level since dirt tends to build up in the system. In addition, extensive re-use of white water can increase bleaching costs since the fines in the white water consume a disproportionately large amount of chemicals and are largely disintegrated and lost. Such overbleaching in order to remove dirt also leads to strength deterioration. It is thus very desirable for a mill producing high-grade papers and pulps to also plan to produce some lower grades such as paperboard where the rejects and white water from the production of the high-grade products can be utilized.

It is in the field of by-products production such as vanilin, lignin plastics, alcohol, yeast, etc., that research has been most active. The developments appear most promising. To date, however, they have not caused any significant change in mill design. There are several reasons for this. Among the most important is that the market for some of the by-products is very limited while others cannot be produced economically in some areas at the present time. Research is, however, proceeding vigorously and it can be expected that the manufacture of by-products will become an important phase of the pulp and paper industry in the not too distant future.

Next to the introduction of methods of waste reduction and re-use in an individual mill perhaps the most important trend in waste reduction is the integration of several mills.

In its simplest form, mill integration involves the combination of a mechanical and/or chemical pulp mill with a paper mill. The savings that can be effected by such an integrated operation are obvious and whenever possible a combined pulp and paper mill is built.

The next step, and one which has been developed to the greatest extent in Scandinavia, is to construct, usually on the same site, an integrated complex of mills using wood as raw material. Such an integrated operation, which may involve a lumber mill, a mechanical and chemical pulp mill, a paper mill, a wallboard mill, a plywood mill and by-product plants, can process the raw material with maximum efficiency as all of the wood delivered to the integrated mills can be put to optimum use and the waste of one operation can form in part, or in entirety, the raw material for another operation. As wood costs continue to rise, an increasing number of lumber mills are entering the pulp and paper field while an increasing number of pulp and paper mills are entering the lumber and wallboard and sometimes the plywood field. It is expected that this trend towards an integrated pulp and paper, lumber and wallboard operation will become increasingly more popular and the possibility of such a combination should be considered in the development of any new project, even if only to the extent of making provision in the mill layout and size of property for the possible future addition of such other mills.

VIII. Process and equipment

(a) *Introduction*

Up to this point this paper has dealt primarily with the influence of automatic control, materials handling, mill layout and mill integration on the trends in modern mill design. Process and equipment have been mentioned but briefly.

In our opinion it is mainly these factors—automatic control, materials handling, efficient mill layout and integration—that characterize a modern pulp or paper mill and have for the most part influenced modern design trends. The influence of any changes and development in process and equipment, while important, has been, we believe, a secondary factor.

However, any discussion of modern trends in pulp and paper mill design would be incomplete without mention of the major trends in process and processing equipment in the various types of mills and processing stages.

(b) *General*

The main trend in process and processing equipment is toward continuous operation. As mentioned previously this trend is closely associated with the trend to automation.

In equipment the trend has been principally the modification of existing equipment to permit automatic control, though in some cases basically new equipment which is specifically designed for continuous operation has been developed.

There is also a pronounced trend to larger capacity equipment both for reasons of man-power savings and capital cost savings. In cases where the increased capacity is obtained chiefly by increasing equipment sizes, this trend is due more to the man-power savings possible since production is greater with approximately the same man-power. In cases where the equipment capacity is larger due to improved machine efficiency such as in the case of screens, for example, the trend is due more to capital cost savings. In the case of a new mill such high capacity equipment occupying approximately the same space as older equipment means lower installation and building costs while in the case of an existing mill high capacity equipment may permit increase of production without high capital expenditure for alterations and increases in the size of the existing buildings.

Some attempts are being made by equipment manufacturers to standardize pulp and paper machinery at least as regards common component parts such as bearings, gearing, framing, etc., but progress in this direction has been very slow. The bulk of the process equipment is still custom made at a correspondingly high cost. As a result of the lack of standardization, the maintenance costs and the inventory of spare parts required are also high. It has been suggested that the solution would be to purchase all equipment from one manufacturer. Unfortunately, no manufacturer individually produces all of the equipment required for a mill and in any case this practice would not seem to be desirable as generally all of the equipment produced by one manufacturer is not necessarily the best. Each manufacturer tends to excel in some types of equipment. There is, however, a definite trend in many mills to standardize on classes of equipment and to purchase for example all motors from one manufacturer, all valves from another, all pumps from another, etc., and in so far as possible with a repetition of a particular size or type. Such standardization can reduce both maintenance costs and spare parts inventory considerably.

Another trend is the purchase of over-sized equipment. Generally the cost of a larger unit is not very much greater than the cost of a unit that meets the present requirements. A larger unit has the advantage that the mill production can be increased with little additional expense. Another advantage is that on start-up the desired production can generally be reached more easily with units larger than immediately necessary, and operation at lower than the designed capacity will in many cases result in better operating efficiencies and lower production costs. The degree to which equipment should be over-sized depends on the expected increase in demand, technical considerations and economics, and must be carefully studied.

Another change in processing equipment and piping has been the extensive utilization of corrosion-resistant materials of construction—stainless steels, nickel, cast irons, monel, copper, bronze, transite, rubber, plastics and ceramics. Homogeneous materials such as copper and stainless steel are preferred as opposed to coated or lined materials such as rubber or plastic coated steels which are more subject to failure. Cast iron, steel, wood and concrete are disappearing rapidly as construction material for process equipment. A very large portion of the new processing equipment being installed in new mills or as a part of modernization programmes is built of corrosion-resistant alloys, or is rubber or plastic coated. Bare concrete chests have virtually disappeared in new or modernized mills and even new groundwood pulp mills now often have all piping of stainless steel.

The trend to better materials of construction is due, in part, to the desire to reduce maintenance costs and in part it is due to product quality considerations. The closing-in of mill water systems and extensive re-use of white water has increased stock and white water temperatures and created conditions favourable to slime formation. Slime colonies develop to troublesome magnitudes in cast iron piping, and on wood and concrete surfaces where they have a chance to cling and grow. A system utilizing corrosion-resistant equipment and piping, and tile-lined chests, that is easy to keep clean and to which slime growths cannot readily cling is one of the best means of controlling slime troubles.

IX. Second-hand equipment

It has been mentioned several times that there has been little change in the basic technology and processes of pulp and paper manufacture and that in general there has also been little change in most of the equipment beyond increase in unit capacities and modification to permit continuous processing.

High unit equipment capacities and continuous processing are very desirable in a large mill as the space saving and man-power saving is considerable. In the case of small mills, however, the space and man-power saving possible through the use of modern equipment with high unit capacities is not very great and in the case of a mill producing a large variety of products continuous processing cannot be used effectively.

There is thus no great advantage in purchasing the most modern equipment for small diversified mills and since the mills that are most likely to be built in Latin America for some time will probably be of this type, the possibilities of using second-hand equipment should be thoroughly investigated. Pocket grinders, for example, have not changed in design in years and might as well be purchased second hand. They seem to last almost indefinitely and a fair number are available since most of the large producers of mechanical pulp have converted or are converting to high capacity magazine grinders.

Second-hand rewound electric motors are perfectly acceptable. Some makes of screens, deckers and wet machines have very long life expectancies and can well be purchased second-hand.

The most expensive single item in a pulp and paper mill is the paper machine itself and in the case of a small mill the purchase of a second-hand machine should be considered very carefully. The useful life of a paper machine is very long. Indeed most of the paper machines in operation today are over thirty years old. In most cases such older paper machines become available on the second-hand market not because they are worn out, but because the capacity is too small for economical operation in North America. If in reasonable condition (and perhaps partially rebuilt, modernized and modified to suit the particular application) a second-hand paper machine can give as satisfactory results as a new machine and usually at one-quarter to one-third the capital cost of a new machine.

It is thus quite possible to use a considerable portion of second-hand equipment in the construction of a smaller mill without appreciable loss in efficiency and with a considerable decrease in capital cost. The mill must, however, be carefully designed in accordance with the best modern practices and the equipment must be carefully selected and investigated for condition and suitability.

X. Conclusion

It is difficult to treat so broad and general a subject as "Modern Trends in the Layout and Design of Pulp and Paper Mills" with any degree of thoroughness within the limitations of a paper. A text book would be a medium more appropriate in size.

This paper will, however, have accomplished its purpose if it has brought attention to the very pronounced influence of automation, materials handling, mill layout and mill integration on the efficiency of a pulp or paper mill, and that there is more to the design of a modern pulp or paper mill than the acquisition of modern pulp and paper machinery. Indeed, to repeat the statement made at the beginning of this paper, it is quite possible to design an essentially modern mill using equipment available a decade ago, and the opposite is equally true—it is also possible to build an obsolete mill using modern equipment.

WATER SUPPLY AND WASTE EFFLUENT DISPOSAL AS FACTORS IN LOCATING PULP AND PAPER MILLS[1]

Julius Grant

From the earliest days of paper making a plentiful supply of water of good quality has been one of the principal factors in determining the site of a paper mill. The advent of machine made papers and of pulp manufacture on a large scale intensified this dependence on water, at any rate from a quantitative point of view. Modern methods of water treatment have to some extent enabled water to be used for pulp and paper manufacture which in the past would have been regarded as unsuitable. The same factors have, however, created the problem of disposing of the waste effluent waters from the mill.

These three factors, namely the quantity and quality of the water and the disposal of the effluent, will be discussed in turn.

Quantity of water required

The amount of water required for the manufacture of pulp and paper will depend largely on the product to be made. Since even under the best conditions water shortages are more common than surpluses, it is as well to err on the high side in assessing likely requirements. Manufacturing requirements per ton of finished product might therefore be reckoned as follows:

(i) Unbleached chemical pulp: 160 m^3.
(ii) Bleached chemical pulp: 180 m^3.
(iii) Paper from pulp: 210 m^3.
(iv) Integrated manufacture of paper and pulp: 360 m^3.

Deviations from the figures given above may arise from a number of causes. Thus in the manufacture of unbleached pulp, the sulphite process will require rather more water than the sulphate process. Similarly the number of bleaching stages will determine the water requirement for the manufacture of bleached pulps.

The above figures include the water required for raising steam, both for process work and for the generation of electrical power required by the respective processes. Consequently, where electrical power is obtained from an outside source (e.g., from a hydro-electric installation), they may be correspondingly reduced. However, they do not include condenser-cooling water used by steam turbines. Unless its temperature involves any objection this, as a rule, can be cooled, returned to its source and either used again for the same purpose or used for process work.

The figures quoted also allow for the recovery of a reasonable proportion of the process water, e.g., as backwater. This proportion, however, will vary considerably according to the type of mill. Thus, in the preparation of pulp (particularly of unbleached pulp) this propor-

[1] Issued originally as ST/ECLA/CONF. 3/L.6.2. Most of the tests referred to in this paper were carried out by the author, and the procedures recommended are based on the author's own experience.

tion is appreciably reduced. The black liquor from the digesters for instance contains a large proportion of soluble matter which cannot be removed, so that the liquors must be sent to waste and the water lost. Even when an alkaline process is used and the liquors go to the recovery plant, much of the actual water present is lost by evaporation. Washings from the green stock also pass out from the system. Short-fibred materials such as straw and bagasse contain a high proportion of fine fibre debris and associated plant structures, many of them in a colloidal suspension, and therefore only removable with difficulty or at some expense.

A certain amount of water recovery is sometimes possible from the bleaching plant, especially from the last stages of washing. However, it must always be remembered that the basic principle of the pulping operation (and this operation includes digestion, washing, screening and also bleaching where necessary), is the removal of the non-fibrous cellulosic and other constituents of the raw material. Since this is done by rendering them soluble and/or washing them out, it is apparent that the re-use of the liquors or washings runs counter to this general principle.

The greatest measure of water recovery, of course, arises at the paper-making stages of manufacture in integrated mills. Here again, however, the extent to which recovery can be effected varies according to circumstances, and in particular according to the papers being made. Long runs of the same type of paper, with few changes and a minimum of breaks, favour a closed back-water system. Frequent changes have the reverse effect. Changes of colour, or even of shade, create particular difficulties for reasons which are familiar to every paper maker.

The methods of recovering back-water are well known. Experience, however, has shown that a useful axiom in a mill having several paper machines running on different types of paper is that each machine should have a self-contained back-water system, and so far as possible should carry its own back-water usage. The latter is frequently not completely possible, even where each machine has its own save-all, and there is often a surplus of back-water which is sent to one or more back-water towers which are usually common to several machines. In an integrated mill such surplus back-water can be turned to good advantage. Thus it can be taken back to the pulp preparation plant and used for washing pulp if relatively pure; if coloured it can be used for filling digesters. There is therefore seldom any excuse for sending back-water to the effluent in such a mill. This point is of treble importance, namely from the points of view of water economy, fibre recovery, and reducing the effluent discharge.

Having decided how much water is likely to be required for the mill, the problem arises how to find it. It may be considered a safe principle to set as a quantity target an amount exceeding the appropriate figure already mentioned by at least 10 per cent. Due allowance should also be made for any future expansion envisaged. Water is one of the most important raw materials of the pulp or paper mill, and in any case no site should be chosen which can provide it only in bare sufficiency.

In the great majority of cases the water will come from one or more of three sources, namely a river, a lake or wells. It is highly dangerous to recommend a site where all the water needed cannot be *seen* at all times of the year, including exceptional seasons. For this reason one should be very chary of wells, and particularly sceptical of local advice concerning them. One is so frequently told that "there is plenty of water underground" by local people who are apt to measure quantities by existing local usages. This information may be given in perfectly good faith, but without any conception of the real implication of 650 m^3 per hour required by (say) a mill making 50 tons per day of paper from its own pulp.

Where there is no alternative to well water, trial borings are a possibility. However, these too have their limitations and difficulties. Wells are notoriously fickle, and may run dry or at low output after a period of use. They may also rob the underground supplies of existing and neighbouring wells, thus possibly leading to litigation. Conversely, they may be robbed after a time by other wells subsequently sunk in the locality. Added to these risks is, of course, the fact that trial borings are expensive, and may not be successful. Moreover, since one would not normally purchase the land before the trial borings are made, there is always the probability that the price will soar if they are successful.

The above does not imply a complete condemnation of the use of well water for pulp and paper mills. It is, however, necessary to tread cautiously. A good geologist, preferably a local man, can be most helpful in the initial stages, and some remarkable achievements have been seen from the much-scorned water-diviner. The difficulty often is to find a genuine one; the man who only takes payment if he gets results is usually reliable, but not very common! Many mills run on well water and have done so for many years, and generally speaking they have the great advantage of a supply which is both good and constant in quality.

Of the two alternative visible sources of water a lake is to be preferred, especially in countries where there are well-defined wet and dry periods or seasons. The lake then acts as a buffer, filling up during the rains and gradually emptying during the dry periods. The large volume of water has the further advantage that it serves as a huge tank, so that any fine suspended matter has a chance to settle out. The composition of the water therefore remains reasonably constant throughout the year. Special advantages arise from the use of water from artificial lakes formed in mountainous areas as reservoirs for town water supplies, or in connexion with hydro-electric schemes. Such water is usually relatively free from suspended matter, and owing to the precipitation of atmospheric moisture which occurs at high altitudes in most parts of the world, it is not affected by general drought conditions. The mill need not necessarily be located near the lake. The water can be piped by gravity quite long distances along the valley at the base of the dam, and in some cases a mill has been conveniently located so that it can take advantage both of the water from a hydro-electric plant (after it has passed through the turbines) and of the cheap electrical power generated.

Rivers, a frequent source of water supply, call for little comment as regards quantity. It is, however, very important when choosing a site to obtain full statistical information as to the flow-rate at all times of the year and if possible for a period of at least ten years previously. In some parts of the world the variations between rainy and drought conditions are astonishingly wide, and an opinion formed under average conditions can be quite misleading. This applies both to the quality and quantity of the water, and it is important from both extremes because the effect of too much water (e.g., floods) needs to be foreseen. Where the lay of the land allows a river to be dammed up near the mill to form an artifiicial lake, many o fthe advantages of lake water result, and flooding risks can often be eliminated. As a rule land liable to flooding is easy to recognize, but floods are not strictly seasonal, and personal judgment by a stranger to the locality may be very misleading. Local knowledge on floods is usually quite reliable, but tends to be exaggerated; this is an error in the right direction.

There are few countries nowadays where official statistical information on the flows of the more important rivers cannot be obtained. Moreover, there is usually a well-informed government department which can advise on these matters from an intimate knowledge of the watershed.

Quality of the water required

In the early days of paper manufacture only water of the highest quality was acceptable. However, the diversity of pulp and paper manufacturing processes and modern methods of water treatment have permitted some relaxation of rigorous earlier standards. It is sufficient today if water is suitable for the purpose for which it is required.

The early standards were based on paper and not on pulp manufacture, and in the days of high grade "handmade" rag paper or papers for writing and printing —wrappings being then virtually unknown. The search for water need not be made more difficult by specifying for *all* the stages of manufacture a quality suitable for the most *exacting* stages.

Tabulated below are the TAPPI specifications (maximum quantities in parts per million) for waters suitable for the manufacture of four different types of paper. A comparison of the figures (e.g., for turbidity) brings out the point just made. It should be noted, however, that the specification for fine papers is not likely to be stringent enough for water for the manufacture of specialities such as photographic base papers, blueprint papers, cigarette papers, facial tissues, etc.

	Fine papers	*Kraft papers*		*Ground wood papers*
		Bleached	*Unbleached*	
Turbidity	10	40	100	50
Colour (Pt units)	5	25	100	30
Total hardness ($CaCO_3$)	100	100	200	200
Calcium hardness ($CaCO_3$)	50	—	—	—
Methyl orange alkalinity ($CaCO_3$)	75	75	150	150
Iron	0.1	0.2	1.0	0.3
Manganese	0.05	0.1	0.5	0.1
Free chlorine	2	—	—	—
Soluble silica	20	50	100	50
Total dissolved solids	200	300	500	500
Free carbon dioxide	10	10	10	10
Chlorides (Cl)	—	200	200	75

These figures apply only to *paper*. For pulp one must assume that the water for the last stages of washing the pulp (e.g., after bleaching), before it goes to the pulpers or beaters of the paper mill, would itself conform to the appropriate standard set out above. For earlier operations the chemical standards of purity can if necessary be lower, although freedom from suspended matter, whether coarse or moderately fine, is always important. For instance, in the case of water used for filling the digesters a liberal tolerance of chemical purity is allowable, since the chemicals in the cooking liquors are added in such quantities that their effect overwhelmingly masks that of any saline matter in the water. Even dissolved organic matter (such as from surface water) is of minor importance, since it is eliminated by the digestion process in much the same way as the non-cellulosic constituents of whatever raw material is used. There are cases of sulphite mills located on the coast using sea water for this part of their process.

Such liberties cannot be taken with water employed for the later stages of pulping, because after the removal of the black liquor the objective is always to effect progressive removal of impurities of all kinds. In this respect saline matter is of less importance than dissolved organic matter, although where a bleaching process is used (usually a multi-stage process nowadays) organic matter in the water is readily destroyed. The resulting increase in consumption of chemicals is usually trivial. Water for the intermediate stages of pulp manufacture (e.g., dilution for screening, etc.) usually comes from some form of recirculated back-water system.

Where a mill is making, for example, bleached market pulp, clearly the quality of the water must at least reach the values given in the table for fine papers. An intelligent use of the flexibility of these standards of water supply as applied to different pulps and papers and to different parts of the same process has been of great help in the location of sites. Thus it has often allowed the use of a site where the supply of high-grade water (e.g., from wells) was not sufficient for the whole process, but which had a source of less pure water (e.g., from a river) to make up the deficit.

The standards set out in the table given earlier call for some comment. Not all of them should be interpreted rigorously. Hardness and alkalinity, though no doubt objectionable in some respects, are not deciding factors in determining the suitability of water supplies; there are many instances of mills making fine papers of a high grade but using water with higher hardness values than those given in the TAPPI specifications. Indeed there is good reason to believe that hard water helps sizing by forming a resinate of calcium, thereby more than offsetting any small additional consumption of alum required to neutrailze the alkalinity of the water. The chief trouble in process work arising from a hard water is scale formation, particularly on the drying cylinders. Where soluble silica is also present some trouble may be caused by very hard and resistant scales which form in the potchers, especially in the presence of hypochlorite bleach liquor.

The iron contents specified are also controversial, although in special cases (such as the manufacture of photographic and ferro-base papers) only very small amounts can be tolerated. In such cases it is the iron content of the pulp rather than that of the water used that is of concern to the paper mill. Iron is supposed to combine with rosin to form dark coloured resinates which lower the colour of white papers, and relatively large quantities in the system undoubtedly do so. An experiment in which soluble iron salts were deliberately added to the beater showed that a surprisingly large dosage was required to produce a noticeable difference in either the iron content or the colour of the paper.

This test made it possible to use a grade of alum containing more iron, and therefore cheaper. The iron content of the paper, it seems, depends only to a small extent on the soluble iron content of the water.

The TAPPI specification makes no reference to chlorides in connexion with fine papers, although these will be included in the dissolved solids. The upper limits given for the other three papers (which incidentally, are rather inconsistent as between kraft and groundwood papers) arise from the tendency of large amounts of chlorides to promote corrosion of certain metal parts in the manufacturing system. This point has to be watched if sea water is used at any stage, or if the fresh water comes from rivers or wells near the sea, where salt infiltration is liable to occur. In the case of fine papers, however, chlorides can also be objectionable because of their effect on the paper itself. There is good reason to believe that, especially under warm and damp conditions and at low pH values, acidity will develop from chlorides present. This in time attacks the cellulose and lowers its strength and durability. This was apparent in papers made in the early days of bleaching powder; the importance of bleach residues left in the pulp was not realized until it showed itself in a most disastrous way.

In some actual specifications drawn up for papers having a maximum degree of permanence the chloride content of the paper was specified as not exceeding 0.05 per cent and the pH value as not less than 6.0. Though chloride contents of this magnitude are more likely to arise from the pulp than from the water, it is most desirable—when choosing a site for a mill for such papers —to ensure that the chloride content of the water does not exceed fifteen parts per million as Cl. To rely entirely on the dissolved solids figure may be very misleading.

Residual chlorine will not arise in natural waters, but may if the supply is being shared with a township. It is specially undesirable if tinted papers are being made.

The figures for free carbon dioxide (which may cause corrosion) and for soluble silica are rather stringent. A low manganese content is desirable; not only can such compounds produce discolouration, its presence in paper for wrapping fatty foods can induce rancidity.

It is neither economic nor necessary to soften water required for process work (although it is essential of course to do so for steam raising). However, a certain amount of process water treatment can be carried out inexpensively. Such treatment invariably starts with some form of coarse straining to remove floating debris, followed by finer filtration, usually through sand pressure filters, to remove coarse turbidity. Where fine turbidity is present or the water is coloured (e.g., peaty moorland waters), chemical treatment must be applied. Simple automatic dosage with alum alone or mixed with ferrous sulphate is usually adequate. It must be followed by coagulation, sedimentation, and filtration of the clarified water through pressure filters. Chlorination to prevent slime formation can conveniently be applied at this stage, and the analyses of the resulting water should then conform to the appropriate specification given above, subject of course to any modifications flowing from the comments already given.

Thus a wide variety of sources of water can be rendered suitable for pulp or paper manufacture. However, having chosen the site and having specified the water purification plant, care should be taken that it is adequate for all types of weather. In some parts of the world, where there may be a large watershed, a river can be transformed by rains in a matter of hours from a placid clear and colourless stream to a muddy coffee-coloured torrent, which would put a strain on any water purification plant. Where this is likely to happen an adequate reservoir of water must be provided to neutralize its effect. In one such case, for example, water was pumped from a river (during its calm periods) up to a small artificial lake in an upland valley, from which it was later withdrawn and treated for process work along the lines described above.

It should be noted that a water suitable for mill process work or for steam raising is, even after treatment, not necessarily a safe drinking water from a bacteriological point of view. In isolated areas therefore, where the same supply of water has to serve both the mill and domestic uses, a portion of the supply should be isolated and subjected to proper chemical and bacteriological examinations at frequent intervals. At least one case is on record where failure to observe this precaution led to a serious outbreak of disease.

Effluent disposal

This is a very wide subject and the following paragraphs cover only those principal aspects which affect the choice of a mill site. Throughout the world river-consciousness is increasing rapidly, even in so-called under-developed countries. Sometimes, notably in small countries with small rivers (such as Great Britain), this has already shown itself by highly restrictive legislation. This creates severe problems for existing mills, and makes it extremely difficult to extend them or to erect new mills; even tidal waters are not entirely exempt from legislative restrictions. These tendencies exist even in countries which possess large rivers and have as yet little industry. It is probably most unwise therefore, to select a site on the assumption that the mill will be able to discharge its effluent into a local stream merely because no restriction has so far been imposed. It is always desirable to consult frankly with the responsible Government or other official department, to indicate the likely volume and chemical composition of the effluent, and to obtain official consent to its discharge.

Where an effluent cannot be discharged into the sea there is seldom an alternative to the use of a river. In some special cases it has been possible to make use, with remarkable success, of a disused mine or a large marsh. Rivers usually flow past towns, villages, or some form of habitation. Even if the rivers contain no fish and have no scenic amenities they may yet be very objectionable if carrying a pulp mill effluent. Rivers are also used in more remote areas for watering cattle (and even human beings), for washing purposes and for irrigation, so that in such places the effluent may even prove to be injurious. Even where the effluent is discharged into the sea care should be taken to study the currents, especially on a "tideless" sea such as the Mediterranean. A case is known where the currents prevailing around the proposed point of discharge would most effectively have carried the effluent, virtually undiluted, on to a local bathing beach some eight miles away! The installation of a pipe line running about 500 metres out to sea in a selected direction overcame this difficulty. In another case, where a large isolated lake was used as a source of process water, it was possible to arrange for this water to be taken from near the head of the lake and the effluent discharged into the middle of the lake, so that its effect was not apparent in the outgoing river.

Another device, which is possible in urban areas, is to segregate the relatively small volume of really bad effluent, partly treat it by sedimentation and coagulation, and then to discharge it into the local sewer where it mixes with the domestic sewage of the locality and is treated with the latter in the usual way. This of course can only be done by arrangement with the sewage treatment authorities who will certainly specify the amount and composition of effluent which they can accept for treatment. Moreover, the method will only apply to relatively small mills using an alkaline process, as sulphite liquor cannot normally be dealt with so simply. In the course of some experiments on these lines it was found that a mixture of diluted black liquor with domestic sewage (to provide nitrogen) could be purified on ordinary coke percolating filters, as commonly used in sewage works. This discovery has since been developed as a process for treating such effluents.

Where paper only is being made, in normal circumstances and assuming the efficiency and good management which goes with an up-to-date plant, there should be no real effluent problem. Suspended fibrous matter is normally the only impurity involved, and it is both easy and highly remunerative to recover this from the effluent.

So far as pulp mills are concerned, the problem is more acute with sulphite mills than with soda or kraft mills, since the latter employ a soda recovery plant which has the dual purpose of chemical recovery and the reduction of effluent. Even so, there are the washings from the green stock after digestion and also the less objectionable white stock washings obtained during and after bleaching. Although these contain less dissolved organic solids they nevertheless contribute suspended matter. Kraft processes should therefore be planned so as to involve a maximum of liquor and washings going to recovery. A recent procedure involves an efficient countercurrent washing method which gives only washings and black liquor of a concentration such that they can be sent direct to recovery. This method therefore is of major importance and very promising; it not only solves the effluent problems, but also improves the efficiency of the recovery process by giving both higher heat and caustic soda recoveries (due to the higher concentrations of organic matter and spent alkali present).

With the sulphite process no complete solution yet exists. Many methods for utilizing sulphite liquor, and two methods of recovering it, exist, but none of them solve the problem completely and economically. Similarly with the mono-sulphite, Celdecor and mechano-chemical processes the problem is as yet unsolved, although the last-named offers possibilities for the application of the counter-current method.

As regards effluent treatment, provision should be made on site for large settlement tanks for removal of most of the suspended matter. If a chemical coagulant is used in a mechanical thickener the sludge is conveniently removed continuously, de-watered on a rotary vacuum filter, and re-used in boards or in low grade wrappings. A method was evolved some years ago which, used in conjunction with dosage with bleaching residues containing chlorine and aeration (to reduce the biological oxygen demand), gave a satisfactory effluent from soda esparto pulp washings.

The standards to which effluents must conform if they are to be discharged into rivers vary considerably in different parts of the world. In Great Britain "pollution" is defined as that which changes the nature or composition of the river, so that *theoretically* the addition of hard water to soft water or warm water to cold water is pollution, and therefore an offence. In practice, however, the quality of the effluent is defined in terms mainly of suspended solids and B.O.D. Hitherto standards of not more than three and two parts per 100,000 respectively, have been used. There are certain tolerances for suspended solids if dilution by the river is high. While reasonable for sewage effluents, these standards are often both inappropriate and unfair to trade effluents, and the whole question is now under revision. It seems that in future the standards chosen will be formulated so as to take more into consideration the nature and volume of the effluent and the flow of the river into which it is discharged.

Few other countries have numerical standards of purity, and the criterion of suitability usually adopted is simply whether the effluent is likely to be offensive or injurious. Effluent disposal can often provide serious difficulties in the selection of a site for a pulp mill, but given a resourceful approach on the one side and sympathetic consideration on the part of the authorities, a solution can usually be found.

THE RELATIONSHIP BETWEEN THE MORPHOLOGICAL CHARACTERISTICS OF THE FIBRES FROM TROPICAL WOODS AND THE QUALITY OF THE PULP AND PAPER OBTAINED FROM THEM[1]

Régie industrielle de la cellulose coloniale

The strength characteristics of a sheet of paper are governed by numerous factors: the nature of the fibres composing it, the chemical and mechanical treatment which these fibres have undergone, and its formation on the paper machine, to mention only the most important.

Most of these factors can be controlled, e.g., by selecting for each given raw material the most appropriate conditions for cooking, for beating, and so on. These conditions can be determined by research and by trials,

[1] A shortened version of the original paper (ST/ECLA/CONF.3/L.6.3), which gives the local and botanical names of the forty-two species studied, their biometric characteristics, their paper-making characteristics, and sixteen diagrams illustrating the relationships studied.

and paper-making methods thus modified and improved. But there is one factor which cannot be controlled, since it is a natural phenomenon—the biometric characteristics of the fibres: their length, diameter and wall thickness. These characteristics have a fundamental influence on the quality of the paper ultimately produced. The extent and nature of this influence has been the subject of long-term study in the research laboratories of the Régie industrielle de la cellulose coloniale and efforts have been made to formulate rules defining the relationships which may exist between biometric data on the one hand and paper characteristics on the other.

The study was aided by the great diversity prevailing in the vast range of tropical woods. The forty-two species studied had average fibre lengths ranging from 773 to 3,302 microns, fibre diameters ranging from 16.6 to 31.0 microns, and average wall thicknesses ranging from 6.6 to 24.7 microns.

When a sheet of paper undergoes a strain, whether from stretching, bursting, shearing or folding, the force applied tends to separate the component fibres which have been felted on the paper machine.

The closer the texture of the power and the greater the cohesion between the fibres the more powerful must be this force. The strength of paper is thus determined by the interfelting of the fibres, brought about by cohesive or frictional forces which developed at the time the sheet was formed on the paper machine.

Although knowledge of these forces is limited, it is nevertheless known that they are inferior to the cohesive force between fibre cells and elementary fibrous tissue, and that their value is considerably affected by the processes of hydration or beating. A microscopic examination of a roll of paper split crosswise makes it clear that the fibres separate. The breaking of individual fibres, if it occurs at all, is a secondary phenomenon.

The influence of hydration and beating on the strength characteristics of paper may be explained as follows. The surfaces of those fibres which have undergone hydration are enlarged; this surface increase leads to an increased number of contacts between fibres and hence to greater frictional force. An increase in fibre surface may also be obtained by crushing, disintegration or fibrillation. These results, though in practice achieved by mechanical treatment, can also be obtained by chemical means. Not only do these treatments allow an increase in the surface contacts between the fibres, they also increase the flexibility of the fibres.

Nevertheless, though various treatments can modify the aptitude for interfelting, the intrinsic biometric characteristics of the fibres themselves play a very important role from the outset.

The first object of the study was therefore to examine the effect of variation in fibre dimensions on tensile, bursting, tearing and folding strengths.

To start with, measurements were taken of individual fibres, separated by maceration in a mixture of hydrogen peroxide and acetic acid at 60°C for a period which varied from twenty-four to seventy-two hours, according to the species.

To ascertain paper-making characteristics, each individual wood was studied separately. In general, ten to twelve cooks were necessary to ascertain the best treatment conditions for each species. The strength characteristics employed in the investigation were determined at a standard freeness of 40° Schopper-Riegler.

Three of these characteristics—breaking length, burst factor and tear factor—were plotted on scatter diagrams in turn against fibre length, wall thickness and fibre diameter, giving nine diagrams in all, each containing forty-two readings corresponding to the forty-two species tested. In all nine cases the points were very widely dispersed. In no case was there *prima facie* evidence of a correlation high enough to justify further statistical treatment.

Though all the results were negative, those concerning the lack ofrelationship between fibre length and paper-making characteristics should be specially remarked. Several years ago it was still almost universally accepted that only long-fibred pulp could produce resistant paper.

Since no relationships of practical value could be established between absolute fibre measures and paper-making qualities, the next step was to explore the relationship between strengths and certain relative, or derived, fibre measures.

Two coefficients were studied, One, relative fibre length (fibre length divided by fibre diameter), expresses the slenderness of the fibre. Earlier researchers who have studied this coefficient has termed it "felting power".

The other, relative wall thickness, gives an indication of fibre flexibility, lengthwise and crosswise, i.e., of the aptitude for folding and stretching. This measure, which may be termed the flexibility coefficient, can be expressed in either of two ways, viz., wall thickness divided by diameter, or lumen divided by diameter. In fact the latter (lumen divided by diameter) was chosen, since the former (which is simply 100 minus the latter) is rather an index of rigidity.

The flexibility coefficient might be expected to have a marked influence on strength characteristics. A simple diagram shows that with thick-walled fibres (i.e., low flexibility coefficient), the contact surface between them is not very extensive. With thin-walled fibres, however, i.e., high flexibility coefficient), the ratio of contact surface to total fibre surface is high.

This expectation was confirmed. A scatter diagram relating breaking length to the flexibility coefficient for the forty-two species under study revealed a well-defined relationship. The relationship was not linear, but parabolic, of the form

$$y = ax^2 + b$$

where y = breaking length and x = flexibility coefficient. Moreover limit curves, separated plus and minus 15 per cent from the principal curve, encompassed all but five of the readings.

Two of the deviations were extremely slight, but the other three deserve special mention. These correspond to the species Kaka (*Phialodiscus plurijugatus*), Ohnon (*Euadenia trifoliata*) and Amon (*Buechelzia coriacea*); Kaka and Ohnon are very soft woods, difficult to preserve. In spite of all precautions, the samples used began to show signs of decay, so that these two deviations can be explained by damage to the fibres. The irregular behaviour of Amon arises from the extreme shortness of its fibres. It has the shortest fibre—under 700 microns—of all the woods examined. This prompts the observation

—an observation which seemed to be confirmed by subsequent studies of other fibres—that though fibre length does not in general affect paper strength value, it has marked influence should it fall below a critical value of about 800 to 900 microns.

This investigation thus leads to the conclusion that it is possible, by establishing an empiric formula, to indicate with 15 per cent accuracy a paper's tensile strength from the flexibility coefficient of the fibre. This margin is not unduly large. Indeed a 15 to 20 per cent deviation is to be expected in calculations of biometric characteristics, while a deviation of 5 per cent is considered normal in tests to determine tensile strength. From the point of view of the paper maker, a general indication is, in any case, sufficient.

If tear factor is plotted against the flexibility coefficient, the resulting diagram seems to indicate a descending straight-line relationship. The readings, however, are too widely dispersed for the relationship to be of practical value. Nevertheless, the conclusions of previous researchers, that thick-walled fibres are necessary to obtain good tearing strength, are confirmed in a general way.

Thus the influence of the flexibility coefficient on the two most important strength characteristics of paper—the breaking length and the tear factor—is inverse. This means that it is not possible in the case of tropical woods to have good values for both these characteristics in a single species.

As to folding strength (the number of double folds a paper can stand), the scatter diagram gives only general indications, since the points are widely dispersed. A species with a low flexibility coefficient will not give a paper with good folding strength; on the other hand, a species with a high flexibility coefficient may (but will not necessarily) give a paper with good folding strength.

Turing to the influence of the other coefficient, felting power, there is a strongly marked relationship between felting power and breaking length, of the form $y = a + b$. Twenty per cent limit curves encompass all but five readings, the three extreme deviations being those previously noted.

A parabolic relationship also connects the tear factor and felting power, 20 per cent limits excluding only three readings, of which two correspond to Kaka and Ohnon.

Therefore, providing the felting power of the species is known, it is possible to give an indication of the tearing strength value of a pulp prepared from this species. The error margin is too great to allow exact tearing strength to be ascertained, but sufficiently accurate indications can be given to enable species to be classified for this characteristic.

The last relationship, folding strength and felting power, gave completely negative results, the readings being almost randomly dispersed.

Because of the foregoing investigations, while throwing a good deal of light on breaking and tearing strengths, had led to no positive means of ascertaining in advance folding strength, it was decided to investigate the relationship between folding strength and the ratio fibre length to lumen diameter (in effect felting power divided by flexibility coefficient). Again the readings were fairly scattered, but an upper limit curve was plainly discernible. Thus, for good folding strength, the ratio fibre length to lumen must be low; the reverse, however, does not hold good—a low ratio does not necessarily indicate a good folding strength. It would therefore appear that though the biometric characteristics of fibres influence tensile and tearing strengths, other parameters, governed probably by the internal structure of fibre walls, play an important role in folding strength.

Summarizing the studies carried out, it appears that:

1. Tensile strength is governed essentially by the flexibility coefficient. The higher this coefficient, the better is the strength.
2. Tensile strength is also governed by felting power. The greater this power, the poorer is the strength.
3. Tearing strength is governed by felting power. The greater this power the higher is the tear factor.
4. Folding strength, although influenced by biometric characteristics and essentially by the ratios, length/lumen and width/lumen, is governed more by other, as yet undetermined, factors.

Tropical woods can therefore be classified according to their paper-making qualities from a knowledge of biometric characteristics. Although this does not provide an exact definition of a paper's strength characteristics it can nevertheless give an adequate approximation.

From conclusions 2 and 3, it would appear that a given tropical wood cannot possess at the same time good tensile and tearing strengths, as felting power exerts an influence in opposing ways on these two characteristics. This observation alone would be enough to condemn the use of individual tropical species. The papers obtained would always lack one or the other of the two main characteristics. Only by the use of a complex mixture or species could a paper be produced which would have satisfactory characteristics in all respects, and which could secure a place for tropical pulps on the world market.

A NEW PROCESS FOR BLEACHING PULP FROM TROPICAL WOODS[1]

Régie industrielle de la cellulose coloniale

Although there is a wide market even for unbleached tropical wood pulp, it appears that it is principally in its bleached form, for the manufacture of writing and printing papers, that tropical pulp will play an important role in the world's pulp supply. For this reason comprehensive tests have been carried out on the bleaching of pulps derived from tropical woods. These have aimed at studying the possibility of adapting familiar methods to this raw material, whose chemical composition differs considerably from that of the pulps that have been used up to the present time.

The bleaching processes today employed in the pulp industry consist of various stages, some of which involve the use of chlorine in different forms: elemental chlorine, alkaline of alkaline earth hypochlorite, and alkaline chlorite and chlorine dioxide. The use of other bleaching

[1] A shortened version of the original paper, ST/ECLA/CONF.3/L.6.5.

agents, e.g., peroxides and certain reducing agents, has in practice been largely limited to the treatment of mechanical pulps.

The bleaching of alkaline pulps, which include those obtained from tropical woods, is a complex operation. The darker alkaline pulps—and this applies equally to conifer pulps—contain colouring matter that has to be eliminated by higher quantities and concentrations of the oxidizing agents.

This gives rise to the danger that the cellulose itself may be adversely affected.

For this reason the bleaching of alkaline pulps is carried out in an ever-increasing number of stages. Whereas originally this operation consisted of only three stages (chlorination, caustic soda and hypochlorite treatments), today in certain plants seven or more successive stages are employed. The treatment with chlorine and soda, or with hypochlorite, is repeated several times and followed by alkaline washings. If a high brightness is desired (over 80 G.E.) it is generally necessary to use chlorites or especially chlorine dioxide.

These conclusions apply also to tropical wood pulps, but the bleaching of these is even more difficult because the woods are generally very dark and often contain gums and resins, whose degrading products remain in the pulp even after thorough washing, giving it a still darker colour.

The first series of tests carried out showed that the classical bleaching processes employed for conifer pulps may also be applied, without great modification, to tropical wood pulps, provided that a not very pronounced bleaching (around 78 to 80 G.E.) is considered sufficient. This brightness was achieved in a five-stage bleaching process, and chlorine consumption was no higher than for conifer pulps.

By increasing the number of stages it was possible to obtain a brightness of over 80 G.E., but only at the cost of a yellowish tinge and considerably reduced strength properties. This suggested that if higher degrees of brightness were desired, it would be advisable, as in the case of conifer pulps, to resort to sodium chlorite or chlorine dioxide.

Although the use of these chemicals is beginning to spread both in the United States and in Europe, two problems are encountered: the high cost of the chemicals, and certain difficulties in the handling of the dioxide. Studies were therefore undertaken to ascertain whether it is possible to obtain a satisfactory degree of brightness in tropical wood pulp without resorting to these products. These studies aimed at increasing the speed of the bleaching reaction by adapting established methods, thus making possible a reduction in the industrial installations for a given bleaching capacity.

The first laboratory tests, subsequently confirmed on an industrial scale, indicated that the speed of reaction between the chlorine and the incrustants was slower for tropical wood pulps than for conifer or straw pulps. For example, a hypochlorite stage lasting four to six hours for conifer pulp might require fifteen to twenty hours for tropical wood pulp. For a given capacity, therefore, much larger installations would be needed to deal with tropical pulp—a serious matter, since construction and maintenance costs are high in tropical countries.

Investigations showed that it is possible to increase the speed of reaction either by using products in their nascent state or by carrying out the operations under special concentration and pH conditions.

Hypochlorite in its nascent state may be obtained by passing a current of chlorine through the pulp containing a specific percentage of caustic soda giving rise to the following chemical reaction: $2\ NaOH + Cl_2$ $NaCl + H_2O + NaOCl$. The caustic soda may be obtained by adding a soda lye to the pulp or may be excess caustic soda from the soda treatment.

From the first tests it was clear that the use of nascent hypochlorite led to extremely rapid bleaching, but this was achieved only at the expense of reduced strength and less stability in the brightness. Ways and means had therefore to be found of controlling the powerful action of nascent hypochlorite so that degradation of the cellulose might be avoided.

A prolonged study was therefore necessary to discover the importance of each of the factors influencing the reaction, e.g., the time the reagents are in contact with the pulp, temperature, concentration, pH number, ratio of chemicals to pulp, etc. After numerous tests, it was possible to establish the optimum conditions for this treatment, i.e., conditions enabling the action of the nascent products to take place without harming the mechanical and chemical characteristics of the fibres.

These conditions, of course, vary according to the nature of the unbleached pulp, its degree of cooking and the brightness desired. Tests showed that it is possible to obtain an average brightness, without any degradation of the pulp, in one stage by applying nascent hypochlorite to a pulp previously treated with chlorine and soda and by paying careful attention to the pH, the concentration and the chemical ratio. Stability was about the same as in the chemical hypochlorite process. A second treatment with nascent hypochlorite gave higher brightness, but there seemed to be an upper limit to the brightness attainable—somewhere between 81 and 83 G.E.

But though it was established that by using nascent hypochlorite it is possible to bleach pulp rapidly and to a higher brightness than is possible with the classical processes, these results have been obtained only in the laboratory. Industrial application presents certain problems.

Because of the rapidity of the process, accurate timing is important. If the operations are intermittent, large timing errors can easily arise, e.g., in the time taken to drain the containers. A continuous bleaching process is therefore necessary.

New studies had therefore to be undertaken, aimed at discovering rapid means of perfecting the bleach without damaging the chemical qualities of the pulp and the paper-making characteristics of the fibres.

The second difficulty likely to be encountered on an industrial scale concerns the effective penetration of the pulp. Tests showed that the more concentrated the suspension, the lower the chlorine consumption and the more effective its action; chlorine should react on pulps of the highest concentration possible. But instant and homogeneous penetration of gas, without great differences in the contact time with different fibres, is difficult to obtain in highly concentrated pulps.

Studies were first made on the effects of gaseous chlorine. Theoretical considerations suggested that if chlorine were placed in contact with the pulp after hypochlorite treatment ,the pulp could be bleached with a very small reagent consumption.

Tests verified this hypothesis. A considerable improvement in brightness was obtained by post-chlorination of pulp previously bleached to 70 or 75 G.E. It was necessary to operate in a strongly acid medium (very low pH) and the best results, from the point of view of bleach as well as brightness stability and strength characteristics, were obtained in a period of one minute. Prolongation of the reaction to two or three minutes had only moderate effects, but marked degradation followed prolongation to fifteen minutes. Thus the action of chlorine on a previously bleached pulp brought to a suitable pH may produce a substantial improvement in degree of brightness.

These tests led naturally to a consideration of the action of sodium hypochlorite in an acid medium. It was shown that the increase in brightness, very slight in an alkaline medium (one point), became more pronounced in an acid medium (three points), and was not dependent on the degree of acidity. The use of hypochlorite in a strongly acid medium, it was concluded, permits a considerable increase in the brightness of the pulp without having an adverse effect on its papermaking characteristics.

The general conclusions to be drawn from these series of investigations may be summarized as follows:

Three new variations of the classical process for the bleaching of tropical wood pulps (or, indeed, for any type of pulp) are available.

These processes, all of which have a high reaction speed, are:

1. *Nascent hypochlorite process:* May be applied to pulps that have undergone previous chlorination and soda treatment. Principal advantages are:

(*a*) High reaction speed;

(*b*) The possibility of easily carrying out continuous treatment with a small-capacity installation;

(*c*) A higher degree of brightness for the same quantity of chlorine;

(*d*) A degree of brightness slightly over 80 G.E. without any degradation of the pulp.

2. *Post-chlorination process:* Makes it possible to obtain, with limited consumption, improved brightness in a pulp that has previously undergone the first three stages —chlorination, soda treatment, and the classic or nascent hypochlorite treatment.

Advantages are:

(*a*) A minimum consumption of products for a given increase in brightness;

(*b*) An extremely short reaction time, permitting continuous operation;

(*c*) A high degree of brightness without degradation of the pulp and without using costly bleaching agents.

3. *Acid hypochlorite process:* May be applied to pulps which have been previously bleached by the nascent hypochlorite process alone or combined with that of post chlorination, that is to say, by any combination of processes.

The possibilities of combining these processes were then studied, leading to the conclusion that the best bleaching method for tropical wood pulps is as follows:

1. One chlorination.
2. One soda treatment.
3. One nascent hypochlorite treatment.
4. One post-chlorination.
5. One acid hypochlorite treatment.

The following examples show the results that can be obtained by combining these new variations of the bleaching process. A hard pulp that had undergone the classical bleaching treatment based on chlorine-caustic soda and three phases of hypochlorination, with a total hypochlorite consumption, expressed in chlorine, of 3.5 per cent, gave the following results:

Brightness: 76
Paper-making characteristics at 40 degrees S.R.:
Breaking length: 7,200
Burst factor: 36
Tear factor: 110
Double folds: 30

After treatment with chlorine-caustic soda, this pulp was treated with nascent hypochlorite, followed by post-chlorination and treatment with acid hypochlorite. For the same consumption of chlorine the results were as follows:

Brightness: 84
Paper making characteristics at 40 degrees S.R.:
Breaking length: 7,300
Burst factor: 41
Tear factor: 110
Double folds: 100

These observations were confirmed by another series of tests carried out with a soft pulp:

	Control (chlorite)	Treatment: Classical chlorine-caustic soda; 2 hypochlorinations	Treatment: Chlorine-caustic soda; nascent hypochlorite; post-chlorination; acid hypochlorite
Brightness	84.5 G.E.	82.0 G.E.	84.0 G.E.
Papermaking Characteristics at 40 degrees S.R.:			
Breaking length	6,000	5,200	5,300
Burst factor	30	26	28
Tear factor	90	80	85
Doublefolds	20	15	20

In neither series of tests were the chemical characteristics seriously modified.

Thus a judicious use of the new variations of the bleaching process preserves the properties of the pulp to the same extent as the chlorine-caustic soda process. These variations can be used on their own or combined with each other in any way, or combined with the classical processes. The principal advantages of these new treatments are: the accelerated speed of operations, the possibility of obtaining high degrees of brightness using low-cost chemicals, a considerable saving in operational costs and a reduction in the initial investment required for new mills.

Because of their great adaptability, the multiple combinations possible, and the relative simplicity of the installations required, these new variations of the chlorine bleaching process may play an important role in the future in the bleaching of tropical wood pulps; they may also eventually be employed in the treatment of other types of pulp for the paper industry.

It would first be necessary to verify these laboratory observations on an industrial scale and to solve the problems of maintaining the pulp at a high concentration, of securing adequate penetration, and of adapting existing installations to the new processes.

LOW COST SUPPLY OF SULPHUR DIOXIDE FOR SOUTH AMERICA[1]

C. J. WALL

Consumers of SO_2 gas in South America have felt the lack of low cost domestic elemental sulphur, partly because of the high price of imported sulphur (about $40 per ton delivered in South America) and partly because foreign exchange shortages limit the amounts that can be imported. Although there are quite extensive elemental sulphur deposits in South America these are located in very remote places. Production costs are very high and transport expensive, so that the cost of domestic sulphur delivered to the consumer is about twice that of imported sulphur.

Countries in many parts of the world have suffered from a shortage of elemental sulphur for a number of years. Their solution has been to produce SO_2 gas from the sulphide minerals of copper, iron and zinc. The sulphide minerals that would be of greatest interest to South American sulphur users are the iron sulphides—pyrite (FeS_2) and pyrrhotite (Fe_7S_8). These minerals are very common and are usually found associated with any ore body. It is estimated that in sulphide deposits throughout the world one half of the contained sulphur is in the form of pyrite or pyrrhotite. Formerly regarded as valueless, these minerals were separated away from the base metal sulphides and discarded along with the gangue. These iron sulphides are easily separated from the gangue mineral by present-day flotation methods and very often may be enriched to a concentrate containing up to 50 per cent sulphur. A new method of roasting these cheap and plentiful sulphides has recently been developed—the Dorrco Fluo-Solids* System; today forty-four commercial and eleven pilot plant FluoSolids systems are in operation or under construction.

[1] The original paper (ST/ECLA/CONF.3/L.6.6), of which this is a shortened version, contains a typical flowsheet of a FluoSolids system for roasting iron sulphides for sulphite pulp mills.

* Trademarks of The Door Company, registered U.S. Patent Office.

These plants are simple, clean and easy to operate. They require a minimum of operating labour and maintenance. The roasting plant can be shut down, for week-ends, or holidays, in a matter of a few minutes by simply stopping the electric motors. During shutdown the large mass of calcines in the reactor lose heat very slowly so that after shutdowns of up to three full days' duration there is sufficient temperature to get back into production of SO_2 by simply starting the feed and air to the reactor without resorting to auxiliary fuel.

Paper mills near sources of iron sulphides will find that a careful study of their location may indicate that this raw material represents a cheaper source of sulphur dioxide than elemental sulphur. When pyrite can be delivered to the user at $11 per long ton, the economics, including both fixed charges and direct operating expense, are favourable to sulphide roasting by FluoSolids if the cost is compared with a delivered cost of sulphur of about $39 per long ton.

These figures do not include any credit for the calcines which contain from 60 to 65 per cent iron when roasting iron sulphides. A FluoSolids roaster at a Norwegian paper mill, for example, is roasting a Norwegian pyrite in transit. The mill purchases the sulphur value in the pyrite and ships the calcine on to Germany where it is used for blast furnace feed. In Canada a large metallurgical company is roasting a zinc sulphide concentrate in transit. It purchases the sulphur value and uses the SO_2 produced for manufacture of sulphuric acid, the calcine being sintered and charged to the blast furnace.

There are undoubtedly situations in South America where sulphur consumers could make arrangements similar to those mentioned above for roasting sulphides in transit. There may also be cases where it would be advantageous to purchase and roast sulphides from old tailing piles or base metal concentrates for their contained sulphur value, stockpiling or discarding the calcines.

ECONOMICS OF WASTE LIQUOR RECOVERY AND BURNING IN THE SULPHATE AND SULPHITE PROCESSES[1]

GUSTAV EDLING

It is well known that about half the dry solids contained in wood are transferred to the cooking liquid during the cooking of this raw material for the production of paper pulp. This is so when coniferous timber is used to manufacture strong pulp; with other raw materials and other pulp qualities the proportion may differ. This paper relates to Swedish practice and refers, unless otherwise stated, to the use of coniferous wood in the manufacture of strong pulp.

The dry solids remaining in the liquor after cooking obviously represent a very considerable value. They consist of about 900 kg of wood substance liberated per ton of airdry pulp, besides salts of inorganic origin. The analyses given below are examples of the composition

[1] Originally issued as ST/ECLA/CONF.3/L.6.7.

of the dry solids in waste liquors from the sulphate and sulphite process.

Table 1

DRY SOLIDS IN WASTE LIQUORS

Analysis of dry solids	*Sulphate* %	*Sulphite* %
Carbon	38.7	45.4
Hydrogen	4.1	4.6
Sulphur	1.8	5.0
Oxygen	28.9	34.3
Inorganic matter	26.5	10.7
TOTAL	100.0	100.0
	Kcal	*Kg*
Net calorific value in oxidizing atmosphere	3,586	—
Net calorific value in furnace	3,308	4,000

Both methods—sulphate and sulphite—are dealt with separately, special attention being devoted to the waste liquor problem of each. Figures are also given to illustrate the heat balances at mills employing these processes.

I. SULPHATE

The first Swedish sulphate mills were built in the early 1870's. Originally, the basic material employed for preparation of the cooking liquid was soda ash (sodium carbonate). It was not until ten years later that a change was made to sodium sulphate, which made possible a considerable reduction in the cost of chemicals. Nevertheless, this cost remained high, and it was realized right from the beginning that recovery of chemicals from the liquor after cooking was, for reasons of cost, an absolute necessity. To enable this to be done, the liquor had to be recovered. In the 1880's a beginning had been made with the use of diffusers for washing the pulp and recovery of the liquor. The liquor thus obtained, however, contained large quantities of water which had to be removed in one way or another before the dry solids could be subjected to the burning necessary for the recovery of the chemicals themselves.

This removal of water was very costly in fuel consumption, as also was the cooking and drying of the pulp. It is therefore easy to understand that in the older Swedish pulp mills fuel consumption was a very heavy charge and accounted for a considerable part of the (high) production costs. Reports show, for example, that a sulphate mill at the beginning of the 1890's was using no less than 1,200 kg of coal per ton of pulp, plus 2 to 4 cubic metres of wood fuel for alkali recovery.

With advances in technique, the possibilities of achieving a better fuel economy steadily increased, and even some decades ago it was already taken for granted that sulphate mills should be self-supporting with regard to fuel requirements. Whether such self-sufficiency in respect of fuel can be attained or not naturally depends on the equipment of the mill, in both the heat producing and heat consuming departments.

Nevertheless, there is no doubt that if, when modernizing older plants or buildings new ones, modern technique and existing experience are completely and properly applied, a sulphate mill can utilize the heat value of the black liquor in such a manner that no further fuel will be needed to cover manufacturing requirements.

1. *Recovery units*

Regarding heat balances in modern soda houses equipped with spraying units, experience is available in Sweden over a long period and from a large number of plants. Practically all the soda houses in Swedish mills were modernized, beginning in 1936, with units, such as Tomlinson or the like, in which the black liquor with a dry solids content of about 60 per cent is sprayed into the furnace.

The heat production obtained in the form of steam in Swedish plants is shown in table 2. The values given are taken direct from practical operating results. In all Swedish soda houses, in fact, measurements for the control of operation are carried out every year, and the figures in the table have been taken from measurements at about twenty plants. Certain plants work with appreciably lower heat production than others. There are many possible explanations for these differences. Inferior heat economy may, for example, be due to poor combustion, low dry solids content of the liquor, excess load, trouble with soot removal in the unit or many other things.

It should be mentioned here that the Bergström-Troback (BT) system has been employed for some years in one Swedish mill and, according to tests made there, furnishes a heat production of 3,325,000 kcal per ton in steam from the steam boiler and the final evaporator. With this BT-system the water contained in the liquor, after the evaporation plant, is removed in a closed evaporation apparatus before it goes to the furnace. The steam from this apparatus is delivered to the steam system of the mill and the liquor is conveyed to the furnace practically free from water.

2. *Liquor evaporation*

As already mentioned, the liquor has a dry solids content of around 60 per cent before being sprayed into the furnace. In Swedish sulphate mills the pulp is washed in diffusers, the black liquor from which has a solids content of around 18 per cent. Thus before reaching the soda house about 5.06 tons of water per ton of pulp need to be extracted from the liquor.

This is done in multiple evaporation plants, which used to be arranged in four stages, and are now more usually employed in five or more stages. With an increased number of stages plant cost will be higher, but the heat consumption less. In the case of new plants, the extent to which each stage will pay must be judged according to each individual case, taking into account the capital costs and actual costs for each stage, as well as fuel and power. Briefly it may be said that under the conditions at present prevailing in Sweden, it is generally quite justifiable to choose five stages for the evaporation plant.

With a vacuum five-stage plant, the heat consumption in steam for evaporation from 18 to 60 per cent dry solids content will be about 719,000 kcal per metric ton of pulp (see table 2).

3. *Cooking and drying*

The heat requirements for cooking and drying in different plants may vary quite considerably owing to differences in technical equipment, efficiency and operating conditions. However, it is not the main purpose of this paper to discuss heat consumption in different departments of the mill. The figures for the consumption of heat for cooking and drying shown in table 2 are based on a large number of measurements taken in Swedish mills.

Table 2

HEAT BALANCE SHEET OF A SULPHATE MILL

Conditions

Liquor containing 1,350 kg of solids per metric ton of pulp.
Net calorific value of the solids (in furnace) = 3,300 Kcal/Kg.
Evaporation in five-stage vacuum unit from 18 per cent to 60 per cent dry solids content of the liquor

	Minimum	*Mean*	*Maximum*
*Heat production*ª			
From recovery unit...	2,700,000	2,950,000	3 150,000
*Heat consumption*ª			
Evaporation.........	719 000	719,000	719,000
Cooking.............	811,000	1,061,000	1,658,000
Drying..............	680,000	861 00	969,000
	2,210,000	2,641,000	3,346,000

ª All figures in Kcal per ton of pulp.

From the above balance sheet it will be seen, among other things, that the amount of heat even from a mill having minimum heat production in its soda house would cover requirements for liquor evaporation, cooking and drying in the case of mills with "minimum" and "mean" consumption. Even in mills with "maximum" consumption it is as a rule possible to effect savings to enable total heat requirements to be covered from the soda house itself.

These figures therefore, based on practical operation, confirm that a modern sulphate mill under the conditions given should be self-supporting as regards fuel requirements.

II. SULPHITE

The world's first sulphite mill was built by the Swede, Carl Daniel Ekman, and put into operation in 1874. In this mill a magnesium base for the cooking acid was employed, but in mills built subsequently a change was made to calcium based liquor. By 1890 there were seventeen sulphite mills in Sweden with a total production of some 30,000 metric tons per annum.

In the sulphate industry, as stated earlier, it was a matter of necessity right from the start to recover the chemicals employed, owing to their high cost. There was no such incentive in the sulphite industry. A very long time passed, in fact, before the dry solids of sulphite liquor began to be utilized on a large scale for useful purposes.

A first step in this direction—and a very important one—was made when Ekström and Wallin solved the problem of producing alcohol from the sugar in the liquor. The first factory to put this idea into practice began in 1909. Nevertheless, only about 20 per cent of the organic substance contained in the liquor is actually utilized by the production of alcohol. At present there are thirty sulphite alcohol factories in Sweden, with a production capacity of about 72.5 million litres of 96 per cent alcohol per annum. This alcohol is employed in the manufacture of beverages, motor fuel and as a basic material in the chemical industry.

The first plant for the proper utilization of sulphite liquor was erected in 1920, and arose from troubles over water pollution. Evaporation was carried out in a plant with thermo-compressors and combustion together with coal took place in steam boilers. The plant was kept in operation for many years, but later closed down.

It was only toward the end of the 1930's that two Swedish plants went into service for the evaporation and combustion of sulphite liquor. Since then developments in this field have proceeded very rapidly and today about twenty plants making use of sulphite liquor are in operation in Sweden. In the largest plant so far erected about 6,800 kg dry solids are fired per hour. Two new plants are projected, where the amount of liquor will be equivalent to 15,900 kg dry solids per hour.

1. *Recovery of the liquor*

The amount of dry solids per ton of pulp remaining in the digester after the cook is completed depends, among other things, on the quaity of the pulp produced. It may be taken as about 475 kg per ton in the case of strong pulps and 635 kg for dissolving grade pulps.

Various kinds of washing methods may be employed in the liquor recovery operation. So far washing on filters has not been used for this purpose in Sweden. Instead, a more complete recovery is aimed at by displacement with waste liquor and water. Displacement may be arranged in the digester, but this prolongs digester-circulation time and lowers the output of pulp from a given digester volume. Displacement may also be executed in the pulp bins, and very good results have been obtained by this method. One plant employing the system has been in operation for seven months with extremely encouraging results.

When considering the conditions under which the sulphite liquor is recovered, it is convenient to introduce two terms by which the result may be expressed in simple terms. The first is the *substance yield* (U), i.e., the percentage ratio between the amount of solids recovered and the amount of solid matter in the digester liquor after cooking has been completed. The other is the *concentration ratio* (f), i.e., the precentage ratio between the solids content of the resultant liquor recovered and the solids content of the digester liquor after cooking has been completed. Experience with the plant mentioned above has shown that it is quite possible in practical operation to obtain results with "U" and "f" values both greater than 90 per cent.

In the calculations here, however, "U" and "f" have been conservatively taken at 80 with a dry solids content in the primary liquor in the digester of 13.5 per cent. On this basis the liquor recovered will contain 0.8 x 1,050 = 840 kg and 0.8 x 1,400 = 1,120 kg dry solids per ton of pulp for strong sulphite and rayon pulp respectively. These figures are equivalent to fuel values, in terms of dry solids, of about 515 and 685 kg coal per ton of pulp, taking a heat value of coal of 6,500 kcal per kg. On the above basis, the dry solids content of the liquor will be 0.8 x 13.5 = 10.8 per cent.

2. *Evaporation of the liquor*

While it is true in the example just given that the liquor recovered contains a quantity of dry solids equivalent to 515 and 685 kg coal per ton of pulp, the liquor is entirely useless as fuel until it has been freed from the greater part of its water content. The liquor's dry solids content must be raised by evaporation to 50 to 55 per cent before it can be used for firing.

At one Swedish plant, put into operation in 1940, evaporation of the liquor was carried right up to the dry state, and the solids fired as a dry powder. However, owing to difficulties of various kinds with this procedure, a change-over was later made to firing the liquor at about 55 per cent dry solids content, and this is also the case with all other Swedish plants. It is known, however, that in two foreign plants, at present under construction, the liquor will be fired in the form of dry powder.

Evaporation of sulphite liquor requires a complicated process presenting many difficult problems. The apparatus employed must be of acid-proof material, which involves high costs. The liquor's high content of calcium and sulphate ions creates a marked disposition to precipitate calcium sulphate during evaporation. The incrustations thus arising must be removable without the operation of the plant being appreciably disturbed. This calls for specially designed apparatus as well as appropriate arrangement and dimensions of the plant.

Two Swedish firms, AB Raméns Patenter and AB Rosenblads Patenter, up to now have been the only suppliers of evaporation plants to Swedish sulphite mills. These two firms, in order to maintain the heating surface in working condition despite incrustation, apply methods which differ in principle. Ramén divides the heating surfaces into a number of units, in such a way that *one* of these can be subjected to washing with water, without otherwise disturbing operation.

Rosenblad applies the channel alternation principle. This means that heat exchangers are made exactly alike on the liquor and steam sides, so that when incrustations have arisen on the liquor side of the heating surface, a switch-over can be arranged, and for a certain period the liquor side may work as the steam side. The incrustations, which are water soluble, are then removed by the acid condensate arising during operation. The washing action is intensified by circulation pumping of the condensate.

It is obvious that the large amounts of water which must be removed from the liquor before it can be employed as fuel require methods with low heat consumption per kg of evaporated water. The Swedish plants are all made as multiple-effect stations. The simplest arrangement with these is the multi-stage *vacuum station,* in principle arranged as for evaporation of black liquor in sulphate mills. With such stations the number of stages has to be selected to suit the conditions mentioned earlier in respect of black liquor evaporation. As a rule, at least five stages seem to be justified. The last stage in such a plant works under vacuum at a temperature of 50-60°C, while the steam is delivered to the first stage at a pressure of approximately 2.8 kg/cm^2.

In a five-stage vacuum station the heat consumption is about 150 kcal per kg of water. A lower consumption of specific heat is attainable if the evaporation plant can be arranged as a back-pressure evaporation plant. The waste steam from the last stage in such a plant leaves at such a high pressure that it can be used in the manufacturing processes to replace other steam, e.g., in the distillation plant, on the paper-making machine or in other plants consuming low-pressure steam.

It is the quantity of such low-pressure steam from the evaporation station which may be employed for useful purposes that determines the capacity limit per stage of the back-pressure plant. If in a particular case this amount of steam is given, the evaporation capacity of the plant will be equal to this amount, assuming that only one evaporation stage can be employed.

The total capacity will be approximately twice as great with two stages and four times as great with four stages. One is not entirely free to select the number of stages. With an increase in the number of stages a higher steam temperature is required in the first stage, and the properties of the sulphite liquor do not in fact allow a particularly high temperature.

In Swedish plants, so far, there is no experience with temperatures higher than about 168°C. Should it be desirable for the back-pressure steam from the last stage to have a temperature of about 120°C, the station can obviously be arranged with a maximum of four stages, as each such stage allows a temperature difference of about 12°C. The specific heat consumption for a back-pressure plant corresponds in the main to the heat losses to the surrounding air and is practically independent of the number of stages. It may be taken as amounting to one third to one fifth of that for a five-stage vacuum plant.

High temperatures in a back-pressure plant aggravate trouble with incrustation of the heating surfaces. It has been found by experience, however, that even these problems can be surmounted.

An evaporation plant for sulphite liquor should always be planned in the light of the conditions governing each individual case. A combination of vacuum and back-pressure plant may sometimes be possible. In sulphite mills combined with alcohol factories some very interesting possibilities, favourable in respect of heat consumption, have been found for directly combining distillation of the fermented liquor with the evaporation.

It should be mentioned that when considering liquor evaporation plants the possibilities of employing thermo-compressors also deserve study. It is possible with such equipment—according to prevailing conditions—to obtain a useful amount of heat equivalent of from 22,000 to 44,000 per kWh. A thermo-compressor requires clean steam to ensure reliable running; a Swiss firm has designed a washing device in which the evaporated steam is cleaned before reaching the compressor. Experience in the salt and sugar industries in Switzerland has confirmed that with this washing it is possible to run such a compressor with only a short stoppage for cleaning once a year.

So far there is no plant in Sweden employing thermo-compression for evaporation of sulphite liquor.

3. *Firing sulphite waste liquor*

After the liquor has been evaporated to a dry solids content of 55 per cent, it has a calorific value of about 2,000 kcal/kg. Whether any special arrangements in respect of combustion chamber, etc., are required for burning will depend on conditions in each individual case.

If a small amount of sulphite liquor is to be fired in a furnace where large amounts of other fuels are burned, it may be possible to spray the liquor direct into the furnace through a nozzle in which the liquor is atomized. With comparatively large amounts of liquor special arrangements are called for. Questions of furnace space and combustion arrangements are of particular importance when the liquor is to be fired alone or where it is to constitute the main part of the total quantity of fuel. In some cases it is quite possible for a sulphite mill to be self-supporting in respect of fuel, providing the liquor is utilized properly.

To allow the water remaining in the liquor to evaporate rapidly in the furnace, a high temperature is required around the waste liquor nozzle. In a modern fully cooled combustion chamber the requisite temperature cannot as a rule be attained with liquor firing alone. It is, however, frequently possible with uncooled furnaces having bricked walls. Experience covering many years is available from such plants, i.e., shows that firing of the liquor is quite as trouble-free as firing with oil.

At the Loddby Sulphite Mills in Sweden, around the year 1950, a special device was developed for the firing of sulphite liquor which has now found employment in a number of plants under the name of the Loddby Furnace. This furnace consists in principle of a sheet metal cylinder, which is bricked in. The waste liquor is delivered through a nozzle in the outer end plate, and air is conveyed tangentially along the whole length of one or two generatrices. The length of the Loddby furnace is about 3 m, and the inside diameter 1 m to 1.20 m. The capacity seems to be 4,500 to 6,300 kg of liquor per hour.

It is possible for four Loddby furnaces to be arranged for firing a steam boiler, in which pulverized coal, oil, waste wood and sulphite waste liquor are to be used either simultaneously or separately. The Loddby furnaces are placed in the two side walls. The four oil burners are located in the two other walls of the boiler furnace. Coal is fired through burners in the four corners and the waste wood in a Dutch oven. Such a plant is in operation and is giving fully satisfactory results.

When using the Loddby furnace, it is possible to fire the liquor whether or not other fuels are fired at the same time, and even irrespective of whether the main furnace walls are cooled or not. With the high temperature prevailing in the furnace, drying and combustion of the liquor proceeds rapidly. Up to a given quantity of liquor per unit of time, combustion of the liquor is complete. With a further increase in quantity of liquor, combustion (of the liquor) in the Loddby furnace is not complete, and final combustion takes place in the boiler furnace. Investigations of plants in operation have shown that the combustion taken as a whole is practically complete, i.e., without losses due to unburnt substance in the ash.

When firing substantial quantities of liquor in a steam boiler, it may be difficult to find space for the large number of Loddby furnaces which would be required. Efforts are being made therefore to find other means of designing firing devices for the liquor. At a plant now under construction, in which about 31,750 kg of liquor are to be fired per hour, this problem has apparently been solved.

The waste liquor is a fuel rich in ash, requiring special arrangement of the heating surfaces of the boiler. Whether trouble will arise in keeping the heating surfaces clean will depend to a certain extent on the temperatures of the tubes and their distribution. Troubles increase also with increasing flue gas temperature. The boilers have to be made with large furnace chambers of great height, and superheaters preferably with suspended coils. Suitable soot removing devices must be built in. The steel shot cleaning method has also been applied for soot removal in economizers and air preheaters.

4. *Heat balance*

Table 3 gives the heat amounts in steam which can be obtained when firing with sulphite waste liquor, containing 55 per cent solids, and the quantities of dry solids per ton of pulp stated under the heading "Recovery of the liquor" (see page 385).

As previously stated, these dry solids are equivalent to 515 and 685 kg coal per ton of pulp for strong sulphite and rayon grade respectively. With liquor having a dry solids content of 55 per cent when fired, the *liquor's* fuel value represents 470 and 625 kg coal per ton of pulp for strong sulphite and rayon grade respectively. Whether or not this amount of fuel will suffice to meet the heat required for manufacture will be governed by circumstances in each particular case. To throw light on this question, table 3 also includes the heat requirements for evaporation of the liquor and for cooking and drying. The heat consumption for drying has been calculated at the same figures as for sulphate mills. Heat consumption for cooking has been investigated at a number of plants and the values arrived at are summarized in the table.

Table 3

HEAT BALANCE SHEET OF A SULPHITE MILL

Conditions	*Strong sulphite pulp*	*Rayon pulp*
Quantity of solids in primary liquor (kg per ton)	1,050	1,400
Primary liquor solids content (per cent)	13.5	13.5
U=f (per cent)	80	80
Quantity of solids in recovered liquor (kg. per metric ton)	840	1,120
Net calorific value of the liquor[a] as fired (kcal per kg	2,000	2,000
Boiler efficiency (per cent)	80	80
Heat production[b]		
From liquor combustion	2,347,000	3,200,000

Heat consumption[b]	*Strong sulphite pulp* *Min.*	*Mean*	*Max.*
Evaporation	950,00	950,000	950,000
Cooking	719,000	961,000	1,477,000
Drying	680,000	861,000	969,000
	2,349,000	2,772,000	3,396,000

	Rayon pulp *Min.*	*Mean*	*Max.*
Evaporation	1,300,000	1,300,000	1,300,000
Cooking	1,011,000	1,330,000	1,600,000
Drying	680,000	680,000	680,000
	2,991,000	3,310,000	3,580,000

[a]After evaporation in a five stage vacuum station.
All figures in kcal per ton of pulp.

It will be seen from the figures given that the heat requirement with minimum consumption is lower than the amount of heat produced with liquor firing. The amount of heat produced with liquor firing has, however, been estimated conservatively, as regards both the amount of heat produced with liquor firing has, however, been estimated conservatively, as regards both the amount of dry solids recovered and the efficiency of the boiler. Liquor evaporation has been taken as occurring in a five-stage vacuum station, whereas in some cases, e.g., where back-pressure evaporation can be employed, the heat consumption will be appreciably lower.

The difference in heat consumption for cooking and drying, between the best values and the worst values, is very large. These values have been taken directly from measurements at mills in actual operation, and the great differences suggest that in many cases possibilities exist for obtaining considerable savings in heat consumption.

This observation is borne out by practical experience at a number of mills. As in the case of the sulphate mills, problems of secondary heat have not been taken into account. They are nevertheless of the utmost importance, particularly for mills producing highly-processed pulp. The importance of a well-planned secondary heat system to the whole manufacturing process can hardly be overestimated.

5. *Plant cost*

It is difficult to state general rules for cost of plant in different cases. Nevertheless, Appendix 1 gives some costs for a sulphate mill, while corresponding information relating to a sulphite mill is shown in Appendix 2. The costs stated are approximate and are based on the price levels prevailing in Sweden in March 1954.

The costs relating to sulphite waste liquor evaporation (Appendix 2) are of special interest. Hence the ratio between cost of plant and the current price for coal evidently plays a large part in judging the economy of a plant of this kind. It may be remembered that with the price levels which have prevailed in Sweden up to now, all plants so far built for sulphite waste liquor evaporation have provided profits through fuel savings.

If fuel prices were lower, the economic advantage would be less. The calculation in Appendix 2 shows that the "savings" or replacement value of coal when sulphite liquor is utilized as fuel lies around $11 to $12 per short ton. This is about the same price at which coal can be purchased in Sweden at present. These calculations are very conservative, however; for instance a short amortization period (ten years) has been allowed compared with the estimated length of life. This means that high capital costs have been allowed, decisively affecting the calculation.

Appendix 1

Black liquor utilization in sulphate mill

Conditions		
Pulp production	tons per day	100
Dry solids content of black liquor:		
Before evaporation	per cent	18
After evaporation	per cent	60
Quantity of dry solids	kg per ton of pulp	1,350
Soda house boiler	40 kg/cm and 400°C	
Investment:		
Soda house recovery unit (including instrumentation, electro-filter, feed-water pumps, water treatment plant, etc.)		$ 800,000
Building		200,000
	Total	1,000,000
Evaporation plant[a]		200,000
Building		60,000
	Total	260,000
	Grand total	1,260,000

[a] Five-stage vacuum station.

It is not always possible, however, with fuel savings alone as a guide, to judge whether a plant for recovery of sulphite liquor should be installed or not. Many other factors are of significance. It may well be necessary, in the future, to recover the waste liquor, even if the immediate benefits do not appear so attractive as they have been so far with plants already in use. It is hard to say whether water pollution or similar problems, or the need to save fuel and utilize natural resources, will prove to be the deciding factors.

Appendix 2

Sulphite liquor evaporation

		Strong sulphite pulp	*Rayon grade pulp*
Conditions			
Pulp production	tons per day	100	100
Pulp production	tons per hour	4.17	4.17
Liquor from digester			
Dry solids content in primary liquor	kg per ton	1,050	1,400
Dry solids	per cent	13.5	13.5
Concentration ratio	per cent	80	80
Substance yield	per cent	80	80
Liquor to evaporation plant[a]			
Quantity	kg per hour	32,400	43,300
Dry solids	per cent	10.8	10.8
Liquor from evaporation plant			
Quantity	kg per hour	6,300	8,300
Dry solids	per cent	55	55
Quantity of water evaporated	kg per hour	26,000	34,800
Net calorific value of the thick liquor	kcal per kg	2,000	2,000
Boiler efficiency	per cent	80	80
Total operation time per year	hours	7,000	7,000
Total investment costs for plant (including complete evaporation station and building equipment for burning the liquor in existing boilers, etc.)		$550,000	$650,000
Capital costs per year[b] (calculated as 20 per cent of total capital costs as above)	per year	$110,000	$130,000
Fuel saved (coal of 6,500 kcal per kg	tons per year	8,150	10,900
Costs for fuel saved	$ per ton of coal	13.6	11.9

[a] Consisting of a five-stage vacuum station.
[b] I.e., 10 per cent amortization (ten-year period) plus 3 per cent interest (rate 6 per cent); to this is added 7 per cent as a rough estimate of additional operating expenses (repairs, power consumed in the evaporation plant, miscellaneous materials, etc.).

ECONOMIC ASPECTS OF POWER AND STEAM PRODUCTION IN THE PAPER INDUSTRY[1]

G. Ranwez

The paper industry is one in which electric power and steam consumption exert a considerable influence on production costs. The variety of raw materials and the different types of process employed make it impossible to cover all cases in a single study, or, consequently, to determine the optimum conditions. Each individual mill needs to be carefully studied from both a thermal and financial point of view.

There are, however, certain requirements that are common to all pulp and paper mills. Considerable quantities of steam at a pressure of 3 ata. and smaller quantities at 8 ata. are required. Consumption of the latter is irregular, but by taking certain precautions the highest peaks can be absorbed.

The electric power required is usually proportional to the consumption of low-pressure steam (3 ata.), but under abnormal conditions the two can be entirely independent. There should be sufficient reserves of power produced by condensing to absorb any variations.

The mill's production programme and the existence of auxiliary plants will modify the ratio between power and processing steam.

The following estimates are based on model plants in which only the pressure and temperature of the steam differ (see table 1).

Bleeding at 8 ata. and at 3 ata. takes places in the turbines, and a pressure of 0.06 ata. is maintained in the condenser.

The calculations are based on a normal load. Had partial loads been taken into account, it might have caused variations in the bleeding yields, depending on the types of turbine.

It is assumed that 80 per cent of the steam used in the manufacturing operation is returned in the form of pure condensed water at 80°C. The remaining 20 per cent covers losses occurring in the generating plants and mills.

The feed water is evaporated in a two-stage evaporating system; the steam from the second stage heats the water returning from the plant and the condensed water of the condensing turbine. One ton of steam at 3 ata. is taken as evaporating 1.6 tons of water; 0.9 is taken as being the thermal yield of evaporation. (The actual yield is, in fact, somewhat higher). Providing steam is available by bleeding, and that it can be utilized completely, this system is by far the cheapest, both as regards installation and operating costs.

Upon leaving the bleeding pumps, the temperature of the condensed water of the turbine is 40°C or less—it is assumed that upon leaving the condenser of the air ejector it will be 50°C. The power of the circulation pumps is not considered, since it is assumed that all the water utilized passes through the condenser.

The condensed water from the turbine, mixed with that returning from the plant, is heated and the air extracted from it in a direct interchanger and de-aerator, with steam at 3 ata.

The feed pumps transport the mixture to the boiler through an indirect interchanger which receives steam at 8 ata. The condensed water from this heater returns to the de-aerator. The power absorbed by the feeding pump is around 0.00522 kW/tons per metre of lift required. A boiler yield of 86 per cent is assumed. That efficiency is high for the lower pressure units, and in the last stages of the calculation it is reduced to 83.5, 82, 80.8, 80 per cent for 42, 30, 20 and 15 ata.

On the basis of these values it is possible to calculate the net power produced by a ton of steam at 8 ata. and 3 ata. which is piped to the plant and the electrical power produced per ton of steam which goes from the boiler to the condensation cycle.

These values are then applied, by way of example, to a model plant producing 100 tons per day with the following installation and requirements:

15	ton/hours of steam at 3 ata.
4	ton/hours of steam at 8 ata.
4,500 kW	in the plant (paper—pulp)
250 kW	for pumping water used in manufacture
150 kW	various auxiliary units
100 kW	light and workshops
5,100 kW	

Table 1 shows the distribution of power within the different steam circuits in terms of live steam pressure:

It is thus evident that high pressures lead to considerable economy in fuel consumption. However, installation costs have also to be taken into account.

Table 2 is compiled on the basis of the following assumptions, which would vary only slightly with the

[1] A shortened version of the original paper, ST/ECLA/CONF.3/L.6.8.

Table 1

Pressure ata	KW produced per ton of steam to plant: 3 ata (a)	8 ata (b)	Total (c)	kW lacking (condensation 5,100—(c)) (d)	Tons steam to condensation cycle (e)	Tons steam from boiler (f)	Consumption of fuel oil (tons per ton of paper) (g)
90	2530	666	3196	1904	8.5	33.3	0.612
60	2340	593	2933	2167	10.1	34.9	0.632
42	2000	483	2483	2617	13.2	38.0	0.687
30	1765	403	2168	2932	15.8	40.6	0.735
20	1360	269	1629	3471	20.3	46.1	0.815
15	1110	183	1293	3807	25.5	50.3	0.876

(f) Steam to plant x 1.22 + (e) + 0.4 ton for losses in the turbine.

Table 2

POWER COSTS PER TON OF PAPER

(*Argentine pesos*)

Pressure data	*Fuel*	*Amortization inst. machinery, boiler turbine*	*Amortization inst. building and electrical equipment*	*Personnel*	*Cost of thermal and electrical power*
90	157.5	31.40			227.70
60	162.5	27.70			229.0
42	179	25.70	17.30	21.50	243.50
30	190.5	25.70			255.0
20	208	23.60			270.40
15	228	22.10			288.90

pressure: an amortization of 6 per cent over twenty years, 7,800 working hours per year, fuel oil at 270 Argentine pesos per ton, four workers for supervising, three maintenance workers in each shift, a cost of 6,500,000 Argentine pesos for buildings and electrical equipment.

The difference in the cost of power (thermal plus electrical) is remarkable; the higher the cost of fuel and the lower the cost of machinery, the more pronounced will be the difference.

Many installations utilize low pressures and can improve their power costs by installing additional turbines, provided that the output of existing units is reasonable.

It is expedient to make the maximum use of extracted steam as the electrical power thus obtained is very cheap, although the mistake should not be made of believing that it costs nothing at all.

Power is a costly item in paper making. In general there is a tendency to increase existing pressures. Every case requires detailed study which should take into account the cost of machinery and fuel, operational difficulties and safety measures.

THE ASCHAFFENBURGER PROCESS OF MANUFACTURING NEWSPRINT FROM BAGASSE[1]

RUDOLF SCHEPP

The manufacture of newsprint from sugar cane bagasse has frequently been suggested, since bagasse fibre is cheap and might be expected to compete easily with the normal basis of newsprint (80 per cent groundwood and 20 per cent unbleached sulphite pulp). The cost of bagasse at the sugar mill is determined solely by its value as fuel, and the subsequent costs involved in getting the bagasse to the pulp mill (removing the pith, pressing into bales, drying, etc.) are mainly labour costs. Bagasse thus appears to offer considerable advantages over wood as a raw material, since wood has to be planted, cultivated, cut, transported, barked, stored and chipped. It is this financial advantage which makes it economic to treat bagasse by a chemical process; indeed, unbleached chemical pulp from bagasse is cheaper than the mechanical and chemical pulp mixture usually used for newsprint. Because of its special characteristics bagasse cannot be converted into pulp by the normal mechanical process, and a suitable cooking process is absolutely necessary.

Although all known previous experiments aimed at producing newsprint from bleached bagasse, it was decided, for reasons of both cost and quality, that experimental work should be directed to the production of newsprint from unbleached bagasse pulp.

The difficulties of manufacturing good quality pulp from bagasse are well known. The raw material is unequal, some parts being relatively easy to cook, others showing strong resistance; the resultant unbleached pulp is dirty and dark in colour.

The inequalities in the raw material are due to the physiological structure of the sugar-cane stem. The ground tissue consists of short thin-walled cells, which we call pith. A transverse section shows the pith extending right across, with the fibre bundles embedded therein. Passing from the outside to the inner part, the cells become larger and wider, though the wall thickness does not increase correspondingly. The fibre bundles are irregularly spread over the transverse section, denser at the edge, the interstices larger towards the centre. Each fibre bundle contains four vessels, three sieve-like, the fourth forming a thick-walled ring vessel. Finally, at the surface is found a thin but very dense epidermis composed of two layers, the lower consisting of attenuated, poorly perforated, parenchymatous cells, the upper of skinlike or squamiform formations, arranged diagonally to the parenchymatous cells of the lower layer.

The cells of this epidermis dissolve very slowly and incompletely during the cooking process, leaving troublesome residues in the finished pulp which usually appear as dark-coloured pollutions.

The reaction of each of the three main elements—pitch, fibre bundles, epidermis—to the cooking process is very different. The pitch offers the lowest resistance to the penetration and influence of chemicals. The inner fibre bundles dissolve much more easily into single fibres than does the external layer, with its high lignin content.

[1] A slightly shortened version of the original paper (ST/ECLA/CONF.3/L.6.9), which gives details of the production cost estimate.

The epidermis usually breaks down only into larger cell-particles.

Investigation in the Aschaffenberger laboratories proved that if the different parts of the stem are processed separately, the yield of the pith part is about 15 per cent lower than that of the other part. The physical properties of the pith as well as the fibre part proved to be surprisingly favourable even in unbeaten state, whilst the epidermis appeared in this respect to be completely useless. It is especially striking that pulp made out of pure pith is already, in an unbeaten state at 40 S.R., very suitable for parchment and at the same time shows already a folding endurance of more than 6,000. The tearing strength of the pith is, of course, considerably below that of the fibre.

Whilst the pith and the fibre bundles can be separated from each other with surprising ease, the epidermis unfortunately tends to adhere to the fibre bundles.

The pith may be removed in two ways: (*a*) mechanical treatment in the dry state, followed by sieving; in this way many fibres escape; or (*b*) mechanical treatment in the wet state, the pith-cells being washed away. Excellent results have been obtained with the wet treatment.

The proportions of the three elements vary with growing conditions and the age of the stems. On average, however, the dry substance of the stem consists of 5 per cent epidermis, 50 per cent fibre bundles from the external layer with a high lignin content, 15 per cent inner fibre bundles, and at least 30 per cent pith. If the various elements are cooked separately, it becomes clear that the fibres in the external bundles are longest, those in the inner layers being considerably shorter. The fibre cells of the external layer have much thicker walls than those of the inner layer.

As a rule, when bagasse is processed it is not in a fresh state since harvesting is rarely continuous. In those countries with a long grinding season—up to eleven months—it is desirable to process fresh bagasse to avoid the expense of baling and storing. A further advantage is that newly dried bagasse yields a better quality pulp. In this case pith removal by the wet method is advisable.

In most countries, where the grinding season is much shorter, the bagasse has to be dried and stored before it is processed. The composition of these pressed bales of stored bagasse is very different from that of fresh bagasse. The proportion in which the different elements are found is upset, e.g., much of the pith trickles away with the molasses when pressed. Moreover, when bales are stacked in a tropical climate, a strong fermentation process starts within a few days. During fermentation, the colouring matter in the epidermis is partly destroyed, which is welcome; but on the other hand, the growth of many kinds of fungi, which lead to troublesome pollutions, is facilitated. If the pith is removed by the wet method, the coloured mycels of the fungi are separated at the same time. A very clean raw material is obtained which yields a much brighter pulp than does uncleaned bagasse. It is a pity that the removal of these strongly coloured spores is not possible without simultaneously separating off the pith, since the latter has no detrimental effect on the pulp.

To make newsprint from unbleached pulp, much depends on obtaining the best possible bright pulp. Fundamentally, the choice lies between the neutral sulphite process and an alkaline pulping method. The first is preferred since (*a*) the difficulties caused by lack of homogeneity in the material are easier to overcome, (*b*) brighter pulps are produced, (*c*) relatively few chemicals are required, (*d*) a higher yield is obtained, and (*e*) the method offers the possibility of adaptation to the pulp quality required, i.e., different qualities of paper can be produced, varying in strength, softness and opacity.

Another reason for the conclusion that a modified neutral sulphite is the most suitable method for making newsprint from bagasse is its avoidance of any hydrolysis, thus giving high yield and pulp qualities of a high degree of polymerization. A carefully regulated per-hydrolysis makes it possible to adapt the pulp character to the final product desired, i.e., to make pulp of qualities comparable with those of semi-chemical pulp. Those parts of the sugar cane which are difficult to defibrate can be made to yield a regular hard pulp; and soft quality pulps can be produced which are excellent for bleaching and which show first-class properties for the manufacture of fine paper.

To obtain a regular, even pulp, a loss of substance of about 17 per cent must be reckoned on, mainly due to the freeing of the pentosans. The subsequent cooking with sodium sulphite can be greatly varied. Generally, cooking temperatures of 150 to 160°C are practicable. Sodium sulphite is added in quantities corresponding to between 8 per cent and 16 per cent of the absolute dry weight of the bagasse, with about 2 per cent of additional sodium as buffering. Yields then vary, according to the quantity desired, between 55 per cent and 68 per cent. Given a well prepared and cooked pulp, yield will be about 60 per cent. A higher figure means almost semi-chemical pulp qualities; 68 per cent yield corresponds to the limit of technical defibration. Higher yield of course involves loss of strength and quality in the papers produced.

PHYSICAL TESTS ON BAGASSE AND SPRUCE SULPHITE PULPS COMPARED

	Bagasse neutral sulphite	*Bagasse sulphate*	*Spruce sulphite*
S.R.°	70°	70°	45°
Breaking length	7.000 m	7.000	8.500
Folding endurance	2.000	1.500	4.000
Bursting strength	35	30	60
Tearing strength	125	100	150
Initial wet strength	90	45	120
Whiteness	54 per cent	33 per cent	64 per cent

By "initial wet strength" is meant the strength of a paper before the drying process. It is this figure which determines whether the machine can be run at normal speed. Insufficient tensile strength in the wet paper imposes a low running speed. Spruce sulphite is, of course, superior to bagasse pulp in breaking length, folding endurance and tearing strength. But if the qualities of groundwood pulp are taken into account, it is evident that neutral sulphite bagasse pulp is not inferior in quality to the conventional mixture of groundwood and spruce sulphite pulp.

A comparison of the physical tests on newsprint papers from bagasse and on standard newsprint showed the bagasse newsprint to be superior in breaking length and folding endurance:

		Bagasse	Standard newsprint (spruce)
Breaking length	m.d.	3,810	2,570
	c.d.	1,670	1,400
	Ø	2,740	1,985
Folding endurance	m.d.	17	8
	c.d.	4	2
	Ø	11	5
Whiteness		56	59

The Aschaffenburger method for manufacturing newsprint from bagasse may be summarized as follows:

The pith is separated from the dried bagasse either by a hammer-mill and sieving or by special wet treatment. The bagasse is then heated with water up to 125°C, the water is run off and the bagasse rewashed with hot water according to a special method. The cooking liquid, containing 10 kg caustic and 3.5 kg sulphur per 100 kg of dry bagasse, is then pumped into the digester. After washing out, the cooked material is brought to a suitable sorting machine; those parts remaining uncooked are then mechanically defibrated in a refiner. After careful sorting, the pulp is then made into newsprint by adding filling material and rosin.

Several hundred tons of bagasse have been processed on an industrial scale by this method, and newsprint has been made from this pulp on large paper machines. Papers both of 100 per cent bagasse pulp and of bagasse pulp mixed with 10 per cent conifer pulp have been produced.

The resultant papers have been printed in Germany on normal rotary presses and have been well received.

The estimated production cost of the slush pulp, $68, is about the same as that of a mixture of groundwood and sulphite, as estimated by FAO experts. This estimated production cost is well below present world market prices.

COST ESTIMATE BAGASSE

PROCESS: NEUTRAL SULPHITE OR MONOSULPHITE

(Production cost in dollars per ton of slush pulp)

	Unbleached pulp yield 62 per cent			
	Quantity	Unit cost	Cost per ton	Total
Bagasse cleaned	1.60	10.00	16.00	16.00
Chemicals (kg)				
Sodium hydroxide	160	0.077	12.32	
Sulphur	48	0.030	1.44	
Miscellaneous			1.00	14.76
Operating expenses				
Steam (and power) (m.t.)	4.3	1.65	7.10	
Water (m^3)	75	0.013	0.98	
Labour: (man/hr)				
Operating		1.70	11.90	
Repair	0.5	2.50	1.25	
Repair and maintenance materials			2.00	
Factory supervision and overheads			5.00	
Depreciation on plant and equipment			9.00	37.23
Estimated production cost of slush pulp				67.99

THE DEFIBRATOR CONTINUOUS SEMI-CHEMICAL PULPING PROCESS[1]

AKTIEBOLAGET DEFIBRATOR

Although the fundamentals of semi-chemical pulping of wood were known twenty-five or more years ago the development from the laboratory stage to industrial production took quite a long time. Once started on an industrial scale, however, production increased rapidly, especially in the United States; output of semi-chemical pulp in that country in 1952 was about 740,000 tons and the preliminary figure for 1953 is 925,000 tons.

Ninety to ninety-five per cent of this production is used in the manufacture of corrugating board. Semi-chemical pulp can also be used, either alone or mixed with other pulps, for a wide variety of paper and board grades. Its high hemi-cellulose content makes it easy to refine, and it can be bleached to almost the same brightness as regular bleached pulp, while retaining surprisingly good strength properties. A steadily increasing number of uses are likely to be found for semi-chemical pulp.

Practically any type of ligno-cellulosic material can be processed into semi-chemical pulp provided proper chemical treatment and suitable agents are selected. Some species of wood which are not readily pulped by the conventional processes can be advantageously made into semi-chemical pulp; this process does not therefore necessarily encroach on the raw material supply of existing pulp mills. Such types of pulpwood as unmarked wood and small dimensions of wood, e.g., slabwood, can be used. It is also possible within limits to process a mixture of different types of wood, which gives the process a particular importance in the exploitation of subtropical and tropical woods.

[1] This is a very slightly shortened version of the original paper, (ST/ECLA/CONF.3/L.6.10), which includes photographs of the machines described and a chart showing the sequence of operations in the Defibrator process.

Deciduous woods are particularly suitable for the semi-chemical process by virtue of their relatively low content of lignin and high content of cellulose and hemi-cellulose.

In the United States, deciduous woods have become the chief source of raw material for semi-chemical pulp. However, both in the United States and Europe increasing quantities of coniferous woods are being processed by the semi-chemical pulping method because of the large savings effected in wood consumption.

In the course of the last ten years a large number of ligno-cellulose materials have been investigated in the laboratory of A B Defibrator to establish whether they could be semi-chemically treated.

The various semi-chemical processes offer considerably higher yields than the full chemical processes but this advantage was partly balanced in the earliest stages by a higher cost for chemicals, calculated on the basis of pulp produced. By recovery of used cooking liquor and other improvements in the chemical and mechanical process, however, the cost of chemicals can be substantially reduced.

Depending upon the type of raw material, amount of chemicals used, etc., the yield may vary from 60 to 85 per cent of the dry weight of the wood. This compares with 40 to 50 per cent reached in the conventional chemical pulping processes. The high yield obtained in semi-chemical pulping processes is of great importance if the supply of raw material is limited; this is one of the reasons why semi-chemical pulp is likely to gain even in forest areas which until now have been the chief suppliers of pulp and paper. Important, too, is the fact that the semi-chemical pulp mills can be built in relatively small units and still be economic. Sulphite and sulphate mills built today must be of considerable size if unit cost is to be kept low.

As far as tropical and subtropical regions are concerned the supply of wood is usually abundant; thus the need for strict economy in wood utilization is not so imperative. But the costs of felling and transporting wood from such forests to industrial sites are usually so considerable that a high yield pulping process is indispensable if competitive manufacturing costs and prices are to be obtained.

Up to now a number of different semi-chemical processes have been developed, both continuous and batch processes. For various reason A B Defibrator recommends the continuous semi-chemical process, particularly when a completely new plant is contemplated without relation to some previously existing pulp mill.

The advantages of a continuous semi-chemical pulping system as against a batch system may be enumerated as follows:

(a) Smaller units required; therefore less space needed.

(*b*) Greater flexibility.

(*c*) Closer operating control, often automatic.

(*d*) Lower maintenance cost.

(*e*) Saves electric power and steam.

(*f*) Requires less man-power.

(*g*) Smaller installation costs and building costs.

In North America there are at present ten mills, in which nineteen Defibrators have been installed, with a combined annual capacity of 260,000 tons of semi-chemical pulp. Semi-chemical mills using Defibrators are also established or being built in Denmark, England, Finland, France, Germany, Norway, Sweden and Switzerland.

In the special continuous semi-chemical pulping method developed by A B Defibrator the raw material is impregnated with a solution of chemicals at atmospheric pressure and temperature conditions. (In a modification of the process the impregnation is carried out under pressure). The impregnated material is then continuously few by a "rotary feeder" into the extended pre-heater equipped with conveyor screws with interrupted screw flights. These screws are designed to exert a considerable mixing action on the material, ensuring a uniform heating up and complete distribution of the chemicals. The heating is done by direct introduction of steam at a pressure of from 8 atmospheres (110 p.s.i.) to 12 atmospheres (170 p.s.i.) depending upon the raw material under treatment and the chemicals employed. The size of the pre-heater is selected to correspond to the capacity of the plant and the desired pre-heating time, which may range from fifteen minutes up to two hours or more. The pre-heater can also be constructed for heating in consecutive steps, for instance if successively raised temperatures are desired, to suit a pre-selected digesting diagram.

After passing through the pre-heater the material is conveyed to the grinding zone of the Defibrator plant where the final defibration is taking place before the material is released from the high pressure steam environment to atmospheric conditions. A considerable part of the heat of the steam can be recovered as hot water at temperatures around 60° to 70°C.

In the Defibrator the treatment can be adapted for the production of different kinds of paper pulps, unbleached, semi-bleached or bleached.

Depending on the type of chemicals used, the pulp passes through presses or filters for recovery or re-use of as much as possible of the chemicals. This removal of the chemicals from the pulp is of advantage for the further processing of the pulp and avoids stream pollution.

Depending on the type of pulp produced and its final use the pulp may be refined in one or more steps. When needed for high grade products the pulp may also be screened.

The development of modern high precision and high capacity disc refiners has greatly widened the application of semi-chemical pulp for different grades of paper. The Raffinator type RF designed by A B Defibrator is particularly suited for refining semi-chemical pulp. High precision setting of disc clearance makes it possible to reach and reproduce the desired refining effect. The capacity of the Raffinator is very high, and the refining action is so effective that screening and other after treatment can be reduced to a minimum.

MODERN PULP-SCREENING EQUIPMENT AND SYSTEMS[1]

KARL LINDGREN

An investigation of raw materials available in the world for the production of pulp has shown that an increase in production cannot be based on long-fibred coniferous wood alone, even allowing for large-scale plantations of fast-growing species of softwoods suitable for pulping. An increasing amount of pulp will therefore come from shorter fibred raw materials: from broad-leaved species of timber, and from residues. In general it may be concluded that the quantity of paper made from pure long-fibred pulp will tend to decrease while that from mixed pulps and from short-fibred pulp alone may be expected to increase.

Higher demands on quality—both for long-fibred and short-fibred pulp—are also to be expected. Cleanliness is one of the factors greatly influencing the classification of the pulp, since in many cases it determines the fitness of the material for certain kinds of paper and board. It follows therefore that choice of screens and screening systems is of very great importance.

The ideal screen—one able to remove all dirt from the pulp—has not yet been invented; at present much of the dirt found in a pulp is able to pass through the holes or slots in a screen plate. Moreover, in some kinds of screen, dirt particles initially larger than the holes or slots may eventually pass through, following retention on the screen long enough for them to be broken up into smaller pieces. The efficiency of a screen depends on its design—the time the pulp remains in the screen, the kind and the quantity of dirt present in the pulps, the pulp consistency and the overscreening percentage.

The overscreening percentage, or the overflow, is perhaps the most important factor. It contains acceptable fibres together with a concentration of dirt particles. To prevent too large an amount of acceptable fibres going out with the rejects from the screening department, it is necessary for most kinds of pulp to adopt a multi-stage screening system.

Certain types of screens have a greater ability to remove long particles (slivers and shives) than spherical and round particles; others remove the round dirt particles but are less effective in removing the shives. Consequently a combination of various screen types in one screening system is often advisable. While it is important to choose the right screen for a certain kind of pulp, it is even more important to choose the right screening system. Most kinds of pulp contain free ray cells, fibre fragments and other fine particles, all of which may be termed "naught-fibres". These particles should also be regarded as a kind of dirt. In sulphite pulp, for instance, a great part of the resin is to be found on the "naught-fibres". By removing these so-called "naught-fibres", the sulphite pulp will have a lower resin content and increased brightness. Removal of this unwanted matter will also improve the quality of pulps prepared from waste paper and from agricultural residues such as bagasse.

Separation methods differ in the types of equipment used, but the most efficient entails spraying the pulp at low consistency against a moving wire of fine mesh. Sometimes, even after correct screening, the pulp still contains too much dirt and other steps have to be taken.

The dirt enters the pulp during the manufacturing process together with the raw material and the water. To obtain a pure pulp it is necessary to bark and sort the wood. Straw, bagasse and similar raw materials must be cut, well screened and dusted before cooking.

If the moisture content of the chips is not uniform, and this condition is not equalized by steaming before cooking, chemical absorption will be uneven. Furthermore if the maximum cooking temperature is reached in a short time, some of the chips are likely to have a discoloured core which is difficult to defibrate and may give rise to a considerable amount of impurities. Tropical hardwood and similar raw materials give pulps to varying quality; mixed together these qualities may cause serious difficulties of the kind just mentioned. Another important factor is how the pulp is treated as it passes from the digesters to the screening department.

The investment costs of a screening department laid out in the best possible way are not high. The pulp need not be cleaner than is required for its ultimate use. For certain qualities of pulp a high-class screening department may give a satisfactory result even on wood which has not been perfectly barked. The saving in raw material and labour will quickly offset the difference in investment cost between a first-class screening department and a cheaper one. The features characterizing the most common screen types are outlined below in six main groups A—F:

GROUP A. FLAT DIAPHRAGM SCREENS

These low-frequency vibratory screens operate at 200-500 vibr/min. and are generally equipped with slotted screen plates. Most sulphite mills and many sulphate ones still use a great number. In new installations, however, fewer screens of this type are to be found and usually only for the final stage of screening.

As a rule flat screens are arranged in series, and it is usually necessary for the unscreened pulp to be fairly well diluted at several points along the screen line. When screening unbleached sulphite pulp, the consistency of the ingoing fibre suspension is often 0.5 to 0.7 per cent, while the consistency of the screened pulp may be around 0.25 to 0.35 per cent owing to dilution during the screening process. Where only flat diaphragm screens are used, the consumption of water will be very high, leading to increased investment cost for thickeners, pumps and pipe lines as well as greater power consumption. Although flat diaphragm screens have a high capacity for separating spherical impurities, they tend to allow long impurities (shives) to slip through. The slots of the screen plates are arranged in the direction of flow, and as the shives in the fibre suspension also align themselves in this same direction, there are many opportunities for them to pass through the slots. This applies particularly to the last screens on the line, where the dirt concentration is high.

The capacity of flat screens is rather low and the space required per ton of screened pulp is consequently high.

[1] Originally issued as ST/ECLA/CONF.3/L.6.11.

Moreover, as well as being sensitive to variations in the quantity and consistency of the pulp being screened, they require a good deal of maintenance. Often the plates have to be cleaned while the unit is running, and since it is necessary to do this from the outside, dirt may get into the accepted stock during these cleaning periods.

Group B. Low-consistency frequency rotary screens

To this group belong those rotating screens working at a frequency of 100 to 400 vibrations per minute.

Among the best known are those made by Partington, Banning & Seybold and Bird.[2] The two last-mentioned types have a higher capacity per m²/screen plate area than the first, mainly because the construction with the screening drum is more deeply immersed in the stock, so that a bigger screening area is in action. Though normally employed as knotters before paper and board machines, they are occasionally used for other purposes.

Like all low-frequency screens they operate at low consistencies and are sensitive to even small variations, a fact which may result in stoppages to alter screen plates when changing from tone quality to another.

During recent years, European manufacturers have begun to replace this type of unit with high-frequency vibratory screening equipment especially for those pulp qualities considered hard to screen.

Group C. High-frequency flat screens

A high-frequency screen may be defined as a screen which, when influenced by a power acting on the fundamental parts of the screens or the screen trough, receives such a pulsation that the forced acceleration to its numerical value surpasses the gravity (g) for points on or close to the fundamental parts.

The first high-frequency screen—according to this definition—was the Jönsson flat screen, developed in Sweden in 1935. This type and those of recent years employing the same principle, find their main use as knotters and coarse screens for sulphite, sulphate and mechanical pulp and as screens for wallboard, strawboard and waste paper. Many are also in operation for fine screening sulphite and sulphate pulp and some are placed as knotters before paper and board machines.

Screens in this group work at a frequency of about 1,500 vibrations per minute and the most favourable consistency is between 0.8 to 2 per cent. The Ahlfors screen also belongs to the same group. Developed in Sweden, it is a diaphragm screen (like the the plate screens mentioned in group A) and runs at a frequency of about 900 vibrations per minute.

With the Ahlfors screen the flow of pulp is from underneath and upwards—opposite to that in the usual flat screen. This prevents the heavier particles of dirt from coming into contact with the screen plate itself but instead they settle on the vibrating diaphragm underneath, and from there are transported out of the system.

The screen plates are cleaned automatically by a water spray working from the side of the accepted stock; this prevents dirt getting into the pulp during cleaning periods.

[2] Said to be used by about 95 per cent of the paper and board producers in the United States.

The Ahlfors screen may be considered as a development of the low-frequency flat screen and is used in the same screening position. Capable of operation on stock at the rather low consistency of 0.8 to 1.0 per cent, it has a capacity (per m² screen area) four to five times higher than that of the usual flat screen. Moreover, providing the fibre consistency and the quantity entering the unit are constant, the Ahlfors screen requires little maintenance.

Group D. High-frequency rotary screens

During tests with the Jönsson screen, it soon became evident that while this equipment solved some problems very well, it was less suited to overcome others. Investigation proved that screening could take place at a high consistency on account of the high-frequency principle, with a considerable reduction in water consumption. Furthermore, the unit has a high capacity per m² screen area and a low power consumption.

Research was then directed towards designing a vibratory screen able to carry out those screening operations for which the Jönsson unit was not really satisfactory. Eventually the Jönsson-Lindgren screen was developed and first tested in January 1943. In the United States this screen is known as "the Bird Vibrotor screen" The Jönsson-Lindgren screen, as well as the Lindblad screen, which appeared later, is designed so that the vibrating power is concentrated on the centre of gravity of the screen drum. This means that all points along the periphery of the screen drum will receive exactly the same *circular* vibratory movement.

A few years ago two more types of vibrating rotary screens came on to the market, one designed by Voith in Germany and the other by Lamort in France. Like the two screens mentioned above, these also operate at a frequency of about 1,400 vibrations per minute, but are constructed in such a way that the vibrating power is not concentrated on the centre of gravity of the screen drum. When a screen plate is working submerged in a fibre suspension its movement is restrained by the suspension and this restraining effect varies greatly with pulp qualities and is greater the higher the fibre consistency. Further, the effect is considerably increased in the case of screens with plates having a smaller open slot area. At a certain vibratory frequency it is then necessary to add more power in order to obtain a vibratory amplitude which will give the required screening result.

From a practical point of view, this means that the unblance moment or the size of the unbalance weights must be chosen to suit the consistency and quality of the fibre and the slot width of the screen plates. This is simple for screens where the vibratory power acts on the centre of gravity of the screen drum. For these screens, an increase of the unbalance moment brings about a direct proportional increase of the vibration amplitude of the drum. The conditions are different for screens where the vibratory power is not acting on the gravity centre of the screen drum. With a high restraining effect in the case of these types of screens, it is expected that the vibration amplitude of the screen drum will become vertical or elliptical with vertical orientation.

For these screens, if an increase of the screen drum amplitude is wanted, it is also necessary to increase the unbalance moment but the result does not give a corresponding proportional increase of the screen drum amplitude. Instead, there will be a considerable increase of the amplitude for those parts involved in the vibration movement (and carrying the screen drum) but not directly taking part in the actual screening work.

Consequently the Voith and Lamort type of rotating vibratory screens may be said to form a separate group.

The main reason for the increasing use of high frequency rotary screens is their ability to work at high-fibre consistencies, resulting in high capacity per m^2 screen plate area. A high vibratory frequency will disperse, more efficiently than a low one, the network of fibres which is always formed in a fibre suspension. This, and the fact that the friction coefficient for the passage of fibre through the slots diminishes with increasing frequency, is why a high-frequency screen is able to work at a higher fibre consistency than a low-frequency unit. A vibratory screen will have its maximum capacity when the fibre consistency is so high that a further increase will result in no further dispersion of the network of fibres. This network blocks the screen plate and in extreme cases allows only water to pass through. The result is an increase of the fibre consistency outside the screen plate, causing a quick drop in capacity. The best fibre consistency for a vibratory screen varies with the fibre quality and the slot width, as well as with the product of the vibratory frequency and amplitude, a factor influencing the pulsation through the screen plate. The best fibre consistency is generally around 1.3 to 2 per cent.

The Jönsson-Lindgren and Lindblad screens generally operate at a vibratory amplitude of 3.5 mm. Maximum capacity is achieved at the highest fibre concentration possible with minimum dewatering of the suspension. If under ideal conditions the amplitude is increased, the increase in capacity will be extremely small but the increase in power consumption will be considerable. If running conditions have to be changed for any length of time, it is essential to alter the unbalance moment (and hence the amplitude) correspondingly. Thus the unblance weights should be placed so that they are easy to change.

High-frequency rotary screens with slotted screen plates are characterized by their ability to remove spherical and rectangular particles. On the other hand they have a tendency to allow dirt such as slivers and shives of similar or lesser size than the slots to pass through the screen plates. However, if operated with an overflow quantity of 15 to 20 per cent, large quantities of shives are removed. This indicates their usefulness in the first screening stage, even if a considerable amount of shives are, in fact, present.

Screens of the high-frequency rotary type find use for the fine screening of all kinds of pulp and to an ever growing extent as screens before paper and board machines.

As a general rule it may be said that for pulps containing large amounts of dirt of round shape, vibratory screens should be used, whereas for pulps in which the dirt is mainly of the shive type, centrifugal screens should be used.

Group E. Centrifugal screens

Until about 1930 flat screens with slotted plates were mainly used for the fine screening of pulp after it had passed over coarse screening equipment. Lack of space, however, often made it impossible, when enlarging the production, to fit this type of unit. Consequently centrifugal screens—the only other effective ones for this purpose on the market at that time—started coming into use. Frequently these screens were run (incorrectly) with only a very small overflow which resulted in the dirt particles being broken up during the rather hard treatment given by this type of unit. Thus the number of dirt particles passing through the holes of the screen plates were multiplied. Trials with finer holes led to the particles becoming smaller and increasing in number; only when about 15 to 20 per cent of the quantity of pulp entering the centrifugal screen was taken off as overflow—for further treatment in screens of another type[8]—were good results obtained. It is only during the last decade in fact that the importance of correct consistency of the fibre suspension entering the screen and correct dilution of the pulp during the screening operation has been fully understood. There are a great number of centrifugal screen types; in the Scandinavian countries, for screening sulphite and sulphate pulp, the Biffar is the type most widely used. Recently the Canadian Cowan screen has appeared on the market and gives very good results, especially on mechanical pulp.

If no dilution water is added and if the screened pulps from, say, a Biffar or Cowan horizontal shaft centrifugal screen are examined, it will be found that the short fibres pass the screen plates first. Reckoned from the entering side to the overflow outlet the quantity of long fibres in the screened pulp shows a continuous increase and the fibre consistency a corresponding decrease. The freeness of the unscreened pulp thus varies considerably from inlet to outlet. With a screen plate having the same hole diameter and hole pitch, both at the inlet and the outlet ends, this means that the unscreened pulp will show an increasing fineness of the fibre network on the screen plate towards the outlet. At an ingoing consistency of, for instance, 0.4 per cent the consistency of the overflow may for certain fibre qualities reach 2 per cent. Examination of the cleanliness of the screened pulp discloses a considerable increase towards the outlet side and this despite the fact that the pulp inside the screen plate will show a growing concentration of dirt. Such an examination indicates that the fibre consistency in every part of the screen ought to reach such an optimum value that a thin layer of fibres is formed against the entire screen plate.

To obtain maximum capacity and cleanliness, these screens should operate with a pulp input consistency as high as possible, and with the addition of water so regulated that the consistency of the pulp within the screen may be lowered in line with the increase in freeness and hence with the pulps ability to form a filtering layer. A correct consistency in all parts of the screen means more than the choice of hole diameter. It may well be possible, by other means, to achieve just as good if not even better screening results without resorting to the existing practice of diluting the pulp.

Centrifugal screens are used for dealing with many different fibre qualities. Above all they are characterized by the eeffctive way in which they will remove sliver— and shive-type dirt. Their ability to remove spherical dirt particles, however, is limited. Moreover they have the disadvantage of giving harsh treatment to the pulp causing the dirt particles to break up and thus making it more difficult to remove them.

[8] Usually low-frequency flat screens.

Group F. Vortex separators

Vortex separators have been in use for a long time, in particular for treating stock before it enters a pulp and board machine. Modern practice has determined that the best method for overcoming many screening problems is to use Vortex separators in combination with screens. These separators will partly ease the work of the normal type of screen, and partly remove from the fibre suspension certain kinds of dirt impossible or hard to get rid of by the use of screens alone.

The centrifugal force employed in this type of unit is created by introducing the suspension to be treated tangentially at the head of the stationary vertically placed apparatus, at a pressure which varies with the design but which, in each case, has to suit the velocity required. The inlet is shaped and arranged to obtain a uniform downward motion of the pulp. The impurities separated during this downward whirling flow are removed at the bottom while the treated pulp passes through a separate outlet.

Lately interest has been centered on the Bauer Centri-cleaner; it is said to be possible with this apparatus to remove dirt of much smaller size than is feasible with other separators. Moreover it is claimed that the Centri-cleaner will remove dirt of lower specific gravity than that of the fibres themselves.

Vortex-type separators may be divided into two groups. The first comprises the Dirtec, Vortrap, Hydrafuge, Assablador and Odag units, and the second the Bauer Centri-cleaner. The first are distinguished by relatively long cylindrical parts connected to each other by locally placed, more or less abrupt, choking devices designed as short cones, or characteristic choking arrangements, for the various units in the group. The other group is characterized by a relatively short cylindrical entrance head with a jointed long conical part.

Units belonging to the first group provide less effectively for the layer flow with the result that those particles in shape and weight more closely related to the fibrous material will not be separated so well. At every choking arrangement considerable disturbances may spoil already performed separation work. Since the various units in this group differ in principle only in the design of the choking devices, it may be said that separating results depend on the extent to which the various choking devices disturb or facilitate separation. Their actual performance can be determined only by testing.

In a unit belonging to the second group, the total forces acting on a particle in the suspension will be higher than in members of the first group. Further the layer flow is continuous and comparatively undisturbed by variations in feeding pressure from outside. However, with this apparatus the suspension enters the unit at a higher pressure than is the case with the other types, thus power consumption per unit volume of the suspension to be separated is greater. As always when aiming at perfection, there is an increase in cost.

All Vortex separators are made in different diameter sizes; the larger units for coarse separation work, those of medium diameter for primary and the smallest for secondary separation treatment. As with screens, the overflow principle is used, and pulp is treated in primary units followed by secondary units[4] to take care of the overflow. The accepted pulp from the secondary units is preferably mixed with the pulp conveyed to the primary units.

[4] Often working at higher consistency.

The fibre consistency is of decided importance when using Vortex separators and the lower the consistency the better the result. Although for some qualities an acceptable result may be obtained at a consistency up to 1 per cent, in general it should not exceed 0.5 per cent, and for qualities with a high dirt content no more than 0.3 per cent.

Screening systems

1. *Unbleached and bleached sulphite pulp*

The screening equipment in most sulphite mills in Europe, as elsewhere, usually comprises a set of flat screens either alone or in combination with centrifugal units. When first used on sulphite pulp, centrifugal screens were mistakenly run without an overflow, resulting in an insufficiently clean pulp. The transformation of existing screening departments during the last ten years, however, has seen the introduction of centrifugal screens as primary screening units. They are usually run with an overflow of about 20 per cent, the overflow pulp being treated on flat screens of the diaphragm type (as described under group A) or on high-frequency flat screens such as the Ahlfors. In some cases screened pulp from the last screening step is returned to the primary screens.

During the last eight years, rotating high-frequency screens belonging to group D have come into greater use on unbleached sulphite pulp. In such cases they operate with an overflow of 20 per cent, and the overflow pulp is treated in the same way as described above when using centrifugal screens as the primary units.

The advantage has already been pointed out of a screen so designed and so placed in the screening system that the shortest time possible is taken for the pulp to pass through the screening unit. In other words, flow velocity within the screen should be high. This flow velocity, uninfluenced by the design of the screen, naturally increases with the volume of the overflow. As a rule, a satisfactory velocity through the screen and a good screening result may be expected with overflow volumes of 20 per cent or more. Thus from the cleanliness viewpoint the kind of screen chosen for the primary step is of less importance.

In sulphite pulp the impurities consist of bast and shives, bark particles, etc. In some cases the sap wood is impregnated with tannin from the bark making its lignin insoluble in calcuim-bisulphite liquor. This sap wood then appears in the pulp as very thin and rather hard slivers. If there are many such impurities, centrifugal screens should be used in the first screening step, since these most effectively remove long impurities. If, on the other hand, most of the impurities arise from bark, vibratory screens are preferable for the first stage. If no special kind of impurities predominate, either type of screening unit will give about the same degree of cleanliness. Recently demands for higher purity have increased with the result that many mills have added Vortex separators to treat either the whole of their pulp or that part coming from the secondary screens. Sometimes even double screening is employed. With this method, both vibratory and centrifugal screens are used, thus taking advantage of the first type of screen's ability to remove short and round impurities and the other's to remove long impurities.

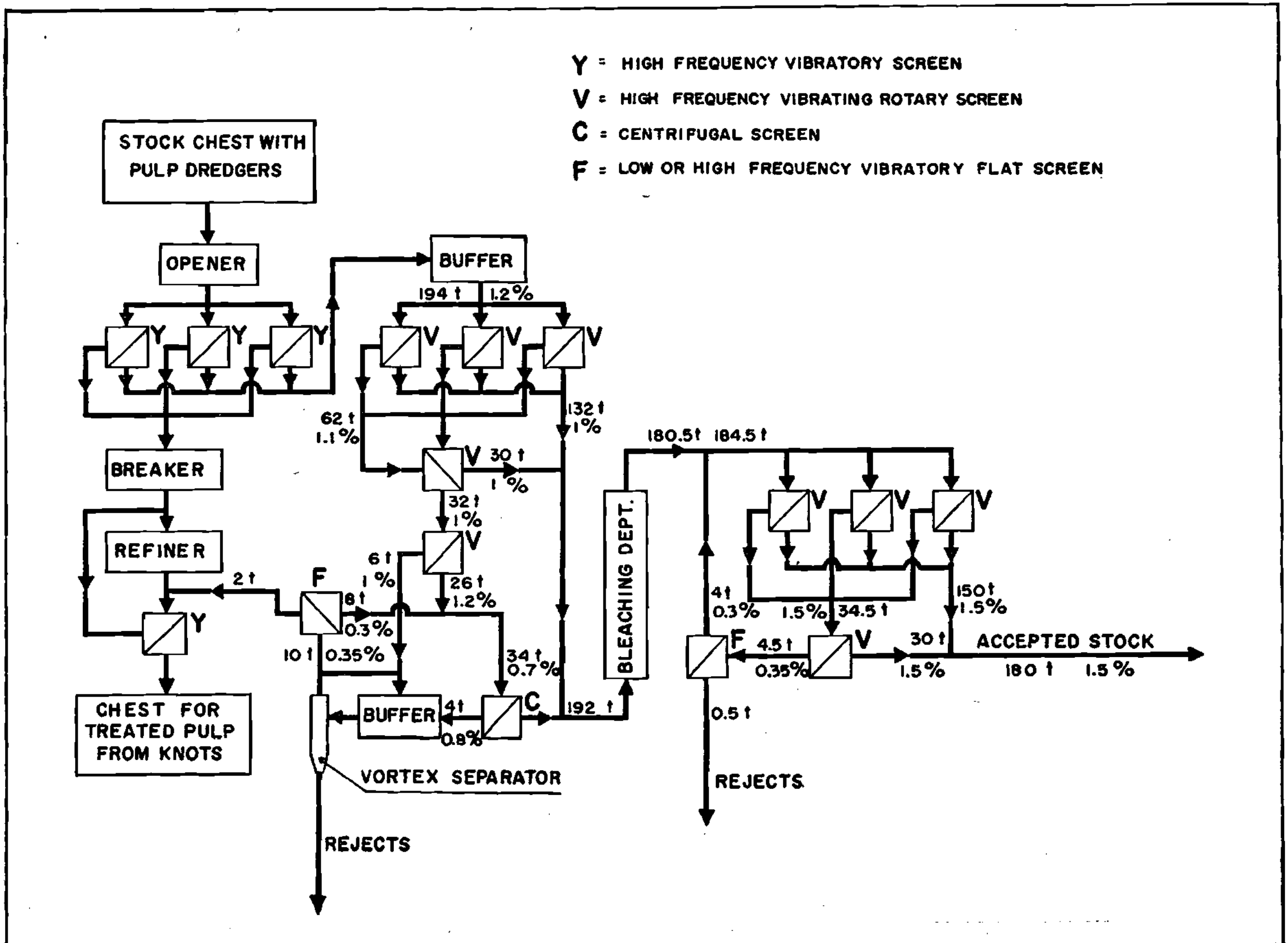


Figure 1

FLOW SHEET FOR SCREENING DEPARTMENT IN SULPHITE MILL

Figure 1 shows a flow sheet for a screening department in a sulphite mill. Here the pulp is transported, by means of a pulp dredger from the bins, at a consistency of 15 to 17 per cent to openers. From the openers the pulp is conveyed to knotters of the flat high-frequency vibrating type.[6] The separated knots are passed on to some kind of hammer mill (breaker) for a first disintegration and then to refiners. From the refiners the pulp goes to a screen of centrifugal type or, for example, to a Jönsson screen. A certain overflow quantity is returned to the refiners.

The coarse screened pulp coming from the Jönsson knotters goes to a buffer chest with a capacity sufficient for at least thirty minutes' production. On proper and efficient screening, it is essential that the quantity and consistency of the pulp flowing to the screening department should be as constant as possible. The buffer chest may be placed after the Jönsson knotters, since these units are not so sensitive to variations in consistency and quantity as are fine screens. In many cases, however, buffer chests are also placed directly after the openers. In such cases the consistency regulator has to work together with a special kind of separator that will allow only the fibres to pass, retarding the knots from the suspension taken as impulse pulp to the regulator. Such a unit has been on the market for many years. After consistency and quantity regulation, the pulp from the buffer chest is pumped to the screens in the first screening stage, in this case comprising rotating high-frequency vibrating units coupled in two steps. The object of this two-step screening arrangement is to allow as high a velocity flow through the screens as possible. The screened pulp obtained is the accepted stock. The overflow from the first step is double screened, first by passing it through a vibratory unit and then through a centrifugal screen, pulp from the latter also being taken as accepted stock. Both the vibratory and the centrifugal screens are run with a certain quantity of overflow which is passed to a smaller buffer chest. From here the pulp is pumped through Vortex separators working so that part of the separated pulp goes back to this chest. This is necessary because these separators always have to work at full load in order not to be influenced by a possible decrease in the overflow quantity. So placed, Vortex separators render good service, especially as they effectively relieve the load on the succeeding screen. It is, however, essential that they do not operate with too high a consistency (0.30 to 0.35 per cent and sometimes lower is recommended).

The screened pulp is then passed either to a low-frequency flat diaphragm screen, or a high-frequency flat unit of, say, the Ahlfors type, whence it receives further treatment in the centrifugal screen. With this double screening of the overflow pulp, the vibratory screen removes the round impurities and the centrifugal screen the long ones. The best method no doubt would be to take the overflow from these two screens right away from the system and use this pulp for secondary qualities. Economically, however, this is not always possible, for it is necessary to get as much good fibre as feasible from the overflow pulp.

Vortex separators primarily remove impurities having a higher specific gravity than the fibres, but they also remove impurities of different shape to the fibres. They will remove round impurities more easily than long ones, although at a low consistency. They will also separate a considerable amount of shives. The flat screen after the Vortex separators is equipped with slotted plates and has a tendency to let some of the longer impurities pass. Thus despite the use of Vortex separators followed by the flat screen, it is necessary to allow for shives passing through. However, the screened pulp may be returned to the centrifugal screen and so a further opportunity to remove these shives from the system is obtained.

The screening of bleached pulp is much easier than the screening of unbleached pulp. High-frequency rotary vibrating screens are preferable on account of their ability to work at a high consistency. Though it is necessary for the screening of bleached pulp to have a pure (and thus perhaps a more costly) supply of water, the quantity required when screening at high consistency is small. This means a smaller water purification plant, a lower consumption of power for pumping, and smaller dimension pipelines for pulp and water.

The arrangement given in figure 1 aims at obtaining the best flow conditions within the screens themselves. Here the pulp coming from the bleaching department goes first to three vibrator screens (arranged in parallel); from these a certain overflow quantity is taken and transferred to a fourth screen. From the screens in this first step the overflow pulp is taken to an auxiliary screen, such as a flat diaphragm or Ahlfors-type unit, and the screened pulp is then returned to the primary screens.

Figure 2 shows a screening department, in which flushing outfits are used for the pulp bins. In such cases the pulp is flushed to a smaller buffer chest for pumping over Jönsson screens. Under these circumstances the pulp will not be greatly defibrated, and the Jönsson screens, beside taking care of the knots, will also remove large quantities of undefibrated pulp. The same conditions will be found when pulp with a high Roe number is produced and the pulp is blown under pressure from the digesters. This method of operation is less common in Europe than in the United States. During blowing the pulp is defibrated, though strong sulphite and the so-called high yield pulps will not become sufficiently defibrated in this way.

From the three Jönsson screens the screened pulp goes to a filter, for dewatering to about 16 per cent dryness before treatment in an opener. The filter has therefore to be equipped with press rolls. The prior removal of knots is necessary in order not to damage the filter wire.

From the opener the pulp is passed on to a buffer chest and then—in the first step—to centrifugal screens, the overflow pulp from the last screen usually having a consistency of 0.6 to 0.9 per cent. In the second step vibratory screens are employed, preferably working at a consistency of 1.2 to 1.4 per cent. Hence the reason for a dewaterer being shown on the flow sheet. If this thickener were removed, the capacity of the vibratory screens in the second step would be decreased.

Knots and undefibrated pulp from the first three Jönsson screens go to an opener and then to another Jönsson screen. The accepted pulp from the last Jönsson screen passes to the fine screens in the second step. This pulp is usually considerably more dirty than that coming from the first three Jönsson screens and is thus preferably taken to the second step, where double screening is used. In principle the second screening step is similar to the corresponding step shown in figure 1.

[6] Usually Jönsson knotters.

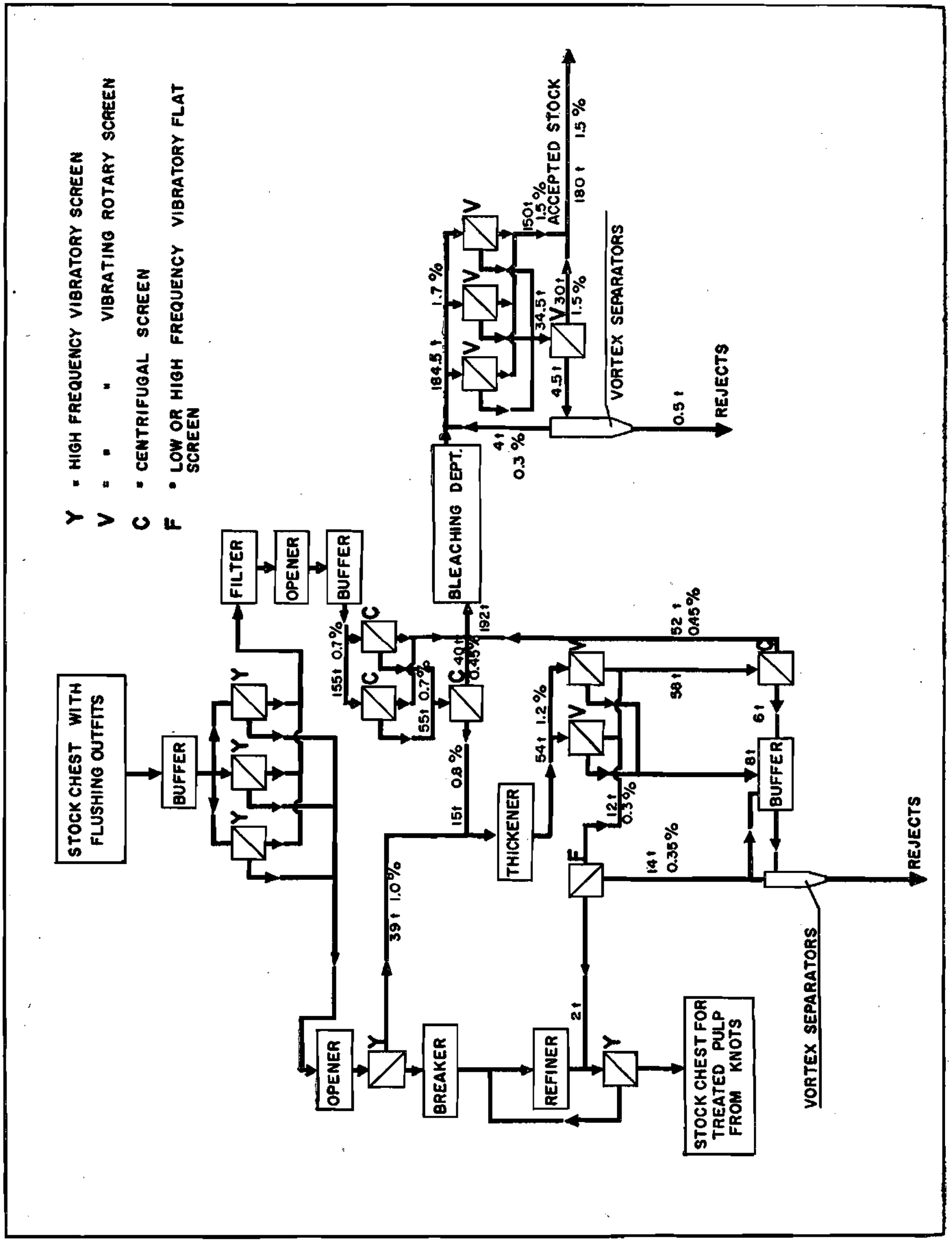


Figure 2

Flow sheet for screening department in sulphite mill

(see text)

In figure 2, for the bleached pulp, the flat screen indicated in figure 1 is replaced by a Vortex separator. The arrangement illustrated in figure 1 is perhaps preferable, though Vortex separators may be used with good results.

Figure 3 shows an equipment arrangement for double screening the entire pulp quantity. This is only necessary, however, when especially high quality is desired, or when the pulp contains an exceptional quantity of impurities.

For the double screening of unbleached sulphite pulp the question of which screen—vibratory or centrifugal—should be placed first in the system is always a debatable point. Vibratory screens are very sensitive to the degree of defibration of the pulp and their capacity (output) diminishes considerably with a poorly defibrated pulp. Centrifugal screens are less sensitive since to a great extent they serve as openers. The result is, however, as previously mentioned, that impurities easy to

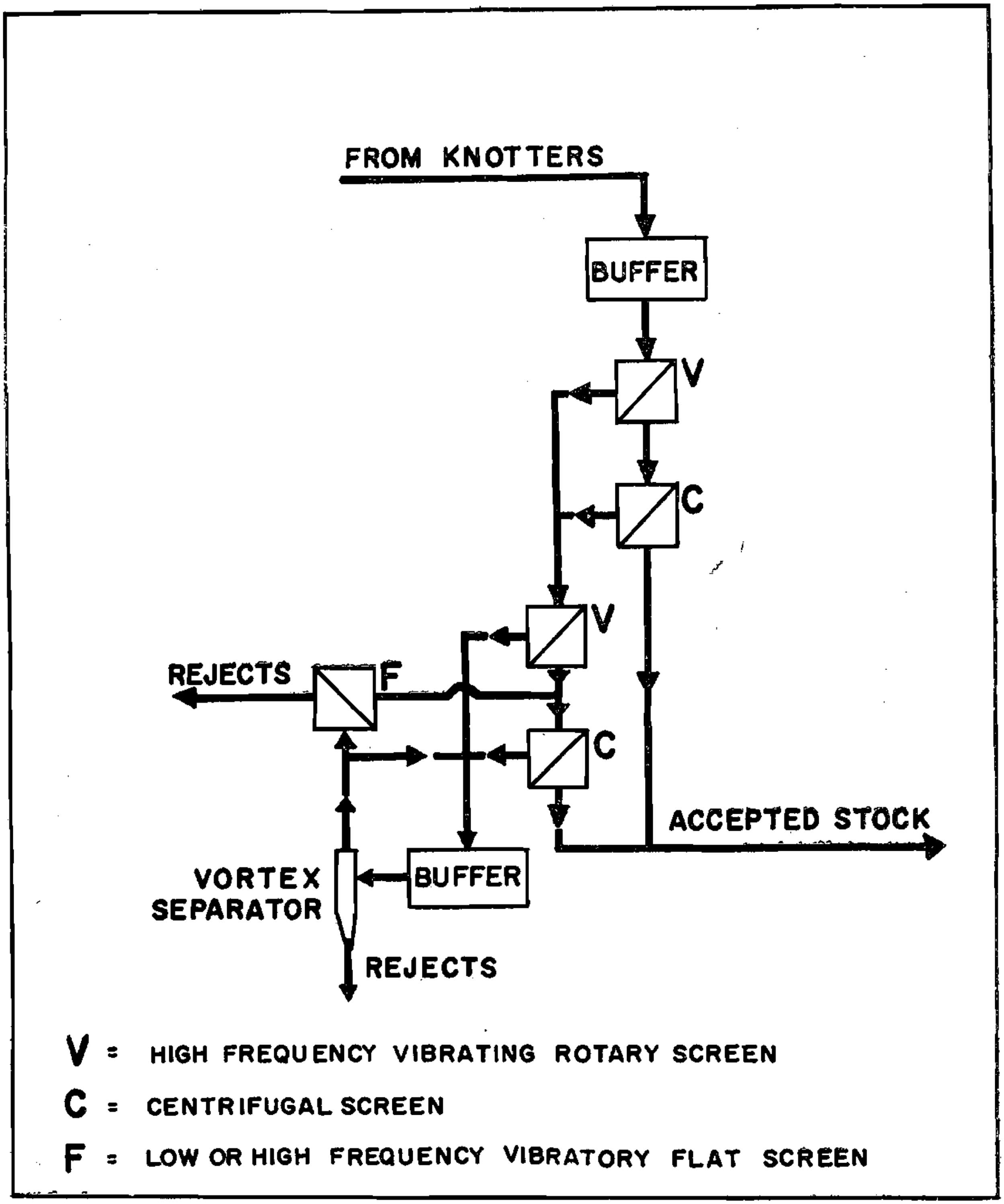


Figure 3

Double screening arrangement

(see text)

defibrate are broken up in the centrifugal screens and often to such a size that they are impossible to remove. Consequently vibratory screens should be used in the first screening step with sulphite pulp. Particles of bark and similar impurities are then removed with minimum risk of defibration for the pulp which is to be further treated in centrifugal screens. In certain cases a minimum amount of barking is undertaken in order to save wood and labour. In such cases the use of Vortex separators directly after the coarse screens may be considered. If, however, these separators are to operate efficiently, it is necessary for them to work at a consistency of 0.4 to 0.5 per cent. Bark particles and other impurities easily broken up are then removed before the screening department proper and the risk of defibration within the screens is largely eliminated. Screening of the entire pulp quantity in Vortex separators is, however, expensive, because of the higher power consumption. Moreover, power consumption goes up with increased dilution and there is therefore some temptation to reduce the efficiency of the Vortex separators by increasing the fibre consistency at the inlet. In the writer's opinion, however, such a reduction is incorrect.

Although in many cases all the screened pulp is treated in Vortex separators, it is preferable to place these units before, rather than after, the screening department so as to remove the dirt as early as possible. Dewaterers should then be placed between the separators and the screening department proper (when using either vibratory or centrifugal screens) in order to obtain a suitable consistency.

Clearly, then, there are many different ways in which the screening of sulphite pulp may be carried out. The individual capacities of the different screening units have to be taken into account and the way these units are placed in the system must be decided in the light of the particular circumstances.

The foregoing comments apply to the screening of coniferous sulphite pulp. For broadleaved sulphite pulp the same screening principles may be adopted but the choice of unit size will be different. As a rule, pulp from broadleaved species contains many small short impurities and sand, but few long impurities. A combination of rotating vibratory screens, flat screens and Vortex separators is therefore recommended. For this short-fibred pulp, screen capacity is almost double that for sulphite pulp from spruce. The sizes of the impurities are such that slot widths of 0.25 and 0.20 mm may be chosen for the rotating vibratory screens and 0.20 to 0.15 mm for the screens in the second step. In the case of bleached pulp, slot widths of 0.20 mm should be used in the first step, and 0.18 to 0.15 mm in the second step.

2. *Bleached and unbleached sulphate pulp*

Nowadays the coarse screening of sulphate pulp is generally carried out with Jönsson screens fitted with plates having 4 to 6 mm diameter holes. In Europe, where the usual practice is to wash sulphate pulp in diffusers, the pulp, after washing and regulating to a consistency of 1.0 to 1.2 per cent, is passed over Jönsson screens. In the USA washing of sulphate pulp is largely done on filters before which are placed the Jönsson screens, to treat the unwashed pulp at a temperature of 60° to 80°C. In this case it is possible to screen at a consistency of 2 to 2.5 per cent, with the pulp inlet submerged in the screen trough to avoid foaming. After the knotters centrifugal screens are usually employed, arranged in two steps. Sometimes centrifugal screens are used in the first step with flat screens in the second, while some sulphate mills are still equipped with only flat screens for treating unbleached pulp.

Sulphate pulp usually contains large quantities of shives and also a great number of impurities emanating from the bark. Moreover, barking is much less thorough in sulphate mills than in sulphite mills.

When unbleached sulphate pulp is used for the manufacture of kraft and similar quality papers, the pulp is only slightly refined and hence contains many shives and small particles of bark. These impurities do not lower the quality of paper; nevertheless they sometimes result in the pulp fetching a lower market price.

In an integrated mill producing kraft and bag paper, etc., there is no great need for clean pulp. Two sulphate mills in Sweden have for many years only screened their pulp over Jönsson screens. At one of these mills, producing 80 tons of pulp[6] per twenty-four hours, two Jönsson screens (with plates having 5 mm diameter holes) are employed as knotters and four (with plates having 2.75 mm diameter holes) as fine screens. The other mill with a production of only 25 tons per twenty-four hours uses only one Jönsson screen with 2.75 mm diameter holes in the screen plate. Though this is the simplest arrangement possible, the pulp obtained is not sufficiently clean for export.

A high degree of cleanliness is required for unbleached pulps used for the production of special qualities such as cable paper, etc. For such qualities one Swedish sulphate mill uses the double screening method with centrifugal screens in the first step (after coarse screening) followed by vibratory screens. Centrifugal screens are placed in the first step so as to take advantage of their "defibration-ability"; the loss of good fibres owing to the digesters being blown at a rather low pressure and the pulp in consequence being only slightly broken up is thus reduced. Some impurities, such as bark, etc., are of course broken up and pass through the round holes of the centrifugal screens. Another virtue of this arrangement is that the capacity of vibratory screens when treating pulp which has passed through centrifugal screens is 30 to 50 per cent higher than when treating less well defibrated pulp coming from the knotters.

The bleaching of sulphate pulp demands the same high cleanliness as sulphite pulp. In principle the screening department should be arranged according to the arrangement shown in figure 2, with centrifugal screens in the first step (for the unbleached pulp) and double screening for the second. Treatment of the bleached pulp should be as indicated in figure 1 and figure 2. If manufactured from broadleaved species of timber, the arrangement for screening sulphate pulp will be different, since the impurities are partly of a different kind. Moreover in many cases, for the unbleached part, rotating vibratory screens are better suited than centrifugal screens.

3. *Groundwood*

For the screening of groundwood traditional practice is to first pass the pulp from the grinders over a shaker screen with big holes, where large splinters are removed, and then to the coarse screens proper.

Fine screening is usually carried out with centrifugal

[6] In terms of bone dry material.

screens arranged in three steps. From the coarse screens the pulp goes to centrifugals (arranged in parallel) in the first step and the overflow, which varies from 10 to 30 per cent according to mill practice, passes to other centrifugal screens in the second step. The overflow from this step goes to the third step, from there to refiners of various types and then back again to the third step. All coarse material, such as sawdust, etc., from the first and second steps is thus circulated until sufficiently refined to pass through the screen plates.

In non-integrated groundwood mills the screened pulp from all three-screening steps is pooled and treated as one common stock. In a fully integrated operation, however, screened pulp from the first and second step will often be taken off and used for better quality paper, that from the third step being diverted for coarser grades. Screen plate perforations vary, in the first step generally between 1.5 and 1.8 mm, in the second between 1.3 and 1.6 mm and in the third between 1.0 and 1.4 mm.

More recently the Canadian or so-called Cowan (centrifugal) screen has appeared on the market and gives very good results. This unit is equipped with two screening zones of which the first (representing about one third of the total screening area) has coarser perforations than the second. Good cleanliness is claimed with a first zone plate perforation of 1.25 mm and despite operation with an overflow quantity of only 5 per cent.

In Scandinavia a great number of Rottrom screens are also in use on groundwood and give excellent results. Jönsson screens[7] in groundwood mills are being increasingly used for coarse screening, and as a rule are placed immediately after the grinders where they operate at a fibre consistency of 1 to 1.5 per cent. If many splinters of more than one decimetre in length are found in the pulp a simple grid is placed in the inlet chute to the screens to prevent the inlet studs becoming plugged. To stop good fibres accompanying the rejects, it is of the greatest importance to choose a hole pitch appropriate to the hole diameter most suited for the quality of pulp to be screened. If plate perforations of 4 mm are used, the quantity of wood splinters removed will be much greater than it would be with 5 to 6 mm perforated plates. Neglect to cater for the rejects means an increase in wood consumption, though pulp quality will be improved and the load on the fine screens and refiners decreased.

The bigger the quantity of splinters the greater the amount of useful fibres which will pass with them as overflow from the different screening steps. Thus an increase in the quantity of splinters means an increase in the quantity of good fibres which will go through the refiners and be reduced to lower quality material. This is particularly regrettable, for the longest and most valuable fibres will be destroyed. Eventually the wood splinters will be ground to flour or to square fragments that will pass through the plates of the screens in the third step. The difficulties will then be increased, especially when it is remembered how much sawdust can find its way into the pulp, as well as numerous square fragments of broken wood from the ends of logs.

Some of these particles will pass straight through the round holes of the screens, and can be extremely troublesome in subsequent manufacture of paper. All of them will absorb size and dyeing materials disproportionately, while the bigger ones may give trouble on the wire or bring about breaks in the paper web. Others may give rise to difficulties in calendering.

In cases where rejects from the coarse screens are treated in refiners and the product from these is passed on to a combination of screens and third-step refiners, there is no doubt that as many splinters as possible need to be taken out with the coarse screens, in order to keep down the load on those screens in the first and second steps, and to minimize the quantity of good fibres passing to the third-step refiners. However, it is doubtful whether the cost involved in this method of treating the splinters is economic, bearing in mind the low value of the product obtained. On the other hand patent applications have been made for a new method which aims at utilizing these coarse screen rejects for the manufacture of building board. This board has first-class qualities. Moreover its production would allow a higher price to be obtained per ton of coarse screen rejects, taking into consideration present prices prevailing in Scandinavia per ton of first-quality groundwood.

The capacity of centrifugal screens to remove small fragments of broken wood and other similar impurities from groundwood pulp increases of course if the hole diameter of the screen plates is reduced. But this raises the power consumption per ton of pulp as well as removing a large amount of long valuable fibres which will be broken up later in refining.

During the last four years the A. Ekströms Maskinaffär company, with which the writer is connected, has paid special attention to groundwood screening and has obtained some interesting results. Tests have been made to determine the possibility of using rotating vibratory screens. As has been mentioned before, the centrifugal screen has a tendency to permit fragmentary particles of wood to pass through while the vibratory unit tends to allow the passage of splinters. Tests in different groundwood mills showed that with pulp from a traditional pattern screening department employing centrifugal screens, a great amount of wood fragments and similar impurities (and also quite an amount of splinters) could be taken out with vibratory screens. Thus, when aiming at high cleanliness with groundwood, double screening may be recommended without hesitation. The investigations also showed that at a fibre consistency of about 0.3 per cent, Vortex separators can remove considerable amounts of fragmentary wood. Consequently in planning screening arrangements for a groundwood mill it is possible to think in terms of either vibrator screens or Vortex separators. However, vibratory screens seem to be more suitable as their power consumption is lower and—since they can operate at a higher fibre consistency—less white water is needed. In addition it was found that pulp taken direct from the coarse screens and passed through vibratory units provided an acceptable stock.

Examination of screened pulp from centrifugal and vibratory screens shows that the total amount of impurities is about the same for both types, but the former leave in a greater quantity of fragmentary wood particles while the latter leave in a greater amount of splinters. However, both these impurities may cause breaks on the wire when paper is being made and therefore represent serious hazards to high-speed production.

When operating with vibratory screens on groundwood for the manufacture of newsprint, slot widths not exceeding 0.30 mm should be used. With this slot width,

[7] Equipped with plates having 4 to 6 mm holes.

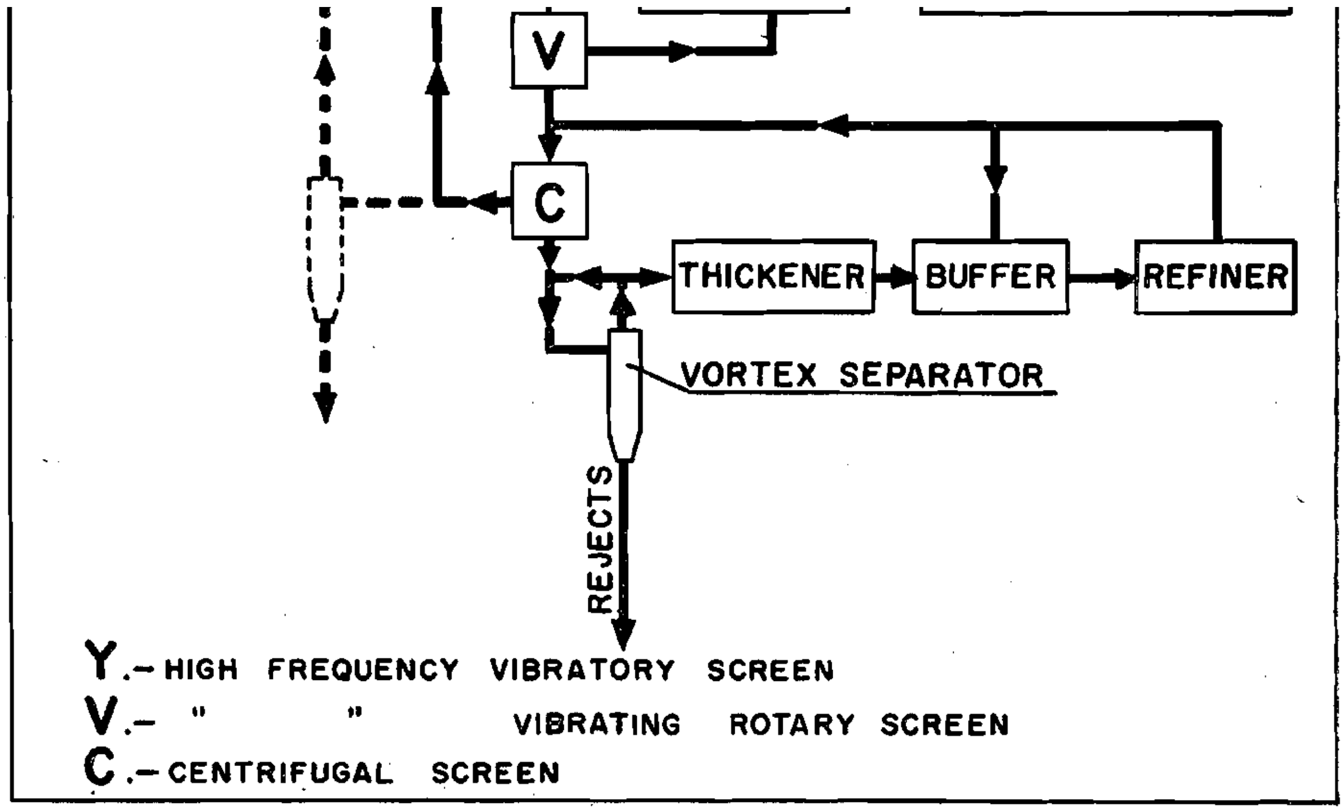
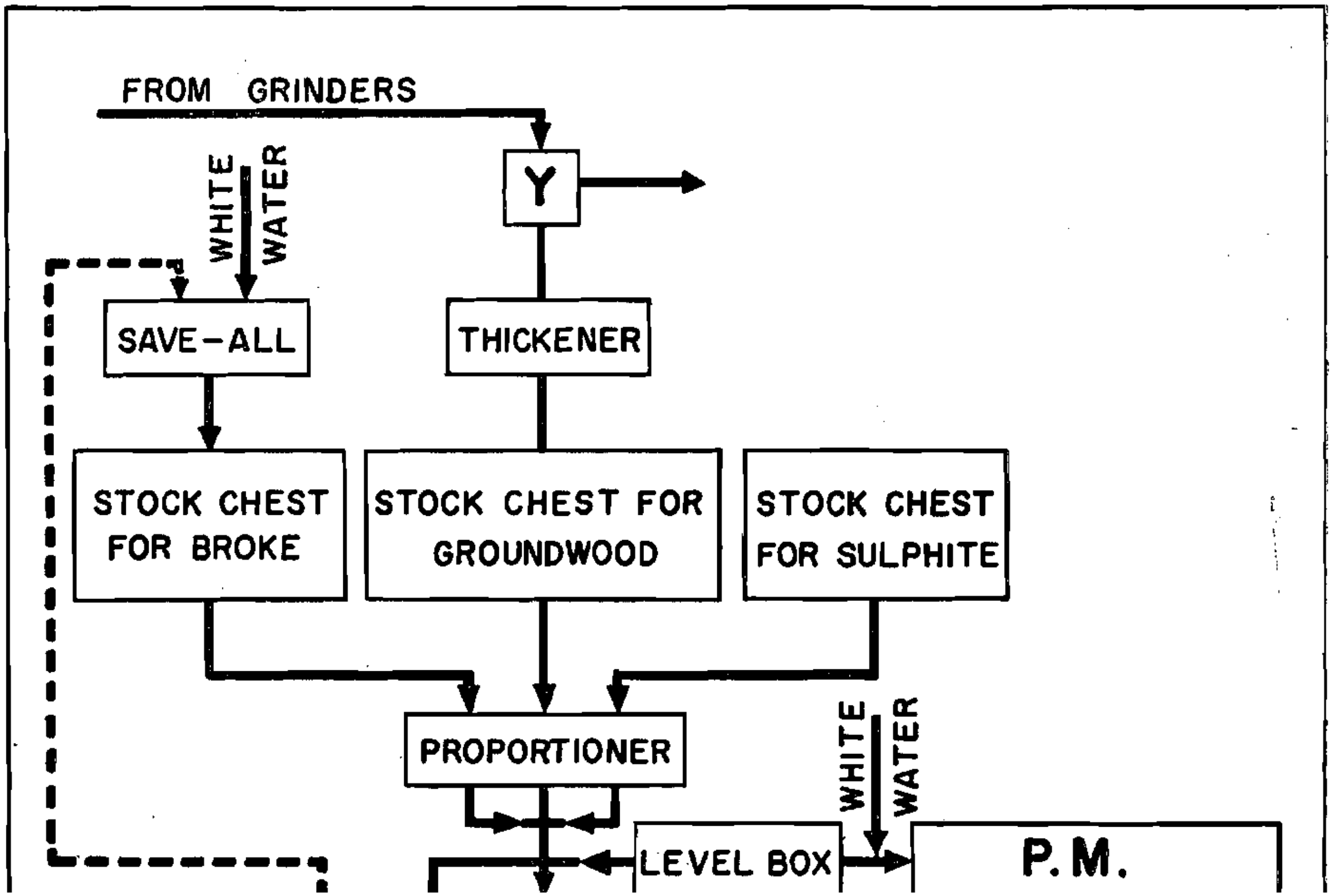


Figure 4

PROPOSED SCREENING DEPARTMENT IN INTEGRATED NEWSPRINT MILL


FROM GRINDERS
WHITE WATER
Y
SAVE-ALL
THICKENER
STOCK CHEST FOR BROKE
STOCK CHEST FOR GROUNDWOOD
STOCK CHEST FOR SULPHITE
PROPORTIONER
WHITE WATER
LEVEL BOX
P.M.

and provided the screens operate with an overflow of at least 20 per cent, a very good quality pulp is obtained. A very interesting point brought out by this research is that groundwood pulp (after coarse screening) passed through vibratory screens alone with slots 0.30 mm wide, will show an increase in strength of up to 10 per cent. The reason is, of course, that vibratory screens allow the long fibres to pass through.

On the basis of these investigations an integrated mill now being built to produce newsprint will be equipped with a screening department as illustrated in figure 4, i.e., with the screening department arranged in direct connexion with the paper machine. The pulp will go direct from the grinders to Jönsson screens, fitted with plates having 4 mm diameter holes, and then via a dewaterer to a storage chest. From this groundwood chest and from those for sulphite pulp and broke, the stock will be passed to a proportioning outfit and then, after mixing to the proportions desired to a set of vibratory screens. From these the accepted stock will go to a level box—the overflow passing back to the inlet to the vibratory screens—and the main amount, after mixing with white water, will pass to another level box ahead of the paper machine. In this particular case, therefore, rotating vibratory screens serve partly as screens in the first screening step and partly as knotters before the paper machine itself. The great advantage of such an arrangement is the high fibre consistency used throughout the entire system, lowering the amount of circulating white water needed and hence the surface area required for the dewatering equipment.

The overflow from the vibratory screens goes to a centrifugal screen and the accepted material from there either back to the inlet of the vibratory screens or (as the dotted lines in figure 4 indicate) via Vortex separators to save-all and then to a stock chest for broke. In the overflow from the centrifugal screen will be found all the separated impurities from the vibratory units and great quantities of splinters. These splinters are treated in the centrifugal screen since this is most suited for the purpose, ensuring that the screened pulp eventually returning to the vibratory screens will be as splinter-free as possible. After dilution to about 0.25 or 0.30 per cent, the overflow from the centrifugal screen is treated in Vortex separators in order to remove coarse splinters and rough fragments of wood. Since the power required to convert these coarse particles to useful material is high, and since they also considerably lower the pulp quality, it is best to remove them from the system for further treatment. Accepted pulp from the Vortex separators goes via dewaterers to a buffer chest and then via refiners back to the centrifugal screen.

Extensive investigations have been made in recent years using different kinds of refining units for the treatment of groundwood rejects; no type of refiner so far used has given satisfactory results. If this refining problem could be solved the most simple system of screening in groundwood mills would be to place the set of screens in a first step, from where the overflow after dewatering could be taken to refiners and from these refiners returned to the inlet of the screens in the first step. Such a simplified screening arrangement would be possible providing the dirtiness of pulp from the refiners did not exceed that of the pulp from the coarse screens.

The persistent call for increases in speed on the paper machine demands higher quality and thus better screened pulp. This may eventually require a departure from the traditional design at present employed in the screening of groundwood pulp.

4. *Waste paper*

The re-use of waste paper within the paper and board industry is constantly increasing. Among the highest qualities of waste paper are box boards, periodicals and books made of material free from groundwood. Nowadays, this waste paper is generally treated in different types of hydrapulpers at a temperature of 60° to 80°C with caustic soda added for de-inking. The pulp is then screened, usually over Jönsson units fitted with screen plates having 2 to 3 mm diameter holes. In the case of "waste paper pulps" containing up to 70 per cent of short fibres, the somewhat high temperature prevailing results in a high capacity per screen unit. At an ingoing fibre consistency of 2 to 2.5 per cent, and fitted with a plate having 2 mm diameter holes, one screen will have a capacity of 40 tons of pulp[8] per twenty-four hours, and 90 tons when the plate hole diameter is 3 mm.

After screening, washing and bleaching, the pulp is again passed through either centrifugal or flat screens. One flat screen will have a capacity of 13 to 15 tons of pulp[8] per twenty-four hours. Recently, high-frequency rotating vibratory screens have also come into use on de-inked pulp from waste paper. The following table shows the operating capacity (with excellent cleanliness) of these screens of various plate slot widths and input consistencies.

Tons of pulp[a] per twenty-four hours

	Consistency					
	1.0	*1.3*	*1.5*	*1.8*	*1.9*	*2.3*
Slot width:						
0.30 mm		90			135	
0.25 mm	75					100
0.20 mm	50		60	65		

[a] Bone dry material.

An assortment of waste paper of medium qualities involves no great difficulty. Pulping usually takes place in a hydrapulper or beater and the defibrated pulp is to a great extent screened on Jönsson screens. If defibration is good and the pulp does not contain any appreciable amount of string or other impurities, such as material from the backs of books and periodicals, the pulp may be treated direct on Jönsson screens equipped with plates having 2 or 3 mm diameter holes according to the quality desired. At a consistency of 1.0 to 1.3 per cent and with 2 mm perforations, capacity per twenty-four hours may be reckoned at 18 to 20 tons,[9] and 40 to 50 tons[9] with plates having 3 mm perforations. The quantity of rejects usually varies from 1 to 5 per cent.

The treatment of low-quality waste papers requires a combination of different kinds of units, if acceptable results are to be obtained. Pulping is usually undertaken in hydrapulpers equipped with a ragger and junk remover. Waste paper of low quality contains impurities of both higher and lower specific gravity than the fibres themselves. The former may largely be removed in Vortex separators, while the latter need to be extracted by screening. The presence of great quantities of im-

[8] Bone dry material.
[9] Bone dry material.

purities of different kinds and abundance of undefibrated paper fragments necessitates separation in two screening operations. First of all, coarse screening after which the pulp obtained is useful for the medium layers in boards of lower quality, and then finer screening to provide a pulp suitable for the manufacture of the top layers or of paper where the demands for cleanliness are higher.

Coarse screening is preferably carried out in Vortex separators at a consistency of 0.4 to 0.8 per cent. From here the pulp goes to centrifugal screens such as Dilts classifiner, or to Jönsson screens. From this screening step the accepted pulp may conveniently be treated in a hydrafiner to deal with the small undefibrated fragments passing the screen plates. If the pulp is to be used for paper manufacture, further screening is recommended with high-frequency rotating vibratory screens.

The overflow from the screens goes via an opener to another screen often of the Jönsson type. In such a case the screen plate perforations depend entirely on the efficiency of the opener but should not exceed 4 mm as the lighter impurities, often very small, are removed from the system at this point. Special attention should be given to the choice of hole pitch, depending partly on the ability of the openers to break up the paper fragments, and partly on the amount of impurities to be separated. Following the treatment described the screened pulp is returned to the hydrapulper or the Vortex separators before the screening department.

5. *Straw and bagasse*

For coarser qualities, straw is usually pulped by cooking with lime or caustic soda. Screening directly after the digesters is impossible, since the pulp is then only slightly defibred, still retaining its original straw structure. After digestion the pulp is usually pumped from a chest via a centrifugal disintegrator, where a certain crushing of the undefibrated material takes place, and then to wash filters or wash beaters equipped with dewatering drums. After washing, the pulp goes via rifflers and dewaterers to beaters for further treatment and then to Jordan refiners and screens prior to reaching the board machine. In the United States of America, a great number of Jönsson screens are used in this position, and usually with plates having round holes 3 mm in diameter and at a pitch of 6 mm. For such a screen, operating at a fibre consistency of 1 per cent, a capacity of 40 tons of pulp[10] per twenty-four hours is generally obtained. Factors governing the screen capacity are the chemical treatment during cooking, cooking time and the degree of defibration. Screening on the simple basis described will give a very satisfactory result for straw-pulp intended for 0.009 corrugating board, etc.

For higher qualities much more effective screening is necessary. The unbleached, unscreened pulp not only contains shives but also many round impurities such as sand, grain and different kinds of weed. For higher qualities of straw pulp it is necessary to remove the greater part of these impurities by effective dusting, and dry screening the raw material before cooking.

In the case of poorly defibrated pulps, the great quantity of long impurities present calls for the use of centrifugal screens in the first step, after treatment at low consistency in Vortex separators. The overflow from the centrifugal screens is preferably double-screened (in centrifugal followed by vibratory units). In principle the system used for straw pulp will be the same as that for good sulphite. The overflow from the centrifugal screen and the vibratory screen in the second step may either be returned to the digester department (after a possible treatment in Vortex separators) or discharged as rejects.

Jönsson screens are also employed for screening unbleached straw pulp of high quality. For coarse screening plates with 3 mm diameter holes are used, and for fine screening 1.5 mm diameter holes in the first step and 1.0 mm diameter for the second.

High frequency rotating vibratory screens are well suited for screening bleached straw pulp, especially as the operation can take place at high consistency. Plates with a slot width of 0.20 to 0.25 mm should be used. In general the impurities are rather small and when accumulation in the trough takes place, they tend to fasten in the slots. It is, therefore, necessary to pay particular attention to shower pipe efficiency. Moreover the quantity of impurities difficult to extract is considerable unless the straw has been properly treated before cooking to remove grain, nodes and dirt.

For use on bleached pulp rotating vibratory screens should operate with a 3 to 5 per cent overflow, which may be treated either in a second screening step or in a beating unit after dewatering. With an integrated mill the screens can be placed immediately before the paper or board machine and thus replace knotters which are generally equipped with screen plates having rather wide slots. By using high-frequency vibratory screens, with a slot width of 0.25 mm ahead of a paper machine it is claimed that so many small particles are removed that dewatering on the wire is considerably facilitated.

With bagasse the great problem is its high content of non-fibrous material pith. The pith consumes great amounts of chemicals in cooking and bleaching and reduces the strength properties of the final product. From the pure pulp screening point of view methods similar to those for straw may be employed, but this does not take into account the question of pith removal. Nevertheless after cooking and screening some of the pith may be removed by using raycell filters.

6. *Screening ahead of paper and board machines*

A number of different screen types are in use for this purpose. While early practice was to install low-frequency rotary screens (as described in group B), nowadays a great number of high-frequency vibratory screens (group D) are also used.

The screens before a paper or board machine fulfil a double purpose; they remove impurities from the pulp and also disperse flocculations in the pulp suspension, thereby allowing the formation of a better sheet on the wire. For integrated mills, the first function is less important, since screening proper takes place in the pulp or groundwood section of the mill. Accordingly the screens ahead of the paper machine serve mainly to remove fibre bundles formed during the beating process and to improve the fibre dispersion. In such cases it is quite sufficient to have rather wide slots in the screen plates. In mills using imported pulp finer slots are used to facilitate the removal of dirt collected during transportation. While in certain mills knotters ahead of the paper machine have been discarded in favour of Vortex separators, in some cases subsequent experience has led

[10] Bone dry material.

to the reinstallation of these units on account of their special ability to disperse the fibres. The most common practice is to use both knotters and Vortex separators, with the latter installed either before or after the knotters and immediately before the paper machine itself.

The older low-frequency types of screen are sensitive to variations in fibre consistency, especially for coarse fibre qualities, and should therefore be equipped with screen plates having rather wide slots for higher consistencies. Moreover capacity per screen unit is low, which results in a large floor space being required for modern high-capacity machines. At a suitable fibre consistency high-frequency rotating vibratory screens have a much higher capacity than the low-frequency units. In addition, since they are less influenced by variations in fibre consistency and quality, they are especially well adapted to serve as knotters before paper and board machines where production is not confined to one grade. With these units it is possible, without difficulty and without changing screen plates, to treat both coarse and fine fibre qualities at high or low fibre consistency. Furthermore it is feasible to do so with considerably finer slot widths in the screen plates than is practicable when using low-frequency screens.

For fine and other heavily sized papers it is necessary, when deciding upon the choice of screen, to bear in mind that the pulp should be treated in such a way that as little air as possible gets entrained with it. If the pulp contains a great amount of air, part of the air will escape during screening in high-frequency vibratory screens and this freed air may cause foaming difficulties for certain sized qualities of pulp. These difficulties can be eliminated, however, if the pulp level within the screen drum is kept at a certain height, and if the vibrating pulp outlet is connected to the stationary outlet box for screened pulp in such a way that the screened pulp in the screen drum communicates directly with the pulp in the outlet box. The outlet box for screened pulp also needs to be made in such a way that de-aeration is possible. It is then possible to eliminate foaming difficulties by using a common type of foam breaker in the outlet box.

Rotating vibratory screens have the highest capacity at high consistencies. For example, for screening coarse pulp made from low-quality waste paper with a high content of impurities the maximum consistency is 0.8 to 1.3 per cent. For kraft paper and strong sulphite requiring only light beating, the corresponding figure would be 1.0 to 1.4 per cent, and for unbleached sulphate and sulphite 1.3 to 1.5 per cent. For qualities which require heavier beating and for short-fibred stock 1.5 to 2 per cent, and for newsprint 1.3 to 1.8 per cent. If full advantage is to be taken of the high capacity of rotating vibratory screens, they should, as a rule, be run at a higher fibre consistency and the accepted pulp diluted later. High-frequency screens of this type have a greater fibre-dispersing ability than low-frequency equipment, and the screened suspension from them seems better able to maintain its condition for a longer period without flocculation. This property has been demonstrated in a practical way many times. Replacement of low-frequency screens by high-frequency units has resulted in better sheet formation on the wire and a paper with a more even look through than was previously obtained. In one mill with four paper machines manufacturing certain types of board (including ivory board), it was found that the machine speed could be raised after installing a high frequency screen with slots 0.30 mm wide. Production was increased by 10 per cent and yet the board had a more even look through.

For corrugating medium and similar qualities, where the raw material consists of 75 to 100 per cen semi-chemical pulp, the screens used should be of the rotating high-frequency type. The freeness of this kind of pulp is very high and if low-frequency screens are employed the fibre consistency usually has to be kept too low. In some cases it has been found that rotating high-frequency screens (fitted with slots 0.30 mm wide and operating at a fibre consistency of 1 per cent) working as knotters before a paper machine producing corrugating medium have reached a capacity of 30 tons of pulp[11] per twenty-four hours. Using a slot width of 0.40 mm, capacities of 43 tons per twenty-four hours have been recorded though the cleanliness was much less.

It is usual to run knotters before paper and board machines without an overflow. Where there is an overflow this is usually treated on screens of the low-frequency type and the screened pulp returned to the system in various ways. Vibratory screens of the Jönsson type have been used as after-screens and, more frequently, rotating high-frequency vibratory screens of the smallest type having a screen diameter of only 500 mm and a working width of 400 mm. The dimension of auxiliary or after-screens and their most suitable place in the system depends on so many different factors that a general flow sheet cannot be given.

Where knotting equipment is run without an overflow, the impurities can be removed only with the help of a water shower from a spray pipe placed inside the drum. The spray water passes through the slots in the screen plates and the coarse particles are transported away in a specially shaped chute. Spray pipes within the screen drum, however, have a limited capacity depending on the design of the pipe and the spray water pressure. To obtain a good result a higher water pressure is required for finer slot widths than for wider ones. Nevertheless, if the quantity of impurities in the suspension is high, the capacity of the spray pipe may be too low despite the use of rather high water pressure. The impurities then accumulate in the screen trough with the result that some of smaller size (normally removed by the screen) pass through the slots and thus lower the degree of cleanliness; at the same time some impurities prevent the passage of fibres through the plates and thus decrease the capacity of the screen itself. It is therefore usually desirable to operate with a certain overflow treated subsequently either on after-screens or Vortex separators. A combination of knotters and Vortex separators has for many years been advocated by the Bird Machine Co. This is effected by continuously bleeding the Bird screens at the bottom and, after dilution, passing this flow through one or more Vortex separators, the accepted stock being returned to the pulp inlet of the screens.

Similar installations have also been tested in combination with rotating vibratory screens. With Vortex separators, to obtain a really good result on the type of dirty pulp described, a fibre consistency no higher than 0.3 per cent is recommended. For fine paper and other bleached and unbleached qualities with small amounts of impurities, an overflow is not necessary as the capacity of the spray pipe will then be sufficient to remove the impurities separated by the screen.

[11] Bone dry material.

When screening board-quality stock with a high content of groundwood, or straw or bagasse pulp in rotating high-frequency screens having slot widths finer than considered necessary up to now, it is essential to take great care in assessing the screen capacity. It is also necessary to pay attention to the fact that screening through finer slots than previously used may cause such an increase in separated impurities that a second screening step has to be installed.

Vortex separators in combination with these screens may be used to great advantage. They are, however, unable at reasonable fibre consistencies to separate the very small grains which are present, for example, in straw pulp and in bagasse pulp, though these may be largely removed by screens with plates having 0.20 to 0.25 mm slot widths. If the quantity of such impurities is so great that an accumulation takes place in the screen trough, the installation of a second screening step is recommended.

On machines producing boards, the pulp for the top and bottom layers of the sheet requires finer screening than pulp for the middle layers. For the middle layers Jönsson screens can often be used, while for the top and bottom layer, where unbleached or bleached sulphite or sulphate pulp is used, screens with slotted plates should be employed. For especially high qualities slotted screen plates should be used for all the layers.

As a rule each cylinder mould should have a separate screen. If, however, the same quality pulp is always being supplied simultaneously to the three or four cylinder moulds which provide the middle layers, one screen will suffice for these layers, the screened pulp from the unit being distributed to the different cylinder moulds.

Conclusions

Though screening departments must be planned in accordance with certain main principles, every screening problem needs to be treated as a separate case. The science of screening, if such a pretentious expression may be used, is not an exact science but rather a feeling for the right combination of the equipment available and the application of ideas verified by actual tests.

It is not sufficient merely to equip a screening department with the most modern units, in strict accordance with accepted rules. The different units must be given careful attention, and properly maintained and run in accordance with instructions. All too frequently these simple but excellent rules are neglected.

THE MODERN PAPER-MAKING MACHINE APPLIED TO THE UTILIZATION OF SHORT-FIBRED MATERIALS[1]

Ralph C. Heys

Introduction

The paper now presented is confined to an analysis of the application of the modern Fourdrinier type of paper machine for the manufacture of papers from a weight of, say, 20 grammes per square metre to 300 grammes per square metre or thereabouts; on the one hand, it does not consider the manufacture of multiple boards, which, almost without exception, are made on cylinder mould or vat machines, and, on the other hand, only a brief reference is made to that type where a single large dryer is used in the manufacture of such specialities as cellulose wadding.

Before attempting to describe what the author, considers to be a modern paper machine with characteristics making it particularly suitable for the manufacture of paper from short-fibred stock, some clarification is needed as to what the term "modern paper machine" really means.

First, he maintains without reservation that a newly manufactured paper machine *is not necessarily a modern machine;* unfortunately new machines are still being built to obsolete designs, using patterns which should have been scrapped long ago. The capital cost of such a unit may be lower, but the difference in price between it and a modern machine, which has a potential for increased production and speeds, should not be a deciding factor, as the purchaser has mortgaged his future.

Advances which have been made during the last ten years for increasing production—especially in speeding up well-designed machines originally built as early as 1924 for conservatively running at 200 metres per minute and which now make newsprint at 450 metres per minute and over—illustrate quite well that any paper machine designed today should have the possibility of being speeded up, as the life of such a machine can well be over thirty years.

On the other hand, there is no need to complicate the design unnecessarily with non-essentials and expensive gadgets; a modern machine should be as simple as the circumstances dictate; automatic devices which become essential with higher operating speeds may be added when and as required.

Secondly, there are many older paper machines which —if constructed by reliable paper-making machinery engineers—are not only suitable for the quality of paper required and speeds at which the paper can be manufactured, but, after reconstruction, can be considered modern in the widest sense of the term.

The essentials of a modern machine vary with the type of paper to be manufactured, but certain elementals are common to all machines whether these are to run at 30 metres or 600 metres per minute. Moreover, generally speaking, most older-type machines made by well-known builders can be modified to incorporate these improvements.

I. Fourdrinier

The flow box and slice should be considered as one unit designed to conform with hydrodynamic principles. The slice should be readily adjustable both vertically and horizontally so that the lip may be located in a proper rela-

[1] Originally issued as ST/ECLA/CONF.3/L.6.12.

tion to the centre of the breast roll; this adjustment can be of great importance, especially on a machine designed to make a wide range of papers.

Provision is always made to adjust the slice lip across the machine to give an even flow on the wire, but it is also important to have a rigid breast roll carried on ball or roller bearings, which will retain their alignment. Some paper makers are now cambering the breast roll to compensate for the deflection on this roll. It is important that every provision be made to get an even caliper at the slice rather than attempt to correct for irregularities once the sheet has been formed.

Wherever possible the slice should have a fixed width, otherwise the design is unnecessarily complicated; the surplus sheet width can be trimmed off and taken to the hog pit beneath the couch.

There is no need for deckle straps to form the sheet edges (except where very heavy papers are to be made) and a simple strip of rubber or other materials carried from the slice 1.5 to 2 metres down the wire is all that is required.

The table rolls should be light but rigid and carried on bearings which will maintain their alignment; they should be capable of horizontal and vertical adjustment.

The flat or vacuum boxes need to be rigidly constructed; the suction box outlet should be of ample proportions and the unit provided with a water and air separation system which allows individual vacuum to be carried in each flat box, as required.

In general, the couch should be of the suction type; it should be large enough in diameter to minimize wire slip and can be fitted with one, two or even more vacuum compartments. The vacuum pumps should have sufficient capacity to attain a vacuum of 20″ Hg., with a moderately beaten 60 grammes per square metre sheet.

The return wire rolls should be rigid and rotate on ball or roller bearings.

The wire length depends on the type of paper to be manufactured and the speed of operation.

Where a shake is used this should be of modern design—many of which are available.

The flat boxes may be oscillated, but this is not considered essential.

A removable Fourdrinier section to simplify the wire change is an advantage in the case of machines with a wire width of 4 metres and could be considered essential over that width, but a machine is not obsolete because it does not have a removable wire frame. A cantilever suction couch will meet most wire change requirements for narrow and medium-width paper machines.

The main reasons for a removable wire frame are:

(*a*) Saving time in changing a wire; most machine crews can change a wire on a non-removable in four to six hours, and on a removable in one and a half to three hours.

(*b*) There is less risk of damaging a wire.

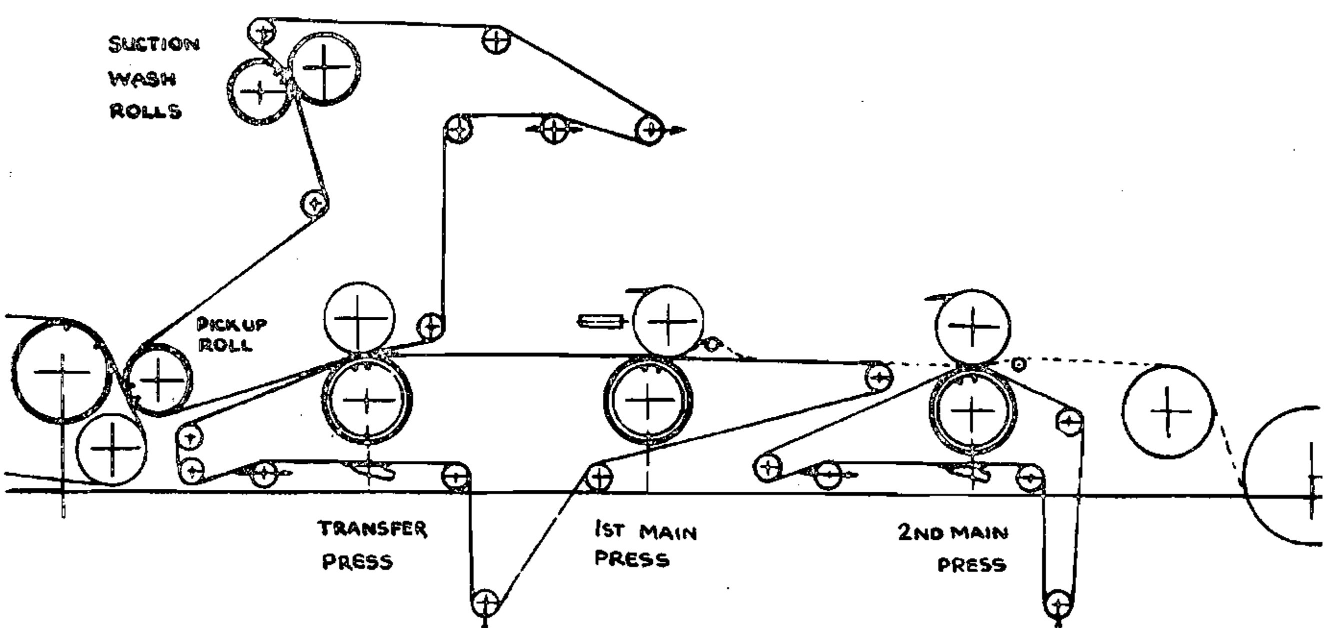
(*c*) There is less risk of damaging the table and wire rolls.

A removable wire frame does not, however, enable a machine to make better papers or increase production once the wire is on the machine.

Vacuum transfer is now a possibility for all types of paper on any machine; it is of especial importance for papers with a low wet strength coming off the wire and for saving breaks on a high-speed machine, enabling the use of a greater proportion of ground wood or shorter-fibred stock.

II. Press section

The general adoption of the suction roll has made possible many combinations of press rolls and the press design can be varied to suit the purpose in mind. For high-speed news, two suction presses have been standard for many years; the latest machines are equipped with vacuum transfer and are designed for speeds of at least 600 metres per minute, using as many as five suction rolls, including a suction felt cleaner and a vacuum transfer roll after the suction couch roll (see sketch 1). Other machines for making free beaten tissues at high speeds also use two suction presses (see sketch 2).



Sketch No. 1

For a paper machine press part designed to make a wide range of papers up to speeds of 250 metres per minute, the author suggests a suction first press followed by a second plain press, followed by a reverse press (see sketch 3).

For higher efficiency he would make the first suction press a Simplex Press which is a single suction roll with two top rolls (see sketch 4).

Smoothing rolls, which are intended to eliminate wire and felt marking, would follow the presses.

The main essentials for a good press section are:

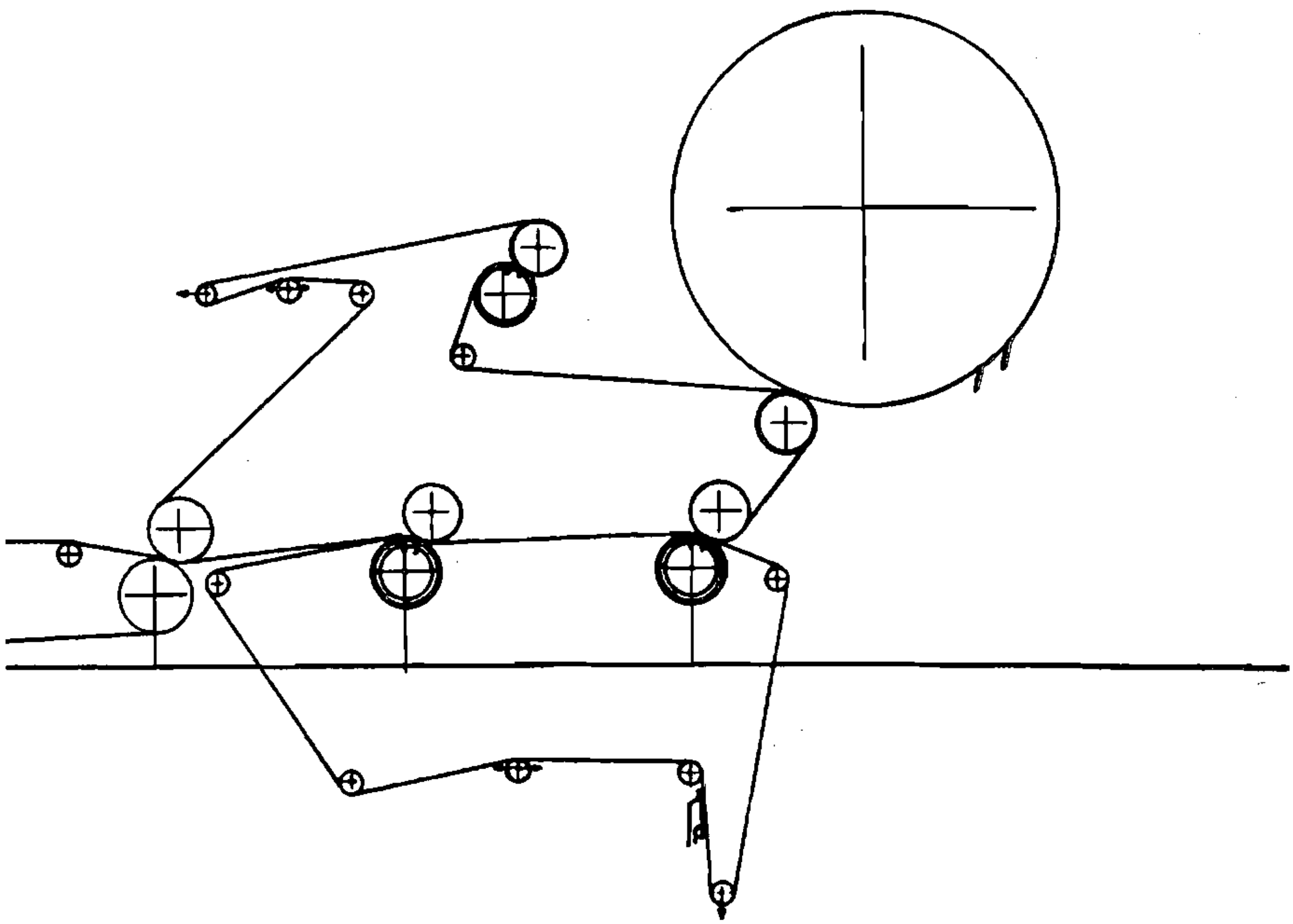
(*a*) Simple and open felt runs with as few felt rolls as possible and—if practical—without outside felt rolls (see sketch 5).

(*b*) Short draw from couch to first press, to second press and to dryers.

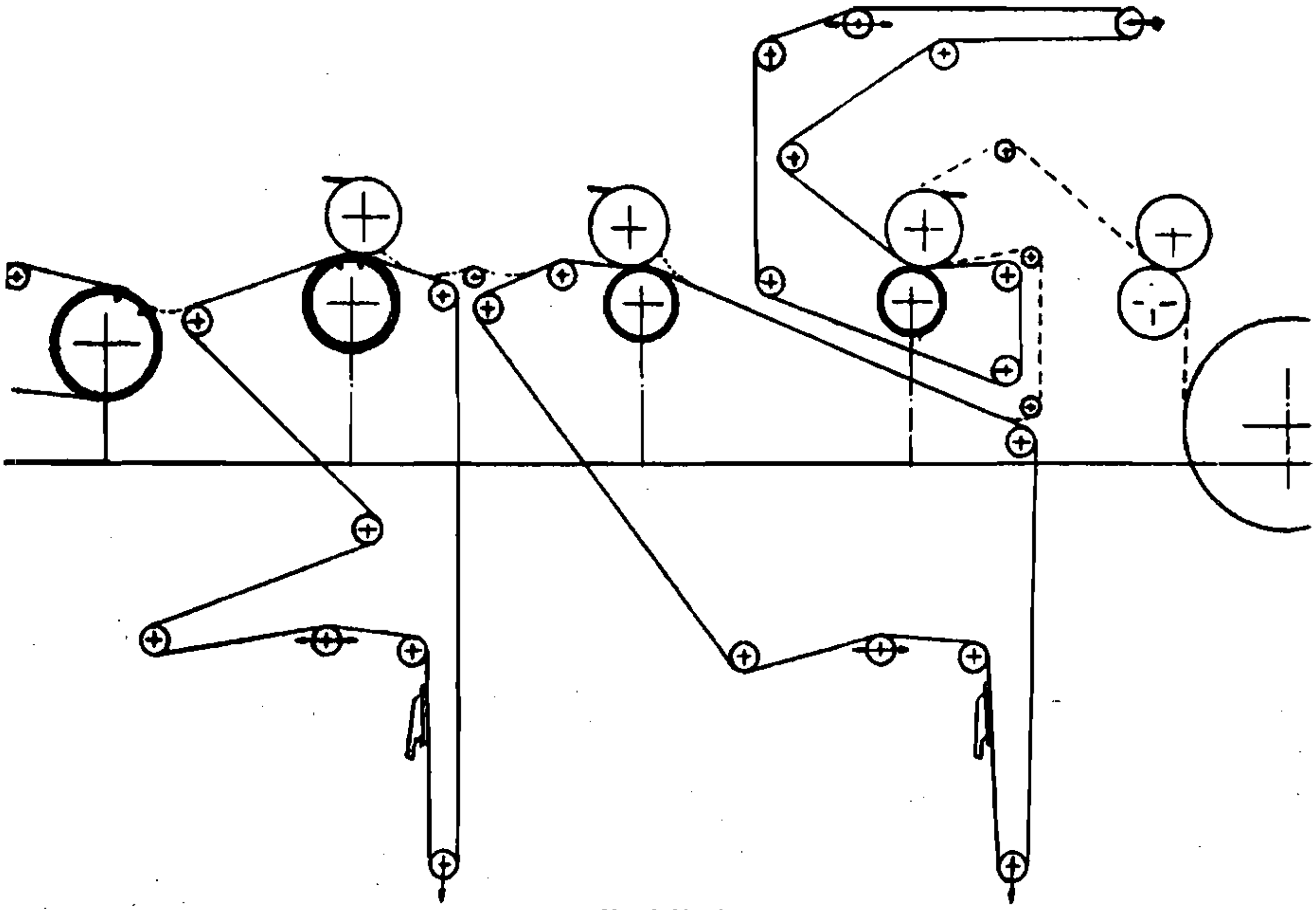
(*c*) The top rolls should be as heavy as practical and designed to give the minimum required line pressure; end weighting not only disturbs the evenness of the nip due to deflecting the top roll, but also sets up high stresses since the combined camber of bottom and top press rolls can only be correct for one set of loading conditions. It is particularly dangerous, especially with suction rolls, to load the top roll unevenly at the drive or tending side of the machine to correct the moisture content or caliper of the sheet. These faults are usually caused by a bad slice or other Fourdrinier defects.

(*d*) The felt rolls should be rigid, dynamically balanced and rotate on anti-friction bearings.

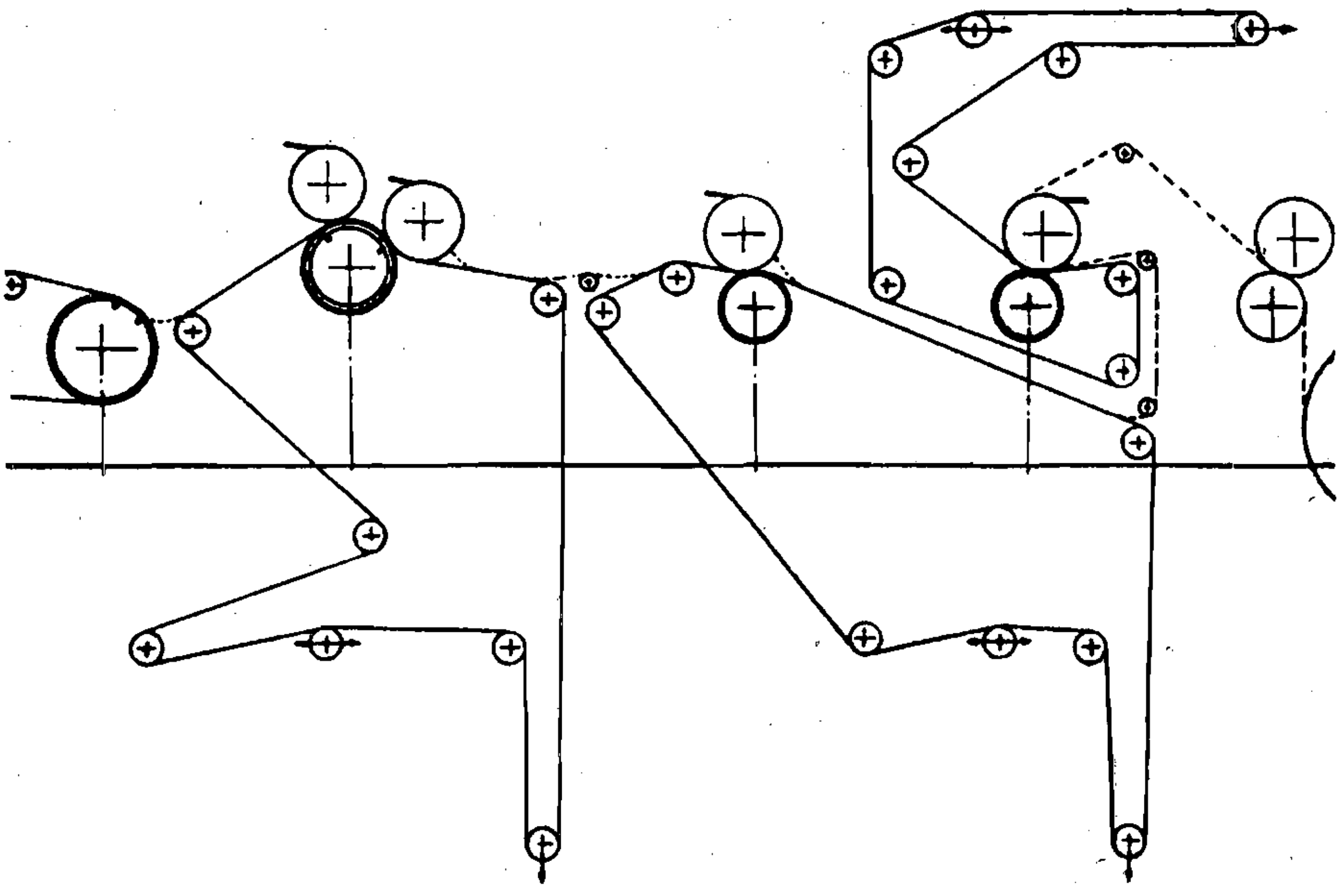
(*e*) The loading system should be flexible; the reverse efficiency of the lever and weight system is so low and the cause of so much trouble that it can now be considered obsolete. Hydraulic pneumatic and spring leading systems are common.



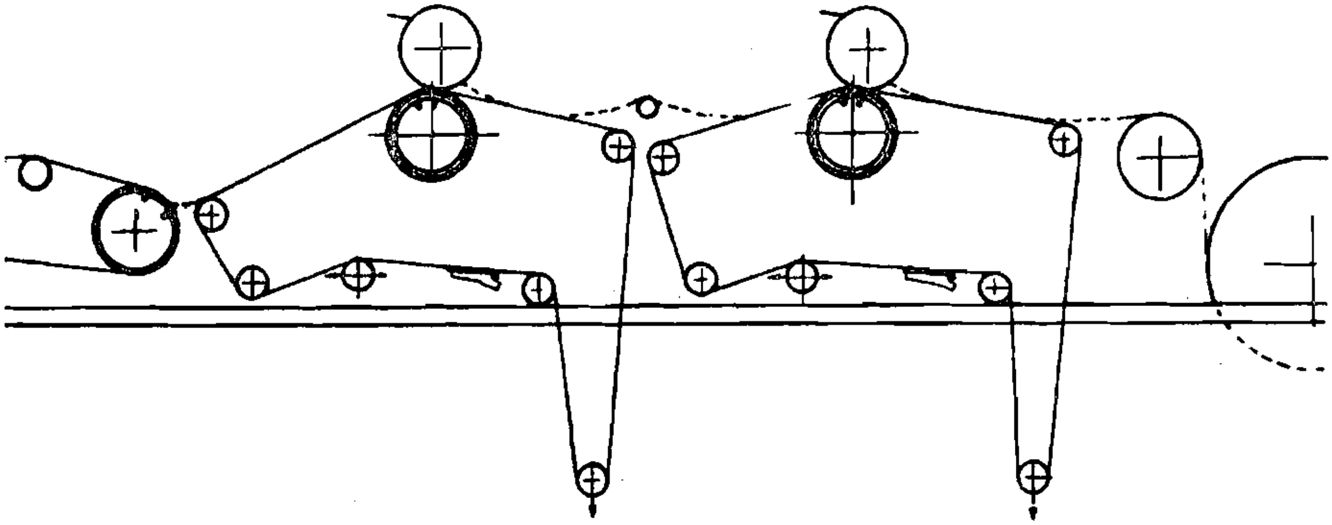
Sketch No. 2



Sketch No. 3



Sketch No. 4



Sketch No. 5

III. Drying section

The modern paper machine drying section is not so stereotyped as it has been in the past. Then there were either several sections of 1.25, 1.4, or 1.5-metre diameter cast iron dryers (edsigned for a steam pressure of 2 atmosphere) or a cast iron M.G., or "Yankee", dryer from 2.5 to 4.5 metres diameter (designed for a pressure of 1.5 to 2 atmospheres). Less frequently, a combination of the two, using an M.G. dryer with pre- or after-dryers (or both pre- and after-dryers) was found.

With high-speed, high-production machines for news and certain types of kraft papers, several sections of 1.5-metre diameter cast iron dryers are still standard design, but they are built for a steam pressure of 5 atmospheres or even higher (see sketch 6). High-speed kraft machines sometimes have a marking press after the first section of 1.5-metre dryers and sizing or inter-calendering rolls after the second section of 1.5-metre dryers, followed by another section of 1.5-metre dryers (see sketch 7).

Machine coated papers are now manufactured at speeds in the region of 375 metres per minute.

On the other hand, machines for manufacturing cellulose wadding and facial tissues have but one M.G. cylinder (about 3.5 to 4.25 metre diameter) using steam pressures in the region of 8 atmospheres; these high pressures necessitate special iron alloys and welded steel cylinders are used with success (see sketch 8).

A further type of high-production machine merits mention and this is used to make crêped tissues; it has a large crêping cylinder, 3 to 3.5 metre diameter, followed by one or two sections of 1.5-metre dryers, over which the crêped sheet is dried (see sketch 9).

All the drying sections mentioned above are designed to run at speeds in the region of 600 metres per minute.

A slower machine, which runs at 150 metres per minute, makes high-class tissues, cigarette paper and the like; it has single-tier dryers followed by a double-tier dryer (see sketch 10).

With reference now to the more versatile type of machine for general purposes, which is of especial interest to South America, this can be confined to two types.

The first, for making banks and bonds, etc., has a series of 1.5-metre diameter dryers, with or without an inter-calender unit or size press, followed by a further section of 1.5-metre dryers. This drying section is very similar to that shown in figure 6, except that it has fewer cylinders and the steam pressures used are much lower—of the order of 0.5 atmospheres.

The second type is what is known as a universal drying section and emanates from Europe; it consists of a series of 1.5-metre dryers into which is interposed a large dryer for machine glazing one side, as and when required.

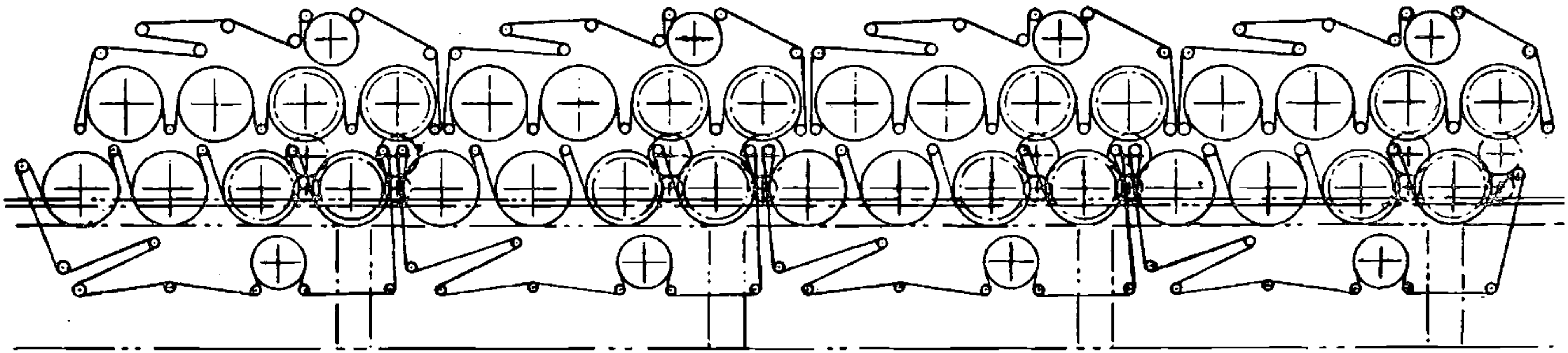
There is a great deal to be said for a drying system of this kind where the paper maker is called upon to supply a large variety of papers, but like all compromises, it is not nearly so efficient as a drying section designed to make a particular type of paper; however, not many paper makers outside Sweden, Finland, Canada and the United States of America are in the happy position of being able to keep a machine on one particular grade and product.

An up-to-date steam and condensate system is used with the above drying sections; it is extremely efficient, especially when compared with installations of some twenty years ago, and allows a great saving in steam consumption on the machine.

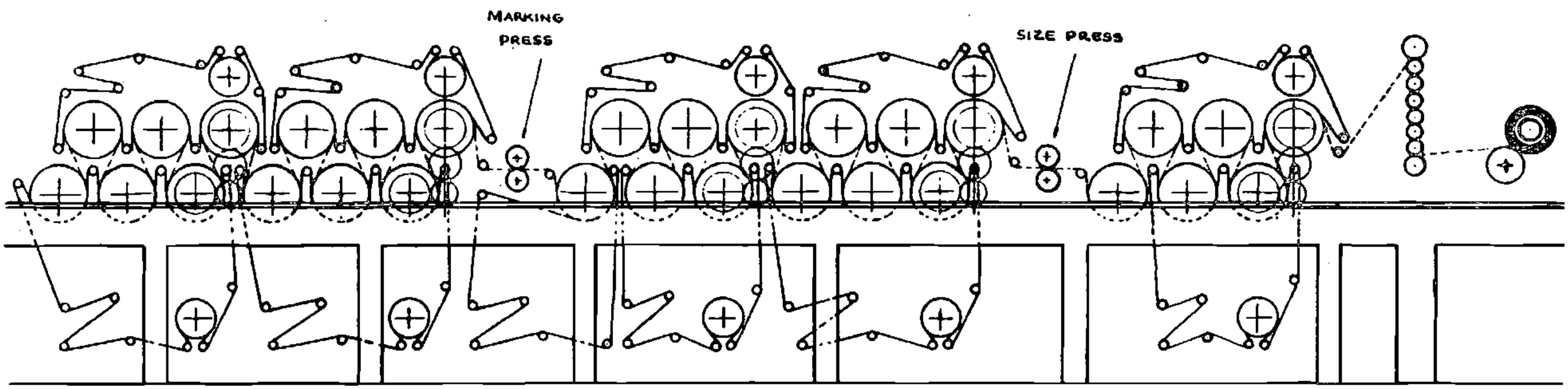
The dryers should be driven smoothly and it does not really matter whether large open gears are used (one dryer gear having celeron teeth and the other steel, semi-steel or cast iron teeth), or whether a totally enclosed small gear drive is provided.

There are examples of open gears running quietly and smoothly at 450 metres per minute, and a drying section should not be termed "out-of-date" simply because the gears may not be totally enclosed and running in an oilbath.

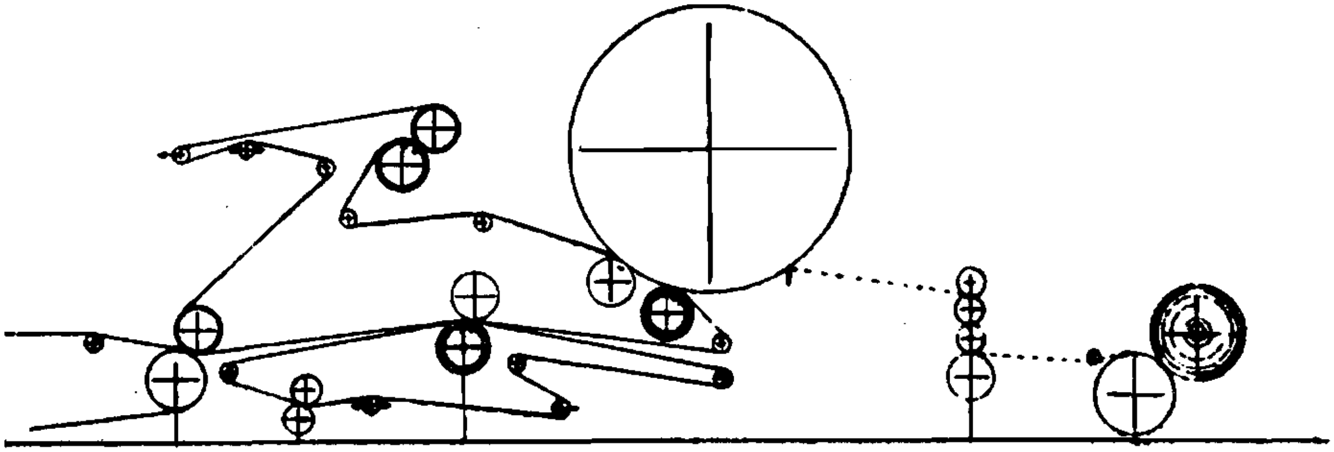
The author's own Company has, for many years, supplied drying sections in which only two dryers per section are driven and the remainder powered by the felt; providing the system has been installed with the proper "know-how", this method has much to commend it, both from an initial capital cost and maintenance standpoint.



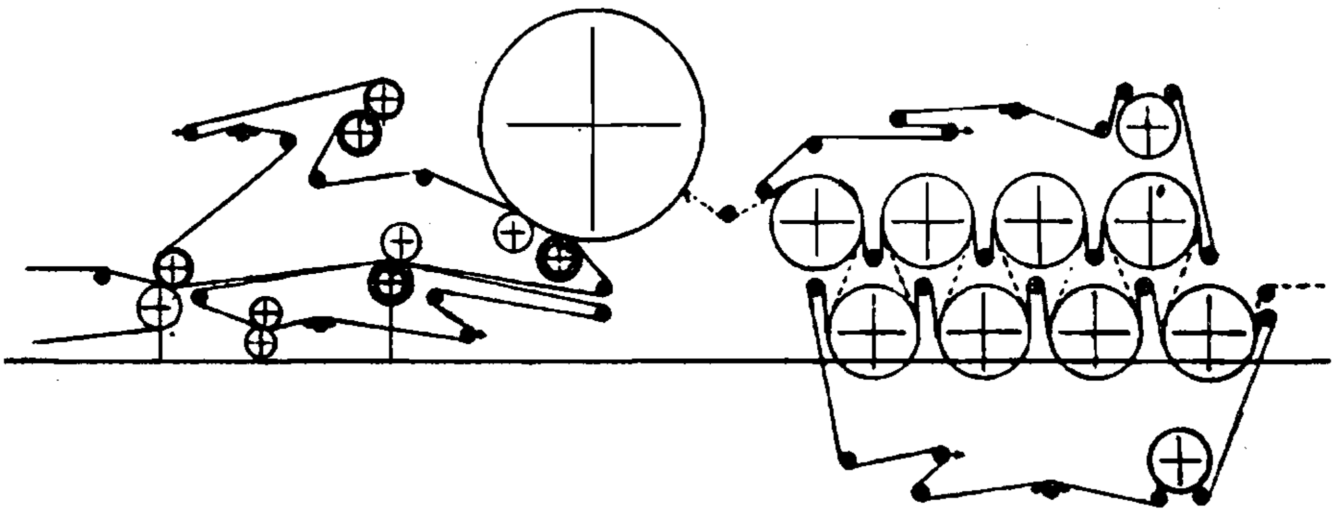
Sketch No. 6



Sketch No. 7



Sketch No. 8



Sketch No. 9

IV. Calender

The calender stack is essentially the same as when first designed. The prime requisite is that the bottom roll be rigid and that it should keep in alignment; anti-friction bearings are desirable, but not essential.

Older machines usually have bottom roll bearings, which could well be replaced by those of a more modern design, allowing higher speeds and holding the alignment, as well as better able to absorb shock loads.

V. Reeler

Some form of drum reeler is now almost universally recommended; it does not have to be hydraulically or pneumatically operated, although this would be desirable for a new machine.

The tendency is to make larger reels of paper and now it is not uncommon practice on high production machines to manufacture reels 2 metres in diameter.

VI. Drive

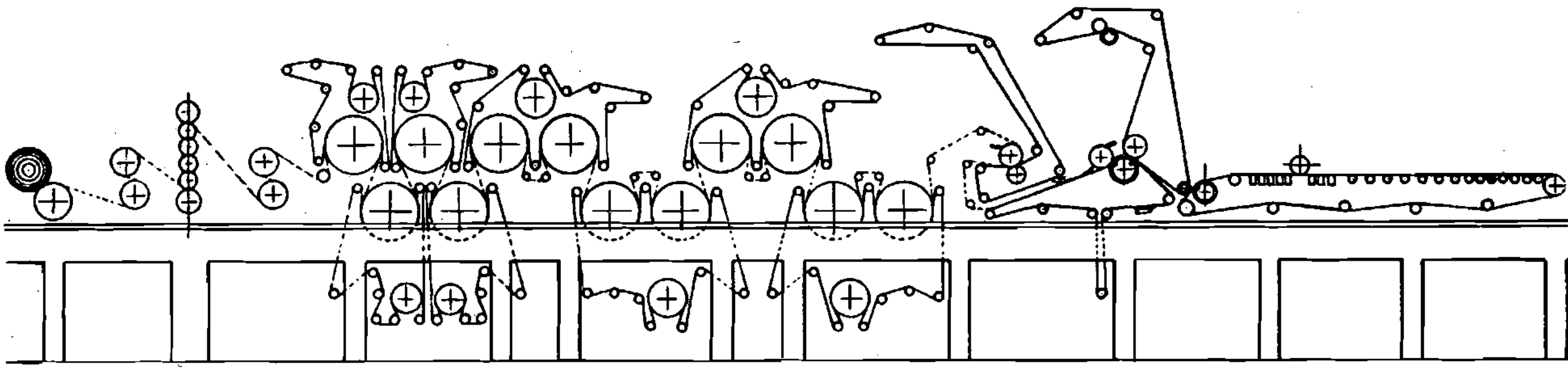
Until recently this part had had less attention than the machine itself; although it is of the greatest importance that the over-all speed should be steady, the individual speeds between sections, especially at the wet end should be capable of fine adjustment and be controlled within very close limits.

The author has been surprised many times to see a good machine fitted with an indifferent drive and hear the paper maker complain of excessive breaks—breaks which finally have been proved to be the fault of the drive alone.

Today very reliable mechanical and electrical drivers are available. There are, however, also many cheap imitations which decrease machine efficiency so much that it would be better to consign them to the scrap heap.

The author has endeavoured to highlight briefly what he considers to be the essentials of a modern paper machine. Before applying these principles to a machine specially for making papers from short-fibred new materials, he would just like to mention modern methods of preparing stock; this does have an important bearing on machine design and particularly on the speeds at which the sheet can be formed.

Short-fibred stock from straw and esparto has been in use for many years; its main interest is in countries which do not have wood resources and have to import both chemical and groundwood pulp; the usual treatment after digesting, washing and bleaching has been to use beaters and this has resulted in a stock which, if over-



Sketch No. 10

hydrated, became so slow as to be unusable, and at best has been so slow in draining and drying that, even with longer drainage times, obtained by using a longer Fourdrinier wire, more presses and more dryers, it has been much more economical to use imported wood pulp, except for certain specialty esparto papers, mainly manufactured in Scotland.

Since about 1940 there have been great developments in the understanding of pulp preparation. More selective treatment can be given to individual pulps, resulting in more even treatment to the fibres, giving a freer stock on the wire, with better drainage properties. In consequence higher speeds and machine efficiencies can be obtained without impairing the quality of the paper on the reel.

This type of preparation plant confines a preparatory machine to a particular function, i.e., breaking, hydrating, refining, or shortening of the fibres, for which it is specially designed.

Furthermore, proportioning systems are available and being further developed, which allow the introduction of different types of fibres into the preparation system, at points where they can receive a treatment designed to bring out their best qualities for the type of paper being made. Thus the paper maker can use long-fibred pulp and short-fibred pulp (including waste paper) in correct proportions to achieve the characteristics desired in the paper he is manufacturing. The author believes that this development, together with the tendency for freer beaten stock will, more than any other single factor, enable the economic use of short-fibred stock, and for this reason a machine to use this type of pulp should be designed for much higher speeds than would ever have been suggested, even ten years ago; so much so that, for general use, such a machine should have a speed range of, say, 35 to 350 metres per minute as a minimum.

Since it is not possible to consider every type of paper which can be manufactured from short-fibred stock, the author suggests that the paper machine should be of a universal character.

Bearing in mind the principles expressed for a modern machine, a broad specification would be as follows:

	Design speed	35 to 350 metres per minute.
SLICE	Combined flow box and slice	Lip adjustable horizontally and vertically in relation to the breast roll–open construction of the projection type. Fixed deckle width.
FOURDRINIER	Wire length	23 to 30 metres.
	Wire width	Between 3 and 4 metres, depending on the width of finished reel required.
	Breast roll	On bal lor roller bearings, at least 500 mm diameter, rubber covered steel or centrifugally cast bronze.
	Table rolls	On ball or roller bearings, at least 500 mm diameand horizontally and at least 150 mm diameter with rubber covered steel or aluminium tubes.
	Vacuum boxes	Six to eight.
	Dandy roll	Open ended; or provision for dandy roll after the second or third flat boxes.
	Return wire rolls	At least 200 mm diameter, centrifugally cast bronze shells on ball or roller bearings. All doctored and showered, including automatic wire guide and well-designed stretch.
	Suction couch	Cantilevered, 750 to 900 mm diameter.
	Shake: of modern design, adjustable whilst machine is in operation.	
	Removable wire frame–optional.	
	Hog pit: under couch with motor driven agitator.	
PRESS SECTION	First suction Simplex Press, at least 750 mm diameter–granite top rolls.	
	Second plain press, at least 550 mm diameter, granite top rolls, but suction press, 600 mm diameter for speeds higher than 200 metres.	
	Third reversing press–granite top roll, suction press for higher speeds. Granite rolls about 650 mm diameter on roller bearings, with pneumatic raising, lowering and loading mechanism.	
	Felt rolls mounted on roller bearings with auto guide and well-designed stretch; rubber covered, about 200 mm diameter.	
	Smoother rolls–at least 550 mm diameter.	
DRYING SECTION	Pre-dryers, 1.5 metres diameter.	
	M.G. dryer, 3 to 3.5 metres diameter.	
	After-dryers, 1.5 metres diameter.	
	Open gear celeron and cast iron or gearless dryer drive.	
	Felt rolls, about 200 mm diameter, on roller bearings.	
	Automatic felt tensioner and felt guides.	
	Rope feed from second press.	

CALENDER	Seven bowls, with bottom roll about 600 mm diameter, of chilled iron of 80° Scleroscope, on Michell or roller bearings; intermediate rolls, 450 mm and 350 mm diameter on roller bearings.
	A pulper under the machine calender to repulp the broke, for pumping back to the stock chest or screen (see sketch 11).
REELER	A Pope type reeler for reels at least 1.25 meters diameter, with pneumatic control.
DRIVE	Mechanical drive, either vee rope or flat belt, with enclosed bevel or worm gearing, depending on machine and line shaft speeds.
	Variable steam turbine, with exhaust steam used for process purposes, or variable speed electric motor drive.
	As an extra, or where the wet strength of the sheet at the couch is is low, vacuum pick-up should be seriously considered.

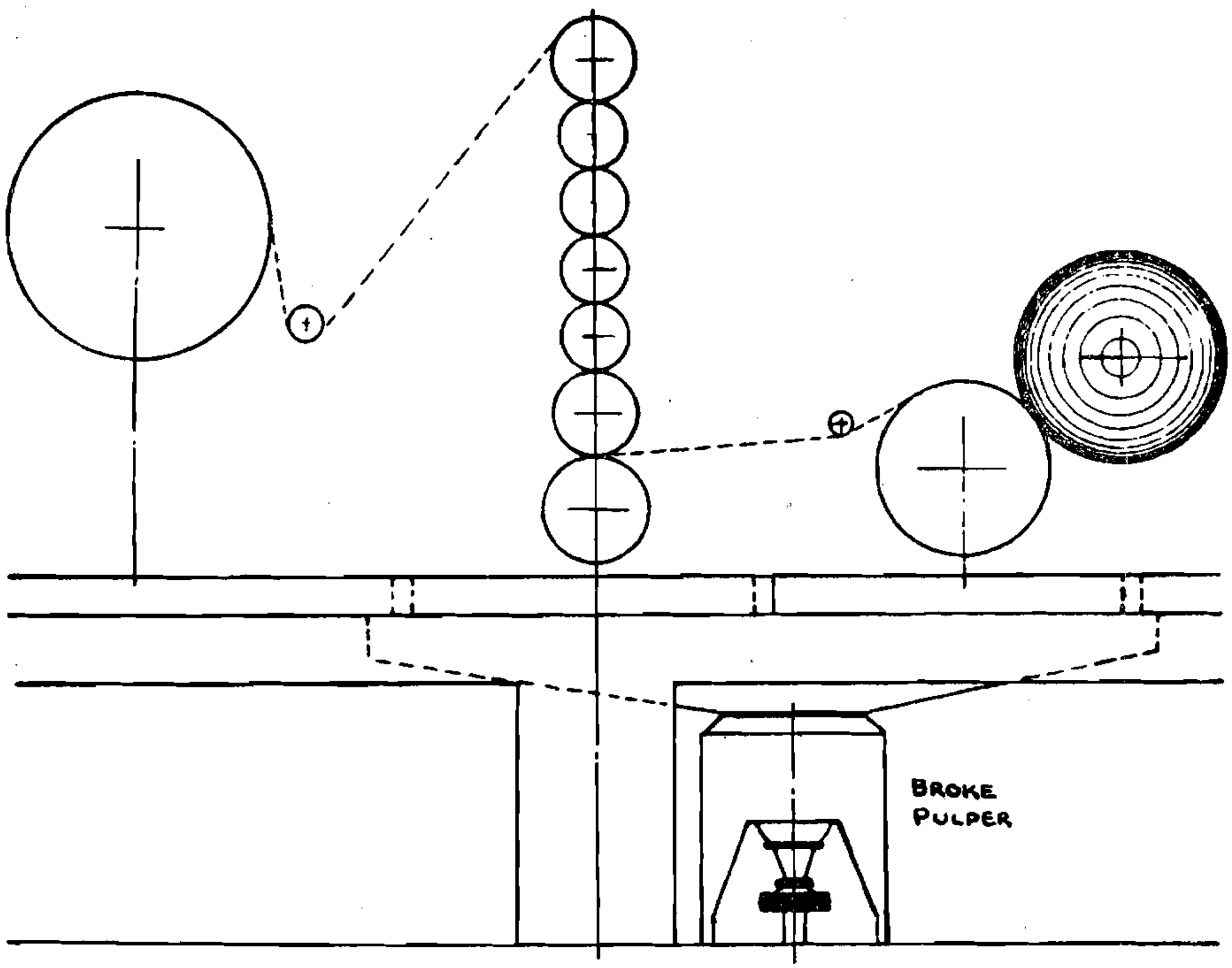
In the author's opinion sufficient attention has not been given, so far, to the possibilities of duplexing low-strength papers, not only to give an even sided sheet, but also to improve the strength of the paper.

As early as 1929, W. H. Millspaugh made experiments manufacturing duplex news, which was afterwards used for an issue of the local paper. This newsprint was run on the machine at 300 metres per minute—which was fast at that time. The paper printed extremely well and ran through the printing presses with fewer breaks and less trouble than standard newsprint of the same weight. Vacuum formation was used on the paper machine and the sheet formed over large suction rolls (see sketch 12).

Further experimentation is taking place with vacuum sheet formation, which may well prove of great interest.

A more orthodox duplex machine would use two Fourdrinier wire parts and, with the addition of vacuum-pick-up, could well be made to run at high speeds and give comparable production to a single Fourdrinier machine making heavier sheets from better stock (see sketch 13).

It has been proved that the combined strength of two sheets of paper bonded under proper conditions is greater than that of a single sheet having the same weight as the

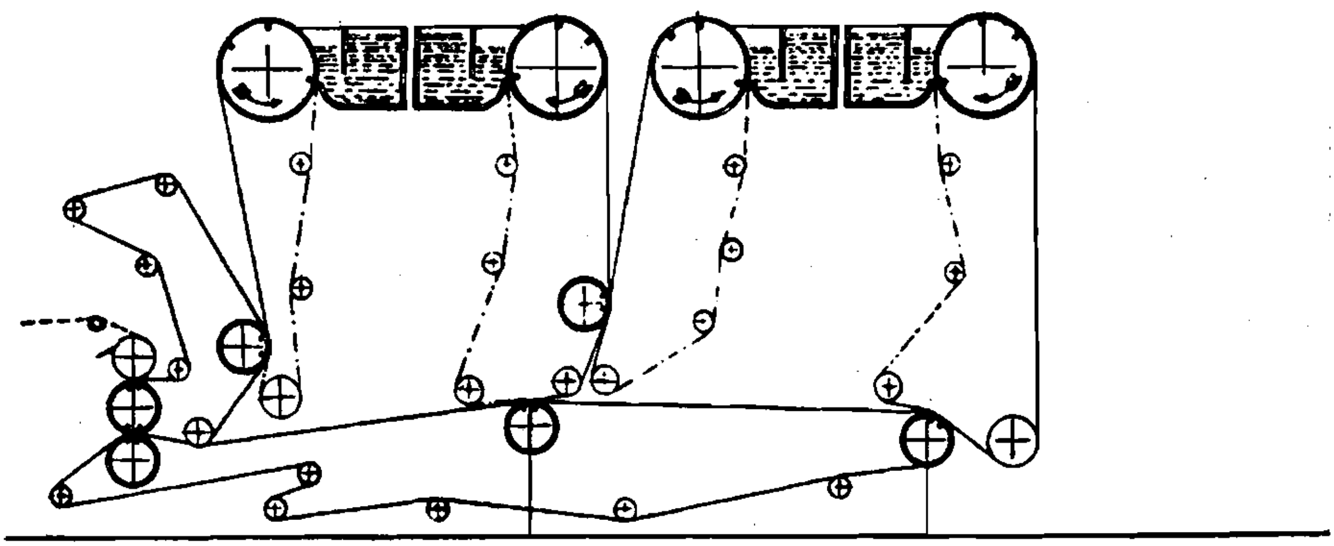


Sketch No. 11

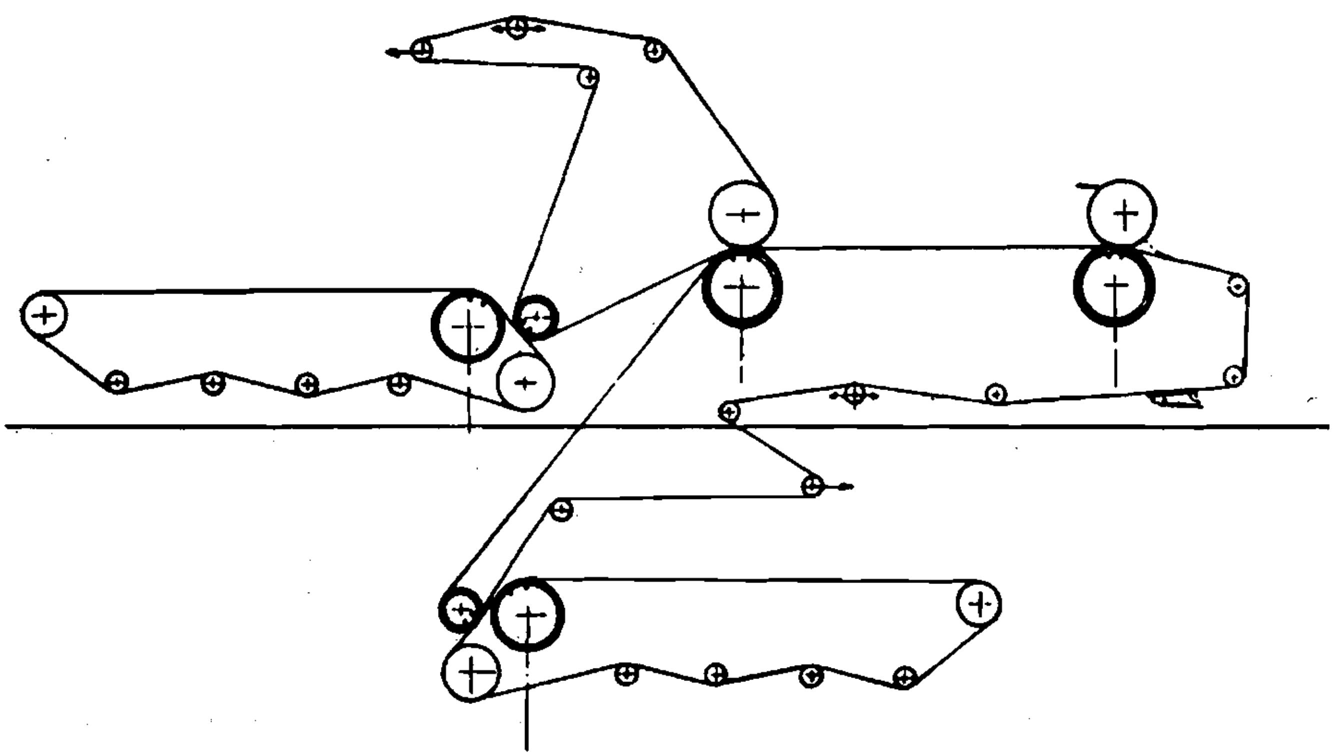
two sheets and made from the same pulp, receiving similar treatment.

There should be a case for substituting duplex papers made from short-fibred stock, for papers now made from long-fibred stock.

In conclusion, it is apparent that short-fibred pulps will be used more and more to make paper, especially in countries which do not possess a local supply of long-fibred raw materials. Moreover, intensive research which is now being applied to the utilisation of short-fibred pulps will extend the range of papers and speeds at which papers from them can be manufactured economically. In addition experience which has been gained in designing machinery for the high-sped production of paper from long-fibred pulps will also be extremely valuable in the design of machines to manufacture paper from short-fibred materials.



Sketch No. 12



Sketch No. 13

IMPROVED QUALITY AND PRODUCTION FROM EXISTING PAPER-MAKING EQUIPMENT[1]

F. T. PETERSON

INTRODUCTION

Through the process of continued engineering development and technological research, each month new processes and methods become known to the paper industry. New designs for paper-making equipment and new production techniques are being promulgated, all of which aim at manufacturing paper at the highest possible rate, with continually more exacting quality standards, at the least possible cost.

This paper comments on various machinery and production design principles and does not go into new processes. It is concerned with two main aspects only: stock preparation and paper and board machines. It confines itself to a discussion of the possibilities of improving existing paper-making machinery already in operation. Reliable sources have estimated that of the increase in world production which has taken place in the last twenty years, only 60 to 70 per cent is accounted for by new installations, the other 30 to 40 per cent having resulted from improvements to machinery already in existence.

This suggests that there is a wide field of study and application for improving existing paper-mill machinery, especially for those desirous of expanding production and improving quality standards, but lacking the necessary capital for new plants.

STOCK PREPARATION

The several functions of the stock preparation or beater room may be distinguished and defined as follows:

1. *Pulping or slushing:* transforming the raw stock or pulp into a suitably slushed, pulped or defibred condition ready for the second or refining process.

2. *Refining:* first, treatment of the stock to complete the defibring of the fibre bundles remaining after the slushing or pulping process; secondly, imparting the desired hydration or wetting characteristics in addition to the necessary brushing or fibrillating treatment.

3. *Cutting:* shortening the fibres to give the stock its final treatment prior to use on the paper machine.

For many years, a single machine—the Hollander beater—attempted to accomplish all these three, essentially incompatible, operations. Today three separate machines, the hydrapulper, the hydrafiner, and the Jordan refiner, are available.

The action of the *hydrapulper* is extremely simple. Stock is fed into a large cylindrical chamber and the violent pulping action imparted by the impeller circulates the stock in a vortical path. This action continues until the stock particles are broken down and small enough to be transported to an auxiliary machine such as the hydrafiner to complete the work or to begin the refining action.

With its extremely high capacity, its quick action and its low power consumption, the hydrapulper is claimed to be the most efficient machine to date for pulping and slushing.

There are two types of hydrapulper: the batch unit, into which a predetermined amount of stock is fed, pulped and then dumped into a chest for eventual refining, and the continuous type, where continual feeding and extraction takes place. The latter has a higher capacity and is most applicable to waste paper systems, newsprint and kraft systems, etc., where high tonnage is necessary.

The *hydrafiner* is an adaptation of the standard conical refiner and consists simply of a conical plug and shell with easily removable liners, generally of cast chrome or high stainless steel, designed not only to impart the best characteristics to the stock, but to minimize wear.

It has the following functions:

1. To complete the defibring of stock slushed by the hydrapulper or other primary slushing device.

2. To fibrillate, brush and groom the stock, thus increasing the fibre area so that the fibre is more susceptible to hydration.

3. To develop the highest possible tearing strength inherent in the stock.

4. To perform all these refining functions without any appreciable cutting or change in freeness of the stock.

5. To build up a moderate amount of tensile and bursting strength. The hydrafiner, not being a cutting unit, merely assists in the initial stages of strength development, an operation completed by the cutting action of the subsequent Jordan type refiner.

The hydrafiner can be used either as a batch unit, the stock circulating from a chest through the hydrafiner back into the chest until optimum refining conditions are achieved; or operating continuously, individually or in multiple units, and feeding the stock to the third phase.

The essential feature of the hydrafiner is that it is designed to operate with low power at high speed, thus according a gentle brushing, hydrating and fibrillating action; thus effective fibrillation, brushing and brooming, effective hydration, with quick increase in tear and little change in freeness characteristics is obtained without materially shortening the fibre. When cutting action is called for, the *Jordan refiner,* operating at lower speeds and higher power, is appropriate. The cutting action reduces tearing strength almost immediately, whereas the tensile and bursting strengths increase much more rapidly; freeness drops off quite rapidly and the shrinkage value increases.

Mill experience shows that refining is only effective up to the maximum tear development of any fibre. Beyond that point, a cutting machine (the Jordan refiner) is more efficient if further strength development is desired.

The hydrafiner has certain special uses. For example, on straw or esparto and various types of vegetable fibres,

[1] The original paper (ST/ECLA/CONF.3/L.6.13), of which this is a condensed version, includes eight pages of photographs and charts illustrating the construction and performance of certain of the items of equipment referred to. It also includes many suggestions for improving existing machinery not mentioned here.

semi-chemical pulp, refining of groundwood tailings, etc. (where defibring is the aim and fibre shortening undesirable), the hydrafiner, owing to its gentle brushing action, is extremely effective.

Improved quality and production from existing beater rooms call for the installation of three separate groups of machines to perform the three prime functions of stock preparation: (1) hydrapulper type of machine to do the pulping and slushing; (2) hydrafiner type of machine to do the refining; and (3) Jordan refiner type of machine to do the cutting.

The first step might be the installation of a Jordan between the machine chest and the paper machine itself. This would immediately lighten the work-load of the Hollander beaters. This offers another advantage to the paper maker. By having a Jordan between the machine chest and the machine, he can make an immediate correction to the sheet characteristics, by underbeating slightly in his beaters and finishing the stock treatment work in the Jordan.

The next step could be to put in a hydrapulper type of machine for pulping and slushing, dumping the batches directly into the Hollander beater. Thus the Hollander would be relieved of initial work of slowly slushing or pulping the baled stock and could be concentrated wholly on refining.

These two steps will relieve the Hollander beater of 50 to 75 per cent of its work-load, making possible a decided increase in production.

The final step would be the replacement of the Hollander beater by a hydrafiner type of machine. This would complete the change-over and the three machines would each be doing the job for which they were designed.

Paper and board machines

At the wet or forming end of the machine a serious problem is that of entrained air in the stock, with its adverse effect on the quality and quantity of production. A development for removing entrained air is a device known as the *Deculator*, which is installed between the machine screen and the headbox and consists simply of a cylindrical tank with a baffle in the centre.

The stock to be introduced to the headbox of the machine is pumped into this tank under pressure and impinges upon the baffle in the centre of the tank. This releases the entrained air and the deaerated solution falls to the bottom of the tank, whence it is taken to the machine headbox. The liberated air is removed from the top of the tank by means of a vacuum pump and condenser arrangement.

Among the many advantages of removing entrained air are:

1. Reduction of slime and flocs, and disappearance of foam on the surface of the stock in the headbox or vat.

2. Improved smoothness on both sides of the sheet, and production of a tighter formed sheet, thus reducing porosity.

3. Possible increase of drying rate in the dryer section due to more efficient water removal on the wet end.

4. Reduction in steam consumption by virtue of a drier sheet being fed to the drying section.

In one mill the installation of a Deculator led to an increase in speed of 33 metres per minute, with a corresponding increase in production. In a mill making glassine paper the removal of entrained air enabled speed to be increased from 107 to 122 metres per minute. In a mill manufacturing certain types of hardboards, the consistency in the headbox was reduced from 2.2 to 1.4 per cent. The saving on foam killers amounted to $125 a week.

Design of the headbox or flowbox is most important. Correct design should aim at keeping the fibres evenly distributed and suspended in the stock solution and sufficiently agitated. This can be achieved by introducing such units as the *hydranamic* inlet, various types of flow spreaders, using rectifier rolls within the headbox, etc.

In the press section of the paper machine, the use of suction rolls will almost invariably improve production by permitting a drier sheet to be fed into the dryer section thus giving that section a higher working capacity.

Automatic control equipment, such as moisture control indicators, dryer temperature indicators, press loading indicators and recorders can help to both improve quality and increase output.

The modification or even complete reinstallation of existing machine drives may need to be considered. Faulty drives giving improper draw control between sections can be a source of considerable production losses. Mechanical or electrical drives, however, correctly engineered and installed, can do much towards improving production.

VII. Review of the development prospects for pulp and paper industries in selected Latin American countries

DEVELOPMENT PROSPECTS FOR ARGENTINA'S PULP AND PAPER INDUSTRY[1]

SILVIO GAGLIARDI

Paper and board consumption in Argentina in 1954 has been estimated at some 400,000 tons a year, distributed as follows: 90,000 tons for newsprint and magazine paper, 260,000 tons for sundry papers and 50,000 tons for board. Production, made up of 30,000 tons for newsprint and magazine paper, 250,000 tons for sundry papers and 50,000 tons for board, amounted to 330,000 tons. The deficit was thus 70,000 tons, some 60,000 tons of which correspond to newsprint. The equivalent in chemical pulp of the products consumed is 210,000 tons, and 40,000 tons of mechanical pulp. As domestic production represents 45,000 and 32,000 tons respectively, an annual deficit of 165,000 tons of chemical pulp and of 8,000 tons of mechanical pulp has to be met with imports.

A steady increase in paper and board consumption is foreseen. It is estimated that by 1960 it may reach 600,000 tons, of which 200,000 tons will be newsprint and magazine paper and 400,000 tons sundry papers and boards. In other words, 250,000 tons of chemical pulp and 250,000 tons of semi-chemical and mechanical pulp will be needed. Current expansion plans indicate that the country's production capacity will be by that time 350,000 tons of paper, 75,000 tons of chemical pulp and 60,000 tons of semi-chemical and mechanical pulp. Thus there will be a deficit in production capacity of 250,000 tons for paper and board, 175,000 tons for chemical pulp and 190,000 tons of mechanical and semi-chemical pulps. A broad field for development therefore exists in this industry, not only as regards raw material but in the making of paper and board as well. Several projects are being studied, based on the use of domestic sources of raw material. These include the following: wheat straw, black sorghum, sudan grass, picanilla and tacuara bamboo, castilla cane, sugar-cane bagasse, salicaceous species such as willow and poplar, American pine and *Araucaria angustifolia* from Misiones.

[1] This text is a condensation of the statement made by Mr. Gagliardi, Vice President and Manager, Celulosa Argentina S.A., at the meeting.

DEVELOPMENT PROSPECTS OF THE PULP INDUSTRY FOR SPECIAL PAPERS IN THE PROVINCE OF CORDOBA, BASED ON THE PALM TREES OF THE AREA[1]

S. LLORENS, J. MUHANA AND W. GINZEL

In the north-west of the Province of Córdoba there is a wooded area, where the palmtree *Trithrinax campestris,* commonly known as palma, palmera or caranday, predominates. The leaves of these palmtrees are suitable for the production of pulps for paper making; they are easily and economically collected, and, as new ones grow each year, the forest can be exploited permanently, thus ensuring a regular supply of raw material.

According to data supplied by the Dirección General de Agropecuaria de la Provincia de Córdoba, it is estimated that there are, in the districts of Sobremonte and Tulumba, some 180,000 hectares of *Trithrinax* palms, with a density per hectare ranging from 500 to 1,500 trees. On the assumption of an average annual yield of 200 grammes per tree, the area could produce a minimum of 20,000 tons of pulp suitable for making strong kraft-type or absorbent papers, such as blotting paper.

It would be advisable to install pulp and paper mills near the plantations to avoid difficulties and expense in transporting raw materials. Sufficient water is available, together with waste disposal facilities, while there is abundant fuelwood in the region.

The palm trees grow in districts where the economy has not been greatly developed. Thus their exploitation as a raw material for the paper industry would tend to open up the whole north-west of the province, while at the same time considerably raising the living standards of the inhabitants.

[1] A shortened version of the original paper (ST/ECLA/CONF.3/L.7.9).

DEVELOPMENT PROSPECTS FOR THE PULP AND PAPER INDUSTRY IN BOLIVIA[1]

JONNY VON BERGEN

Consumption of paper and board in Bolivia in 1954 was estimated at some 2,200 tons and that of newsprint at some 3,500 tons annually. The actual requirements of various types of paper and board are about 5,000 tons annually, but since imports are restricted for lack of foreign exchange, there is a great scarcity of paper of all types, so that this demand cannot be met.

There is one mill for board which uses mainly *paja brava* (a type of straw) and has an annual output of 750 tons, and there is a project to establish in the near future a mill to produce 5,000 tons annually of bleached chemical pulp and paper from sub-tropical woods. Extensive forests of such wood are found in the country.

[1] This text is a condensation of the statement made by Mr. von Bergen, President, La Papalera S.A. (Bolivia), at the meeting.

DEVELOPMENT PROSPECTS FOR THE BRAZILIAN PULP AND PAPER INDUSTRY[1]

José Carlos Leone

In 1953, Brazil consumed 170,000 tons of chemical pulps, 206,000 tons of mechanical pulp—including waste paper—146,000 tons of newsprint and 250,000 tons of other papers and boards. The respective production figures were: 51,000 tons of chemical pulp, 104,000 tons of mechanical pulp (including waste paper), 43,000 tons of newsprint and 220,000 tons of other papers. In other words, domestic output met requirements to the following extent: chemical pulp, 30 per cent; mechanical pulp, 52 per cent; newsprint, 30 per cent; other papers, 97.3 per cent.

Chemical pulp is made in fourteen mills, one of them having an annual capacity of 35,000 tons while the other thirteen average slightly over 1,000 tons each. Paper—other than newsprint—is manufactured in fifty-three mills with a total capacity of 246,000 tons; 68 per cent of these mills had annual capacities below 5,000 tons, while only five could produce more than 10,000 tons a year. There is only one newsprint mill, having a daily capacity of 100 to 120 tons. Absence of detailed statistics prevents any true assessment of domestic capacity for making mechanical pulp; all that can be confidently asserted is that eleven mills have an aggregate capacity of 55,000 tons, but there are other small mills distributed mainly throughout the states of Paraná and Santa Catarina.

Newsprint production—unlike that of other types of paper, which practically meets demand—shows no great expansion in Brazil. Various factors have hampered its development, among them the exemption of newsprint from import duties, the high cost of the equipment required for large-scale production and the inadequate domestic output of mechanical pulp. Meanwhile, the growing imports of newsprint have an unfavourable impact on the country's balance of payments. In 1950, Brazil spent nearly $8 million on newsprint; in 1953, the figure rose to $19 million, placing this product fifth on the list of Brazilian imports.

[1] A condensed version of the original paper (ST/ECLA/CONF.3/L.7.2) which contains eleven tables of paper statistics and forecasts of future demand.

By 1960, it is estimated that the demand for paper and board will have risen to 539,000 tons, 187,000 of which correspond to newsprint and 352,000 to other papers and boards. Pulp requirements to meet a production of such size would be 191,000 tons of chemical and 208,000 tons of mechanical pulp.

The exchange reform introduced in October 1953 has, by making imported goods more expensive, awakened the interest of industrialists, particularly as regards pulp production. The Government, moreover, has rerecently taken a keen interest in the expansion of the pulp industry, which has been included among those industries considered as basic to the country's economic development. Taking into account only the plans for expanding the capacity of integrated pulp and paper mills—which are almost certain to be put into effect—there should, by 1960, be a minimum increase in paper production of some 96,000 tons.

There are in Brazil four main sources of raw material for the pulp and paper industry. These are:

1. The virgin forests of Paraná pine *(Araucaria angustifolia)*, of which the wood provides an excellent pulp for wrapping papers, and is already used by the largest pulp mill in the country;

2. The eucalypt plantations in the São Paulo region, the pulp of which is suitable fo rthe manufacture of writing and printing papers;

3. Sugar-cane bagasse from the states of Pernambuco, Alagoas, Rio de Janeiro and São Paulo, the use of which is already being successfully practised in the last-named state and is likely to be extended in the near future; and finally;

4. Tropical woods from the north, which for the time being offer long-term potentialities.

Taking into account the specific conditions of location, energy, economic size of the mill and other technical or economic factors, only the two first-mentioned sources of supply may be said to deserve consideration for the immediate expansion of pulp and paper capacity. Bagasse and tropical woods will undoubtedly also represent very important resources, once the problems defined above have been overcome.

EXTRACTS FROM "THE FOREST AND FOREST INDUSTRY SITUATION IN CENTRAL AMERICA" A REPORT OF THE FAO FORESTRY MISSION FOR THE COMMITTEE FOR ECONOMIC CO-OPERATION IN CENTRAL AMERICA (ECLA)[1]

Costa Rica

In 1951, paper consumption in Costa Rica totalled 3,850 tons, including 1,800 tons of newsprint. Until 1953 demand was covered entirely by imports[2] mainly from Canada and the United States. In September of that year the La Perla pulp and paper mill began operations, and is still the only one in existence (1954). It is designed for an annual output of 3,000 tons *abaca* waste fibre. The raw material used is supplied by two *abaca* cleaning factories, the quantity available being estimated as sufficient to make 12 tons of paper a day, and it has already been proved that, with adequate care, a good quality kraft paper can be made.

Potential future sources of raw material for making pulp and paper include the forests of Heredia and Alajuela, San José and Puntarenas, and Limón, covering respectively some 400,000, 160,000 and 130,000 hectares. The first-named provide the most favourable conditions, as the topography is flat, and the San Carlos and Sara-

[1] This text is essentially the same as that of the abstracts presented at the meeting as ST/ECLA/CONF.3/L.7.7, but information on Costa Rica has been added and adjustments made to conform to the final text of the FAO Mission's report.

[2] In 1951, the value of these imports amounted to 939,000 dollars, representing approximately 1.7 per cent of Costa Rica's total imports.

piquí rivers, besides forming an excellent natural transport system, provide an abundant source of water. Sufficient raw material could be made available to supply a pulp mill of economic size, but detailed study of the composition and density of the forests is required.

A group of industrialists prepared a project based on using the species *guarumo (Cecropia peltata)* and *poró (Erythrina peoppigiana)* as raw materials for pulping. The quantities of these species are not, however, thought to be sufficient to supply a pulp mill of economic size.

As to the other raw materials required for the paper industry, Costa Rica produces limestone, salt and kaolin. At present the electric power capacity is deficient, but it will improve considerably once the Government's electrification plan, with the recommendations made by the Integration Programme's electrical mission, is put into effect.

Finally, short-term fibrous resources are available in the form of *abaca* fibre, in sufficient quantity to provide the Central American countries with wrapping paper and some kinds of writing and printing paper. From the long-term point of view, the broad-leaved species obtainable from the virgin forests in Heredia and Alajuela, in the north of the country, might be taken into account.

El Salvador

In 1953, El Salvador's total consumption of paper and board reached approximately 6,000 tons, about 2,750 tons of which were newsprint. With a total population of slightly over 2 million, *per capita* consumption may be reckoned at roughly 2.9 kg. As El Salvador has no existing pulp or paper industry, all supplies are at present imported,[3] mainly from the United States and Canada.

Only the pine forests situated to the north of the country, near the border with Honduras, might be considered as a possible source of wood material for pulp and paper. However, it is believed that supplies from this area could not satisfy the requirements of a pulp mill of economic size.

In some places, "escobilla" *(Sidi rhombifolia)* has been planted to prevent soil erosion, although the altitude of the areas concerned is not particularly suited to its growth. The bark is suitable for the production of textile fibre and the stalk (1 to 2 cm in diameter and approximately 2 m in length) represents a possible but very limited source of short-fibred raw material which might be used for pulping.

Because of the lack of suitable raw materials and the present low domestic consumption of paper and paper products, there seems little prospect of El Salvador manufacturing its own supplies of pulp and paper for some considerable period to come.

Guatemala

In 1952, Guatemala's total consumption of paper and board amounted to 6,753 tons, including 2,428 tons of newsprint. With a population of rather less than 3 million, consumption *per capita* may be reckoned at roughly 1 kg. Except for some small quantities of wrapping paper and board, all supplies are imported,[4] mainly from the United States and Canada.

It has been estimated that by 1965 the country's annual requirements of paper and paperboard including newsprint, will have reached about 12,000 tons.

At present (1954) there is only one paper mill in the country—Industria Papelera Guatemalteca—situated in the Escuintla district. The raw materials used are *racate limón* or *citronella* grass; the company having its own plantations of the second. These materials are first distilled by steam to extract the oil. The plant has a capacity of about 12 tons per day but operation has been somewhat sporadic owing to marking difficulties arising from the quality of the product.

Guatemala has abundant forest resources. From a pulping point of view probably the most important long-term sources of raw material in the country, and perhaps in the whole of Central America, are the typical tropical broad-leaved forests in the immediate surroundings of Lake Izabal. Pine forests *(Pinus oocarpa* and *P. caribaea)* cover the neighbouring mountainous area, and thus could provide an important source of long-fibred pulp for chemical pulping.

Elsewhere, in the region of Peten, are found other extensive areas of tropical broad-leaved forest and in the district south of Huehuetenango, a large area under pines. Bad terrain and lack of communications, however, exclude the possibility of either of these areas being considered as potential sources of pulpwood supply, at least for the time being.

Apart from the forest resources, sugar-cane bagasse and henequen waste are available, but in very small quantities.

With regard to chemicals, there is sufficient lime and salt but materials such as saltcake, sulphur, alum, etc. would have to be imported.

Although consumption of paper and paper products in Guatemala is increasing, it is not at present sufficient to support commercial operation of another mill in addition to that of Escuintla. This mill could in fact supply most of the country's needs of wrapping paper and board if product quality and the mill's efficiency were improved, and providing it worked at maximum capacity. From the long-term point of view the Lake Izabal area appears to offer the most favourable prospect for increasing local production capacity.

Honduras

Consumption of paper and paper products in Honduras has been increasing at the rate of about 4 per cent per year; it amounted in 1953 to over 2.7 thousands tons (including nearly 500 tons of newsprint). At present all supplies—equivalent to 1.7 kg *per capita*—are imported, chiefly from the United States and Canada. The country has at present no pulp or paper industry.

With 43 per cent of the land under forests, Honduras possesses several potential sources of raw material for pulp and paper, but unfortunately lack of transport facilities in some places and inadequate supplies of water in others preclude their exploitation for this purpose in the near future.

[3] The value in 1951 was 1,655,000 dollars.

[4] The value in 1952 was 2.6 million dollars (equivalent to 3.4 per cent of total imports).

Nevertheless in the area around Lake Yojoa—a region served with a good highway—there are large stands of pine, chiefly *Pinus oocarpa*, which it is estimated could maintain supplies to a pulp mill with a capacity of 100 tons a day, sufficient to meet the needs of the entire Central American market, and to give an exportable surplus by 1965, estimated at some 21,000 tons.

Elsewhere in the Yoro district—an area comprising about 250,000 hectares—there are other large resources of pine *(Pinus oocarpa* and *P. psuedostrobus)*. With proper sustained yield management it has been calculated that these resources could meet the demands of a pulp mill of at least 50,000 tons a year capacity and probably very much more.

Stands of broad-leaved species and plenty of conifers are found in the Olancho district and guaramo *(Cecropia)* suitable for making newsprint is said to grow abundantly on the banks of the Paulaya river. Immediate exploitation is impossible, however, owing to lack of communications.

So far as chemicals, fuel and power are concerned, Honduras has plentiful supplies of good quality salt and limestone in the Lake Yojoa and Yoro districts, but wood, which is expensive, is the only available domestic fuel. Present production of electricity is insufficient to meet the country's industrial demand, though a large-scale hydro-electric plant is projected at the Rio Lindo falls, and could supply a large pulp mill.

It is evident that domestic consumption of paper and paper products in Honduras will not be sufficient to support production from a pulp and paper mill of economic size for many years to come. Nevertheless, reports indicate that the country possesses large resources of raw material suitable for pulp, especially in the regions of Yoro and Lake Yojoa, which should be borne in mind for the future.

[5] 1951 value just over $500,000.

Nicaragua

Total consumption of paper and board in Nicaragua in 1953 was approximately 2.3 thousand tons (of which about 750 tons were newsprint), or around 2 kg *per capita.* The entire supply is imported, mainly from the United States and Canada.[5] No pulp and paper industry exists in the country at present.

Nicaragua has considerable resources of timber potentially suitable for pulpwood. The coniferous forests in the district of Nueva Segovia, an area covering approximately 170,000 hectares, could supply high quality pinewood, but mountainous terrain, lack of transport facilities and an inadequate water supply prevent the installation of a pulp and paper mill, at least in the near future.

About 670,000 hectares in the El Cabo and Zelaya districts are thinly covered with *Pinus caribaea.* The forest has, in many places, been depleted by fires, poor exploitation and the pasturing of animals. Even so, it is believed that this area, given proper management, could maintain supplies to a pulp and paper mill of economic size. The terrain is favourable for road building and certain rivers in the region (Coco, Huahua and others) could serve as a source of water and as a means of transport.

South of Zelaya, broad-leaved forests cover an area calculated at over 6 million hectares, but exploitation is at present impossible owing to a complete lack of communciations.

It is concluded that many years will elapse before domestic consumption of paper and paper products in Nicaragua is likely to reach sufficient proportions to support a pulp mill of minimum economic size. Moreover, before any pulp and paper scheme based on the woodland resources of the El Cabo and Zelaya districts could properly be considered, a system of sound forest management would have to be developed and reafforestation measures introduced.

DEVELOPMENT PROSPECTS FOR THE CHILEAN PULP AND PAPER INDUSTRY[1]

Corporación de Fomento de la Producción

Although the paper industry in Chile meets domestic demand to a greater extent than is true of most of the Latin American countries, it is still largely undeveloped. Over the last five years, 57 per cent of newsprint requirements and 15 per cent of those for all other paper and board, plus 85 per cent of the chemical and 10 per cent of the mechanical pulp used in production, have had to be met by imports. This means in fact that imports have amounted to 13,700 tons of newsprint, 3,400 tons of other paper and board, 26,700 tons of various kinds of chemical pulp and 1,400 tons of mechanical pulp. Average figures (1949-1953) for apparent consumption and production of paper and board are shown below:

Average consumption of paper and board during the period 1949–1953

(tons)

	Apparent consumption	*Production*
Newsprint	24,000	10,300
Paper for writing and printing	14,600	13,100
Wrapping and industrial paper	18,100	17,900
Board	4,200	3,800
Other unclassified papers	2,900	1,600
Total	63,800	46,700

Domestic production of all paper and board has increased by 11.5 per cent over the past five years. Imports have declined, however, so that apparent consumption has remained constant.

[1] A shortened version of the original paper (ST/ECLA/CONF.3/L.7.4), which includes fifteen statistical tables, three maps and nine charts.

A single company has supplied 96 per cent of total domestic production, and is the only one to make newsprint, writing and printing paper. The remaining output corresponds to numerous small plants whose capacities, with one or two exceptions, do not exceed a 1,000 tons a year.

As regards chemical pulp production, there is only one mill in the country, using wheat straw and employing the Pomilio soda-chlorine process. It has an annual capacity of 5,500 tons. All the pulp is bleached, and is used by the same mill to make writing papers. Production at this single mill has fallen off by 20 per cent in recent years, because the increasing use of combine harvesters in the wheat fields makes the supply of raw material ever more difficult. Apparent consumption of bleached pulp has remained practically constant, however, since imports have increased.

Unbleached pulp comes entirely from abroad. Save for an occasional fluctuation, some 17,000 tons a year have been used.

The two rayon and short-fibre mills have increased their imports of dissolving pulp by 50 per cent since 1949, reaching the figure of 3,400 tons in 1953.

Mechanical pulp, using insignis pine *(Pinus radiata)*, began to be made in Chile several years ago. In 1953, productive capacity amounted to 18,000 tons a year, coming from two mills which make the pulp for their own use.

During the five-year period ending in 1953, apparent consumption and output reached approximately the figures shown below.

	Apparent consumption (tons)	*Output (tons)*
Bleached chemical pulp	10,700	4,600
Unbleached chemical pulp	17,700	—
Dissolving pulp	2,900	—
Chemical pulp	16,600	15,200

Total demand in 1960 for paper and board is estimated at 119,400 tons, of which 41,000 tons would correspond to newsprint and 78,400 to other paper and board. The demand for mechanical pulp is set at 45,300 tons and for chemical pulp at 55,500. Dissolving pulp requirements for rayon are estimated at 10,000 tons.

Chile is in an excellent position to meet all its present and future requirements for pulp and paper, and even to become an exporter of these products. Not only are abundant fibrous raw materials available, in 6 million hectares (8 per cent of the country's total area) of natural forest consisting of broad-leaved temperate zone species and extensive plantations of *Pinus radiata*, but also the other essential requirements for the development of the industry.

According to tests made, the natural forest in the south of Chile includes several species suitable for making chemical pulp. The *Pinus radiata* plantations have been established in the last twenty-five years, particularly in a district in the south-central sector, some 300 km in length by 70 km broad, where they cover nearly 200,000 hectares. These artificial forests grow at the annual rate of 20 solid cubic metres, barked, per hectare. This means, since there are no difficulties in the chemical or mechanical pulping of the wood, that the plantations represent a vast productive potential, which would amount to nearly 200,000 tons of pulp by 1960.

Development plans envisage an ever more complete utilization of the wood available, particularly that from *Pinus radiata*. The International Bank for Reconstruction and Development granted a loan to a private Chilean company for $20 million, guaranteed by the Corporación de Fomento de la Producción. It is to be used to build two new mills. The first, which will eventually produce 47,250 tons a year of bleached and unbleached pulp and 10,500 tons of kraft paper, is to be located at the confluence of the Laja and Bío-Bío rivers. The other, on the southern bank of the Bío-Bío, opposite the city of Concepción, will have an annual capacity of 44,000 tons of newsprint and 6,600 tons of board. The building of both mills has already begun and it is expected that they will enter production in 1956-1957.

Industrial utilization of the pine plantations on as complete a scale as possible, means that a minimum annual output of 700,000 tons of pulp will be attained within the next fifteen years. This would require total investments amounting to nearly $200 million.

The first part of this plan would be to install a rayon mill, with an annual capacity of 60,000 tons. Some 50,000 tons would be available for export. According to tests made to date, insignis pine wood is perfectly suitable for making this type of pulp, and its manufacture would meet part of the growing needs of Latin American and European countries.

DEVELOPMENT PROSPECTS FOR PULP AND PAPER IN COLOMBIA[1]

MANUEL ARCHILA M.

The report prepared by the Currie Mission, and sponsored by the International Bank for Reconstruction and Development, estimated Colombia's annual *per capita* paper consumption at 3.26 kg in 1951. The annual increase in demand was set at 6 per cent, which would mean that demand in 1955 would amount to about 65,000 tons, thus justifying the installation of a domestic paper industry.

The following may be considered as potential sources of raw material:

(*a*) Some tree species from tropical or sub-tropical forests;

(*b*) Sugar-cane bagasse; some 170,000 tons of dry bagasse are available each year, and at present are used only as fuel;

(*c*) Rice straw; production of this cereal is increasing very rapidly, particularly in the districts of Tolima and the Cauca Valley, where climatic conditions and modern irrigation systems allow almost continuous harvests to be obtained;

(*d*) Several species of willows, eucalypts, pines, etc., which could be artificially cultivated over large non-forested areas to provide raw material for a paper mill.

The Instituto de Fomento Industrial is currently engaged in a detailed and systematic study of the forests in the middle valley of the Magdalena river, with a view to installing a pulp and paper mill. The materialization of this project depends on whether it is technically and economically feasible.

The only mill at present operating in Colombia is

[1] A shortened version of the original paper (ST/ECLA/CONF.3/L.7.3), which contains geographic and economic data on Colombia and statistics of paper consumption.

Cartón de Colombia S.A. It uses imported pulp, bagasse and waste paper, and has an annual output of 12,000 tons of wrapping and writing paper, and 12,000 tons of paperboard. It is planning to expand its output to 36,000 tons a year in order to meet the demand for papers of the kraft type.

The sugar-producing region of the Cauca Valley combines favourable conditions for the installation of a paper industry based on bagasse; the coal in which the area is rich could replace bagasse as fuel for the sugar mills; moreover the harvest is continuous and not seasonal as in other sugar areas.

DEVELOPMENT PROSPECTS FOR THE MEXICAN PULP AND PAPER INDUSTRY[1]

NACIONAL FINANCIERA, S.A.

Mexico buys abroad all of its newsprint, part of its chemical wood pulp requirements and certain papers requiring rather more advanced technique. These imports reach a yearly average of 290 million pesos a year —some $23.2 millon—which, although a negligible amount in the world market, is very significant for a country like Mexico which has limited resources for meeting the needs of its economic and demographic development. In 1951, these purchases represented 4.25 per cent of all imports, and 12.5 per cent of the trade balance deficit.

Over the last twenty-five years, some thirty paper mills have been established; by 1954 they consumed 105,000 tons of raw and bleached pulp, and about 18,000 tons of mechanical pulp. Mixed with waste paper—purchased locally and, exceptionally, abroad—these pulps are used to make all the wrapping paper, board, writing and printing paper for Mexico's requirements. A direct survey conducted among the manufacture revealed that chemical pulp production had risen to 51,000 tons in 1954. The remainder—54,000 tons—continued to be bought on the world market together with newsprint and other papers which require very specialized manufacture.

Estimates drawn up by FAO and by the Nacional Financiera, S.A. show that the maximum Mexican demand for pulp will reach 118,000 tons in 1960. Newsprint consumption—the present level of which is approximately 70,000 tons a year—will have risen to 87,000 tons by the same year. In a period slightly exceeding five years, Mexico will require roughly 30,000 tons more of chemical pulp and 80,000 tons of mechanical pulp.

Conscious of the impact which these purchases have on its trade level and balance of payments, Mexico is studying methods to avoid such problems as well as the pitfalls of self-sufficiency. The aim is to eliminate, within two years, the present deficit of 54,000 tons of chemical pulp. New mills have been built, some of which were already completed in 1954. Improved working methods have been introduced and some expansions have been made.

By 1956 at the latest, a minimum of 100,000 tons of chemical pulp will be produced, although this figure should rise to 137,000 tons if all the mills work at full capacity. The Nacional Financiera, S.A., between 1950 and 1953, granted credits for 245 million pesos—some $19.5 million—to the new mills. Meanwhile private enterprise has invested at least a similar amount. If to this is added the investment made by the Compañía Industrial de Atenquique, which began operations in 1946, it appears that Mexico has spent over $70 million in a decade with a view to attaining self-sufficiency in its raw and bleached pulp requirements.

Even so, there are still two problems to solve, relating to the production of newsprint and of special papers. Newsprint at first encountered a major obstacle—the excessive resin content of Mexican conifers. In the south of the United States, however, where there are similar varieties, the resin has been eliminated and ordinary mechanical pulp has been made. After a careful study of locational factors, it has been found that the forest area of Michoacán, with its centre in Uruapán, possesses the best conditions. An investment of $10 million will enable its woods to be exploited and a mechanical pulp mill to be installed with an annual capacity for 36,800 tons. This tonnage, mixed with 5,200 tons of chemical pulp, will be used to produce 40,000 tons of newsprint, sufficient to cover 57 per cent of present consumption and 46 per cent of that estimated for 1960. Other projects intended to hasten self-sufficiency depend for their execution on the development of the road network and of power plant, on the growth of domestic savings and on the possibility of obtaining foreign credits. If Mexico had the resources needed to exploit all its coniferous forests, it would become an exporter of chemical pulp and of newsprint. Moreover, it might enter the world market with other raw materials, such as sugar-cane bagasse, which is being successfully used by the Compañía Industrial de San Cristóbal, and will shortly be used also by a new mill being built at Ayotla.

Imports of certain types of paper requiring very specialized manufacture amount, on an average, to about 5,660 tons a year (1949-1950), with a value of some 38 million pesos. Of these, the only one that can be eliminated in the near future is cellophane paper, imports of which exceed 5 million pesos each year. It will be produced in Monterrey by Celotex, S.A., on the basis of alpha cellulose, to be made by Celulosa Chihuahua, S.A., which is one of the new mills now nearing completion.

[1] A shortened version of the written statement sent by the Nacional Financiera S.A. (ST/ECLA/CONF.3/L.75).

DEVELOPMENT PROSPECTS FOR THE PULP AND PAPER INDUSTRY IN PARAGUAY[1]

FREDERICK H. VOGEL

In 1950, total apparent consumption of paper and board was estimated at 1,766 tons, 438 of which correspond to newsprint, 465 to printing and writing paper, 490 to wrapping and packing paper, seventy-three to board and 300 to boxboard and other unclassified papers. Demand was met entirely by imports.

[1] This text is a condensation of the statement made by Mr. Vogel at the meeting.

By 1960 it is estimated that consumption will be 4,300 tons, of which 600 will be newsprint and the remainder other papers and boards.

Recognition of the importance of its forest resources to the national economy has led the Government of Paraguay to take particular interest in the possibilities for pulp and paper development. It has, for that reason, requested the technical assistance of bilateral and international organizations to prepare a plan for the rational development of integrated forest industries, including pulp and paper manufacture, agriculture and stockresettlement.

Eastern Paraguay has vast raw material resources, with its 7 million hectares of almost virgin sub-tropical broad-leaved forest. This area, according to field surveys on the Upper Paraná, gives an average yield of 100 cm per hectare from 100 different species. Laboratory studies have determined that as many as eight-three of these species can be pulped together in any proportion to produce an adequate commercial pulp of uniform character.

The Paraguayan stretches of the upper Paraná river offer very substantial hydro-electric possibilities, as well as a combination of other important factors, including abundant raw materials, excellent agricultural opportunity, a favourable living environment and available access to one of the principal river communication systems of this continent.

Although there are some unfavourable economic factors which have limited industrial development in the past, such as the very scanty population in the forest zone and disequilibrium in the foreign exchange situation, the Government of Paraguay is today deeply interested in overcoming these adverse factors by positive action to encourage both domestic and foreign investment.

Apart from their pulp and paper possibilities, these extensive forest resources, thanks to their location near the population centres of Latin America, may well have great economic significance in the future.

DEVELOPMENT PROSPECTS OF THE PULP AND PAPER INDUSTRY IN PERU[1]

RAMÓN REMOLINA

Peru currently consumes 42,500 tons of paper, of which 14,500 (34 per cent), including all newsprint, are imported. Of the 28,000 tons of paper produced within the country, 22,500 tons (80 per cent) were manufactured from sugar-cane bagasse, waste paper and rags, while the remainder was made from imported pulp. Nearly all wrapping papers and boards are produced from bagasse pulp; not only have domestic requirements been met, but a small surplus of about 2,000 tons a year has been exported mainly to Bolivia, Ecuador and Colombia.

Forecasts for 1960 indicate that domestic production will rise to 41,000 tons, while imports should amount to 21,000 tons. Some 34,000 tons (83 per cent) of the domestic output will probably be made from bagasse and waste paper, and the remainder from imported pulp.

[1] This text is a condensation of the statement made by Mr. Remolina, Sub-manager, Banco de Fomento Agropecuario del Peru, at the meeting.

To meet this increased demand, the country's paper mills—particularly Paramonga—are being suitably enlarged.

A considerable number of special papers are imported; their individual volume of consumption is too small to justify local manufacture. This, however, is not the case with newsprint, which is the largest imported item. Hence the project prepared by the Banco de Fomento Agropecuario del Perú includes the manufacture of mechanical pulp for newsprint, using cetico *(Ceocropia)* wood as the raw material.

Bagasse pulp and rice straw are two other sources of pulping material in Peru. Newsprint can be made from the former, and the country's annual supplies of bagasse exceed 600,000 tons. Rice straw has not yet been carefully studied; production of this cereal is concentrated in three valleys in the northern zone of the Peruvian coastal provinces. As much as 400,000 tons annually can be collected, and part of this could be used to make pulp for paper.

DEVELOPMENT PROSPECTS FOR PULP AND PAPER IN URUGUAY[1]

ASOCIACIÓN DE FABRICANTES DE PAPEL DE LA UNIÓN INDUSTRIAL URUGUAYA

The latest complete and reliable official data are those for 1949, since the production of 30,000 tons estimated for 1950 undoubtedly represents the prospects at that time rather than the actual amount produced by the country's mills. Thus, in order to determine the current position (1954) private estimates have to be used, and any forecast of future demand for paper and board must be based on data prior to 1950.

[1] A shortened version of the original paper (ST/ECLA/CONF.3/L.7.8).

In 1949, out of a total consumption of 42,734 tons, 19,501 tons corresponded to domestic production and 23,233 tons to imports. Of these, in turn, 17,034 tons were newsprint—all of which is imported—and 6,199 tons coresponded to other papers and boards. *Per capita* consumption in that year amounted to 18.1 kg, made up of 7.2 kg of newsprint and 10.9 kg of other papers and boards.

Estimated paper consumption during 1954 stands at an annual 55,000 tons, of which only 28,000 are produced in the country. The 20,500 tons of newsprint required are all imported, together with 6,500 tons of other papers and boards. This is equivalent to a *per capita* consumption of 22 kg, 8.2 kg corresponding to newsprint and 13.8 kg to other papers and boards.

Current production of paper other than newsprint amounts to approximately 50,000 tons, leaving a surplus of 22,000 tons annually in relation to consumption. To balance consumption and demand for all grades of paper, the following solutions are proposed:

(*a*) To complete additional installations for the production of some paper and board which is at present imported (glassine, cigarette paper, bristol board for cards used in accounting, etc.) It is hoped that capacity to manufacture these products will rise by 5,000 tons annually, enabling imports to be limited to 1,000 or 1,500 tons.

(*b*) To promote, through agreements with other governments, exports of some paper grades which may be of interest to other countries (especially neighbouring ones), with a view to satisfying their immediate needs, at least until their own capacity is enlarged. It is impossible to foresee the tonnages that could be exported, since these mostly depend upon the relevant exchange agreements.

(*c*) To produce domestically at least one-third of the present newsprint consumption. This will be the easiest problem to solve, provided that economic and financial arrangements can be made between the government, publishing houses and paper manufacturers. Its solution would also encourage domestic production of mechanical pulp, which is the most important raw material for newsprint manufacture.

In order to estimate future demand for paper and board, *per capita* paper consumption was correlated with *per capita* income, 2 per cent being taken as the average growth rate of income. For 1960 this method of calculation showed a demand for approximately 67,000 tons, 27,000 of which correspond to newsprint and 40,000 to other paper and board.

No less than 10,730 tons of chemical pulp and 2,458 of mechanical pulp were imported in 1953. In addition, 3,800 tons of straw pulp were produced locally by the soda-chlorine process. Fibrous raw material resources are very limited and the market is too small to allow the installation of units of economic size which could produce the different types of pulp required. It would therefore be more advantageous for the country to enter into an inter-Latin American co-operation plan and take part in the development of neighbouring countries' projects by investing capital in exchange for a guarantee, on the part of these countries, to allow duty-free exports of given quantities of pulp to Uruguay.

As regards mechanical pulp, however, the situation is different. The large plantations of poplar and eucalypt established during the last few years could easily cover the needs of a new mechanical pulp mill with an annual capacity of 8,000 tons. Such an output would suffice to meet the annual newsprint demand and to replace imports of this pulp. Recently one of the paper-making firms has put into operation an interesting installation for making dark mechanical pulp which is particularly suitable for the manufacture of wrapping paper and boxboard.

DEVELOPMENT PROSPECTS FOR PULP AND PAPER IN VENEZUELA[1]

Corporación Venezolana de Fomento

The strong currency and the ready supply of dollars which characterizes Venezuela's economy have, so far as production and consumption of paper and board is concerned, given rise to considerable imports of all types of paper. This in turn has meant that there is little incentive for investigating and developing the use of domestic raw materials. Until 1953, Venezuela produced only 15 per cent—7,718 tons—of its paper and board requirements, in a mill operating on the basis of imported pulp and waste paper. Consumption in that year amounted to 68,870 tons—12.5 kg *per capita.* It was distributed as follows: 20.4 per cent for newsprint; 19.3 per cent for printing and writing paper; 15.2 per cent for wrapping paper, 20.5 per cent for board and boxes, and 24.6 per cent for other papers and boards.

Domestic output consists of wrapping paper, mainly of the type used for cement sacks. At the beginning of 1954 another small mill for making toilet paper was installed in Guacara, a town near Valencia.

It is estimated that consumption of paper and board will rise to 91,200 tons (14.3 kg *per capita*) by 1960.

Although Venezuela has tropical softwoods which can be used for pulping, they are difficult to exploit because of the high cost of labour and transport. This directs the immediate prospects towards the use of sugar-cane bagasse as raw material for a pulp and paper mill. The Corporación Venezolana de Fomento has prepared a project for producing 13,500 tons of paper a year. The output would be distributed as follows: 3,500 tons of printing and writing paper; 5,500 tons of paper for multiwall sacks, 1,000 tons of wrapping paper, and 3,500 tons of corrugating board. Installation costs are estimated at 20 million bolívares. Meanwhile, private enterprise has formed a company with a capital of 25 million bolívares for a pulp mill with an initial annual output of 25,000 tons, to be expanded later on to 35,000 tons. This pulp will be used to make wrapping, and kraft papers, ordinary board and corrugated board for boxes. At a later stage, the company will probably put into execution a plan for using the country's timber resources as its raw material. For this reason, the exact location of the mill has not yet been decided.

[1] A shortened version of the original paper (ST/ECLA/CONF.3/L.7.6), which included seven statistical appendices, a map indicating the location of sugar-mills, and five charts showing trends in paper consumption and availability of bagasse.

VIII. Financing of Latin American pulp and paper development

FINANCING PULP AND PAPER DEVELOPMENT IN LATIN AMERICA[1]

THE SECRETARIAT

INTRODUCTION

The problem of financing pulp and paper development in Latin America is part of the larger problem of releasing, securing and channelling investment funds into all branches of the continent's economic activity. The causes and consequences of chronic capital shortage in the less developed regions of the world and, specifically, in Latin America, have been discussed in innumerable official and private publications in recent years. The present paper makes no attempt to deal with this problem.

The capital shortage, it should be remarked, is a relative one—relative to the tremendous capital needs occasioned by rapid economic development. In point of fact, the rate of investment in Latin American countries is, on the whole, rather high, gross investments amounting to some 16 or 17 per cent of gross output. Only a fraction, somewhere between a quarter and a third, currently finds its way into manufacturing industry. Of this fraction, perhaps half represents reinvestment rather than new investment. And pulp and paper is but one of many branches of manufacturing industry in urgent need of development.

It is natural therefore to ask: how urgent is that need? How can the claims of pulp and paper be balanced against competing claims? Answers to these pertinent questions lie outside the scope of this paper, and indeed the answers will vary from country to country. But it is perhaps possible to indicate briefly some of the considerations which have to be taken into account in reaching decisions of this kind.

Such considerations are primarily, but not exclusively, of an economic order. They concern national economic policies and the institutions through which those policies are effected, whether they are planning boards, central banks, development corporations or fiscal systems. It may be assumed that the flow of private investment will, other things being equal, be directed into those channels which offer the best prospects of remuneration after taking into account the risks involved. From this standpoint, the prospect of the pulp and paper industry's securing the capital it needs would seem to depend entirely on the rate of profit to be expected as compared with those to be looked for in alternative channels of investment.

Other things, however, are far from being equal; indeed it is the essence of planning, whether this consists of the mildest economic interventionism or of comprehensive regulation, that those branches of economic activity the planner considers important should be encouraged.

[1] Originally issued as ST/ECLA/CONF.3/L.8.0.

All the Latin American economies are free enterprise economies. But all Latin American governments are preoccupied, some intensely so, wth the problem of ensuring that economic development takes place in an orderly, balanced, programmed fashion; this gives rise to the need, firstly, to ascertain development priorities and, secondly, to take steps to ensure that these priorities are made effective. The means available for making priorities effective are many and varied: state enterprise, state lending, lending by public and semi-public institutions, discriminative taxation, tariff policies, preferential exchange rates, and so forth. The extent to which these various means are employed differs from country to country in Latin America. But it is safe to say that nowhere can governments afford to allow development patterns to be set solely by the investment flows that would correspond to freely competing profit expectations. To attempt to assess the likelihood of pulp and paper ventures obtaining the necessary capital by comparing estimated rates of profit in that industry with those obtainable in other fields would therefore be both naïve and fruitless.

An examination must rather be made of the criteria for deciding what fields of investment a government should sponsor or encourage, and of how the pulp and paper industry measures up to these criteria.

Ideally the development priority rating of a particular project would be based on a marginal social productivity assessment. An examination of the availability and location of the physical resources required would be followed by an estimate of the project cost. This would include fixed capital (distinguishing foreign exchange needs), operating capital (with separate estimates of foreign exchange needs for any materials, fuel and spares that need to be imported, payments to foreign technicians and interest on foreign capital) and indirect costs not allowed for in the planned project, such as additional power, transport and community facilities. From the gross total should be deducted various cost offsets which, in the main, flow from the indirect costs; e.g., the opening-up of new raw material supplies may permit the development of other industries based on that material or materials found in association with it; by-products, not taken into account in the original project, may enable an associated development to take place; some of the community facilities may have a value not confined to the project, and so forth.

The net cost of the project can now be compared with its contribution to the national income over the expected life of the productive assets. The foreign expenditures involved can be compared with the export-earning or import-saving power over the same period. Both these criteria offer a means of comparing one project with another in economic terms, and thus assessing development priorities.

This is the ideal procedure, but in practice the ideal is seldom attainable. Firstly, there are usually considerable margins of error attached to even those estimates which at first sight seem capable of fairly exact measurement. Secondly, it is extremely difficult to measure the indirect costs, and even more difficult to reduce the possible cost offsets to figures. Finally, there are considerations lying outside the economic field which may call for a readjustment of benefit-cost assessment.

Clearly, it would be outside the scope of this paper to attempt to measure the development priority which should be accorded to pulp and paper projects in each Latin American country; only the governments concerned possess all the data permitting such a calculation to be made. It is possible, however, to offer a few observations.

Other papers submitted to this meeting contain original data relating to the capital requirements for, and production costs at, hypothetical mills to be established in various parts of Latin America. These models provide an indication of the orders of magnitude involved. One conclusion which may be drawn from these models is that about 50 per cent of the total capital required will normally have to be spent abroad. This sets a lower limit to the foreign exchange needs for servicing foreign capital, since foreign capital may also be sought to meet locally incurred capital costs.

Consider, for example, one of the hypothetical mills which has been the subject of pre-conference study: a 30,000-ton annual capacity pulp mill to manufacture unbleached sulphate pulp from mixed tropical woods in the Yucatán region. It is estimated that to establish this mill a total capital would be required of $14 million. This would cover land, buildings, the cost of mill machinery and of erecting the mill, investment in the forest, the provision of housing and community facilities, capital costs during the erection period and working capital. Foreign capital would perhaps be obtained for about half the total amount, say $7 million. Now capital charges, as the cost sheet shows, amount to $43 per ton of product. The capital "import content" will probably be less than half this amount, since foreign capital will probably be at a lower rate of interest, covering machinery purchase; $20 would be a reasonable approximation.

Actually, this $43 is not the whole of the capital charge, since the capital costs on the forest operations are separately included in the pulpwood cost, of just under $20 per ton. A part of this is for equipment which will be purchased abroad; assuming that $7 of the unit pulpwood cost represents service on foreign capital, this gives a total capital "import content" of $27 in the cost of production per ton. None of the cost components other than capital charges call for substantial foreign expenditures. In this instance all the chemicals will be obtained locally. If it is assumed that clothing, felts, wires, etc. ($2 per ton) are purchased abroad, all repair and maintenance material ($3) likewise, and if half ($2) of the contingency item is taken into account, then the total import content amounts to $34 of the cost of production per ton. Comparing this with the c.i.f. cost of unbleached sulphate pulp, there is an import saving of $100 to $110 per ton, and an annual saving of around $3 million. If the life of the assets is reckoned at 10 to 15 years, this means an aggregate saving over that period of $30 to $45 million.

To take another example, a 60,000-ton integrated paper mill at Amapá, costing around $40 million, would have an import content (capital and other items) in its mill cost per ton of about $80 to $100. This, at current prices, corresponds to an import saving of about $100 per ton, or $6 million annually.

These examples give a very rough indication of the import-saving value of new pulp and paper projects. If a bigger proportion of the capital were raised abroad, including some risk capital requiring a higher return, the import saving would diminish. Since the cost estimates allow for only a conventional rate of profit (12 per cent) on investment capital, a part of any additional profit obtained would also have to be repatriated.

Nevertheless, the figures just quoted suggest that pulp and paper projects will have a considerable import-saving value. It is not possible, of course, to say how this value compares with that which might be expected in other investment fields. And in any case, it would not be wise to set too much store on the import-saving power of pulp and paper investment. The experience of pulp and paper development in Latin America over the last two or three decades suggests that the main effect of new indigenous production is not to replace imports but to enable latent, hitherto frustrated, demand to become effective. With limited foreign exchange resources available, the tendency, is increasingly to give more and more priority to capital equipment items in total import programmes. This may operate through quotas, setting quantitative or value limits to the volume of paper which may be imported, or through tariffs, allowing prices to damp down effective demand. In other words, pulp and paper imports are already below the level that would correspond to a full and free satisfaction of internal demand. Thus the establishment of a new pulp and paper project will not necessarily lead to a commensurate reduction in pulp and paper imports; rather it will admit of local paper consumption standards rising to a level more appropriate to the stage of economic and cultural development reached in the country. This of course, is a real gain which must be taken into account. Governments embarked on campaigns to reduce illiteracy and raise educational standards will not be oblivious to this fact.

The establishment of a new or enhanced local paper supply can permit many other developments to take place. For example, it may facilitate the setting-up of a local book-publishing industry, with all its cultural implications, or of bag, carton, cardboard box, manufactured stationery and various other paper-converting industries, which did not exist before.

It may open up new possibilities in wood-using industries. There is a general impression that the key to opening up the mixed tropical forests for the exploitation lies in integrating the activities of appropriate groups of wood-using industries—pulp and paper mills, plywood and sawmills, fibreboard mills, etc., so that some of the heavy development costs can be spread. This view is not borne out by the investigations which preceded this meeting, and in all the calculations which have been made it has been deemed safer to make the pulp and paper estimates independent of other forest product enterprises; not, however, independent of all other developments since, as explained in Paper 3.02, the sites have been located so as to take advantage of impending developments in other fields. This procedure has been dictated partly by the technical difficulties of planning other elements of an integrated group of industries, partly because the investment costs in pulp and paper heavily outweigh those which may be envisaged in the other industries. In consequence, many of the items that appear as charges in the pulp and paper calculations will contribute to lowering the capital cost of subsequent developments in other wood-using industries.

This introduction has sought simply to make clear which aspects of financing Latin American pulp and paper development cannot be dealt with in the scope of this paper, and at the same time to set out some of the considerations which must influence governments in determining what priority should be accorded to investment in this field. The following paragraphs indicate in very general terms, the size of the problem involved —the investment which is likely to be necessary if the rise in the region's paper needs over the next few years is to be met from the continent's own resources.

The size of the problem

Other papers submitted to this meeting have shown (a) that particularly favourable conditions exist for the development of pulp and paper industries in many Latin American countries, and (b) that, in view of prospective world supply conditions, such a development of indigenous production will be necessary if paper consumption in these countries is to increase at a reasonable rate.

A development of indigenous production of pulp and paper on the scale required will, however, require heavy investment. It is impossible to give any very precise figures since, as is made clear by the following table, so much depends on the scale of operations and on the kind of mills that go to make up that development.

Table 1

Capital requirements for selected pulp and paper mills of various types and sizes

(*Millions of US dollars*)

Capacity (thousand tons annually)	*Newsprint mill*[a]	*Sulphate pulp mill (bleached)*	*Integrated paper mill (bleached)*	*Non-integrated paper mill*
15	—	13	17	8
30	17	18	24	11.5
60	25	27	38	18
90	32	35	53	—

[a] Newsprint, United States. All others, Yucatán model.

However, by making reasonable assumptions as to the probable size of future projects and as to the proportion of them which will be established as integrated projects, it is possible to arrive at the following approximate figures:

Table 2

Capital requirements of a Latin American pulp and paper programme

	Programme				
	Newsprint	*Other paper and board*	*Mechanical pulp*	*Chemical pulp*	*Capital requirements (million $)*
	(thousand tons annual capacity)				
Total 1950–65 capacity additions, if all realized (includes capacity completed since 1950 or currently under construction, and all other projects in sight, ranging from advanced planning stage to preliminary study)	140	465	190	580	515
Further capacity required over and above the foregoing totals, assuming that pulp and paper imports will be maintained:					
A. Given only minimum economic growth	220	375	255	35	220
B. Given favourable economic development	435	1,000	525	445	800

Thus present plans, very freely construed, imply a total investment of $515 million over the period 1950-1965, or an annual investment of about $35 million. The amount of investment that would be required over that period, assuming that only minimum economic growth were realized, to assure a reasonable standard of paper consumption without incurring an increased burden of imports, is about $750 million, about $50 million annually. If a more favourable economic development took place, then over $1,300 million investment would be required, or about $90 million each year.

These figures would cover the construction and equipment of the industrial plants themselves, the necessary forest investment, and most, though probably not all, of the concomitant heavy investments for power capacity, transport facilities, and the like.

For a realistic discussion of the potentialities for paper and pulp development in Latin America, the question of the supply of capital must therefore be taken into consideration. The purpose of the present paper is not to propose specific solutions, but merely to supply some factual background information for a consideration of the general problem of financing.

The rate of investment in Latin American countries is, on the whole, rather high. Gross investments amount to some 16 or 17 per cent of gross output, or about $7,000 million (at 1950 prices).[2] Out of this total, something between 25 and 35 per cent, say $2,000 million, may be in manufacturing industry. Thus the direct capital requirements for new paper and pulp capacity on the scale mentioned above, might represent about an additional 5 per cent of total industrial investment in Latin America.

At first sight, this figure may appear to be modest. But it must be remembered that this would be the figure for gross investment in manufacturing, and that replacement investment is a sizeable proportion of the total. Furthermore, a large part of the remaining net capital formation represents self-financed additions to the capi-

[2] ECLA *Economic Survey of Latin America*, 1951-52, p. 89. Conditions were more favourable at that time than they are today. The current proportion is probably no more than 14 per cent.

tal of existing industries. Since it is mainly the financing of new industrial plants, that is under consideration here, the relevant figure with which to compare the annual requirement of $50 to $90 million would be the amount of capital annually channelled to industry in the form of bank loans or long-term capital raised on the capital market. No reliable figures are available for such a comparison, but it can safely be assumed that, on this basis, the capital requirements for the desirable development of the paper and pulp industries would appear to represent a very considerable addition to the demand for capital from internal sources.

Before turning to a consideration of the various possible sources of finance, it may be as well to enumerate the main purposes which the capital raised will have to serve. Here it is only possible to generalize, but a typical case might show that about 40 per cent of the total is needed for the purchase of machinery abroad, another 3 per cent for foreign "know-how" (engineering and other consultancy fees, etc.), 10 to 15 per cent for forest investment (including housing, but excluding equipment, already included in the preceding figure for machinery), 30 to 25 per cent for buildings and such local capital costs as community facilities and transport, and 8 per cent for working capital. These figures reflect the investment pattern for a 60,000-ton pulp mill in an undeveloped area. They would vary from site to site, and with mill size. For an integrated paper mill, a higher proportion of the total would be required for machinery, perhaps up to 50 per cent, and a lower proportion for forest investment and other headings.

Normally one would expect that domestic capital would be forthcoming to cover at least the locally incurred items, and some of these (forest investment, community facilities, transport and the like) are of the kind that should encourage public loans at reasonable rates of interest, since they constitute developmental expenditure in its wider sense.

Source of capital

Domestic capital may be forthcoming either from the state itself or from private investors. The state has, of course, means of encouraging private investors.

The degree of state participation in investment varies widely between the different countries, although there seems to be a tendency in most Latin American countries towards direct state action. Argentina is about to enter on its second five-year plan, and in a number of other countries many projects are being carried out by state development corporations, either of a comprehensive kind or formed to deal with a particular supply difficulty. Of the more important countries, Mexico is the one in which there is the greatest degree of state participation in investment. In every year between 1944 and 1952, the proportion of total investment accounted for by government expenditure has been between 40 and 50 per cent.[8]

In the past, pulp and paper expenditure has not, save in one or two cases, figured in the first rank of industries to be developed by government initiative in non-industrialized countries. Other and more basic industries have usually been considered to have a prior claim, either because they have been deemed to hold a key position of more prominence in a balanced programme of development, or because they have been considered to be capable of replacing more, or more essential, imports. Nevertheless, in Argentina, Brazil and Mexico, the governments all plan direct large-scale expansion of the pulp and paper industries. These countries, in addition to possessing the most comprehensive government development plans, are those which offer the largest markets for paper at the present time. Argentina, Brazil, Chile and Mexico are the only countries with significant book-publishing industries. Moreover a number of other Latin American governments, while they may not as yet have embarked on any specific investments in this field, are known to be closely interested. The alacrity with which they have solicited the despatch of Survey Missions under the Expanded Technical Assistance Programme, and the close attention they have given to the resultant reports, bespeak a more than academic interest. It is, in fact, becoming increasingly recognized that for a variety of reasons, some of which have been referred to in the introduction to this paper, investment in pulp and paper should not be accorded a low priority. Thus while each government will inevitably have to decide its own priorities itself, in accordance with the total economc situation confronting it, the coming years will probably bring rather more government interest than has been displayed in the past, in the shape of both direct government investment (or investment by quasi-government institutions) and of encouragement offered to private investors.

The practical difficulties of channelling personal savings to investment in manufacturing industry have been found to be very great in Latin America. Although capital markets exist in some of the larger countries, their scope is very limited. Only in Argentina is the volume of security transactions appreciable in relation to income and investment.

In the absence of well-developed capital markets, internal financing of private investment has to rely to a large extent on self-financing by enterprises, the most direct form of application of savings for investment purposes, or on group subscriptions or on bank loans. As far as self-financing is concerned, although it is of great importance in many countries, it is by definition not a means of developing a new industry, and although it will undoubtedly have its part to play in any pulp and paper programme, it is certainly not capable of supporting expansion of a small industry on the scale envisaged above.

Hitherto much of the financing, from domestic resources, of new industrial enterprise has been in the form of credits from private banks, special investment banks, or, in some cases, even from central banks. So far as the commercial banks are concerned, rates of interest are high, as is to be expected, while many of the loans are only of short term with the necessity of frequent renewal. Generally speaking, it seems unlikely that new pulp and paper mills will be able to rely on them for more than their working capital which, as has been seen, accounts for but a tenth or less of the total capital required.

The absence of large and well organized capital markets, however, by no means implies that the possibility of raising private capital for new industrial investment is negligible. Private capital does exist, and can be mobilized, without necessarily passing through agencies and institutions typical of countries in a more advanced stage of development. And in recent years a number of large-scale industrial ventures, calling for large capital invest-

[8] ECLA *Economic Survey of Latin America*, 1951-1952, p. 89.

ments, have been financed by domestic private capital, sometimes with the participation of government financial institutions, in a variety of ways, including private subscription.

This means that there is a considerable reserve of private capital which can be tapped for new pulp and paper ventures, providing ways and means of mobilizing it can be found. And indeed this is what one might expect in countries where the need for modern and well organized financial institutions has not yet been strongly felt. It is customary to lay emphasis on the low level of per capita savings in the less developed countries. It is often overlooked that here an average figure tells far less of the whole story than in advanced countries, for both the income and capital frequency curves are much steeper, the contrasts in wealth much sharper. A corollary of this is that the possibility of raising capital by concentrating on a relatively narrow band of higher incomes is much greater.

Loans from the International Bank or the United States Export-Import Bank constitute the main sources of official foreign long-term capital. To secure these loans projects have to satisfy relatively severe criteria of necessity for economic development. Out of more than 100 credits to Latin America authorized by the Export-Import Bank between the beginning of 1946 and the middle of 1953, two were for machine tools and industrial equipment, two for textile machinery and one for a plastic material factory. In addition there were a few for chemical plant and heavy industry, but almost three-quarters were for the development of electric power, transport systems or mining and metal processing. In the value of credits authorized, the preponderance of these three groups was even greater.[4] The loans granted to Latin American countries by the International Bank for Reconstruction and Development have been overwhelmingly for the construction of power stations.

However, there has been recently one important loan by the International Bank for the development of a pulp and paper project in Latin America—$20 million to Chile—and the possibility of others must not be ruled out. A pointer, if needed, is to be found in the reports of the general survey missions despatched to various countries by the International Bank at the request of member governments. The object of these missions is to make recommendations for long-term development programmes after evaluating, in the light of the over-all economic situation, the relative claims of the various sectors of the economy, and of the fields within each sector, for priority in investment. Most of these missions have reported insufficient utilization of forest resources and envisaged a place for pulp and paper making in a balanced forest porgramme. Where specific recommendations have not been made by the missions, it has usually been because of lack of industrial experience relating to the pulpability of non-traditional materials. One might suppose, therefore, that a soundly based, well prepared scheme for pulp and paper, integrated into a balanced general programme of economic development, would, if submitted to the International Bank along with a request for a loan, receive very careful consideration.

It is well known that since the war the principal international flows of private capital have been from the United States to Canada and Latin America and from the United Kingdom to the sterling area. United States direct net private investments in Latin America were about $1.5 billion in the period 1950-53, of which $858 million represented reinvestment by American interests (see table 3).

Unfortunately there is an obvious tendency for these funds to flow into particular countries and industries. Thus, of the $1.4 billion of "new" investment in the years 1946 to 1950, more than $600 million went to Venezuela and a further $180 million to Brazil, no other country receiving more than $100 million. Almost 90 per cent of the money going into Venezuela and two-thirds of the total to Latin America went into the petroleum industry, while manufacturing industry received less than 10 per cent (though about 20 per cent of reinvestments are included). More recently, however, the proportion going to manufacturing industry has

[4] Export-Import Bank of Washington—16th semi-annual report to Congress.

Table 3

NET UNITED STATES DIRECT INVESTMENT (A) AND REINVESTED EARNINGS (B) IN LATIN AMERICA, BY INDUSTRIES[a]

(Millions of dollars)

		1946–49[b] Total	1950	1951	1952	1953
Manufacturing	A	90	64	116	80	..
	B	233	49	96	94	..
Trade	A	93	18	38	11	..
	B	46	12	23	30	..
Agriculture	A	25	−7	22	−4	..
	B	90	14	15	11	..
Mining and smelting	A	65	29	60	120	..
	B	10	4	48	15	..
Petroleum	A	748	−62	−31	79	..
	B	106	10	75	137	..
Public utilities	A	−43	−3	−7	21	..
	B	58	9	10	11	..
Miscellaneous	A	63	7	11	18	..
	B	23	7	9	8	..
All industries	A	1,027[c]	47	209	324	93
	B	535[c]	105	276	305	172

[a] Net capital movements exclude ship sales to United States-controlled foreign operators.
[b] Figures not strictly comparable with subsequent years, since they have not been revised according to the 1950 United States census of foreign investment.
[c] Total does not add up to the sum of the parts owing to later revision of the former.

been increasing; in the years 1951-52 it represented about a third of the total, both for "new" investment and reinvestment. But the only two countries which received considerable amounts of capital for manufacturing industry were Brazil and Mexico.

In a recent United Nations report, prepared for the Economic and Social Council, on the international flow of private capital,[5] it is pointed out, in the discussion of the movement of capital for the development of manufacturing industry,[6] that these two countries, together with Argentina, where there had been considerable investments in earlier periods, are those which offer a market large enough to make profitable the mass production methods for which foreign capital is needed.

This observation is not, of course, directly pertinent to the pulp and paper industry, which is a highly mechanized industry once it has moved out of the handicraft stage. A more relevant consideration is whether the size of the domestic market will enable mill operations to be carried out on a scale that is economic in relation to alternative supply sources. Determining the economic size of a plant in Latin America is no easy matter—some of the complexities are dealt with in Secretariat Paper 3.03. But generally speaking it can be said that already there are at least ten, and perhaps more, domestic markets in Latin American capable of sustaining pulp and paper production in economically-sized mills, and increasing demand in the coming years will probably add another half dozen to the list.

Hitherto, however, it would seem (judging from the scant evidence available on this point) that little or no "abstract" private foreign capital has found its way into the pulp and paper field in Latin America. There are two main reasons for this. Pulp and paper has not offered returns as attractive as those in, for example, oil and mining; and this field is so specialized that it has not engaged the attention of the private foreign investor.

Nor can it be expected that the situation will undergo any significant change in the near future. But there is a possibility that "particular" private foreign capital, arising in pulp and paper industries in other parts of the world, may seek outlets in Latin America in the particular industrial field with which it is technically familiar. Two different considerations might bring this about. Firstly, there may be some industries, particularly in Europe, which, by reason either of market limitations, home or foreign, or of increasingly stringent raw material supplies, are denied opportunities of reinvesting in their own country; it would be logical for them to seek outlets in their own field abroad. Secondly, a number of well-established paper industries in countries lacking pulpable resources and depending on imported pulp are becoming increasingly concerned about the prospects of securing the increasing amounts of pulp they will require in the future from their traditional sources of pulp supply. Such anxiety may well lead them to take an interest in assisting the development of new sources of pulp supply. This is by no means as far-fetched as it sounds. German capital is already helping to develop the production of rayon pulp in Chile, partly for export to the important West Germany rayon industry. Similar development for the West European paper industry could well attend any initial successes experienced in the exploitation of Latin American tropical woods for pulp.

[5] *The International Flow of Private Capital*, New York, 1954.
[6] *Op. cit.*, p. 49.

In fact, to refer again to the report just quoted, mention is made in the same section of one leading characteristic of investment in manufacturing industry which bears on the present problem, namely, that much of the capital investment is of the most direct kind, i.e., the setting-up of subsidiaries in Latin America by firms established in the more industrialized countries. Not all that is said in the report is strictly applicable to the case of the pulp and paper industry, but this solution is obviously a simple one if it can be reached. It simplifies the problems of the authorization of the import of machines, of obtaining technical assistance and of the possibilities that, in the earliest stages at least, production would not be at strictly competitive prices. On the other hand, it must not be overlooked that direct investment of this kind involves the country concerned in capital servicing costs which may, under certain circumstances, impose a strain on the balance of payments situation.[7]

Capital flows from Europe to Latin America in the form of direct participation or through the setting-up of subsidiary branches of European industrial establishments, have been very small in recent years. It deserves to be mentioned, however, that in a very recent Franco-Brazilian Agreement, dated 24 April 1954, the French Government, amongst other things, declared its willingness to authorize French enterprises to participate in Brazilian firms or to install branches on their own account in Brazil.[8]

Commercial credits

So far this paper has discussed in general terms the financial contributions towards pulp and paper development that may come from internal sources or in the form of imports of long-term capital through the granting of loans, the participation in equity capital or the establishment of branches of foreign enterprises. One other important form of external assistance deserves special mention—credits extended by foreign suppliers of equipment for pulp and paper making.

This can be of considerable importance since, as already mentioned machinery costs represent about 40 per cent of total capital requirements, on average. The proportion could fall as low as 30 or 35 per cent, but in the case of an integrated paper mill it might well rise to over 50 per cent.

Table 4 shows the value of exports in recent years of pulp and paper-making machinery from the United States, Canada and the leading European exporting countries to Latin America. It can be seen that, before the war, by far the greater part of these exports was supplied by Europe. In the post-war years the United States has been the largest supplier, although recently the share of Europe, and particularly of Western Germany, has increased considerably. In 1953, more than one-third of the total Latin American imports of pulp and paper-making machinery originated in Western Germany. More detailed information, by individual countries of origin and destination, is given in appendix tables I and II.

[7] Many countries, especially Argentina, used up a large part of the foreign balances accumulated during the war in re-purchase of foreign-owned assets.
[8] See *Moniteur officiel du commerce et de l'industrie*, No. 1609, p. 1417.

Table 4

EXPORTS OF PAPER AND PULP-MAKING MACHINERY[f]

(*Thousands of current dollars, f.o.b.*)

Country of origin	*1938*		*1950*		*1951*		*1952*		*1953*	
	Total	*of which to Latin America*	*Total*	*of which to Latin America*	*Total*	*of which to Latin America*	*Total*	*of which to Latin America*	*Total*	*of which to Latin America*
United Kingdom	3,565	—	5,838	456	5,799	655	8,971	1,073	11,514	733
Western Germany	6,277[a]	861[a]	2,797	57	8,130	564	16,858	772	19,556	2,416
Belgium-Luxembourg	..	..	293	—	387	—	850	15	1,105	258
France[b]	178	65	1,087	113	1,201	192	1,273	290	..	..
Italy	22	2	375	189	1,048	252	2,061	1,092	1,263	787
Austria	398[c]	[c]	49	—	11	11	863	4	2,644	14
Sweden	1,400	8	3,812	371	4,001	277	4,525	149	3,902	518
Finland	—	—	—	—	2,028	44	2,087	—	..	..
TOTAL OF EUROPEAN COUNTRIES LISTED	11,840[d]	936[d]	14,251	1,186	22,605	1,995	37,488	3,395	39,984[e]	4,726[e]
United States	1,079	334	14,411	1,572	12,982	3,320	18,042	3,811	11,900	2,264
Canada	—	—	1,098	31	1,059	7	915	69	595	44
TOTAL OF ALL COUNTRIES LISTED	12,919[d]	1,270[d]	29,760	2,789	36,646	5,322	56,445	7,275	52,479[e]	7,034[e]

Source: National Trade Statistics.
[a] Whole of Germany.
[b] Including machines and parts for working woodpulp, paper and cardboard.
[c] 1937.
[d] Excluding Belgium-Luxembourg.
[e] Excluding France and Finland.
[f] Further details of trade in pulp and paper-making equipment are given in two tables in appendix I.

In the period of acute shortage in the first post-war years, exporters of industrial equipment were in a position to demand pre-payment of part of the price and payment of the rest at the time of shipment or shortly after. But those times are now past, and the last few years have seen a renewal and strengthening of the pre-war trend towards the provision of fairly long export credits by the exporters of capital goods.

This trend is not difficult to explain. With the drying-up of the free international flow of long-term capital after the First World War and, at the same time, the tendency towards more vigorous investment policies in the less developed countries, the problem of capital shortage has become acute almost everywhere, and not least in Latin American countries.

From the point of view of government policy, in the less developed countries, the possibility of importing equipment on some years' credit gives some relief, provided that the investment in question can within a short span of years contribute to improve the balance of payments, through saved imports or increased exports.[9] From the point of view of the private investor in the less developed countries, this kind of commodity credit is often an essential condition for his investment's being at all possible, because internal credit cannot be had in sufficient amount, or only at interest rates which may be so high as to be prohibitive. In any case, interest rates are likely to be higher than those which would eventually be charged in the country exporting the equipment.

For the exporting country, on the other hand, the granting of favourable terms of payment has increasingly become a weapon in the competition for export markets. The ability of the exporting firm (or its bank) to take upon itself the additional financial burden (including the risk) of such credits, is, however, very limited in most cases. Therefore, special banking facilities for the provision of export credits[10] have been instituted in most of the major exporting countries.

The present trend is for such export credit arrangements to be given more scope, and this is to be welcomed as a *pis aller,* since it does amount to at least a modest flow of capital from the highly industrialized to the less developed countries, although it must be stressed that it would be more desirable for this kind of credit to be supplied by one or more agencies specialized in the granting of international medium-term credits, and for the exporters to compete for markets through low prices and high quality, rather than through generous credit facilities.

Although Denmark is of little importance as an exporter of pulp and paper-making machinery, a recent official report on the question of export credits may be mentioned as symptomatic of present thinking in these matters in European countries. The report recommends government credits in favour of importing countries other than the OEEC countries.[11] Eastern Europe, Spain and a number of Latin American countries are mentioned as countries for which such credits might be made available, and it is explicitly said that "in the case of a fall in business activity in Denmark, it might prove desirable to combat the depresson through an expansion of such credits for exports rather than through an expansion of credits for public works or similar traditional weapons.[12]

In view of the potential importance of export credits for the particular question of pulp and paper development in Latin America, some further information on the arrangements now in force in some European countries is given in Appendix II.

[9] Failing this assumption, such commercial credits would, of course, mean only a postponement of balance of payments difficulties.

[10] And special arrangements for export credit guarantees.

[11] As for exports to the OEEC countries, such credits would presumably not be compatible with the rules of non-discrimination to which the member countries have pledged themselves.

[12] See *Finanstidende,* Copenhagen, 11 June 1954, p. 1094.

Hitherto, German, Italian and French firms have been more disposed to grant long-term credits than, for example, their United States or British counterparts, but symptomatic of new thinking in the latter countries are the views expressed by Senator Homer E. Capeheart, Chairman of the United States Senate Committee on Banking and Currency, on his return from an extended investigatory tour of Latin America.[13] A bill promoted by the Senator, already voted by the Senate, would restore the status of the Export-Import Bank as an independent agency and enable it to expand its operations. It is hoped that, if this Bill becomes law, the Bank will find a means of satisfying the needs of the export community as regards the long-term financing of capital goods export sales.

Conclusions

Assuming that the economies of Latin American countries develop favourably in the coming years, then the expansion of the pulp and paper industry by 1965 to the point where it is capable of satisfying reasonable demands for paper, without incurring an import burden higher than that of today, would call for an annual investment of around $90 million over the period 1950-1965. Should economic growth be limited to a bare minimum rate, an annual investment of $50 million would suffice.

The realization of all present plans for expanding capacity, including those at a very early stage of study, would imply an annual investment over the period of $35 million. The rate of investment currently and in recent years seems to have been at or near this figure.

The considerable amounts of capital involved prompt the question; what priority should pulp and paper be accorded in a balanced development programme? This question can only be answered in the light of the special circumstances confronting each national economic programming authority. Its claim at first sight is not high. It is not a basic industry. Though import-saving, it is probably less so than some other manufacturng industries. A pulp or paper mill, by itself, requires little labour in relation to the capital employed. Usually, however, a pulp or paper project will be accompanied by forest investment and development. This requires considerably more labour. It opens up possibilities of developing other wood-using and associated industries. It creates a fresh nucleus for industrial development. It may form part of a co-ordinated programme of resources utilization. In addition, an enhanced domestic production of paper facilitates the development of many varied paper-converting industries with important labour-employing and import-saving possibilities. Finally, there are powerful non-economic reasons why domestic production of paper should be increased.

For these reasons the interest of Latin American governments in promoting pulp and paper investment may be expected to increase. This may take the form either of direct investment or of assistance and encouragement given to private investors. For the same reasons it should prove possible to secure additional amounts of foreign official capital. An influx of foreign private capital could be encouraged by appropriate action on the part of Latin American governments; one form this might take is the setting-up of Latin American subsidiaries of overseas concerns.

[13] Reported in *Export Trade and Shipper,* 19 July 1954, p. 9.

Machinery costs represent the biggest item in total investment, and the supply of foreign equipment on favourable long-term credit terms can make a very important contribution to Latin American pulp and paper development. Nevertheless, an annual investment over the period of $90 million (implying well over $100 million a year during the next eleven years) is a target which is bound to prove difficult, and perhaps impossible, to attain. Since a wide margin of failure would entail a serious lag in paper consumption standards, hampering both material and cultural progress, conscious efforts on the part of Latin American governments seem to be required.

Appendix I

Table I

Imports of pulp and paper-making equipment from selected countries[a] into Latin America

(*Thousands of current dollars, f.o.b.*)

Country	*1938*	*1950*	*1951*	*1952*	*1953*[b]
Argentina	250	1,011	582	266	111
Bolivia	—	—	1	—	—
Brazil	73	803	1,951	3,212	4,670
Chile	310	62	141	104	131
Colombia	42	6	601	813	52
Costa Rica	—	125	56	60	4
Cuba	269	211	92	29	72
Dominican Republic	1	—	13	—	—
Ecuador	—	—	—	57	—
Guatemala	—	11	11	—	—
Haiti	—	20	—	—	—
Honduras	—	—	—	—	—
Mexico	21	389	1,545	2,041	1,517
Nicaragua	—	—	—	—	—
Panama	—	—	—	—	—
Paraguay	—	—	70	—	1
Peru	268	29	94	139	189
Salvador	—	1	—	12	2
Uruguay	34	94	103	522	205
Venezuela	2	27	62	20	80
Total, Latin America	1,270	2,789	5,322	7,275	7,034

Source: National Trade Statistics.

[a] Germany, Belgium-Luxembourg, France, Italy, Austria, Sweden, Finland, United States and Canada, United Kingdom.

[b] Figures for France and Finland are not available for 1953.

Appendix II

Export credit arrangements in some Western European countries

The following notes briefly describe the present position as regards special credit facilities for exports in six Western European countries.[1] The notes are concerned only with export credit proper. In addition, practically all Western European countries have well-developed systems of export credit *guarantee*. These, however, are less relevant from the point of view of the present paper and, therefore, are not further described in the following notes.

(1) *Western Germany*

Export credits in Western Germany are provided through the Ausfuhr-Kredit AG (AKA) established

[1] The notes draw heavily on an article by Emil Gsell and Heinz Allenspach, "Langfristige Exportcredite", in *Aussenwirtschaft,* Berne, December 1953.

Table II

IMPORTS OF PULP AND PAPER-MAKING EQUIPMENT FROM SELECTED COUNTRIES IN 1952

(*Thousands of current dollars, f.o.b.*)

Importing countries	*Exporting countries*											
	United Kingdom	*Western Germany*	*Belgium Luxembourg*	*France*	*Italy*	*Austria*	*Sweden*	*Finland*	*Total of European countries listed*	*Canada*	*United States*	*Total of conutries listed*
Argentina	20	56	—	—	—	—	100	—	176	—	90	266
Bolivia	—	—	—	—	—	—	—	—	—	—	—	—
Brazil	897	376	15	290	477	4	21	—	2,062	68	1,082	3,212
Chile	35	57	—	—	—	—	—	—	92	—	12	104
Colombia	1	—	—	—	—	—	—	—	1	—	812	813
Costa Rica	55	—	—	—	—	—	—	—	55	—	5	60
Cuba	—	—	—	—	—	—	—	—	—	—	29	29
Dominican Republic	—	—	—	—	—	—	—	—	—	—	—	—
Ecuador	—	—	—	—	57	—	—	—	57	—	—	57
Guatemala	—	—	—	—	—	—	—	—	—	—	—	—
Haiti	—	—	—	—	—	—	—	—	—	—	—	—
Honduras	—	—	—	—	—	—	—	—	—	—	—	—
Mexico	81	171	—	—	558	—	7	—	817	1	1,223	2,041
Nicaragua	—	—	—	—	—	—	—	—	—	—	—	—
Panama	—	—	—	—	—	—	—	—	—	—	—	—
Paraguay	—	—	—	—	—	—	—	—	—	—	—	—
Peru	1	—	—	—	—	—	12	—	13	—	126	139
Salvador	—	—	—	—	—	—	—	—	—	—	12	12
Uruguay	1	112	—	—	—	—	9	—	122	—	400	522
Venezuela	—	—	—	—	—	—	—	—	—	—	20	20
TOTAL, LATIN AMERICA	1,073	772	15	290	1,092	4	149	—	3,395	69	3,811	7,275
WESTERN EUROPE, UNITED STATES AND CANADA	4,888	12,595	271	633	686	111	1,651	419	21,254	753	12,628	34,635
REST OF WORLD	3,010	3,491	564	350	283	748	2,725	1,668	12,839	93	1,603	14,535
TOTAL WORLD, 1952	8,971	16,858	850	1,273	2,061	863	4,525	2,087	37,488	915	18,042	56,445
1953	11,514	19,556	1,105	732	1,263	2,644	3,902	..	40,716	595	11,900	53;211

Source: National Trade Statistics.

Note: Swiss exports of paper-making machinery cannot be distinguished from other types of machinery.

in March 1952. This is a consortium of the large regional and State banks and some private financial institutes. The total amount of export credit which, according to present rules, can be provided through the AKA is DM 870 million. The maximum length of credits is four years. The rates of interest charged were at one time rather high, but have recently been reduced to 5 to 6 per cent. At the end of 1953, the AKA had promised credits for a total amount of DM 573 million, of which DM 456 million had been utilized. Thus, the credit ceiling of DM 870 million has not been reached. Of the total amount of credits granted at the end of 1953, about four-fifths were in respect of investment goods.

The present provisions for export credits in Western Germany are generally considered to be inadequate and German exporters are pressing for an improvement of the system by an increase in both the maximum duration of credits and of the total amount of credits that can be granted. One of the factors hindering an extension of the system is, of course, the large surplus of Western Germany within the European Payments Union which binds a large part of the lending power of Western Germany in credits to the Union.

(2) *United Kingdom*

No government-sponsored institution exists in the United Kingdom to provide funds for exporters wishing to extend credits to overseas buyers, and only recently have non-governmental institutions of this sort started operations. Even if it had been felt that the normal financial institutions were inadequate for the purpose, exchange regulations until recently prevented the granting of credits of more than two years. In addition, half the payment had to be made at the time of loading. In July 1952 the maximum credit period for investment goods was raised to three years with provision for a prolongation to four or five years and since then it has been clear that the Government is now prepared to look much more favourably on the provision of long-term credits to foreign importers.

The only official body concerned with export credits is the Export Credit Guarantee Department of the Board of Trade, which was set up as long ago as 1919, but whose scope and importance have greatly increased since the war, and in particular since the Export Guarantee Acts of 1949 and 1952.[2] Its function is, however, strictly the insurance against default by a foreign creditor for any of a wide range of reasons, and it has powers to issue policies which are not commercially justifiable, where political considerations make particular transactions desirable. It therefore exists to encourage the exporter to give credit and not to provide the funds.[3] By an extension of its powers announced in the 1954 budget speech, which enables it to issue guarantee policies to the banks supplying the finance as well as to the exporter, it is now able to help the exporter to offer credit terms which might otherwise strain his normal borrowing powers.

This change in the Department's powers followed soon after, and made less important, the setting-up in March

[2] The face value of credits guaranteed annually is about £400 million. Before the war it was about £25 million.

[3] In August 1953, the Department made a loan of £10 million for ten years to Pakistan, but this was an isolated case, and met with sharp criticism.

of a company called the Manufacturers Export Finance Company, sponsored largely by firms in the engineering industry. The purpose of the company is to take over from the exporter part of the burden of extending credit. It will itself extend credit to a foreign buyer, if the transaction has been guaranteed by the ECGD.

Apart from this, the main firms whose purpose is to extend export credits are usually connected with a particular industry, such as Air Finance, Ltd., or with exports to particular countries, such as the Commonwealth Development Finance Co., Ltd.

(3) *France*

In France, the provision of special export credits is organized through the Banque Française du commerce extérieur (BFCE). This bank, which is a semi-official institution, was established in 1946. The BFCE does not itself grant the credits, but by giving its endorsement (aval) to the bill drawn by the exporter on his bank, it enables these bills to be mobilized by rediscounting in the money market or with the Central Bank.

Originally, the export credits obtainable by this procedure were limited to durations not exceeding two years. As from March 1950, however, the credits can be prolonged for a period up to five years, provided that the risk is covered with the Export Credit Guarantee Company (Compagnie française d'assurance pour le commerce extérieur).

In addition to the export credit proper, the BFCE can also give its "aval" for credits to cover the production period (up to two years) for export products. Thus, through the utilization of both means of financing, export credits for a period up to seven years are available to the exporters.

(4) *Italy*

Towards the end of 1953, the Italian Parliament passed a law on medium-term export credit insurance and finance. This law provides for an extension of the activities of the Instituto centrale per il credito a medio termine (Mediocredito) to cover export credits, in addition to the financing of Italian industry which had hitherto been its sole purpose. The Mediocredito is to assist the export trade by taking over a share of at most 75 per cent of the credit granted to the exporters by the banks specializing in medium-term credit.[4] The duration of the export credits may not exceed three years, except for special cases where the export credit guarantee (which is handled by a separate State Institute) covers a longer period.

[4] In Italy, ordinary commercial banks are not allowed to grant medium or long-term credits.

(5) *Belgium*

In Belgium, the financing of exports is assisted through two semi-official institutes, the Société nationale de crédit à l'industrie (SNCI) and the Institut de réescompte et de garantie. Both of these can re-discount the long-term credits given to exporters by the ordinary commercial banks, and they can also give credits directly to the exporters.

The Institut de réescompte et de garantie takes over export bills provided that they are endorsed by the Central Bank and have a duration of not more than two years. Both export credits proper and credits to cover the production period for export goods can be re-discounted by the Institute.

Export credits with a duration of from two to five years are granted by the SNCI, either through re-discount of bills or through the direct granting of credits to the exporter. Here again, the endorsement of the Central Bank is required. These longer-term credits can cover only the export credit proper, not the production of export goods.

Thus, by utilizing both institutes the export industry has finance at its disposal for a total period of seven years, viz., two years of production credit and five years of export credit proper.

(6) *Netherlands*

In June 1951, a semi-official institute for export financing, the N.V. Export Financiering Maatschappij was established. Its financial means consist of a credit of 100 million guilders from the Bank for Reconstruction, and, in addition, it can issue bonds in the capital market and borrow in other ways, as required.

The purpose of the Maatschappij is to extend medium and long-term credits to exporters. Normally the duration of the credits is from three to seven years. During the first year of its existence the total amount of credits given was 79 million guilders. The credits were overwhelmingly for exports of capital goods.

BASIC PRINCIPLES FOR FINANCING NEW PULP AND PAPER PROJECTS[1]

KARL F. LANDEGGER

SAVINGS IN EXCHANGE

A paper mill is one of the best exchange-saving investments that a Latin American country can make. A new paper mill built in Latin America will require a foreign exchange investment equal in value to approximately eighteen months value of its production. A mill making 15,000 tons of paper a year will cost, depending on the quality of the paper produced, between $4 million and $8 million for buildings and equipment, allowing also for a moderate amount of working capital. Of this amount, $2.5 million to $6 million will be required for importing machinery and equipment, while the remainder will consist of local expenditures and working capital. The lower figure relates to a mill producing unbleached pulp and paper and dependent on outside electric power; the higher figure to an integrated mill producing high quality bleached pulp and paper, and including a steam and power plant, and electrolytic plant, a water treatment plant and all the necessary mill services—a mill where the raw material enters at one end of the mill and the completely finished product leaves the other end ready for the ultimate consumer without dependence on outside utilities or services.

[1] A slightly shortened version of the original paper, ST/ECLA/CONF.3/L.8.1.

Figures are given in dollars only for the purposes of illustration; the foreign exchange commitment would not necessarily be in dollars. The machinery and equipment would, in fact, come from the country which, from the exchange point of view, is able to supply it without disturbing the payments balance of the importing country.

The annual production of a 15,000-ton mill has a c.i.f. value of between $2.5 million and $4.5 million. The machinery could therefore be amortized—from the exchange point of view, that is—within twelve to eighteen months. In other words, the mill would within twelve to eighteen have supplied paper, that otherwise would have been purchased abroad, to the value of the equipment purchased abroad for the mill's construction.

Profits

As to profits, the total investment, including buildings, plant, machinery and equipment, is in general repaid out of profits within five to ten years, depending on local circumstances—the cost of the installation, the price obtainable for the product, and so forth.

The paper industry in all Latin American countries is a profitable one. In Brazil, for example, there were, in 1939 paper mills with a total of sixty-two machines and an aggregate annual production of 112,000 metric tons. Brazil today has 137 machines with an annual production of approximately 320,000 metric tons; actual existing capacity is somewhat higher than this, but some is unused, mainly because of power limitations. The investments involved in the expansion of the Brazilian paper industry have been largely earned out of production. Only a little new outside capital has entered the industry and this has been quickly repaid.

Good earnings for paper mills in Latin American countries are necessary to attract the capital to build mills. They are all the more necessary because history shows that this industry has to build itself up mainly out of its own earnings.

More mills needed

Latin America's pulp and paper import deficit today amounts to about 897,000 tons, made up of 275,000 tons of pulp and 622,000 tons of paper. This represents an annual import bill of about $160 million to $170 million. To replace these paper imports, about twenty integrated mills with a daily production of 100 tons each would be needed, while ten pulp mills of similar capacity would be required to replace the pulp at present being imported.

Competely modern mills, correctly built, would cost about $10 million each if integrated and roughly $6 million if for market pulp only; total investment required for the thirty mills, would therefore be of about $260 million. Thus, with an investment equivalent in value to about 1½ years' imports, the present needs of Latin America could be covered.

This is reckoning only with present standards of consumption. Average consumption in Latin America is today seventeen lbs *per capita* per annum. If this were to increase only by twenty lbs *per capita* per annum, bringing it up to about one-tenth of North American average consumption, about fifty additional 100-ton mills would be required.

As the standard of living in Latin America increases and as remaining illiteracy is wiped out, a considerable rise in production can be expected in most Latin American countries. Clearly the pulp and paper industry in Latin America has a tremendous future in the next ten or twenty years.

Preliminary steps

Practically all Latin American countries have available in abuandance the raw material for paper making, usually at lower costs (per ton of finished paper) than in either Scandinavia or North America.

Experience has shown that in Latin America land and raw material resources, be they hardwood forests, bagasse, straw or other short-fibred materials, are comparatively easy to secure. However, it is necessary that local capital provide sufficient financing for roads, buildings, warehouses, etc. This point cannot be over-stressed, because the first prerequisite for a sound, economical pulp and paper mill is that a local group be found with sufficient interest and capital to undertake the preliminary work and to follow this up by successfully raising the required capital for all the local expenses for the entire project.

Many proponents of pulp and paper mill projects have no idea of the vast amount of research and preliminary work which has to be done. Fibrous raw materials must be analysed in suitable laboratories; testings of water, soil and fuel etc. must be made. The supply facilities of chemicals and transportation must be analysed in detail. There will be many cases where $30,000 to $40,000 has to be expended before a preliminary project indicating the approximate price of the plant and equipment can actually be drawn up.

Provided that the raw material is assured at a reasonable cost and that sufficient capital is available for land, buildings and erection of machinery and equipment, then it will be easy to approach the suppliers of machinery and equipment for assistance through medium term credits. The amount of down-payment required, the length of credit involved, etc., will vary, of course, with the circumstances. Responsible firms are glad to assist enterprises in their negotiations with their own Governments and private banking institutions, with the development banks which exist in most Latin American countries, with the Export-Import Bank in America, the World Bank, Export Credit Insurance in England, etc. In all such negotiations it is necessary to present the lending institutions with a complete well-thought-out project setting out in detail all the mill costs, estimated costs of the pulp and paper to be produced, market analyses, and so forth.

Management

One important requisite for obtaining support from Latin American financial institutions is an assurance that the mill will be in experienced operating hands. In those cases where a country lacks sufficient experienced personnel to satisfy this condition, there are European and North American organizations with a background of successful experience willing to accept management responsibility for a limited period until local personnel are fully trained.

It is also possible to make arrangements for leading paper and pulp concerns in Europe and the United States to provide the management staff for a number of years. Either arrangement will assure the mill of long years of successful operation.

Currency

Availability of foreign exchange can be a problem. In general it takes two to three years to bring a project, either for building a new pulp or paper mill or for substantially enlarging an existing plant, from the first enquiry through the signing of the contract to the final granting of the import licence and the enlistment of the necessary capital.

In practically all the Latin American countries the currencies available for importing capital goods change from time to time. While in a given country dollars or sterling may be available today, in two years' time, when the import licences are actually being granted, these currencies may be unobtainable, while it may be relatively easy to obtain for example French francs or Deutsch marks.

The clearing arrangements which Latin American countries have with equipment-exporting countries must always be considered. It is best in the preliminary stages of a project not to decide definitely where the machines will eventually be procured.

Time and money will be saved, both by the promoters of the mill and by the firm interested in building the mill, if the decision regarding currency is deferred until the project is sufficiently advanced for the details of the import licence to be discussed with the authorities. At that stage the contracting firm erecting the mill should be able to adapt itself to the existing currency situation, supplying the machinery and equipment as far as possible in the currencies which the Central Bank is then willing to allocate.

Conclusions

Summing up:

1. Latin American countries are greatly in need of expanding their pulp and paper-making industry.

2. The paper industry has proved a profitable investment both for private industrialists and for Government and private lending institutions.

3. The foreign exchange required to import the plant and equipment may be saved in twelve to eighteen months by the pulp and paper produced by the new equipment.

4. Local capital is required at least for land, buildings, erection of machinery and down-payment for the machinery. Provided the mill has an acceptable balance sheet, a substantial part of the machinery can be supplied on medium term credit.

5. It will be necessary to adapt equipment procurement to the currency situation and trade agreements of the particular country.

6. It will almost inevitably be necessary to make a preliminary project before a final project giving definite costs and prices can be worked out.

The expansion of the paper industry in Latin America is certain. The speed with which the development will take place depends on the observance of the above basic principles.

PROSPECTS FOR INVESTING CAPITAL IN THE ARGENTINA PAPER INDUSTRY[1]

Confederación Nacional Económica de la República Argentina

The pulp and paper industry in Argentina

Argentina has for many years been regarded as one of the countries best equipped to develop a large-scale pulp and paper industry. This view is based on the growing consumption of pulp and paper and on the country's excellent prospects for producing the necessary raw materials. Two of the more important forest areas are the Paraná Delta—where poplar, poplar-willow and some pines, which are particularly able for pulping, show a remarkable growth—and Misiones, in the north-east of the country, where Paraná pine and eucalyptus—both of primary importance for making pulp and paper—grow very rapidly.

The total paper and board consumption in Argentina in 1951 was estimated at about 450,000 tons. This figure cannot be regarded as representing normal consumption; rather, it reflects a still restricted supply situation.

Even so, the Argentine paper industry is, in relative terms, less important than that of some other Latin American countries. Its capacity is sufficient to meet only about 60 per cent of total paper consumption, while pulping capacity only satisfies just over 30 per cent of the industry's requirements, i.e., about 20 per cent of the country's total needs. Dependence on foreign sources for supplies of paper and its raw materials has been curbing domestic consumption. This is particularly true of newsprint, consumption of which has fallen sharply in recent years. Based on forecasts of future requirements, it has been calculated that Argentina's paper industry can be expanded to produce 441,000 tons of paper by 1955; 719,000 by 1960 and 1,103,000 tons by 1965.

Normal consumption of newsprint is estimated at over 200,000 tons a year. Domestic manufacturing capacity however does not exceed 25,000 tons; the remainder has to be imported.

The second five-year plan has provided for a series of measures aimed at promoting pulp and paper development. These measures do not exclude foreign capital investments. On the contrary, such investments are required. The industry's high capital needs, the type of machinery required, and so forth, justify such financial collaboration, while at the same time the development possibilities offer interesting prospects for foreign capital.

It is true that Argentina's existing reserves of pulping raw material are limited in relation to present domestic requirements. The only important sources of conif-

[1] A slightly shortened version of the original paper, ST/ECLA/CONF.3/L.8.2.

erous raw material for chemical pulp are the Paraná pine forests in the province of Misiones, and these forests are not very extensive. There are, however—and this is a very important fact—exceptional conditions for creating artificial forests, with astonishing yields, on a scale sufficient to ensure a secure future for the domestic paper industry. Annual yields of timber per hectare in the Delta zones and in Misiones province amount to as much as fifteen and even thirty cm.

In recent years the domestic paper industry has undergone an interesting development. Total mechanical productive capacity of the 53 existing establishments is estimated at some 300,000 tons. This output has not yet been realized because many of the installations are very recent.

The fundamental restriction for the expansion of the domestic paper industry has been, and continues to be, the lack of the necessary raw materials. Coniferous forests suitable for chemical pulp are few, there have been obstacles to the extended use of bagasse, while the paper-making possibilities of wheat straw are limited.

Argentina's fibre potential in hardwood forests, bagasse and straw is very great. The province of Misiones, with 2.3 million hectares of forest, at present offers an exploitable area of 1.5 million hectares, estimated to contain some 150 million cm of standing timber. Assuming 30 per cent is reserved for more profitable uses, some 63 million tons would be available for pulping. Extracted at the rate of 1.8 million tons per year, these forests are capable of supporting an annual pulp production of 810,000 tons. The delivered cost of this raw material may be estimated, on the basis of an average distance of 30 km to the mill, at 90 Argentina pesos per cm.

Three other areas offering good prospects are 5 million hectares of forest at Salta, where the 500,000 hectares already under exploitation contain 35 million cm of wood; 1.2 million hectares at Tucuman where the 200,000 hectares currently exploited contain 14 million cm; and a million hectares of forest at Jujuy, with 21 million cm in the 300,000 hectares already being exploited.

As regards bagasse and wheat straw, it is estimated that sufficient quantities of these residues could be made available for pulping to enable the production of 59,000 and 94,000 tons of pulp respectively; present output is only 3,000 tons of bagasse pulp and 24,000 tons of straw pulp annually.

Thus Argentina's raw material potential is immense. The urgent need to utilize these resources is well stated in the FAO/ECLA study *Possibilities for the development of the pulp and paper industry in Latin America.* Remarking that North America today accounts for over 60 per cent of world production, the study states that "any shift in the balance between supply and demand in that region can have serious repercussions on the international market for pulp and paper. Pulp and paper prices are sensitive in the world market and, in times of inflated prices, countries largely dependent on imports of pulp and paper encounter difficulties in satisfying their needs". There is therefore need for Latin America to diminish its "degree of dependence on extra-regional supplies if the satisfaction of its rising requirements is to be free from interruption".

In the past some of the plans for establishing paper industries in Argentina have been ill-conceived. Either they have been based on a complete or partial dependence on imported pulp or, if based on domestic raw materials, they have failed to take into account the need for long-term continuity of supply. The Government's present plans for developing the pulp and paper industry in Argentina are free from these criticisms; indeed, great emphasis is laid on the need for planned utilization of resources and permanency of raw material supply.

The Argentine government has, under Law 14,222, provided special regulations to facilitate the entry of foreign capital. Article 1 of this law[2] provides that: "foreign capital entering the country for investment in industry and mining, either for installing new plants or in association with existing ones for their expansion and modernization, shall enjoy the benefits granted under this Law". Article 2 states that foreign capital may enter "in the form of foreign exchange or of machinery, equipment, tools and other productive goods necessary for the integral development of the activity in which the investor is engaged". Article 6 says: "two years from the date when the foreign capital investment shall have been inscribed, the investor shall have the right to transfer to the country of origin the liquid profits emerging from that investment, to a total of 9 per cent on the capital registered as remaining in the country on each subsequent annual balance sheet". Under article 12 "the Government, upon authorizing the entry into the country of each investment, may: (*a*) totally or partially exempt goods brought into the country from payment of customs duties; (*b*) declare in the "national interest" the new activity entering the country and apply in its favour the development and protective measures laid down in the law of 5 June, 1944 for the development and protection of industry".

It should be noted that the newsprint industry was declared of national interest in 1954, thus qualifying for certain protective measures, e.g., the establishment of import quotas for the imported product, and the imposition of additional development duties on imports which threaten the domestic product.

These preferential measures, allied to the circumstances which have already been described, assure the Argentine paper industry of an exceptionally propitious field of action.

It is of the utmost importance, in the view of the Confederación General, that those who have seen and understood the country's prospects should seek to develop them simultaneously in the field of raw materials and industrial production, by creating forests or promoting their sound management and utilization through the installation and development of industries on the highest possible level of functional efficiency. The magnitude of the investments involved require that strict precautions be taken; plans should include not only the accurate determination of the raw material supply, but also of other fundamental factors—water supply, power, fuel, chemicals, domestic market possibilities, export prospects, transport, etc. The Confederación General Económica believes that its views will be shared by all those who recognize that temporary solutions, which disregard the prerequisites for sound, permanent development, will ultimately create problems more serious than those which they are designed to solve.

[2] The translation of the articles is unofficial and subject to modification.

FINANCING PULP AND PAPER COMPANIES IN THE UNITED STATES A COMMERCIAL BANKER'S POINT OF VIEW

A. Newell Rumpf

The paper industry in the United States was founded in 1690 and is therefore much older than certain of those industries which today outrank it in size. It is the sixth largest industry in the United States, with both capital investment and annual sales at about $7 billion. Its products are in ever increasing daily use by all sections of the population. Technological developments and increased standards of living have broadened the market for paper products in all phases of commercial and consumer activities.

The paper industry depends upon abundant timber, water, and pulp supply for its activities and its geographical location is dictated by these requirements. However, over the years the industry has witnessed a vast shift in plant location and product output. Originally concentrated in the north-eastern states, the industry moved westward through the northern half of the country; its output then consisted primarily of newsprint, book and bond papers. In the past two decades there has been a tremendous expansion in plant facilities in the southern states, whose abundant resources of southern pine are ideal for the production of kraft paper and paperboard. From a tonnage standpoint, kraft—used for wrapping paper, bags and container board—is today the principal sector of the industry. More recently several newsprint mills have also been established in the south.

The following table shows how production and consumption of paper has grown in the United States:

Year	Production (Thousand tons)	Consumption (Thousand tons)	Consumption (Lbs./capita)
1899	2168	2168	58
1919	5966	6253	119
1939	13510	15949	243
1945	17371	19665	282
1950	24377	29013	382
1953	26459	31323	392

Source: U. S. Census Bureau: A.P.P.A.

Profits of the paper industry have varied widely on relatively small fluctuations in volume output, and the competition for tonnage during periods of reduced demand has been reflected in price reductions. In the depression thirties, the problems of intense price competition were accentuated by excessive senior capital and many companies experienced financial difficulties.

Though the paper industry has had its lean periods, these reverses, for the most part, resulted from over-expansion and, in some cases, from a lack of knowledge on the part of operating companies. A statistical comparison, however, shows that these drops were not caused by the paper industry fluctuating more widely than general business or other particular industries. During the war years paper production was limited by a belated recognition of its essentiality to the war effort. Accordingly, the post-war expansion has exceeded that of many other industries. Recent experience tends to confirm the belief that the paper industry is no longer subject to the wide cyclical swings which have characterized it in the past.

Production in recent times has been running close to, and in fact, for several years was in excess of, rated capacity. In recent years, as indicated earlier, the productive capacity has grown substantially, but even so the industry has had a favourable over-all operating ratio.

The rate of return (after taxes) on stockholder investment in paper and allied product companies compares favourably with other industries. Studies made by the Federal Trade Commission, based on a sample of some 9,000 domestic manufacturing corporations, indicate an average return before taxes of 18.5 per cent during the first quarter of 1954 for all manufacturing industries. The comparable figure for the paper industry during the same period was 20.3 per cent.

It is well known that the paper industry requires a large fixed investment in plant and equipment with resultant heavy overhead charges. This high investment cost made both the lender and the investor cautious at times during its history. Reliable reports indicate that investment in pulp and paper manufacturing facilities may run as high as $100,000 per ton of daily output for pulp and around $70,000 for paper. The fixed investment per employee is about $20,000. Thus any new establishment requires long and thoughtful planning and a high degree of scrutiny on the part of the money lender.

Obviously, an industry which has increased its total assets from $2.9 billion in 1945 (according to the American Paper and Pulp Association) to $7.07 billion at the end of 1952, has required bank financing. This increase in assets has resulted from retained earnings, sale of equity capital, and debt creation. Many loans have been made by the independent banks, while federal agencies such as the Reconstruction Finance Corporation have also made loans which have since been refinanced by the bank and insurance companies.

Such statistics as are available show that the ratio of funded debt to total assets has been increasing over the post-war years.

The paper mill executive seeking new capital is confronted with a choice of either stock or debt or a combination of both. He immediately becomes aware of the fact that he can borrow at an advantageous rate, comparatively speaking; and with a 52 per cent normal tax rate, an interest rate of say 4 per cent is materially reduced when brought down to net after taxes. Preferred stock will cost at least 4½ per cent and probably much more unless trimmed up with a strong sinking fund or the privilege of conversion into common stocks. When he investigates the selling of common stock, he finds that it takes a rather glamorous company to find a ready market for common shares at more than eight times current earnings per share.

A company desirous of procuring capital needed for current operations or for plant betterment and expansion generally consults an investment or commercial banker. Both have their place and seldom do their functions cross; they complement rather than compete with one

[1] A slightly shortened version of the original paper, ST/ECLA/CONF.3/L.8.4.

another. The investment banker acts chiefly as a procurer of equity and long-term capital. The commercial banker concerns himself largely with the extension of short-term financing, with the balance sheet as his chief financial tool.

A commercial bank is always desirous of employing its capital and deposits in companies which have good management, stability of earnings and obvious elements of growth. For the past two decades the paper industry, having these characteristics, has not found it too difficult to finance itself in part by bank borrowings.

Bank loans have been in the following categories:

(1) Current loans—for seasonal and working capital purposes. Generally these loans have been unsecured, although at times, in the case of a relatively heavy financial statement, a pledge of assets (such as inventory, receivables, or fixed assets) has been required.

(2) Revolving credits—which in effect is a guaranteed line of credit for approximately a two year period. These credits are under a formalized agreement, whereby the borrower has a call on the bank for a fixed amount of money at a prearranged rate providing the terms of the agreement are met. Under this arrangement, the borrower pays a commitment fee, generally one-half of 1 per cent per annum, on the unused portion. This permits the borrower to proceed with an expansion plan, knowing that his financing is readily available. Many of these revolving credits are convertible into—

(3) Term loans—borrowings from one up to five or seven years and in rare instances up to as much as ten years. These loans are under a formal agreement and may be either secured or unsecured. If secured, they usually take the form of a mortgage on the fixed assets. Under unsecured agreements the lender relies principally upon the contractual working capital convenant. Other covenants provide for the payment of dividends only out of current earnings through the freezing of net worth and nonpledge of asset clauses.

The term loans are similar in all respects to the pattern followed by the longer term lenders, principally insurance companies. In many instances the commercial bank will take the shorter maturities at a lower rate of interest under a joint agreement with a long-term lender whose maturities may run as long as twenty-five years.

Practically all of the paper companies, with perhaps the notable exception of the largest, International Paper Company, have within the last ten years had recourse to one of the above forms of borrowing.

The borrowings of the majority of producers are probably limited to the largest fifty banks in the United States. These banks customarily share the loans with other similar institutions in order to spread the risk. The banks' experience in the last twenty years with their loans to the industry has been uniformly satisfactory.

A banker has a commodity for sale. It is credit, as intangible a commodity as can be imagined. Credit, of which loans are one form, is a most vital fluid in the economic machine and has made possible the United States' high industrial development. The whole structure of modern commerce is built on credits and banks are agencies through which much of this credit is cleared.

Banks must be interested in the success of their customers and give them service. Loans are one form of service, and the interest received on these loans is necessary to pay overhead, salaries, and to maintain the structure on which the bank's business is carried on. Contrary to the opinion of many, banks actively seek loans. Also strangely enough, unsecured loans are the most desirable for the bank, as they involve a lower cost of administration. Even where the loan to a business is secured, the banker looks forward to the day when he may safely and properly loan without collateral. The banker is not doing a customer a favour when he loans him money—credit is the commodity he sells and that's his business.

What do bankers look into as the basis for their deliberations and decisions on the granting of credit?

1. *Character and ability of management.* This is determined from experience with the individuals who have the responsibility of the conduct of the enterprise, and from their past record and history. The ability is a matter of opinion and individual appraisal, with the operating record a yardstick of measurement. A well-rounded organization, with capable individuals in charge of their respective divisions, is an important consideration. It is important to know of any factional disputes and, in certain cases, to ascertain if voting control is vested in the management.

2. *Financial.* A financial statement can be divided into several parts. The assets are of two major classes; realizable and nonrealizable. Realizable assets are of two kinds —those considered current or realizable over a short period, such as cash, collectible notes and accounts receivable, inventories, marketable securities, and cash value life insurance; and those not liquid nor current, i.e., fixed investments, such as machinery, plant, or property—generally a permanent investment to a continuing business. This latter type of asset, while necessary to business, is not given much weight in a statement by a short-term lender, except possibly as a basis of analysis, to ensure that it is not out of proportion to the capital investment. A nonrealizable asset, as the term implies, consists generally of good will—although this at times may have a value in the case of a sale—and the item of deferred or prepaid expenses, such as advertising, insurance, dues and possibily other items.

3. *Operations.* Bankers are naturally interested in the earning record and examine the profit and loss statements for a period of years. If the record of an individual company runs counter to the industry trend, a red flag appears. The progress, or lack of it, is further reflected through a study of the net-worth position over successive years. Other factors under this heading include plant efficiency, banking performance and trade record, overhead expense, organization morale, and labour relations.

4. *Prospects.* The degree of essentiality of the product and the competitive position of the company is important. A projection of operations, intelligently conceived, is a valuable tool to the credit analyst. Here the banker must also examine the capital expenditure or plant expansion contemplated and be assured of the financial ability to conduct this expansion. The further development of the product and the potential expansion of sales at a profit are essential items in this study.

So far as the pulp and paper industry in the United States is concerned, all the characteristics which surround safe lending procedures are present. While there may be periods of digestion in which some loans may have to be reset, the growth in population, new uses, and the basic essentiality of the product warrant investment. The commercial banks are willing and anxious to participate in this growth.

IX. Special item on newsprint

THE NEWSPRINT PROBLEM[1]

THE SECRETARIAT

The problem of newsprint in Latin America has been touched on in many of the papers submitted to this meeting. The object of the present paper is to state the problem briefly to summarize the data contained in the background papers, and to suggest, as a basis for discussion, some of the possible directions in which a solution, if only a partial solution, may be sought.

Latin America today consumers about 390,000 tons of newsprint annually; Argentina, Brazil and Mexico together account for nearly 70 per cent of the total.[2] Nearly all the newsprint has to be imported, since production capacity within the region is only 55,000 tons. Newsprint needs are expected to grow rapidly. Given only minimum economic development, requirements are expected to rise to 615,000 tons by 1960 and 770,000 tons by 1965. Should a more favourable economic development take place, demand is estimated to reach 726,000 and 985,000 tons by 1960 and 1965 respectively.

If all present plans for expanding newsprint capacity are realized—about 139,000 annual tons in all—there would still remain, in 1965, a very considerable newsprint deficit: 575,000 or 790,000 tons, depending on whether economic development is minimal or favourable. Thus even if the region could rely on maintaining newsprint imports at their present level, by 1965 additional annual newsprint capacity of 220,000 to 435,000 tons (depending on economic growth) would be required if consumption were not to be frustrated. Present plans thus fall far short of even the lower figure. In fact, under either assumption as to the rate of economic growth, newsprint accounts for about 40 per cent of the deficit between expected future regional production and future needs.

SOME ECONOMIC AND TECHNICAL CONSIDERATIONS

The production of newsprint is one of the most specialized paper-making processes, governed by strict product specifications and low margins of profit. Conventional newsprint is produced from a mixture of mechanical pulp (usually from conifers—spruce, hemlock, fir) and chemical pulp (generally unbleached coniferous sulphite or semi-bleached sulphate pulp). Both quality requirements and the economics of the process favour the installation of large mill units based on coniferous woods. This is why newsprint production today is largely concentrated in those regions which enjoy both abundant coniferous resources and easy access to the main consuming centres—North America and Scandinavia.[3]

[1] Originally issue as ST/ECLA/CONF.3/L.9.0.

[2] For details see paper 2.0, *Pulp and paper consumption, production and trade in Latin America*, by the Secretariat.

[3] Japan, however, with coniferous resources and a strong domestic demand, has an important newsprint industry, and in some of the traditional paper-making centres, where newsprint consumption is high, there are important newsprint industries based on imported pulp, e.g., in the United Kingdom. The survival of the latter, however, in no way gainsays the general trend—towards large-scale, integrated production.

Limited markets and the scarcity of conifers explain why newsprint manufacture has elsewhere offered less financial attraction than the production of paper qualities, with less rigid specifications, capable of being produced without technical difficulties from local fibrous raw materials.

However, in the last two decades much attention has been devoted to the problem of finding raw materials to take the place of spruce groundwood. The development work has proceeded along four separate lines:

A. To solve the technical problem of producing mechanical pulp from pines—especially those with high resin content;

B. To produce groundwood of acceptable strength characteristics from temperate broadleaved species by the conventional grinding process, with or without chemical pre-treatment of the logs;

C. To produce groundwood-type pulps from deciduous woods by non-conventional methods which have less destructive action on the fibres than a grinder;

D. To produce newsprint-type papers from low-cost chemical pulps, notably from bagasse.

These different approaches are briefly discussed below, with some comments on the present commercial utilization and future possibilities.

A. *Mechanical pulp from pines*

The problem of producing newsprint groundwood from pines was first tackled by a research institute in Savannah, Georgia, with the aim of finding a way to make use of the pine resources in the South (Alabama, Texas, Tennessee and Georgia). The major difficulty encountered was the high rosin content of the pine species of this area (Loblolly pine—*Pinus taeda* and shortleaf pine—*Pinus echinata* Mill), which leads to pitch trouble in the paper-making process. The problem has been successfully solved and today three mills are operating commercially on these species:

Southland Paper Company. Plant at Lufkin, Texas, started operations in 1941. Daily capacity is 385 tons.

Coosa River Newsprint Company.[4] Plant at Coosa Pines, Alabama, started operations in 1948. Daily capacity 270 tons.

Bowater Southern Paper Company. Plant at Calhoun, Tennessee, started operations in 1954. Daily capacity probably 350 tons.

An additional plant using resinous pine (insignis pine, *Pinus radiata*) is being erected at Murupara, New Zealand.

[4] Subsidiary to Kimberley-Clark Company, Neenah, Wisconsin.

B. *Groundwood from temperate broadleaved woods*

This development is by no means new—in fact the first commercial production of mechanical pulp was probably based on such broadleaved species as poplar or basswood. The utilization of broadleaved species to produce mechancial pulp for newsprint is, however, a more recent development. In North America, groundwood from aspen has been used as an additional blend in the regular furnish to give desirable softness and improve printing characteristics to the newsprint. In Italy, poplars have been used for a number of years to manufacture newsprint; the regular furnish probably consists of about 60 to 70 per cent poplar groundwood and 30 to 40 per cent chemical pulp. In Argentina a similar development has taken place; Celulosa Argentina S.A., in its mill at Zárate, makes newsprint from willow and poplar-willow groundwood,[5] with the addition of chemical spruce sulphite and smaller quantities of straw pulp to reduce the bulk of the paper and increase resistance to picking.

Several processes have been developed to use conventional grinders for the production of mechanical pulp from higher density broadleaved species, such as birch, maple, beech, etc. The general principle in all these processes is to reduce the mechanical destruction of the fibres by softening the wood before the grinding operation. Besides the old steam groundwood process (which gives pulp unsuitable for newsprint because of it's dark colour) there are several processes in which the softening action is achieved through a mild cooking of the logs with various pulping chemicals. The best known is the chemi-groundwood process,[6] in which the billets are impregnated and mildly cooked with a neutral sulphite cooking liquor before grinding in conventional grinders.

Pulps produced in this way have strength characteristics considerably higher than spruce groundwood, approaching those of sulphite chemical pulps. The colour is generally darker but in most cases the pulps respond easily to conventional bleaching processes, for instance, using peroxide of hypochlorite. Other advantages of the process are the considerably lower power consumption as compared with conventional spruce groundwood, and the higher production capacity of the grinders. The main drawbacks are slightly lower yields, higher capital investment in processing equipment and the cost of chemicals. Pulping trials using mixed tropical wood species have not, so far as the Secretariat is aware, been carried out with this method. At first sight, however, it seems likely that the simultaneous grinding of even a few different species in a mixture would involve considerable technical difficulties; firstly, because the impregnation of the various species may require different operating conditions, and secondly, because the operation of a grinder is an art rather than a science, and different woods often call for quite different operating conditions (speed, pressure, burr, etc.), which are adjusted on the basis of long-term experience of highly skilled personnel.

Even if this provisional judgment proves wrong, it is likely that the higher investment and operational costs may make it impossible to produce newsprint economically from tropical woods using a high percentage of this pulp. One way which may be feasible—provided it works technically on mixed species—is to use the chemi-groundwood in a smaller percentage (mainly as a substitute for the chemical pulp fraction, to impart necessary strength characteristics) in combination with conventional groundwood from one or two suitable species which may be found in the second growth forest (e.g., *Cecropia*).

C. *Groundwood-type pulps produced by non-conventional equipment*

In the last two decades several processes have been developed to make groundwood or mechanical-type pulps from wood chips by fibrizing in disk (attrition) mills or refiners. Prior to this operation the chips are softened either by steam (Asplund defibrator)[7] or by chemical treatment.

An interesting process for making newsprint groundwood-type pulp belonging to the second group is the cold caustic soda process developed by the Forest Products Laboratory, Madison, Wisconsin.[8] This consists of pre-soaking the wood chips—usually for 1½ to 2 hours—in a cold, caustic soda solution, followed by a breaking-up of the softened chips in disk refiners. The process is simple to operate and does not require any heavy capital investment.

Different wood species respond more or less easily to this treatment, but as a rule hardwoods give much better results than conifers. The yield is high—between 85 and 90 per cent—and the strength properties are usually superior to those of conventional groundwood. The colour is rather dark, but most of the pulps can easily be bleached in a normal hypochlorite bleaching operation to the brightness required for standard newsprint.

So far, the process has been applied commercially only to the production of corrugating medium and (in one newsprint mill in Italy) pulp for blending with poplar groundwood. Trials have also been made at the Zárate newsprint mill in Argentina, for the same purpose as in the Italian factory. The preliminary results have been promising.

D. *Newsprint from chemical pulp*

If the standard definition of newsprint is discarded and the more fundamental one given in paper 3.12[9] applied, the production of newsprint from chemical pulps alone must also be considered.[10] Because of higher production costs it is evident that this will never be adopted if woods suitable for grinding are available.

Production of newsprint from chemical wood pulp is disregarded in this short summary for two reasons:

(*a*) It is likely that in most cases it will be possible to produce cheaper newprint-type papers from wood by one or other of the methods described above, and

(*b*) It is unlikely that paper made from 100 per cent chemical wood pulp could ever compete in price with imported newsprint even in cases where the imported product has to bear very heavy freight charges.

[5] Paper 4.8, ***Production of chemical pulp and groundwood from willow and poplar-willow***, by Celulosa Argentina S.A.

[6] Developed by the College of Forestry, State University of New York.

[7] Paper 6.10, ***The Defibrator continuous semi-chemical pulping process***, by A. B. Defibrator.

[8] Paper 3.13, ***The use, in newsprint, of bleached cold soda pulps from certain mixtures of Latin American hardwoods***, by G. H. Chidester.

[9] ***Economics of newsprint production*** (paper 3.12), by P. R. Sandwell.

[10] Strictly speaking the pulps produced by the chemi-groundwood and cold soda processes could also be classified as chemical or semi-chemical pulps.

Considerable attention has, however, been paid to the possibility of producing newsprint from annual crop fibres (mainly bagasse) in countries lacking forest resources (for example, Cuba). In this short paper no account can be given of the various methods tried, their relative merits and the technical and economic prospects they offer. But attention may be drawn to the newest development in this field, i.e., the production of newsprint from bagasse by using a prehydrolysis process followed by a neutral sulphite semi-chemical cook.[11] The main advantage of the process seems to be that a pulp is obtainable which is sufficiently bright to meet the requirements of newsprint without the need for subsequent bleaching.

Semi-industrial trials have indicated that the other qualities of the pulp, such as strength, porosity, softness, printability, etc., are acceptable, but no runs have as yet been carried out on modern high-speed paper machines. The cost of production may be determined with fairly high accuracy, and it may well be that possibilities exist in certain countries and areas for an economically successful operation.

Potential raw material resources in Latin America for newsprint

The present production of mechanical pulp in Latin America is based mainly on three different forest resources: the natural fir stands in Mexico (*Abies religiosa*, "oyamel"), the natural and planted pines in Brazil (*Araucaria angustifolia*, Paraná pine), and—in Argentina—the willow and poplar-willow plantation in the Paraná Delta. These resources are fairly limited and can, in their present extent, supply only a small part of the region's total requirements. Thus any substantial expansion of the newsprint industry must depend on the successful realization of one or several of the four non-conventional operations described earlier. The following pages offer comments on the possibilities of using alternative raw materials for a long-term expansion of the indigenous newsprint production in the region. The review is by no means complete; as explained in the introduction, it is intended simply to serve as a basis for discussion.

The raw materials which are likely to be of interest in this context may be conveniently grouped as follows:[12]

A. Pines:[13] natural stands (Mexico, Central America) and plantations (Chile, Argentina).

B. Broad-leaved species suitable for conventional grinding: willow and poplar (Argentina); *Cecropia* (and a few other light-weight species occurring mainly as second growth in sub-tropical and tropical [rain] forests); eucalypt plantations (Brazil).

C. Broad-leaved species suitable for mixed pulping by the cold caustic soda process:[14] mainly mixed tropical woods of medium and low density.

D. Bagasse: only in countries with low-cost fuels and chemicals (Peru, Venezuela, Mexico and—perhaps more doubtful—Cuba).

A. Pine: natural stands and plantations

The natural pine forests of Mexico and Central America, though extensive, are for the most part badly situated from a transport point of view. The various species are mostly of the resinous type—the same or similar to those of the Southern states in the United States of America. As mentioned earlier, those species are now used commercially and with success for the production of newsprint; the pitch trouble has been overcome by methods which apparently are not economically prohibitive. This suggests that the same processes could be used successfully for Mexican and Central American pine. An important difference between the pine forests in the south of the United States of America and those in Mexico and Central America should however be pointed out. The pine forests in the south of the United States of America are all second-growth stands, whereas those in Central America are, to a large extent, mature forests, with large-size trees. It has been stated in the literature that the successful production of mechanical pulp from resinous pines is possible only if the trees are young and relatively free from heartwood. Large-scale trials of the Mexican and Central American pines are therefore necessary to establish their suitability for newsprint.[15]

An assessment of the *economic* possibilities for newsprint manufacture from these resources is of course impossible without a complete analysis of production costs etc., and a comparison with ruling world market prices. In the light of document 3.12,[16] however, certain comments may be made.

It has been estimated that the cost of pine pulpwood in Mexico would be about the same as in the Southern states—$7 to $8 per cm solid volume. Labour will be substantially cheaper but electric power more expensive, except perhaps in some particularly favourable locations. Capital charges are likely to be slightly higher than for a mill of corresponding size in North America. Summing up, it may be estimated that total mill cost under favourable circumstances may be slightly higher than in a mill of the same size in the United States of America or Canada.

A study of the various cost items (paper 3.12) shows that the capital charges—which account for between 40 and 50 per cent of the total mill cost depending on size of operation—fall sharply with an increase of capacity;[17] the difference for mills of 100 and 300 tons daily capacity is not less than $22 per ton, or almost 20 per cent of present f.o.b. prices for newsprint. Since Mexico and Central America are by no means remote from the leading export countries it would not seem that newsprint from a mill with a capacity of less than 200 to 300 tons daily could compete with imported paper. It should be borne in mind, however, (see paper 2.0[18])

[11] Paper 6.9: *The Aschaffenburger process for manufacturing bagasse pulp for newsprint*, by Rudolf Schepp. See also secretariat paper 5.0: *Bagasse for pulp and paper*.

[12] This grouping corresponds broadly to the four lines of development discussed earlier.

[13] The *Araucaria* species, which are not true pines, are not considered here. Their suitability for newsprint is proved and they are used commercially for this manufacture (Industrias Klabin S.A., Monte Alegre).

[14] The chemi-groundwood process offers a second alternative which, however, for reasons given above, is probably of less interest in this connexion.

[15] Information presented at the meeting indicated that these tests have been carried out and have proved successful.

[16] *Economics of newsprint production*, by P. R. Sandwell.

[17] See also secretariat paper 3.03 *mill size, integration, location. A study of investment and production costs in hypothetical pulp and paper mills.*

[18] *Pulp and paper consumption, production and trade in Latin America*, by the Secretariat.

that the Mexican market alone—even assuming unfavourable economic development—will by 1960 be capable of absorbing this quantity.

The plantations of insignis pine in Chile may, in the future, become an important pulpwood resource for newsprint manufacture. From a technical point of view *Pinus radiata* is easier to process than the more resinous pines mentioned above. Furthermore, the plantations—most of which are still young and will not have developed substantial heartwood—are favourably located for pulpwood extraction. A fully integrated newsprint mill of minimum economic size would not be able to place the whole of its output on the Chilean market for some years to come—currently Chile consumes about 25,000 tons of newsprint annually. This suggests that a project with a varied production programme, comprising a newsprint section integrated with a larger pulp capacity, would prove successful, and this indeed is the scheme which has been approved and on which construction is about to start. The indications are that, provided a sufficiently high capacity newsprint mill is established, the production costs will enable the product to compete successfully with the international prices in neighbouring markets.

Finally, attention should also be drawn to the experimental plantations of exotic conifers in the Paraná Delta (Argentina).[19]

B. Broad-leaved species: conventional grinding

Only few broad-leaved species suitable for conventional grinding are available in sufficient quantities in concentrated areas to serve as raw material for newsprint. As mentioned earlier, the willows and poplar willows of the Paraná Delta, which are already exploited for this purpose,[20] are one of the important exceptions.

Another species which may become important as a source for mechanical pulp is *Cecropia,* which occurs in about twenty varieties all over tropical and sub-tropical Latin America. The wood is usually white or yellowish, of low to medium specific weight, and has a fairly high average fibre length; the varieties which have so far been tested have yielded promising results. *Cecropia* as well as some other similar light-weight species occur frequently and in almost pure stands as second growth of the tropical and sub-tropical rain forests. Little is known about the sylvicultural problems (regeneration), but judging from the spontaneous generation and power of growth on cleared land it may be confidently assumed that such problems, if they exist, can be readily solved.

Thus *Cecropia* (and similar species) may in the future become an important source of raw material for the production of newsprint in the region. Since they are mainly second-growth species it is likely that this development will in most cases be linked with the establishment of paper industries based on chemical pulp from mixed tropical woods.

Mention should also be made of the eucalypt plantations in Brazil as a possible source of raw material for newsprint. There are technical difficulties however, in obtaining a good quality newsprint from most of the eucalypt species, and for this reason it does not seem likely that these plantations will offer an attractive solution to the newsprint problem.[21]

C. Newsprint from mixed broad-leaved species

The encouraging results obtained in the tests of mixed Yucatán woods using the cold caustic soda process indicate the possibility of manufacturing newsprint type papers from mixtures of selected species in tropical virgin forests. Such selection does not offer any major difficulties in the forest operation. Provided that the forest stand contains a sufficient proportion of suitable (low density) species it seems likely that the manufacture of newsprint on a limited scale integrated with a large-scale chemical pulp and paper production will be feasible. In any case production of mechanical-type pulps by the cold soda process should be considered as an integral operation for any paper mill project based on tropical woods, since this pulp, besides imparting certain desirable characteristics to many paper qualities, will also be substantially cheaper than chemical pulp.

D. Newsprint from bagasse

The economics of newsprint manufacture from bagasse (see Secretariat paper 5.02)[22] depend above all on cheap material. Since newsprint must be produced in large mill units—to reduce the capital charges per ton—it follows that only under very exceptional conditions will it be possible to use *surplus* bagasse only. The cost of the fibrous raw material will consequently depend on the price of alternative fuels; thus the economic production of bagasse newsprint will only be possible in countries where low-cost alternative fuels are available. Therefore, although the production of bagasse newsprint may be of interest to a few particular countries, it cannot be expected to play an important role in the future expansion of the newsprint industry in Latin America.

Conclusion

A review of Latin America's fibrous resources from the standpoint of the prospects they offer for successful, economic production of newsprint had it been carried out but a few years ago, would have led to conclusions which must have been considered far from encouraging. And indeed today, if attention is confined to the processes whereby well over 90 per cent of the world's newsprint is currently produced, and to the materials which go into its manufacture, the prospects would be only a few degrees brighter.

Technical advances in recent years, however, have multiplied the processes which can be applied to newsprint manufacture, and have immensely widened the range of raw material from which newsprint can be made. It is true that many of these advances are essentially adaptations or modifications of existing processes; it is equally true that many of them have yet to prove themselves on a commercial scale.

It is, in fact, in this latter point that the heart of the problem in Latin America lies. It is technically possible to make newsprint from the region's natural and artificial stands of pine, from the plantations of poplar and willow, from tropical mixtures, from bagasse; from some of these resources newsprint is already manufactured suc-

[19] Paper 4.5 *Pulpwood from plantations of exotic conifers in the Paraná delta,* by Lamberto Solfari.

[20] Paper 4.3 *Pulpwood from salicaceous species of the Paraná delta,* by Enrique G. Valente.

[21] In fact, *Eucalyptus regnans* is the only species which has produced groundwood pulps satisfactory for newsprint.

[22] *Bagasse for pulp and paper.*

cessfully, and economically, in the region today. How far newsprint production, based on any or all of these resources, will expand in the coming years will depend primarily on economic factors—on the suitability of the sites chosen, on the size of the markets available and on the scale of operations.

One final comment: there is no reason to expect that the rapid technical progress of recent years is likely to slow down in the years to come. Each new development, each trial, each experiment will inevitably bring nearer the possibilities of successfully applying, on a commercial scale, the techniques at present available.

Appendices

I

The Meeting: contributors and participants*

1. *Latin American countries*

(*a*) *Official delegation*[1]

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[1] Argentina, as the host government, sent an official delegation in addition to the other Argentine participants who attended in their own capacity as experts. As this was a meeting of experts no other official delegations from governments were present, although some governments sent members of their Embassies in Buenos Aires as observers.

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II

Addresses delivered at the inaugural session of the Latin American Meeting of Experts on the Pulp and Paper Industry on 19 October 1954

1. ADDRESS BY THE ARGENTINE MINISTER FOR AGRICULTURE AND LIVESTOCK, MR. CARLOS A. HOGAN

As a Minister of the Argentine Government, it is a very great pleasure for me to express to this Meeting, in the name of His Excellency the President of the Republic, General Juan D. Perón, our Government's welcome to all the delegates.

The direct importance of this international meeting is linked with the indispensable and fundamental role that paper plays on the modern social scene.

In spite of the valuable assistance rendered by other means of communication, paper is still vitally necessary for the exchange of ideas and the advancement of human culture. The steady increase which may be observed in world consumption calls for a special study of the technical and economic problems connected with its production and distribution.

Published figures stress the large share of paper used for newsprint; it is estimated that in Latin America 400,000 tons go into newsprint out of a total annual consumption of 1,500,000 tons.

Paper provides a wide subject for a speech, because it is so necessary and because it has a place in every civilized activity.

I will not take up your time, however, with arguments and comparisons that you all know and understand. It is sufficient to be fully aware that we are considering a factor essential to the maintenance of human progress, and that as such it requires our keenest attention to the various aspects of the balance that must be assured between an increase in consumption and a corresponding stimulus to sources of supply.

Nor is woodpulp any less important. This valuable product which has so many uses is vital to the paper and other basic industries, as, for example, those connected with foodstuffs.

Both woodpulp and paper products have received preferential consideration from the Argentine Government for many years. Already our first five-year plan has included a special project concerning pulp and paper based on previous research and studies carried out by the Ministry of Agriculture and Livestock.

To our great satisfaction, it was shown that Argentina offers extensive possibilities for pulp and paper production. This is because several of its forest species are highly suitable, while both soil and climate are excellent in the areas which naturally lend themselves to large-scale production of these raw materials.

One of the specific characteristics of the political, social and economic transformation which Argentina wishes to make known to the world, is the desire to obtain a better knowledge of our sources of wealth. A rational exploitation can thus be undertaken for the benefit, not only of the Argentine people, but of the Americas and the whole world.

I formerly declare that this humanitarian and universal principle is in no way an unrealisable or stereotyped hope, but one of the basic purposes of the doctrine which inspires the Government of Argentina, which was adopted as a national doctrine and named *"Justicialismo"* or *"Peronismo"* in homage to its creator and chief executive.

The second five-year plan includes several measures to increase pulp and paper output. These refer, mostly, to provisions for the country's forestry policy—to create, maintain, increase and protect this source of wealth.

Furthermore, we have not lost sight of the pulp resources from crop residues of various agricultural products, which can also be used in the production of different types of chemical pulp and paper.

The Paraná delta, situated at the very door of Buenos Aires, has an area of almost one million hectares, and is of great importance to us for pulp and paper production as its natural suitability as a source of pulpwood provides excellent yields, a fact which delegates will be able to appreciate personally by paying it a visit.

This is a zone from which we shall extract a large part of the raw materials for pulp, supplementing them with others provided by the Territory of Misiones, which not only makes a substantial contribution but also offers truly exceptional conditions for the growth of those species which are of the greatest interest to the industries we are considering.

The Ministry of Agriculture and Livestock is responsible for research on the country's forest wealth and for its encouragement, control and management. The Ministry's technical services are based upon a law drafted for the first five-year plan, and subsequent research has allowed for substantiation and discoveries of great economic importance. I may mention, as an example, the shorter period necessary for the complete growth of some species in Argentina as compared to other countries.

Within the general policy conceived and planned by His Excellency the President of Argentina, the aim of economic independence, towards achievement of which numerous measures adopted by our Government are directed, is in no way incompatible with increasing co-operation between all countries. On the contrary, our own development and the free determination obtained through a control of the fundamental sources of our national economy, enable us today, with more facility than at any other period of our history, to raise the standard of our trade with the rest of the world on equitable terms which are beneficial to all concerned.

In this order of ideas and aims we have promoted the expansion of forestry and its allied industries in this country.

The type of organization and the results obtained must serve not only to aid our economic independence, but also to encourage greater progress in our trade relations with other countries.

In this respect we shall receive with pleasure any suggestions which the delegates and experts may make, not only as regards the organization of production, but also on the output of end-products and the marketing of those goods which interest us.

We are exceedingly pleased that the Economic Commission for Latin America has singled out our country as the host for this Meeting. This is, of course, an opportunity for strengthening the bonds with the representatives of our sister countries in Latin America, and we are at their service, as always, to co-operate with our best goodwill for the attainment of those high ideals which we mutually possess.

Together with these sentiments I want to express my best wishes for the great success of this meeting. It is up to the experts to make the scientific and technical contributions which will form the basis required by Latin American governments to perfect their plans for pulp and paper production, and to contribute, by these means, to the general welfare of our peoples.

In repeating to the delegates the most cordial welcome of the Argentine Government and people, on behalf of His Excellency the President, General Juan D. Perón, I have the honour to declare the sessions of this Meeting open.

2. Address by Dr. Raúl Prebisch, Executive Secretary of the Economic Commission for Latin America

When the Government of Argentina extended its gratifying invitation to ECLA to hold this expert meeting under its auspices at Buenos Aires, it was interpreted by us as further proof of its unswerving support of this United Nations' regional organization. I immediately decided to attend the Meeting personally to demonstrate how much we appreciate this happy gesture. In fulfilling this pleasant duty, I am here to convey the gratitude of the Secretary-General of the United Nations and of the Director of the Technical Assistance Administration to the Argentine Government, to which I should like to add my own appreciation and that of my collaborators at this Meeting. This is the first time that those who lead the technical staff of ECLA in Santiago de Chile have had the opportunity to meet the Argentine public, and it therefore appears to me an appropriate occasion to give the background for the Commission's task.

A substantial proportion of the world's population lives under very precarious social and economic conditions. The striking difference in *per capita* income between the industrial centres and the great masses who live on the periphery of the world's economy is more and more apparent. It constitutes a serious problem which continually arises in the councils of the United Nations. Those who suggest the need for radical solutions naturally do not share the characteristic illusion of the nineteenth century, according to which the free play of international economic efforts would ensure the benefits of greater technical progress in the world for under-developed countries. A vigorous policy for international economic co-operation will alone achieve this aim, not in order to replace a national development policy, but rather to supplement it through the technical and economic co-operation of the more advanced countries.

The United Nations has agreed to collaborate in drawing up this policy of international co-operation, and the Meeting that opens today bears witness to this objective in the technical field. This policy is in its merest infancy, its initial steps are still hesitating and modest, because considerations deemed of greater urgency are absorbing the efforts and resources of the larger countries. The solutions depend primarily upon these countries, and it is our role as officials of the United Nations to continue carrying out the research essential for the establishment of a firm basis for international co-operation, and to link such solutions with each government's individual development programme.

In performing these tasks under the provision of its Charter, the Secretariat of the United Nations acts with complete independence, and is not permitted to receive private instructions from any government. This is to preserve the absolute impartiality of opinion among United Nations officials. It has been a most important factor in the existence of ECLA, and was recognized as such by its Member States when they decided to make the Commission a permanent body.

The problem is of vast dimensions. To transfer the modern productive techniques of the advanced countries to those which are less developed, adapting them to individual conditions, is a task which, in addition to other requisites, demands large capital investments which under-developed countries cannot afford without dangerously limiting the low living standards of their peoples. The aid of foreign capital is therefore indispensable to accelerate the rate of growth, and to rectify little by little the great income disparities between the centres and the periphery of the world economy.

As regards Latin America, the preparatory group appointed by ECLA to present concrete recommendations to the forthcoming Conference of Ministers of Finance or Economy at Rio de Janeiro, considered that, for a period of ten years, the minimum foreign investment required is 1,000 million dollars annually. It also felt that two-thirds of this capital shoud be found by the two internationa credit institutions. Their loans for economic development are thought to be very inadequate, since during the past four years they have averaged only 80 million annually.

These figures are sufficient to provide an idea of the size of the problem. The cost of technical co-operation is also substantial, and to date the available funds have been extremely limited. Progress, however, has been effective. While preliminary steps are being taken in this specific field, a fundamental change of attitude towards the problem of economic development has taken place, and in this achievement the United Nations has played a predominant part. The theory that industrialization, to the extent needed by individual conditions in each country, is an essential requirement for development and must be closely linked with better techniques for agriculture, is constantly spreading and being more widely accepted, despite some deep-rooted doctrinal prejudices which have not yet entirely disappeared.

This meeting will consider one special problem of industrialization, that of pulp and paper. Another meeting which we held two years ago in Bogotá referred to what may be considered an even more significant question from the point of view of industrialization itself, the production of iron and steel in Latin America. Who would have thought some years ago that an international organization, which has amongst its aims the encouragement of reciprocal trade to improve national economies, would summon outstanding world experts who, together with Latin American specialists, would recommend the most efficient methods for industrializing the raw materials of our countries or for taking advantage, through industrialization, of their great consumer power? Does not industrialization endanger international trade? Would it not be more advantageous for the Latin American countries to concentrate their efforts upon exports and leave industry to develop spontaneously without the aid of tariff protection?

Such questions have a clear theoretical answer which much serve as the basis for a development policy. Industrialization is in no way incompatible with the encouragement of exports and international trade; if it were, we, as officials of the United Nations, could not defend it. The plan laid down by ECLA economists is as follows. About 60 per cent of the active population in Latin America is still working at a very low rate of productivity in primary production, principally agriculture. In addition, there is a considerable proportion of the population occupied in artisan-type work with low productivity. It is necessary to give an impulse to greater technical skills, both in agriculture and in these other activities. As greater use is made of technical methods, there can be no justification for the employment of so many workers. Less and less manpower is required for primary production and for other activities with low productivity, while there is an increasing need in industry and services. Exports can only absorb a relatively small proportion of the greater labour availability caused by a more intense use of technical methods. Such manpower, therefore, must be absorbed by industry and services. This is the reason for the close connexion between industrialization and the use of better technical methods in agriculture. There is no incompatibility between them; on the contrary the two processes are complementary, and an extreme in one direction or the other is detrimental to economic development.

If an adequate balance is maintained between these two processes, there is no reason why industrialization should unfavourably affect either exports or, as a result, international trade. It is true that the domestic production of goods which were previously imported, causes a reduction or the disappearance of certain imports. But the latter are soon replaced by other goods. The demand for industrial products and, consequently, the need to import them is extremely great in countries in course of development. Thus, protective measures required by the development of domestic industries only lead to a change in the composition of the goods purchased abroad, without disturbing their growth and always provided that protective measures remain within certain limits.

The customs tariffs, by means of which the large industrial centres control imports of primary products, are of a very different nature. Only a few days ago, an economist from the United States with whom I was discussing problems related to the forthcoming Rio Conference, enquired with great forcefulness: "Don't you consider it incongruous to favour protective measures as a means for industrialization in Latin America and simultaneously show satisfaction at the government policy in the United States to reduce duties there—or at least to avoid their increase?" There is nothing incongruous in such a position. It is inadmissible that the centre of the world economy should have the same economic policy as the countries on the periphery which are in course of development. Higher duties upon a primary product at the centre unfavourably affect both imports and world trade, since there is no reason for the decline in imports of this nature to cause a rise in other imports to offset the initial decrease. In contrast, a decline in imports of one commodity causes an increase in others in the case of a country being developed.

It has been essential to revise traditional concepts in order to penetrate further into the problems of development and to suggest concrete solutions. The doctrine of the international division of labour, based upon free trade, is as naive as the concept of self-sufficiency, of which, fortunately, only harmless traces remain. Both theories undermine development since the former hinders industrialization and the latter obstructs world trade and does not permit countries with primary production to expand their exports with the object of accelerating industrialization.

The tendency for the consumption of industrial goods to grow more rapidly than income, thus causing a steep increase in the demand for imports, provides a typical example in the case of pulp and paper. Paper consumption in Latin America tends to rise more rapidly than *per capita* income. Broadly speaking, it may be said that, in our countries, for every 1 per cent of income growth paper consumption tends to rise by 1.75 per cent; yet this is no exceptional phenomenon. On the contrary, it is characteristic of industrial demand that it must lead to a policy of substituting domestic output for imports. Unless this occurs there is neither growth nor industrialization.

If economic development is accompanied by the characteristic phenomena of external disequilibrium through the marked increase in the demand for industrial goods, which contrasts with the slow rise in the demand for raw material imports in the great industrial centres, then a far-sighted development policy must include measures to encourage domestic production. For pulp and paper there is a further motive for this policy. The current prospects for future supply appear to indicate that the established producers will be unable to meet the probable rise in demand. It is therefore essential to provide new sources of supply, and, among them, those of Latin America which appear to have been scarcely touched. Allowing for a moderate annual rate of increase it can be estimated that, by 1965, consumption will have doubled. In order that this increase may not weigh too heavily upon a world supply that appears somewhat unpromising, Latin America must be prepared to take the fullest advantage of its own raw materials. In the course of our studies we have reached the conclusion that existing development plans for this industry will not cover the requirements. New sources and new processes must be explored.

To contribute to solving such problems, the United Nations, jointly with its specialized agency, FAO, have convened this technical meeting. Careful preparation over nearly two years was required to collect the basic material without which such meetings often waste time in generalizations. The first suggestion for this Meeting dates from one of the first ECLA meetings in recent years. It was made by two distinguished FAO experts, Egon Glesinger and Pierre Terver, who are with us here and to whom I should like to pay tribute now.

Combined with technical subjects we shall also consider the economic and financial aspects of pulp and paper production. To provide some idea of its magnitude, it will suffice to point out that were Latin America to produce the tonnage required to meet the greater demand in 1965, according to reasonable hypotheses regarding the rate of growth, an investment of from 750 to 1,300 million dollars would be required. It may well be supposed that these investments cannot be envisaged in an isolated form, but rather within a general development programme. The mere fact that it may be technically possible to produce pulp and paper in this or that area does not necessarily imply that it would be advisable to do so from the economic standpoint. It is possible that other investments may be more suitable for the economy of a country. And this leads me to another subject to which ECLA is devoting much effort and attention, the programming of economic development. I expect to speak of this subject again in Buenos Aires within the next few weeks.

If the governments of the Latin American countries continue their far-sighted policy of encouragement, there is no doubt that local capital will become increasingly interested in pulp and paper production. Interest has also been shown by foreign capital, and I feel sure that in this respect we shall, in due course, hear a very significant statement presenting such a broad outlook on Latin American industrialization problems that it will impress the experts of our countries most favourably. Formulae that will adequately bring together foreign technical experience, capital from abroad and the initiative of the Latin American entrepreneur will have to be sought. This problem is far from having been solved.

It is necessary to strengthen the Latin American entrepreneur, so that he may meet the competition of foreign capital, may be associated with it, or may receive the technical services of the foreign entrepreneur under more favourable conditions than those at present prevailing. In a large Latin American country, I have recently noticed some concern over a symptomatic occurrence. Local entrepreneurs of a consumer goods industry which was previously well established, are losing the market through the competition of foreign entrepreneurs who are introducing new manufacturing processes. Such methods are also available to the local manufacturers, but they lack sufficient capital to use them. Herein lies one of the roots of the evil which hinders the achievement of reasonable formulae for external co-operation. The Latin American entrepreneur must have access to international sources of both capital and technical knowledge.

ECLA has also made a concrete proposal on this significant matter to the governments which will meet at Rio. This is the establishment of a fund for industrial and agricultural development to make loans to Latin

American enterpreneurs, without government guarantee and through the banking and financial system of each country. It is hoped that for this purpose the United States may be able to devote $50 million over a period of fifteen years, to accrue from a tax which will not burden the United States taxpayer but comes from a Latin American source. I refer to the tax on the profits of United States capital investments in our countries, the yield of which is estimated at some $100 million annually. The collaboration of money markets and of international credit institutions is also anticipated.

I believe that if a measure of this nature were applied with enthusiasm and with conviction it would give a considerable impulse to Latin American initiative in accelerating the development rate of our countries, and would also contribute to lessening the tension which often arises when foreign investments are made in this region.

I have no doubt that this ECLA proposal will be considered with interest at the present Meeting, apart from the technical problems with which it will deal. We have invited outstanding specialists from the United States, Canada and Europe, as well as Latin American experts. All of them will enjoy the facilities kindly placed at our disposal by the Argentine Government and the assistance of experts, both from the official sphere and that of private enterprise, who will doubtless give us the benefit of their wide experience. I wish to express the appreciation of the United Nations for the papers these experts have prepared and for the assistance that their knowledge and experience will contribute to this Meeting.

In point of fact it has not been easy to bring such a large gathering together, nor to prepare the many valuable documents now before the Meeting. It is our good fortune to have the services of two first-class co-directors: Arne Sundelin from Sweden, appointed by FAO, and Carlos Quintana, a Mexican who, having been chosen for this post from within ECLA, merits a special mention. His thinking is clear and well coordinated, and he has faith in the industrialization of Latin America. He is an example of the young and enthusiastic men I have managed to attract to Santiago in order to perform the vast and stimulating task upon which we are engaged. I am now devoting all my energies to it, with the same enthusiasm, though perhaps somewhat moderated, that I once put into my work for Argentina.

I have no doubt, gentlemen, that as regards the financial, and more especially the technical, aspects of pulp and paper, this Meeting will meet with the success anticipated for it by the Argentine authorities, worthily represented by His Excellency the Minister of Agriculture. Nothing gives greater and more legitimate cause for satisfaction to Argentine opinion than the knowledge that its support has been of service to the other Latin American countries. Therefore, I cherish the hope that the Argentine experts attending this Meeting, both officially and as representatives of private enterprise, will be prepared to place their valuable knowledge at the disposal of all. In the expectation that this hope would be fulfilled by Argentina, I was most desirous that this Meeting should be held in Buenos Aires. I trust that such well chosen guests will meet with all the warmth and generosity of Argentine friendship in this city—the friendship of my fellow countrymen. And nothing will give me greater pleasure than to know that in leaving Buenos Aires, one and all are inspired with feelings of keen affection for this great and productive land, and for those who labour here to develop its greatness in peaceful international fellowship.

3. Address by Mr. Egon Glesinger, Deputy Director of the Forestry Division, Food and Agriculture Organization of the United Nations

The opening of the Latin American Meeting of Experts on the Pulp and Paper Industry marks an important date in FAO's history.

In the past half century, pulp and paper manufacture has grown from a rather minor outlet for small-sized roundwood to an industry which is competing with sawmills for first place among forest industries. The world's sawmills still convert about twice as much roundwood as the pulp industry. But in Europe and North America, pulp and paper output already exceeds in value the production of sawmills. In Sweden, pulp manufacture even uses more roundwood than the country's famous sawmills, and in many countries the pulp mills have become heavy competitors of sawmills as buyers of roundwood. The attention given to the development of pulp and paper industries within the framework of FAO's forestry programme, therefore, needs no explanation.

Let me mention briefly the principal events that have led to the conference which opens today:

In April 1949, FAO organized a preparatory woodpulp conference at Montreal.

In June 1949, I was privileged to attend ECLA's second session at Havana in the course of which FAO drew attention to the importance of developing pulp and paper industries in Latin America. From this date grew up a most fruitful co-operation which is based on regular contact, and from whose joint efforts the present Meeting has arisen.

In June 1951, my colleague Mr. Terver presented to the fourth session of ECLA a report on Latin America's pulp and paper prospects which led to the adoption of a resolution inviting FAO and ECLA to undertake jointly the study on *Possibilities for the Development of the Pulp and Paper Industry in Latin America.* This joint study, as you know, was presented to the *fifth session of ECLA held in April 1953* at Rio de Janeiro.

In the summer of 1951, UNESCO alerted ECOSOC about the dangerous implications of a paper shortage, and

In September 1951, ECOSOC passed a resolution requesting the Director General of FAO to advise member governments on a long-term programme to provide all countries with adequate pulp and paper supplies to meet the increasing needs.

Since the adoption of that resolution the acute paper shortage, which had been caused by the Korean raw materials boom, has disappeared. However, the long-term problem remains. FAO, together with the Regional Economic Commissions for Latin America and Europe, has therefore pursued its course of action, in particular:

Sending pulp and paper survey missions to 24 countries to investigate on the spot the raw material availabilities and economic prospects for establishing pulp and paper mills.

Organizing in December 1952 a consultation of pulp experts, to determine the technological possibilities and the prospective cost of manufacturing pulp and paper from tropical woods, bagasse, straw and other less conventional raw materials. The results of this consultation were published in a pamphlet entitled *Raw Materials for More Paper*, which aroused considerable attention and continues to be widely quoted and used. I am happy to welcome here many of those who assisted in that work and upon whose continued co-operation we may still rely.

Preparing a world survey of pulp and paper prospects which will be presented to the next session of ECOSOC. This has just come from the printer and is being distributed to delegates attending this Meeting.

As these actions were proceeding, we felt that the time was approaching when the results of these technical and local investigations should be placed before Latin American governments, industrialists and technicians. In the summer of 1952, therefore, ECLA and FAO decided to convene, in co-operation with TAA, this Latin American Meeting of Experts on the Pulp and Paper Industry as soon as preparations could be adequately completed.

This short historical description illustrates the great importance which FAO attaches to the present Meeting. You will therefore be scarcely surprised if I tell you that M. Leloup, the Director of FAO's Forestry Division, as well as that Organization's Director-General, Dr. Cardon, had both intended to attend at least part of the Meeting themselves. It was a great disappointment to Dr. Cardon that the session of the FAO Council and other urgent meetings prevented him from carrying out this plan, and as for M. Leloup, he only decided quite recently that he could not include this Meeting in his commitments. It is, therefore, my duty first and foremost, to convey to you, on behalf of Dr. Cardon and M. Leloup, their regrets for not being able to join you today and their best wishes for a successful meeting.

It is customary in opening speeches to characterize the conference as a matter of outstanding importance. Let me assure you that I am not resorting to stock phrases when I refer to the significance of this Meeting; in my opinion, the development of pulp and paper capacity in Latin America is a matter of considerable importance for three basic reasons which, since they are essentially independent, reinforce each other. These three reasons are:

I. High paper consumption and high living standards are almost inseparably linked to each other. A standard of living is made up of many elements, but a high standard of living is never achieved without rather substantial amounts of food, textiles, housing materials and certain other essentials. Paper is one of these essentials. Perhaps the size of the Sunday edition of *The New York Times*, compared with that of newspapers in France or Britain, does not accurately measure the relative degrees of civilization attained in those countries. Nevertheless UNESCO's contentions remain true: that a first condition for literacy is the availability of textbooks, and that modern democracy cannot function properly without newspapers of a reasonable circulation and size. It is equally true that modern methods of distribution require huge amounts of packaging and wrapping paper both for efficient distribution and in the interest of public hygiene.

The first reason conferring importance on this Meeting, therefore, is that we must provide for rapidly increasing supplies of paper in all forms, if we want to make sure that the living standards of Latin American people rise at the rate which appears both possible and desirable.

II. The second important aspect of this meeting has already been referred to by Dr. Prebisch. It is the part which pulp and paper factories can play in the industrial and economic development of new countries. I have always believed that pulp factories constitute the right type of investment in the early phases of industrialization wherever the three basic needs of that industry —namely, wood, water and power—are present. This is in contrast with various secondary industries which can function well only within the framework of a reasonably advanced industrial setting and which, for that reason, are less suited for the early phases of industrial development.

These are the considerations which have induced FAO and the Economic Commissions of the United Nations to advocate a measure of decentralization of pulp and paper production, and the establishment of capacity in Latin America and certain other regions of the world which have hitherto relied predominantly on imports for their pulp, their paper or both.

Thus the second aspect of this Meeting stems from the fact that it will contribute to sound progress in Latin America's economic development. It may, at the same time, provide new opportunities for closer co-operation between the industrialized countries of Europe and North America and this region, especially if it should be possible to associate the "know-how" of the big pulp manufacturing countries and the exporting interest of the manufacturers of pulp and paper machinery in America and in Europe with the development we have come together to discuss here today. Professor Gunnar Myrdal, the Executive Secretary of the Economic Commission for Europe, with whom it is my privilege to be closely associated, is particularly interested in this aspect of your deliberations, and had planned to come to Buenos Aires in order to take part personally in your discussions with regard to trade and financing. Unfortunately, the important conference on east-west trade, which is in progress in Geneva, compels his presence there.

III. There is a third reason why this Meeting strikes us, in FAO, as a matter of special importance—namely, that a gradual development of pulp and paper capacity is probably the key that will open the door to that enormous storehouse of wealth constituted by over 900 million hectares of forest located in Latin America. I hope you will permit me to dwell on this particular aspect, both to illustrate what I mean and to dispel some dangerous but widespread misconceptions about the relationship between the size of Latin America's forests and the potential importance of its pulp and paper industries, at least in the foreseeable future.

The vast forests of Latin America cover one-third of the land area of this region; they constitute one-fourth of the whole world's forest area. To illustrate the size of this reserve in more tangible terms, it may be recalled that the present world output of pulp and paper requires annually some 180 million cm of roundwood. If one assumed that all Latin American forests can grow wood at their present average rate of three cm per hectare and that the annual harvest would include one cm of pulpwood, one would find that there are enough forests in Latin America to produce, on a sustained annual yield basis, pulpwood for five times the present world consumption of paper. In fact, Bolivia alone has as many forests as Sweden and Finland combined, which together produce 5 million tons of pulp, or more than three times Latin America's current pulp requirements.

Unfortunately, these statistical illustrations are as misleading as they are striking. The possession of adequate forest reserves by no means implies the possibility of establishing a pulp mill. In fact, even in accessible, homogeneous softwood forests, so many other factors have to be present at the same time that only relatively few offer sites suitable for a pulp factory. This is why Latin America, despite its vast forest resources, possesses so few modern pulp factories. And this, of course, is the principal reason why this conference is meeting here today—to devise a practical programme for changing this apparently paradoxical situation.

First, we must abandon sweeping generalizations and look more closely at the raw material resources at hand. I suggest we distinguish four categories, namely:

A. Tropical forests;

B. Native conifers;

C. Plantations;

D. Bagasse.

This list is not exhaustive. I have deliberately omitted some 100 million hectares of temperate broad-leaved forests, because, save perhaps in Chile, they do not constitute one of Latin America's principal sources of pulping materials; nor do I propose to take up your time by reviewing the potentially significant contributions from straw, bamboo and various other fibres which the papermaker can use. I will confine myself to the principal materials of immediate practical significance.

A. Let us begin with Latin America's evergreen and deciduous tropical forests which represent the overwhelming bulk of the region's forest resources. They cover some 800 million hectares, more than six times the area of all Europe's forests west of the Soviet Union and, in fact, a land area 60 per cent larger than the entire "old continent".

As yet, these tropical woods are not being converted into pulp. Why not? In the first place, because tropical forests are composed of a great variety of species whereas papermakers have been accustomed to use homogeneous raw materials, such as spruce or pine. Secondly, the difference in specific gravity between tropical species is greater than between temperate woods. Thirdly, tropical woods have hitherto been expensive because only few species have acquired commercial value, with the result that tropical forests are "creamed" rather than logged in a systematic way. Hence, extraction costs are high and, in fact, often prohibitive for all but precious woods.

Finally, the industrial utilization of tropical forests is delayed by the fact that skilled labour, good transport facilities, cheap electric power, chemicals and other essential production factors are not available so that the establishment of a pulp and paper factory involves a far heavier investment than in industrially developed areas.

In a way, these difficulties have acted so far as nature's weapon for self-protection, because had these obstacles not existed, industries might have moved in and created even heavier destruction than they have done in some of the temperate forests of the world. Contrary to widespread belief, many tropical soils, especially in Latin America, are of low fertility, the humus cover is frequently thin and deteriorates rapidly on exposure. The soil is sensitive to heavy rainfall and drought and, once the protecting tree cover is removed, erosion sets in and destroys the land. It is, therefore, indispensable that industrial utilization of tropical forests be preceded by the introduction of scientific management programmes which can safeguard the soil and the forests, and ensure permanent productivity.

Such methods for managing tropical forests exist. They have been successfully tested under comparable conditions in Africa and elsewhere. Also, methods for the pulping of tropical woods have been developed and applied for many years in pilot plants with satisfactory results. In particular, it has been found that the heterogeneous composition of tropical forests is not an insuperable obstacle; tropical mixtures of as many as fifty species have been successfully cooked in a digester and have produced better pulps than when a single tropical specie has been used. It seems desirable to establish groups of species so that all wood in a pulping charge should be within a certain range of specific gravity, e.g., from 0.5 to 0.7; these conditions of 'homogenized heterogeneity" can be established without undue difficulty. There are cases, it should be mentioned, where homogeneous wood supplies can be obtained also under tropical conditions. All over the tropical parts of Latin America there are important areas covered by pure stands of *Cecropia (cetico* or *guarumo* or *imbaúba)*; moreover, pure stands of this specie often arise after virgin stands of mixed woods have been clear cut, or after land has been abandoned following banana plantations. *Cetico* is characterized by very rapid growth and has excellent qualities for both chemical and mechanical pulp.

At the present time, foresters in experimental stations all over the world are searching for means of replacing commercially less valuable virgin stands by second growth forests composed of a somewhat smaller number of desirable species. Considerable progress has been made, and in a few weeks from now results from all over the world will be assembled and considered at the Fourth World Forestry Congress which meets under FAO sponsorship in Dehra Dun, India, and which has selected tropical forestry as its principal theme.

It is wisely believed that this transformation of the tropical forests into second growth stands of carefully planned composition offers the ultimate solution, not only for rendering these forests generally useful, but also for building up gradually a large pulp and paper industry in the tropics.

All these problems form the major subjects of this meeting, and I would not dare to anticipate the discussions. I may, however, be permitted a word of warning against the danger of entertaining exaggerated hopes. Progress will be slow; and it must be so if we want to avoid failures and setbacks. But the time has come to make a beginning on an industrial scale, because our knowledge has reached a point when the risk connected with the establishment of a well planned tropical pulp factory is no longer outside the normal range of business practice provided a proper site is carefully selected. We can no longer afford to let Latin America's tropical forests remain idle. This, Mr. Chairman, is, as I see it, the challenge facing this Meeting.

B. Latin America possesses a second significant source of pulp in its native conifers. Though they cover only some three per cent of the total area, they represent some 27 million hectares, or more than the entire forest area of Sweden. Indeed, if they were properly concentrated and accessible, these native conifers would be capable of yielding permanently, on a sustained-yield basis, all the pulpwood necessary to meet Latin America's prospective paper requirements for some time to come.

One must distinguish between two types: most significant are the *Araucarias* of which the best known is the famous Paraná pine, which occupies nearly 10 million hectares in rather close uniform stands in the southern part of Brazil and contiguous portions of Argentina. There already exists in Brazil a large factory producing chemical pulp from *Araucaria,* a species which poses no fundamentally new problems to the papermaker. Artificial regeneration has given satisfactory results, and yields of ten cm per hectare and more are being reported. Even a much lower figure would be sufficient to cover Latin America's pulp requirements if all the Paraná pine forests were put into use for that purpose and placed under proper management. And although a large portion of these forests is badly located with regard to transport, power and other production factors, Paraná pine is bound to remain an important resource for pulp manufacture. However, these big trees constitute a precious reserve for the manufacture of heavy sawn timber and plywood, and should be reserved for these higher uses instead of being put through the pulping chipper.

The second concentration of native conifers lies in Mexico and Central America, especially in Guatemala, Honduras and Haiti. It consists of some 15 million hectares of various pines, most of which are probably suited for pulp manufacture, some already being used for that purpose.

However, a large portion of these pine forests performs important protective functions, and should not be exposed to regular industrial use. Already heavy damage has been inflicted to these stands by over-cutting, excessive grazing, resin-tapping, fire and insects. Therefore only some two million hectares in the Michoacán, the Chihuahua and the Guerrero region of Mexico can be classified at present as a raw material source for pulp manufacture; in due course it may be possible to draw on other portions of Latin America's pines.

C. Plantations of quick-growing pulpwood species represent a third important resource: 250,000 hectares in Insignis pine, which have been gradually established in Chile since the beginning of the century, have become internationally known for their exceptionally high growth rate, and are said to average twenty and often thirty cm annually per hectare. In a few years from now these plantations are expected to yield over 3 million cm of pulpwood annually. One factory to manufacture newsprint is now under construction there, and work is expected to commence shortly on a kraft pulp mill.

Plantations on a fairly substantial scale have been started with *Araucaria* in Brazil and in Argentina, with tropical broad-leaved trees in certain parts of Brazil and with quick-growing poplars in the Delta del Plata. The potential significance of plantations for the supply of pulpwood is considerable, since one million hectares of such plantations could once again produce continuously, in reasonably accessible locations and in concentrated homogenous stands, all the pulpwood which Latin America might require.

Plantations are attractive since they introduce the idea of moulding nature to industry's needs, a procedure which might prove easier or cheaper than the usual course of adapting industry to nature. But the problem is not so simple as it looks. Experience shows that pure, even-aged stands of one species only are extremely vulnerable to insects and disease; it is also believed that monoculture may adversely affect soil conditions. In any case, basing a big new industry on a few hundred thousand hectares of forest plantations, simply because one has not yet been able to solve the problems connected with the use of hundreds of millions of hectares of natural forests, may seem expedient but does not impress me as the sound long-term solution which we have come here to discuss.

D. A fourth and rather important source of pulping materials exists in sugar cane bagasse. Latin America's annual supply of this waste product is estimated between 12 to 15 million tons dry weight.

Now if all the bagasse produced in Latin America were available for industrial conversion, some six million tons of chemical pulp could be obtained, about four times the equivalent of the region's present paper consumption. In fact, only a fraction of the figure mentioned can ever be made available for paper making. Bagasse is the main fuel of the sugar mills, and significant surpluses become available only in modern mills which have efficient boilers, or in locations where cheap alternative fuel is available. Also, the fact that many sugar mills operate only three to six months a year means that bagasse would have to be baled, dried and stored at considerable cost in order to permit continuous pulp manufacture.

Hence, possibilities for establishing a pulp and paper manufacture based on this agricultural residue are more limited than might appear at first sight. However, it is important to remember that long-fibre pulp of good quality can be produced from bagasse by methods which have only recently been perfected, and about which more will be heard in the course of this Meeting. Thus, the already enormous reserve of pulping materials from Latin America's forests can be supplemented by a limited but nevertheless important supply of agricultural residues, which is likely to become of particular significance in Central America and the Caribbean.

The basic impression which this very summary review of Latin America's resources for pulp manufacture is bound to produce, is best characterized by the French term *"un embarras de richesse"*. And yet, despite this wealth, and despite the well-known dynamism and spirit of adventure of Latin America's industrialists, the region possesses to date but few modern installations for the manufacture of chemical pulp, and only one modern newsprint mill.

A closer look at the region's present pulp industry reveals two further significant facts. First, that all the existing pulp mills are based on what one might call the traditional, but in Latin America secondary, sources of fibre; and, second, that despite the abundance of such traditional raw materials as native conifers, forest plantations and agricultural residues, the pulping capacity of Latin America is still only some 500,000 tons or less than one-third of the region's current consumption.

In my opinion, this situation can be attributed in part to the inadequacy in supply and in part to the unsuitability of the raw materials. To be sure the pulping of tropical woods is only in its beginning. However, the growth of a large pulp and paper industry also depends considerably on the general industrial progress of the region, on the availability of capital and equipment and on several similar factors. I sincerely believe that industrialization and general economic conditions for progress have reached a point where they will permit the rather rapid growth of a substantial Latin American pulp and paper industry. I further feel pretty sure that, in the course of this process, it will be found that Latin America's raw materials are far better suited to pulp manufacture than they were previously believed to be.

In making these statements, I am thinking primarily of the tropical forests, both in their present state and that of the second growth stands into which they should be gradually transformed. I must admit that this belief is influenced by a very deep-rooted desire for such a development. For, indeed, the day when pulp will be manufactured from the wood mixtures of Latin America's tropical forests, an almost unlimited quantity will be added to the world's potential supply of pulp and its infinite variety of products. Wood pulp may then acquire an even broader significance in the world's economic life than it has achieved so far, because of the very scale on which pulp could be made available.

Even more important and significant is the fact that the manufacture of pulp from tropical woods is capable of transforming 800 million hectares of waste land into economically productive areas. This could become the greatest extension of humanity's frontiers in our time. It is pretty clear that without some large-scale chemical use, such as pulp manufacture, the tropical forests of Latin America and other parts of the world can scarcely be regarded as significant economic assets. The manufacture of lumber or the extraction of precious wood alone will never provide a satisfactory answer.

In hoping for the harnessing of tropical forests as a major source of Latin America's future pulp industry, I do not overlook the enormous difficulties that have to be overcome and to which I have already referred in the course of this speech. In the course of my professional career, I can remember hearing of many projects for new pulp and paper factories, but also finding out that in the end only a fraction of these projects finally led to the completion of new mills. Between the selection of a zone apparently suited for a pulp mill and the first ton of wood pulp that comes off the machine, there lies a long and arduous road. It is quite usual that site after site has to be explored and rejected until one is found which combines all the technical and economic conditions that warrant the drawing up of blueprints. And even when the blueprints are ready, one runs into the innumerable obstacles of finding the money, getting the proper equipment and, above all, securing the right kind of personnel to start the mill in its operations. I mention these difficulties because I regard it as important that those assembled here today should expect them and, therefore, not be discouraged by them. They have been overcome elsewhere and they will and must be overcome here. It is my sincere conviction that this meeting takes places at just the right moment. The past ten or twenty years have produced the solutions which are needed to establish a modern pulp and paper industry in this important region of the world. Only a small final step is needed. I believe that this meeting has a real opportunity of taking this step. If the time is auspicious, the circumstances of our meeting are no less so. We are fortunate indeed that the Government of Argentina has so generously consented to act as our host.

This is not the first time that Argentina has given proof of its warm support for the various activities of the United Nations. Two years ago the fourth session of the Latin American Forestry Commission was privileged to hold its meetings here in Buenos Aires. Here I would like to refer especially to the fact that one of our valued Argentine friends, Dr. Lucas Tortorelli, General Administrator of National Forests, is at present Chairman of that Commission.

Less than a month ago the Argentine Government was host to the Third Latin American Regional Conference of FAO. It is evident to us all, therefore, that the scene of our meetings is one conducive to a fruitful discussion of measures of international co-operation.

I would like, on behalf of the organization I represent, to express through you, Mr. Chairman, to the Argentine Government, to your good self, and to our many Argentine friends who have worked so hard to make this meeting possible, our warmest and most sincere gratitude. I am confident that this meeting will prove to be an historic event and, furthermore, such a good host and the highly qualified technical help from many lands will demonstrate once again that international co-operation does pay.

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Editions A. Pédone, 13, rue Soufflot, Paris V.

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United Nations Association of New Zealand, C.P.O. 1011, Wellington.

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PAKISTAN
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Publishers United Ltd., Lahore.
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Orders and inquiries from countries where sales agents have not yet been appointed may be sent to: Sales and Circulation Section, United Nations, New York, U.S.A.; or Sales Section, United Nations, Palais des Nations, Geneva, Switzerland.

Printed in U.S.A.
24956–April 1956–4,900

Price: $U.S. 4.50; 32/- stg.; Sw. fr. 19.50
(or equivalent in other currencies

United Nations publication
Sales No.: 1955 II.G.4

E/CN.12/361/Add.1
FAO/ETAP No. 462/Add.1
ST/TAA/SER.C./19/Add.1