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THE MEXICAN CEMENT INDUSTRY

Technology, Market Structure and Growth

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PREFACE

This paper is one of three monographs on the Cement Industry commissioned as part of the BID-CEPAL Programme on Science and Technology in Latin America.

The studies embraced by the Programme cover themes of wide ranging interest within the general area of science and technology in Latin American industry; the spectrum of industries being covered is wide, and includes the building sector, the production of steel and petrochemicals, etc.

Besides its intrinsec interest as an industrial sector per se the cement industry indubitably complements the study of the construction industry and of engineering firms, both identified as priority sectors within the BID-CEPAL Programme. Cement, as a major building material produced in nearly every country in Latin America, and as an important client of engineering firms, is closely related to these two. In addition, the nature of cement production as a continuous process industry gives to it similar features to those found, for example, in steel processing; for such reason this study also illuminates, as well as benefits, from the studies of steel production undertaken by the Programme in various Latin American countries.

However there is a wider relevance of these monographs on cement production and technology than just the linkages with the other sectors which are priority areas of the BID-CEPAL Programme. The main aim of the overall Programme is to study the various ways in which local (domestic) "Research and Development" and related technical activities can effect innovation in production which will induce technical progress/increases in productivity in Latin American industry and at the same time expand the technical base of the productive sector, thus giving raise to the necessary conditions for continuing innovation in the future.

The first monograph on the cement industry identified the technical frontiers of cement-producting technology and the nature and origin of innovation in this sector. It also analysed the channels of technology transfer and access to technology in the cement industry on a world wide scale.

The country monographs are intended to examine how technology produced on the world market is internalised by Latin American cement producers and how the technical base for local innovation at the firm level is developed within the institutional and economic limitations set by the market and economic situation of the individual producer. At this level of analysis we are not concerned with revolutionising new process technology which will make conventional techniques obsolete; the first monograph demonstrated that such innovations are the product of large scale research and development structures which reach beyond the limits of cement producers and embrace heavy equipment industries, the chemical industry, the instrumentation and computer sector as well as other scientific branches of industry and public research institutions.

Latin American cement producers are customers or clients for the innovations and process technology produced by this scientific-industrial complex; however it is misleading to consider them as passive recipients because of the fact that the technology they use is imported rather than locally developed. When one examines how technical processes are selected, how new investment is planned and executed, how production is achieved from the purchased capital goods; how training is acquired to operate new systems of process and quality control; how the firm negotiates with its machinery suppliers both for technical assistance, engineering reliability and price, we see the firm not as a passive client of externally produced technology but as an active acquirer of technical elements whose function is to obtain the optimum technical mix compatible with his market situation, growth strategy and technological base.

Seen in this light we are forced to extend our definitions of technology and innovations to stretch beyond the technical package of hardware and know-how available on the market for purchase by domestic producers. We need to include in "technological capacity" the process of obtaining the optimal technical mix required by the firm. We must include in "innovation" all the reorganisation of production and systems of process control effected by firms in order to make best use of the elements of technology imported to meet immediate productive ends, and all those activities carried out in order to expand the firm's own ability to modify the equipment and machinery and to substitute its own internal technical capacity for elements of imported engineering or know-how presently purchased externally to compensate for the absence of such elements in the firm, or in local engineering firms.

Thus the relevance of this paper extends the focus on the cement industry, in spite of the fact that the ubiquity of the cement industry claims for itself an important place in any study of industrialisation. While the research on which this paper is based is unfortunately limited because of shortage of time and opportunity, its contribution lies in its attempt to go beyond conventional discussions of technology which equate technology with machinery or productive processes and examine the mechanisms by which such machinery is incorporated into the Latin American industrial structure.

The author would like to thank officials from various cement firms in Mexico for the assistance they afforded in the process of collecting this information. The engineers at the Tolteca Head Office and the Atontonilco plant, the Apasco Head Office and plant, the Cruz Azul Head Office and plant, Cementos Mexicanos in Monterrey and Anahuac offices in the State of Mexico were especially helpful and cooperative. While every attempt is made in the detailed analysis of individual plants to preserve the anonymity of the firms and plants involved, inevitably those with detailed knowledge about the cement industry in Mexico will be able to identify each plant.

Section I

STRUCTURE AND GROWTH OF THE MEXICAN CEMENT INDUSTRY

1. Introduction

In 1975 the Mexican cement industry comprised twenty six plants with a total capacity of just over thirteen million tons a year (see table 1).

The industry sustained a relatively high growth rate over the past ten years (see tables 1, 4 and 5). However there is some indication of a slow-down in demand following the general recession in the economy in 1974-75. Demand is apparently being maintained at higher-than-expected levels and a high growth rate is predicted for the rest of the decade of the seventies. In anticipation of the continued increase in demand, several important expansion projects are in progress or have been completed since the end of 1975 which substantially alter the capacity figures given in table 1. Estimated capacity at the end of 1976 was 15 million tons. 1/ 2/

Demand for cement in Mexico has grown rapidly since the war. Total demand represented by total domestic production minus exports plus imports is shown in table 2. Over the period 1940-1974, cement consumption grew over 2 000% at an anual average cumulative growth rate of 9,4%. 3/ During the same period imports have declined in proportion to total consumption and by 1974 imports represented only a negligible percentage of total consumption. 4/

1/ Throughout this paper the measurement 'ton' refers to a metric ton. The abbreviation tpy refers to (metric) tons per year and tpd refers to (metric) tons per day.

2/ In the calculation of industry capacity figures we have excluded two cement plants. The Cementos del Norte plant - owned by Cementos Mexicanos - has been excluded on the grounds that it produces only puzzolanic and blast-furnaces slag cement and the small amount of clinker used at the plant is produced at the other Cementos Mexicanos' plant in Monterrey and included in the production figures of that plant.

The Cementos Portland Blanco de Mexico plant at Vito, Hidalgo is also excluded since about 80% of its production is white cement. The figures published by the Camara refer only to grey (i.e. ordinary portland) cement and thus severely under-estimate production and capacity at this plant.

3/ The growth rate for each decade is as follows:

1940-50	10.9%	1960-70	8.7%
1950-60	8.5%	1970-74	10.1%

4/ Exports until now have not been a significant part of Mexican production. However there has recently been plans to increase cement exports, especially from the Cementos Anahuac del Golfo plant which was recently expanded and modernised specially for the export market. See "Expansión: 18 June 1976, p. 80: Nacida para exportar".

2. Concentration in the Mexican cement industry: differential growth rates within the industry

With the steady and substantial growth in cement demand in Mexico since the Second World War, productive capacity has expanded to meet the increased demand. Table 3 shows the way in which capacity has increased during this period. However the expansion of productive capacity has not been equal for all firms in the industry; the degree of economic concentration at both regional and national level has increased substantially. Tables 4 and 5 show how the participation of each group within the cement industry has changed since 1965.

The concentration of the Mexican cement industry has been, to a large extent, brought about by the expansion of existing plants belonging to the major companies and groups of companies, and also by the takeover of previously independent companies.

Both the two largest producers have grown by a combination of these two methods. The Tolteca group which was owned by the British cement company APCM Ltd. comprised only three plants in 1965; the original plant at Tula, Hidalgo, the new plant at nearby Atotonilico de Tula, and the Mixcoac plant in the city of Mexico. Since 1965 another new plant was put on stream at Zapotoltic in the State of Jalisco. In addition to the establishment of new plants and the continual expansion of existing ones, the Tolteca group has also acquired control or total ownership of existing cement plants owned by previously independent firms. In 1960 Tolteca bought out the Atoyac plant in Puebla which was owned by local capital and had been in production since 1927. During the 1960's expansions to existing plants and the establishment of the Zapotiltic plant accounted for the totality of the group's expansion. However in 1970 the British firm was forced to reduce their participation in Tolteca to 49% of the share capital; the remainder was bought by a large Mexican Civil Engineering group, I.C.A. Shortly afterwards negotiations were begun for the acquisition of three small plants on the Pacific coast, Cementos del Pacífico, Cementos Sinaloa and Cementos Portland Nacional.

In this way Tolteca has managed to maintain its share of the market expanding its capacity to keep pace with the national growth of the industry. The distribution of regional markets between the major producers will be discussed below.

The non cement activities of the expanded Tolteca's group fall outside the scope of this paper; however it is important to record that the group owns or controls various ready-mixed concrete firms, concrete product companies and gravel quarries, lime plants, real estate and transport companies. Some of these interests were acquired as the result of the reorganisation and merger of the group with I.C.A. In one sense these activities can be seen as forward or backward vertical integration. However in a sense one could argue that I.C.A.'s investment in Tolteca's cement plants comprises backward integration on the part of I.C.A. as a construction company acquiring a major input producer.

Cementos Mexicanos is the other group of national importance which has a similar market share to that of Tolteca (see table 1). The group has also been a combination of the establishment of new plants, the expansion of existing ones, and the acquisition of independently-owned plants. The Monterrey plant was established in the 1920's and has been continually expanded ever since. In 1964 a new Cementos Mexicanos plant at Torreon went into production, followed in 1966 by the plant at Valles, San Luis Potosi. The Merida plant of Cementos Mexicanos was acquired in 1966. Existing plants were expanded throughout the 1960's. In 1973 the Cementos Mexicanos group acquired the Cementos de Bajio plant at Leon from Cementos Guadalajara; and in 1974 Cementos Mexicanos began the purchase of share participation in Cementos Guadalajara's other cement plants and other interests which will eventually give Cementos Mexicanos total ownership and control over the two remaining plants at Guadalajara and Ensenada, Baja California, and the two smal clinker grinding plants in Baja California.

Cementos Mexicanos have also extended their interests to pre-mixed concrete, concrete products and aggregates for concrete; in addition the acquisition of the Cementos Maya group and the Cementos Guadalajara group has extended the group's interests to other companies manufacturing related products such as paper bags and lime.

The Cementos Mexicanos group has undergone a period of rapid growth to increase its national market share from under 9% in 1965 to over 26% in 1975 (see tables 3 and 4). The growth rate of this group was much higher than that of the industry as a whole, averaging 20% per year over the ten-year period 1965-1975 with an even higher growth rate in the 1970-1975 period. This growth is accounted for largely by the take-over of the Cementos Maya and Cementos Guadalajara groups which has consolidated the market position of Cementos Mexicanos in nearly all areas outside the Metropolitan district.

The growth of the Cementos Anahuac group from 12% in 1965 to 18% in 1975 of total national industry capacity is the result of quite different factors from those which enabled the Tolteca and Mexicanos group to expand. Cementos Anahuac was founded in 1943 by local Mexican capital. The Barrientos plant in the State of Mexico had an initial capacity of 34,000 tpy. This capacity was expanded in various stages, and by 1964 the capacity of the plant was 595,000 tpy. In 1968 a new plant at Tamuin, San Luis Potosi, went into production with a rated capacity of 495,000 tpy; by 1971 the Tamuin plant was expanded to 660,000 tpy and a more recent expansion of the plant has increased the annual productive capacity to 1,716,000 tpy. The Barrientos plant has also been expanded and currently has a rated capacity of 1,188,000 tpy.

The Tamuin plant was established with the very definite intention of exploiting possible export markets and from the beginning deposits and bulk loading installations at the ports of Tampico and Veracruz were built as an integral part of the plant's design. However the plant did not appear to be very profitable for the Anahuac company 5/ in the early years and in 1972 Cementos Anahuac were negotiating to sell the Tamuin plant to a North American cement producer, General Portland Cement Inc., which intended to use the plant to supply its Florida and South West markets. However the Mexican Government blocked the negotiations on the grounds that cement is a strategic industry and must not be sold to foreign capital; therefore 49% of the share capital of

5/ See Latin America, 8 June 1973. The Tamuin plant was made a separate company in 1972 in order to facilitate the United States' investment. Cementos Anahuac has a 31% participation in the new company.

Cementos Anahuac de Golfo was bought (in cash) by SOMEX, a parastatal financial institution. The original company Cementos Anahuac retained 30% of the stock of the new company, Cementos Anahuac del Golfo and with the SOMEX funding the new expansions were carried out. Cementos Anahuac del Golfo has subsequently signed a long-term export contract with General Portland and is also reported to be exporting cement to Venezuela and Cuba. 6/

The two plants which form the Apasco group were in no way connected in 1965. Both companies - Cementos Apasco and Cementos Veracruz were independent cement producers owned by local Mexican capital. What has linked them together is the fact that the Swiss multinational company, Holderbank Financiere Glaris has acquired considerable interests in both these companies and from the point of view of the marketing strategy of the two firms they operate within the Mexican domestic market as a group. 7/

The Apasco plant was founded in 1936 with an initial capacity of 100 tpd. By 1960 the plant had been expanded to 1500 tpd. In 1963 Holderbank bought a 49% share in the plant and the process of modernisation was initiated. The old plant has not been totally abandoned and the current installed capacity (1976) of 1,400,000 tpy is totally post-1965 vintage equipment.

The Holderbank holding in the Veracruz plant is only 21% of the share capital, with Cementos Apasco holding a furter 5% ; however this is sufficient to give the Swiss firm control over investment and technical decisions, a control which is reflected in the terms of a wide reaching technical assistance contract between Holderbank and Cementos Veracruz.

The Veracruz plant at Orizaba was expanded to 300,000 tpy from 250,000 tpy in 1972 while much of the existing capacity was modernised. By the end of 1976 the rated installed capacity of the plant was 560,000 tpy. The figures in tables 4, 5 and 6 underestimate the growth of the Apasco group and its potential.

The Cruz Azul group is distinguished from most other companies in the sector by the fact that it is a cooperative society rather than a limited company. 8/ The plant was originally run as a private venture but closed down in the 1930's when it proved to be unprofitable. The government under General Cardenas stepped in to prevent the plant being absorbed by the British-owned Tolteca company and to preserve the jobs of the employees at the plant. Since that time it has been successfully run as a cooperative and has established a second cement plant in

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6/ The amount which the firm exports is not clear. Two long-term export contracts with General Portland have been reported in the press. In 1974, the most recent year for which figures were available, Cementos Anahuac del Golfo is reported to have exported only 171,414 tons, but subsequent years are estimated at much higher levels.

7/ Cementos Apasco has a 5% interest in Cementos Veracruz. Holderbank has a 49% interest in Apasco and a 20% interest in Cementos Veracruz. Holderbank has celebrated technical assistance contracts with both firms.

8/ There are many industrial cooperatives in Mexico which are regulated by special legislation. There is one other cement cooperative - the Nuevo Leon plant of Cementos Hidalgo SCL.

Oaxaca. Its market share has been maintained, and slightly increased over the years and especially in the metropolitan area it provides extremely keen competition for the larger groups operating in the area.

The remaining companies account for only 8% of total capacity; all other independently owned plants have been absorbed by the market leaders. Cementos Chihuahua is the only small firm which has expanded in recent years; a second plant was put on stream in 1972. This company is apparently controled by local capital and enjoys a naturally protected market in the Central Northern region. Rumours that it is about to be taken over by one of the major national producers have so far proved unfounded.

The other independent companies are relatively insignificant as far as market shares are concerned. The cooperative from Cementos Hidalgo SCL has maintained its existence although it is unlikely to be able to expand, especially in the face of the increasing influence of Cementos Mexicanos in the North and East of the country. The other firms enjoy small local markets which lack either the demand or the raw materials to merit expansion, even if the capital were available to such relatively small industrial concerns.

3. Geographical structure of Mexican cement industry

The domestic cement market in Mexico is divided into nine regions as shown in the map in figure 1. Table 7 indicates the market shares of each group in the regions and this distribution is illustrated in fig. 2.

The Central region. The Central region, which included the Metropolitan area of Mexico City and the highly industrialised State of Mexico, is the most important in the country; over 50% of all installed capacity is in this region which, in 1975 accounted for 46% of total domestic production.

The regional market is divided between several firms. Tolteca controls the largest single market share (32% of production in 1975), which is divided between four Tolteca plants in the region (see table 7). Cementos Anahuac has the next largest share with 25% of the region's production supplied from a single plant. The rest is shared between Apasco, Cruz Azul and the small independant plant in Cuernavaca; however it is expected that Apasco's market share will increase following the termination of the current expansion project at the plant. Cruz Azul are also expanding their production capacity and both plants are likely to make inroads into Tolteca's market share, especially in view of the fact that the capacity utilisation at the Tolteca plants has been substantially lower than the industry average for some time.

The North Eastern region. The North Eastern market is the second most important in the country and is centred on the industrial city of Monterrey. The near monopoly in the region enjoyed by Cementos Mexicanos is only threatened with competition from the Cementos Hidalgo plant, which in 1975 accounted for nearly 20% of production in that area.

The South Western region. The South West market, the third largest in the country, is centred on the industrial area of Guadalajara. Production in this region is split between the Tolteca plant at Zapotiltic and the Cementos

Guadalajara plant controlled by Cementos Mexicanos; between these two plants they cover 86% of production in the region. The remainder is accounted for by the Cementos de Acapulco plant which in effect enjoys a protected local market.

In the smaller regional markets one or two groups in effect account for the total production in those areas. However local production in most cases does not cover the whole of the regional demand in these smaller regions where there is relatively little cement production. The shortfall is imported from the major producing regions of the Central, North East, North and Sourth West regions.

In discussing the regional distribution of the Mexican cement market it is important to take note of how the expansion of the major groups over the last decade has altered the regional balance. The new Tolteca plant in Jalisco gave the group an important share of a fast-growing market. The acquisition of the Pacific markets has given the group a 75% share of production in that area which may prove an important market if plans to develop Baja California and the Pacific Coast are carried out. Cementos Mexicanos' expansions have enabled the group to compete in almost every national market in the country. While the Leon plant is slightly marginal to the Central Region, the acquisitions in Guadalajara and Merida have extended the geographical range of the group. The new plants at Valles and Torreon have also given the group a decisive participation in those local markets.

4. Average plant size in the Mexican cement industry

The range of plant sizes in the Mexican cement industry is extensive. The smallest plant has an annual capacity of 115,000 tpy (excluding the 82,000 tpy plant of Cemento Portland Blanco de Mexico) and the largest, by 1976, was the new plant of Cementos Anahuac at Barrientos with a capacity of 1,848,000 tpy.

However, as we discussed in Monograph One, an examination of plant size on the basis of rated capacity is confusing. Some large plants are the result of continual expansion and consist of several small kilns/production lines. Some of the largest Mexican plants are very good examples of this kind of mixed vintage plant. The Monterrey plant of Cementos Mexicanos is in fact organisationally split into two plants (the old plant and the new plant). The old plant consists of four old kilns each with a capacity of 500 tpd (including one kiln which produces only white cement) and the new plant comprises the two newest kilns each with a capacity of 1300 tpd and will incorporate the current expansion - a third 1300 tpd kiln - at present being erected. However there are also three other kilns on site which were the original kilns used by the firms when it started production in the 1920's. But to include these kilns in a calculation of capacity at the plant would be most misleading since they are only used in exceptional circumstances - to meet sudden shortfalls in production arising from breakdowns in other parts of the plant.

Thus to describe the capacity of the Monterrey plant as 1.4 million tpy is evidently insufficient for the information to be of any analytical use. If we wish to use plant size in an analysis relating size of plant to efficiency of the plant, or the technology used in it, it is more helpful to specify that the plant consists in fact of two plants operating at the same place, one of which has much modern and large scale equipment than the other.

There are other plants in Mexico which contain a similar mixture of vintages which defy aggregation into a single plant for analytic purposes. There are also other plants whose production capacity has been planned as a unified and rationalised whole and whose technology range is extremely unvaried. The Cementos Apasco plant consists entirely of plant built since 1964. The original old plant was shut down when the new expansion was completed at the end of 1975; before that date the old plant had been operating entirely separately from the new plant which, from the beginning, had been planned as a totally separate production unit. The new plant now consists of two kilns with theoretical capacities of 1,000 and 1,250 tpd, giving a total annual capacity of 1,155,000 tpy (1976 figures). Although this is smaller than the Monterrey plant discussed above and also smaller than other plants in Mexico, the average kiln size at the Apasco plant is larger than those of other plants, and thus could be expected to achieve technical economies of scale pertaining to large scale production to a greater degree than those plants which have a higher total capacity but a smaller and more varied kiln size. 9/

The largest plant in Mexico, the Barrientos plant of Cementos Anahuac consists of three kilns each of 500 tpd, one kiln of 550 tpd, and two kilns of 1,850 tpy. These kilns have been installed between 1958 and 1970 and thus are relatively modern. All the plant used during the 1940's and 1950's has been scrapped. Nevertheless this plant is not technically homogeneous and rationalised to the degree of the Apasco plant and in terms of technical efficiency does not perform as well. 10/

The difficulties of using plant size as an abstract concept are therefore great, since a single figure of theoretical or rated capacity can hide an enormous variation in kiln size, which can have important effects on technical efficiency and unit costs. However it is generally agreed by cement producers in Mexico that a new plant would not be economically viable unless it were at least 1,000 tpd (330,000 tpy). 11/ However as table 1 indicates, old plants can survive at smaller scales which would be uneconomic for new producers because of the unit cost of capital investment and other items of fixed costs.

It is also important to take into account the fact that a firm which already controls several plants may well be able to establish a plant which is smaller than the generally agreed minimum economic scale for new investment in the industry. This is because such a firm can offer to the new plant economies resulting from multi-plant operations: managerial and technical skills, advertising and the use of an established brand name for example which could compensate for the high cost of small scale investment. An established firm will consider such an investment worthwhile in order to secure the market in an area with growth

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9/ Unfortunately in this study it was not possible to obtain data to test whether or not kiln size was more important than plant size or firm size for economies of scale in cement production. This observation is thus exploratory, aimed at pointing out the problems of using scale as an absolute factor.

10/ See Section II and fig. 3 for detailed discussion on technology and technical efficiency of different plants.

11/ See Monograph One for discussion of economies of fixed and variable costs.

potential, against future competition. 12/ A plant in a region where communication and transport costs were such as to give a local producer very high 'natural' protection, might also find it economic to produce at a smaller scale, even though its costs might be above the average for the rest of the national industry. The Cementos Chihuahua plant at Ciudad Juarez appears to be an example of this sort of situation.

12/ There is evidence to suggest that the production costs and administered prices for the Ciudad Juarez plant are somewhat higher than the national average; however the high transport costs and geographical isolation of the location, plus the potential increase in demand following the Border Industrialisation programme makes this plant an economic proposition even at the small scale of 115,000 tpy.

Section II

LEVEL OF TECHNOLOGY EMPLOYED IN THE MEXICAN CEMENT INDUSTRY

1. Introduction

In this section we will evaluate the level of technology used in cement manufacture in Mexico in terms of the conventional understanding of technology - i.e., the kinds of machines and processes used and the scale at which they are operated. The information contained in this section is based on interviews at company headquarters and visits to five of the largest plants in Mexico. 13/ Additional information on other plants and firms was obtained from published data.

In investigating the technology used by different producers we came to the somewhat obvious conclusion that the most modern, up-to-date technology was employed in plants which were either the largest, fastest growing plants in the sector or/and were plants where access to foreign technical assistance including knowledge of alternative techniques for different stages and processes were provided by a foreign investor in the plant. Nevertheless we observed that the internal technical capacity of a firm was not necessarily correlated either with the level of technology employed, nor with the relationship to foreign investment and access to special data. Furthermore we observed that the rational selection of technology by each plant was not necessarily the most 'modern' or sophisticated and we considered it a positive indication of the technical capacity of the firm the ability to decide to opt for a less sophisticated but more rational alternative.

The discussion of the level of technology in this section is therefore in the context of the conventional understanding of technology referred to above. It should be remembered that the kind of equipment and processes utilised in production by any firm/plant do not define the totality of the technology of a firm since they leave out of account the various factors involved in the acquisition of the equipment and in the internal technical capacity of the firm. These aspects will be discussed in later sections of this paper. Furthermore the use of terms such as 'modern' and 'sophisticated' do not imply value judgements as to the preferability of different processes; it refers to the degree of process control incorporated into different production methods. 14/

The technology in the Mexican cement firm includes all the major innovations

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13/ The plants interviewed and visited are not identified by name in the text since an undertaking not to do so was given at the time the firms agreed to cooperate with the research. Inevitably certain information will enable those familiar with individual firms in the industry to identify them; however; the interest of this study is in terms of the general conclusions rather than the analysis of individual firms' situation.

14/ This point still requires clarification. While increased process and quality control are technically advantageous they are only rational to use when the internal technical resources of the firm are such as to enable such methods to be operated and to result in increased productivity and cost reductions.

in production technology described in monograph one 15/ with the exception of the flash calcinators developed in Japan. However there is a wide range of variation between the technology employed by the different firms and at different plants. Briefly the lag between the development of an innovation on a commercial scale and its adoption by the Mexican producer depends on various factors. If the innovation is to be adopted at all in Mexico it must have undergone very conclusive industrial testing elsewhere; there is no sense in which Mexican firms are willing to adopt risks by adopting a new technique which has not yet been proven. 16/ Secondly the timing and pace of new investment is important; more sophisticated techniques are found at plants which have undergone rapid growth in recent years, which has given them the opportunity to incorporate new technology and recent innovations into new investment. A third important and not unconnected factor is the technological capacity of the firm itself; the more rationally and consciously organised and developed is the firm from a technical point of view, the more likely it is to select, operate effectively and, in some cases improve, newer and more sophisticated production techniques. In Mexico access to technical data on the performance possibilities of new techniques and how they could profitably be used at the Mexican plant is also important for the adoption of innovations. In most cases access to such information and assistance comes from the parent company of a partially owned subsidiary. 17/ However fully owned Mexican firms are able to purchase such information and advice from consultants and machinery manufacturers. 18/ The information is not however generated in the country either by national consultants, industry organisations or the cement companies themselves without access to foreign sources. Consider, as an example, the lack of adoption of the pre-calcinating system.

The main reason on account of which the precalcinating systems have not been adopted in Mexico is their comparatively recent development and the absence of long-run industrial trials of performance and costs. None of the Mexican engineers interviewed considered that the risk involved was reasonable for their company even though in at least two cases plant visits to Japan and Europe had been arranged by one of the Western machinery manufacturers with a licence or distribution agreement with the Japanese manufacturer.

In addition to lack of industrial proof another reason which ruled out the adoption of the precalcinator is the fact that most plants in Japan and Europe where it is currently being utilised are very large plants with kiln sizes up to

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15/ See R. Pearson, Technology, Innovation and Transfer of Technology in the Cement Industry, IDB/ECLA Research Programme in Science and Technology, Bs. As.,1976.

16/ This is a very rational position for Mexican producers as we show in the discussion of the failure to adopt pre calcinators.

17/ If the parent company is a specialist in cement production and particularly in data analysis, process control and automation then it is in a position to supply such information. If the parent company itself is not in the vanguard of such developments it may seek assistance from other sources on behalf of its subsidiary.

18/ Several of the machinery manufacturers have set up local offices in Mexico and intend to set up local production facilities. Meanwhile their local offices act as information, advice and after-sales service centres.

4,000 and 5,000 tpd, which is much larger than any plant or kiln in Mexico. While the manufacturers now state that it is economic for conventional sized kilns, much of the early literature and development was based on high capacity kilns and this impression, even if false, has remained firm.

There is also some indication obtained from the trade literature and from plant visits that the fuel-saving factor of precalcinators is probably smaller than originally claimed. There is also a deep-seated reluctance to use Japanese equipment which represents a new departure for Mexican cement plants especially as most of the firms are extremely satisfied with the performance of European and United States equipment and are reliant on the manufacturers pre and post sales engineering services. 19/

However one feature of this system - the fact that capacity can be doubled without increasing the size of the kiln, together with the smaller fuel load implies that the wear of refractory brick linings would be considerably less than in more conventional kilns. For this reason at least one firm said it was intending to introduce a precalcinate kiln in the near future; however to date no definite decisions appear to have been made. The technology utilised in Mexico incorporates a range of equipment from the now obsolete (for any new investment) to the most sophisticated methods of process control and automation. Of the newest, largest, and most technically advanced plants in Mexico the standard core equipment is the short dry kiln with suspension pre-heater. The most modern version of this is a four stage Dopol preheater kiln with a theoretical capacity of 2,500 tons a day which was put on stream at the end of 1975. This kiln operates in conjunction with an automatically correctable prehomogenisation unit for each raw material in a substantially automatically controlled plant. 20/ There are two other Dopol preheater kilns employed in Mexico. Plant E has one with a capacity of 550 tpd and another with a capacity of 1,850 tpd, which are some five and three years old respectively. Plant A's biggest and newest kiln is a Fuller (Humboldt) kiln with a 4-stage suspension preheater about six years old. Plant B has equipment ranging from 16 years old to its recent installation of a Polysius suspension preheater kiln with a capacity of 2,000 tpd. Plant C's most modern production line consists of a FLS kiln of 1,350 tpd with 4-stage preheater which went on stream in 1975. 21/

All these plants use core equipment which can be described as modern, standard production technology, which is freely available for purchase on the world market. 22/ The preference shown for European equipment, especially for

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19/ More than once I was told that the Japanese were offering "very interesting prices" for their equipment. But it was not worth the risk, even at the prices offered.

20/ This plant is Plant A. The nature of the automation at this plant will be discussed later in this section.

21/ See fig. 3 for complete list of equipment at each stage of production.

22/ Less modern plants/production lines in Mexico use what are now considered obsolete techniques in terms of new investment. There are 4 Lepol kilns, 3 wet process plants, some of which use chains amongst the plants belonging to the groups interviewed. There are several really old wet process kilns made by United States manufacturers which have long since ceased to produce cement making equipment.

Polysius and FLS equipment at these plants is representative of the whole of the Mexican cement industry which considers that these manufacturers provide efficient, reliable and well made equipment, superior to United States made equipment, albeit at a higher price which they have been generally prepared to pay. 23/

Ancilliary machinery is also representative of the standard equipment on the market. In spite of the fact that two of the engineers interviewed (from different firms) expressed the opinion that United States made crushing and grinding equipment was superior to the European equivalents, several of the newer production lines used crushing machinery manufactured by the West German firm of Hazemag which is considered to be the most up to date and efficient machinery of its kind. Plant D was the only plant visited that used mobile primary crushers which are something of an innovation in quarrying for cement production. The primary crushers are of United States manufacture and are used in combination with the Hazemag secondary crusher. In fact three of the five plants visited - A, D and E used Hazemag secondary crushers; Plant B used Allis Chalmers crushers and Plant C used FLS. 24/

Cement grinders, which are all of the tube mill sort with different capacities and, of course, different technical efficiencies, not necessarily related to design or vintage, 25/ were made by FLS in the most part. Plant B's newest grinding equipment was made by Polysius which also supplied plants D and E.

Most of the coolers in Mexican cement plants are the standard Fuller grate coolers which have for some years been considered as the most superior cooling equipment on the market. However Plants C and D have installed FLS satellite coolers on their newest kilns which they consider preferable because satellite coolers have lower maintenance and operating costs. As we discussed in Monograph One, satellite or integrated coolers have only been adopted commercially during the last decade and have still not replaced the grate cooler as the standard equipment. The choice of this cooler by Plant C was obviously influenced by FLS which is the sole machinery supplier to the company. However the choice by Plant D of the planetary cooler probably represents a considered judgement in the context of the total plant design at Plant D.

Cement grinding equipment used in Mexico is universally the standard tube mill design which has to date not been replaced by any more sophisticated or complicated technology. The cement grinders at the newest plants are either FLS or Polysius although some of the older plants still use a variety of mills which

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23/ On at least one occasion where a recent major expansion has been carried out in the form of a near turn-key contract with a United States supplier the reasons given for the choice of supplier were: a) that the supplier was partly limited by the source of the loan obtained to finance the project, and b) that the prices of the European producers were too high.

24/ At least in the latter case the choice of FLS was because this firm's policy was to buy all equipment from FLS who carried out much of the design engineering for the firm.

25/ This is one area in which the firm's internal technical capacity can increase standard equipment performance. This is discussed in a later section.

are no longer manufactured.

Prehomogenisation equipment cannot really be discussed outside the context of an overall examination of the process and quality control procedures at each plant. To some extent such a discussion is contained in the remaining part of this section which deals with quality control and automation. Nevertheless we will include here a brief description of the kind of prehomogenisation equipment employed at Mexican cement plants.

The purpose of prehomogenisation is to preblend raw materials of different qualities to achieve the correct chemical composition before blending. This can be done either by mixing raw materials of different qualities or by blending in corrective additives to inferior quality raw materials. In order to be able to utilise such a system effectively the plant must have the necessary equipment and personnel to carry out analyses on raw materials as they are extracted from the quarry and as they arrive from suppliers. Then the necessary calculations must be made to decide what corrective action need to be taken before the raw materials enter the grinding process. Some homogenisation can be carried out after grinding, but prehomogenisation is preferable since the materials to be blended can be intimately mixed in the grinding process.

If the system is operated effectively the cement producer can expect a saving of 5% to 15% on the use of raw materials and fuels. Prehomogenisation together with a system of electronically controlled dosification systems for raw meal feeding of the kiln can also have important effects on the duration of refractory bricks since the minimised fuel utilisation and control of the raw meal feed enables the combustion process within the kiln to be more finely controlled.

In our sample there were only two plants which operated a prehomogenisation system for raw materials. Plant A intended to introduce one with their next expansion project which is currently in the planning stage; the decisions had been taken on the advice of their machinery supplier for the project who had indicated potential savings as noted above. Plant B was operating a Hewlett-Robinson prehomogenisation unit which pre-blended the limestone and iron ore and clay before the raw meal stage. Plant C had a small unit that homogenised the clay only on the grounds that the limestone was very good quality. Plant D on the other hand has a very sophisticated prehomogenisation unit manufactured by the West German firm of Pohlig-Heckel-Bleichert which has a storage capacity of 4,000 tons. The unit feeds directly to the raw meal grinding plant. The blending process is controlled by the automated quality control proceedures described in the next section.

The bagging plants used by the firms are in some cases fully automatic and in others the bags have to be set up by hand. Plant A has a San Regis (United States) rotary bagger which is only semi automatic in that the bags have to be both fed and lifted off manually. Plant B has similar equipment made by the German firm of Haver and Baeker, also semi-automatic. Plant C uses the same San Regis equipment. Plant D has fully automatic rotary Haver and Baeker machinery and also bulk loading facilities for railway wagons and lorried. Plant E uses fully automatically discharging rotary Haver and Baeker machinery.

The differences in types of machinery and equipment, both core and ancilliary are partly a function of age and size of equipment and partly of the technical capacity of the firm in terms of selection of rational alternatives, and the technical knowledge to use more sophisticated equipment in an efficient cost effective manner. The way in which product quality and the production process is controlled is also a measure of the technology employed by the firm. Although most of the literature on technology in industry is concerned with the kinds of machinery employed, there is too some recognition that the way such equipment is deployed in the process of production is of equal relevance. The last two parts of this section discuss systems of quality control, automation and maintenance employed in the cement plants visited to complete this assessment of the level of technology.

2. Quality control and automation: general aspects

The different processes and equipment described above are compatible with different levels of quality control and automation. While entirely different aspects of cement production, in many ways the kind of quality and process control system in the plants is closely linked to the degree and nature of automation which can be applied to the control process and the analysis procedures; this in itself is a reflection of the kind of automatic control used to operate the plant at each stage of production.

Technically it is important to distinguish between mechanisation and automation; mechanisation means replacing human force and action by mechanical substitutes. Thus a conveyor belt or a close circuit control system which is activated by an electronic signal which sets into motion a series of mechanical operations is in fact mechanisation rather than automation. Automation proper means production and process control with feedback; this is distinguished from mechanisation in that the system if automatic should be capable of adjusting their operation in response to previously determined information. 26/ In practice it makes little difference to the manufacturer whether he increases his productivity by one system or the other and in this section we will follow conventional usage and include in the term 'automation' all types of mechanisation of operations.

In all plants visited there was some form of automatic control of production in the sense that close circuit control existed for at least some stages of production, and in some cases for all stages of production. This implies that the discrete operations - raw meal grinding, calcination and cooling, cement grinding, etc., are controlled from a control panel which transmits instructions to the relevant machine and indicates at the site of control whether the machines is operating normally in terms of power, fuel, throughput of materials, etc. However at only one of the plants visited was there a completely automatic system being installed, in the sense that the whole process was to be controlled from a central control room and to be backed up by a computer programmed to react to information regarding variations in the norms for production determined by previous analysis. Other plants had centralised control in the sense that the control units for all

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26/ See Dennis Gabor, Innovations: Scientific, Technological and Social, Oxford University Press, 1970, p. 48.

stages of the production line were grouped together in a central control room.

Where process control was done by mechanised close circuit techniques, the quality control procedures within a plant were often backed up by small digital computers used specifically to analyse samples of the raw meal and combustion and fuel coefficients and to calculate the necessary corrective action. In some cases the samples are taken automatically from various points of the production process and transported to the laboratory where they are immediately analysed and the corrective action calculated. Such a system is known as an on-line system and is generally connected with X Ray analysis equipment which carries out the necessary chemical analyses in a very short time.

Another aspect of cement production which is intimately connected with the kind of systems used for production and control is maintenance. The more sophisticated the equipment and the more automated the system, the more important is an adequate maintenance procedure to ensure that the equipment is fully operative at all times. Maintenance is also necessary with less sophisticated technology but it is only recently when systems analysis has been applied to cement production that the advantages of a programmed preventive maintenance system have been appreciated. In such a system it is possible to calculate the potential trouble areas which need special maintenance and the minimum frequency with which maintenance procedures must be carried out at all points of the production line.

Although these three aspects - automation, quality control and maintenance - are separate issues, they are nevertheless closely connected. The following discussion of process and quality control at the five plants visited illustrates the connection between them and the way in which more sophisticated equipment and procedures require the refining of certain control functions within the plant, functions which were previously vague and left to the production department to carry out as the situation seemed to require. When we come to discuss the technical organisation of firms in a later section of this paper it will be clear that the refining of these functions discussed here has involved the planned reorganisation of technical departments and personnel within the firms in order to carry them out and to coordinate their operations.

3. Level of automation at the plants

Plant A was operated by close circuit controls for each part of the productive process. There were three control rooms which housed the instrumentation panels and close circuit TV monitors relevant to each stage. The new plant currently under construction would have the whole line of production from the raw mills through the prehomogenisations system to the calcination and cement grinding mills controlled from a central control room. The new plant will be designed to be centrally controlled according to the "one-line straight through" layout system in which there is a single production unit for each operation, all of which can be connected to the same control system.

A study was carried out to see whether it would be advantageous to automate the new plant, but it was decided that there was little advantage to be gained from such investment. The reasons given were the kind of staff employed at the plant who would not necessarily be suitable for operating automatic equipment, yet were extremely efficient in their present tasks. Moreover the cost of employing trained electrical and electronic engineers for maintenance of the automation system made the project uneconomic. They were advised that the 5% savings on materials, and fuel costs would be far outweighed by the cost of specialised personnel.

Plant B is also operated by closed circuit control and the newest production line is centralised. This firm had also decided not to install a computer-operated automation system for various reasons. Firstly, the labour and other costs savings would be more than offset by the skilled labour it would be necessary to employ. Secondly, in the opinion of the firm's engineers, automatic control of cement plants had not yet been technically perfected and the firm was not prepared to invest in the learning opportunity which buying a computer would imply. And thirdly, their policy of not automating was backed up by their parent company who, although a cement multinational with extensive international interests do not specialise in automation. 27/ A further good reason for not automating is the range of vintage of the equipment contained in the plant. Since the plant has been successively expanded by adding new production lines,automation of the whole plant through a central computerised control is inoperable. Thus the investment in terms of both capital and trained manpower could only be spread over the newest part of the plant.

Plant C is also a plant with a mix of vintage equipment where the newest lines of production are operated separately from the rest of the plant. All production lines at this plant have close circuit instrumentation and the controls for the old and new parts of the plant are separate. A small computer was purchased with the aim of controlling the newest kiln according to a written programme but this has not been an entirely successful venture. The programmes for controlling the kiln operation had been purchased on tape as part of a technical assistance package from a foreign consultant. 28/ Unfortunately, while in operation it was found that the variables too often fluctuated outside the parameters set in the programme so that manual operation had to be resumed. Moreover since the data on which the programmes are based was not included in the package, the firm had been unable to rewrite the programmes to take into account actual operating conditions at the plant. 29/

Plant D is the most automated of all the plants visited. This plant consists of equipment which was all installed since 1965 and which has been planned as an

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27/ In comparison with the parent company of Plant D which is the most important company internationally for automation and systems analysis applied to cement production.

28/ The software came from a different consultant from the manufacturer which supplied the hardware.

29/ This is not to say that this small computer in any way represents full-scale automation. Nonetheless it appears that the firm were sold a computer plus software package on the assumption that it could be used to control and optimise the process of the newest kiln. In fact the programme proved too inflexible to be used more than 50% of the time at a conservative estimate.

integrated through-line production unit. The newest kiln was erected and put on stream in 1975 at which date a new control system was installed. The control system consists of a centrally operated computerised system which controls all stages of the production process from the prehomogenisation unit through to the cement grinding mills. At the time of the plant visit all the stages had been connected to the computer with the exception of the primary crushers and the bagging machinery which had been left to a later stage. Also the kilns had not yet been effectively connected to the system at the time of the plant visit because it was claimed that there were difficulties in importing instrumentation signals and other electronic equipment into the country. The software which backs up the computer controlled system is supplied by the technical part of the parent company on the basis of a technical assistance contract between the two firms. In addition the parent company has sent a number of its own specialised engineers to work at the plant, at least during the initial stages of putting the system into operation. These engineers are also responsible for training key local personnel. Local engineers are also trained at the group's training centre in Canada and at the company headquarters in Switzerland.

This plant can be considered to be one of the most modern cement plants in Latin America from the point of view of systems control and automation. In the opinion of the Swiss Technical Director, the only plant which can be compared with this one is a new plant in Brazil, also controlled by the same Swiss multinational. Certainly in the Mexican industry it is the only automated plant currently operating. The technical efficiency of the plant compared to the other plants visited will be discussed at the end of this section; however it is important at this stage to stress that the contribution of the parent company, in terms of trained manpower, training facilities for local staff, software for running the system and general technical assistance on process control is extremely important. This will be discussed in more detail in a later section of this paper.

Plant E, the last plant in this sample, is the largest plant in terms of capacity. This plant is operated by conventional closed circuit control systems and each part of the process is controlled separately. This plant also contains kilns of very different ages; those currently in use were installed in 1958, 1962 and 1964 with three new kilns installed in 1969-1970.

For this reason it has not been considered economic to centralise the control systems for each kiln and production line in the plant. An additional reason given for not proceeding with rationalisation and automation in this plant was the cost of employing specialised engineers for design, programming and maintenance as well as the cost of training lower level operators in the new techniques required of them.

4. Systems of quality control at the plants

As we indicated earlier there is a strong link between the kind of systems control employed at a cement plant and the quality and process control procedures which are carried out. The analysis of these systems at the plants visited clearly shows that relationship, with the most automatic plants requiring more sophisticated control.

The quality control system at Plant A was consistent with the plant's pragmatic approach to automation and process control. The laboratory at the plant is equipped with X-Ray analysis equipment which is used to analyse the chemical composition of the raw materials and of materials in process. The standard analysis carried out covered 10 basic elements and the deviation of the materials from the required standard composition. The X-Ray analysis is not on line, so that samples are collected and prepared manually by trained operators. A digital computer is installed in the quality control laboratory which is used to calculate the necessary correction to the raw materials mixed as the result of the X-Ray analysis. This computer was purchased with the programmes already taped but the department has had to modify the programmes substantially to cope with the large variation of raw materials utilised. 30/ The operating of the digital computer and the programme writing required were learnt by the firms engineers at a training seminar held by Polysius.

The quality control department also has a spectrometer which is used to analyse the oxygen and fuel supply to the kiln to maximise combustion. The spectrometer is also used to determine the size of raw particles necessary to give optimum efficiency in the calcination process. Training for the operation of the spectrometer was also adquired at a machinery supplier's training seminar.

Physical control tests on the performance of the cement produced at the plant in different conditions are also undertaken by the quality control laboratory and a certain amount of research and development into new cements and special-use cements are undertaken. This aspect of the department's work will be discussed in a later section of this paper.

The quality control procedures undertaken at Plant B are part of an overal quality control policy directed from the quality control department at the group's headquarters in Mexico City. Equipment at the plant consists of an X-Ray analysis equipment which, unlike the similar equipment at Plant A, is supplied automatically to the equipment from at least some parts of the process. Daily samples are taken from each quarry and of the purchased iron ore and at the secondary crushing stage samples are taken and analysed every 2 hours. The prehomogenisation unit is where the control procedures are centralised. Two hourly samples are analysed by X-Ray analysis to check both the composition of the raw meal feed entering the kiln and the effectiveness of the blending process within the homogenisation unit. The material is tested again as it leaves the storage silos and enters the kilns in order to be able to predict the nature of its 'burnability' and thus the required fuel oxygen mix. At the final grinding stage the quality of the gypsum as well as the efficiency and fineness of the ground cement is monitored. At this stage various physical tests on the final product - setting time, resistance, compression and expansion are carried out before the cement is bagged and distributed.

30/ Note that this modification was carried out by the firm's own engineers in contrast to the use of the samll computer purchased by Plant C to control calcination. Note too the decision taken by this firm to install a prehomogenisation system in the new expansion project to cope with variations in raw materials.

At this plant there is no spectrometer although a nearby plant of the same group has one which is available for use. The central quality control department of the group also has a spectrometer in the Mexico City headquarters. The function then of the quality control procedures at the plant is to control the raw meal mix in order to stabilise the calcination process within the kiln which will save on the wear of refractories and on the fuel utilisation. Policy for quality control is set by the central department which also handles non-routine matters such as analysis of new raw materials, in conjunction with the technical departments of tha parent company.

There is also a technical department at this plant, separate from the Quality Control department whose function is to carry out studies designed at increasing productivity and efficiency at the plant. While it is difficult to separate this kind of process control activity from that of quality control, the functions of this Technical Department are really those of planning and analysis rather than ongoing control procedure and for this reason I have chosen to discuss this department in terms of the technical organisation of the firm and plant, and the research and development activities undertaken, which forms part of the later section of this paper on technical capacity.

Quality control procedures at Plant C differs little from the basic functions outlined above for plants A and B. X-Ray analysis equipment at Plant C is automatically connected to the plants for the purpose of receiving samples for analysis. Hourly samples are taken from all the strategic points in the process (see above) and the results of the analysis are fed into a digital computer which calculates the necessary corrections. As at Plant B, the quality control procedures carried out at Plant C are directed by the policy of the company's Quality Control department; in the case of this plant, however, the company headquarters and this plant are in fact located at the same place so that although each has its separate staff and facilities there is constant interchange between them. The functions of the group's Quality Control department will also be discussed in the section dealing with technical capacity and innovative activity. However it is worth mentioning at this stage that the Quality Control department is the most technically dynamic of the technical departments of this company and that studies to improve efficiency of plant and equipment and to rationalise plant operations at this plant are likely to originate if not be implemented by the Quality Control department rather than a differentiated department such as the Technical department discussed with relation to Plant B.

The quality control procedures at Plant D are in effect more sophisticated versions of those carried out at the other plants; in addition to more sensitive and automatic equipment,samples are taken at more frequent intervals and corrections to the materials mix, fuel and oxygen inputs, etc. are calculeated to a finer degree. X-Ray analysis is truly on-line at this plant in the sense that not only are the samples automatically retrieved from the plant and fed to the X-Ray machine for analysis but the results of the analysis are automatically communicated to the computer which calculates the corrections necessary and sends instructions to the apparatus which measures the proportions of the raw meal mix. Samples of the raw meal mix are taken every 12 minutes allowing for constant process control. Altogether samples are analysed from 8 set points in the production process and at each point corrections are calculated by the computer and corrections made.

There are other advanced control techniques used at this plant which are not used at any of the other plants studied. To operate these techniques the plant has the benefit of the group's technical departments and the varied experience of the international activities of the parent company. The access to this information and to various services is effected through the technical assistance contract which also provides for training local staff as well. At the Quality Control department of Plant D there was a chemical engineer from the parent company training local operatives to use the automated and sophisticated process control systems.

At this level of automation it is difficult to separate out the quality control procedures from the over all system of process control. Unfortunately it was not possible to obtain a breakdown of cost figures which would have given some indication as to the advantages of this kind of technology over more conventional process and quality control procedures. 31/ However, fig. 4 at the end of this section does indicate that in terms of technical parameters - in particular labour and fuel utilisation - this plant is more efficient than the other plants visited. 32/ However, as we discuss in the next section of the paper, it is equally true that the reliance of this plant on its parent company for technical assistance in running the plant is extremely heavy; were the parent company to withdraw from Mexico it is doubtful if the plant could be operated by purely local staff. 33/

Insufficient information on the quality control procedures at Plant E were obtained to make possible any kind of comparative analysis with the rest of the plants. As we understand Plant E's quality control procedures are based on X-Ray analysis which is not online, which is not backed up by any automatic calculation system (digital computers).

5. Maintenance systems

It has become increasingly important as the technology used in cement production has become more complicated and costly, and the scale of individual kilns and plants has increased that there are adequate maintenance procedures which will ensure that the physical depreciation of the plant is minimised and that the 'down time' or the length of time for which the plant must be shut down for repairs and maintenance is as short as possible.

31/ In order to carry out a comparative cost analysis of the different kinds of technologies at the plants it would be necessary to examine in great detail training costs, costs of skilled labour, and to cost in some way the technical assistance and research effort carried out by the parent company as well as the price the Mexican subsidiary pays for such services. It has not been possible to obtain all the detailed information relevant for this point.

32/ Again, the kind of labour involved and its relative prices have not been investigated.

33/ This is discussed at greater length below. The problem is not just short term training problems, but the fact that, for example the programmes for the computer are worked out using the company HQ's data banks and equipment.

Although maintenance was always carried out at cement plants it is only in recent years that maintenance procedures have had to be systemised in order not to interfere with other production aims. The most recent and complex maintenance system applied to cement plants is that of programmed preventive maintenance. In this system all parts of the plant and equipment which require maintenance are catalogued and a programme is worked out which determines the frequence and the order for the maintenance of each item. In this way all equipment is regularly maintained rather than just being given attention when it begins to cause problems.

To some extent the kind of maintenance system adopted at each plant reflects the level of technology, and technical capacity utilised. It is also important to note the source of preventive maintenance systems as implemented by each plant.

At Plant A, where the machinery and processes used were described as conventional and where there was no automatic process control, the plant's technical staff were installing a system of preventive maintenance. The impulse for this change in maintenance procedures was a seminar given in Europe by FLS, one of the firm's major technology suppliers,which was attended by several plant personnel. On the basis of this seminar the staff began to install the system in 1973 and it should be fully implemented in time for the new production line to come on stream.

At Plant B the maintenance procedures were not stressed as a major form of improving unit costs of production. This plant, in common with all plants in the group were studying the possibility of the implementation of preventive maintenance with the help of technical assistance from the parent company.

Plant C, on the other hand, was installing a system of preventive maintenance and stressed the importance of the system as part of a long-term reorganisation of production and process control. The project was scheduled to take three or four years to complete and is being carried out with a technical assistance contract from FLS, the firm's equipment supplier. At the time of the plant visit the information necessary for the full operation of a preventive maintenance system was being collected and coded. The information thus obtained will be programmed by a computer the firm intends to install for purposes of company administration and a separate terminal is to be installed to operate the maintenance programme. Both the technical assistance contract and the staffing of the maintenance departments (see later section on technical capacity) reflect the importance to this company of preventive maintenance. The project being undertaken at the plant is meant to be a pilot project; with the knowledge and experience gained at this plant the firms own engineers intend to adopt a similar system in every plant in the group.

At Plant D the preventive maintenance system is an integral part of operating an automated plant. The preventive maintenance programme was calculated at the parent company's technical headquarters using their data banks and programmes. The necessary information about the plant and equipment was obtained from the plant according to the programmes set out by the maintenance department of the international company and the completed programme was delivered to the plant. Maintenance procedures at this plant are extremely frequent and thorough; the electronic equipment which works the automatic system is revised and checked and cleaned every 24 hours; this imposes a very high skilled manpower load on the operation costs of the plant. Less sensitive items of equipment are revised at less frequent intervals - for instance the secondary crushing equipment is checked every seven days. The whole maintenance programme is directed by a Swiss engineer from the parent company whose official title is Head of the Technical Office. Maintenance policy and procedure are the responsibility of such Office which not only programmes the maintenance of all equipment and organises the distribution of work between the various maintenance sections but is also responsible for providing working drawings of each part of the equipment for use by the maintenance technicians. It also sends a montly report on all matters connected with production to the head office of the parent company.

It is difficult to compare this kind of system of maintenance to those installed elsewhere at plants with different levels of precision control technology. The engineers at Plant E claim to be installing a system of preventive maintenance on the basis of experience in other branches of industry. The system, according to this firm, does not require computer programming; what it does require is systematic analysis of the maintenance needs of each part of the productive equipment. The maintenance needs are analysed by an 8-member-strong Maintenance Diagnosis and Planning team, while the actual maintenance procedures are carried out by an execution team comprising 80 men. Clearly if the plant were more automated the maintenance procedure would be more exacting and require more trained personnel. However the approach of this plant differs from that of the previous two plants in that it bases its maintenance programme on the resources of the firm itself. Nevertheless the problems of comparing the system in this plant with that in Plant D are beyond the scope of this research. What is important to note is that maintenance has now become an important part of the technology and management of a plant in response to developments in the kind of technology being employed. This has enormous implications on the development of a firms' internal technical capacity necessary to operate the plant it purchases, a capacity which is assumed ubiquitous in most conventional discussions of technology and choice of technique. This point will be further developed in the section on technical capacity later in this paper.

Having described the technology at the five cement plants visited and the control systems used to manage that technology we will now attempt a tentative assessment of the relative efficiency of each technology.

Section III

TECHNOLOGY ACQUISITION IN THE MEXICAN CEMENT INDUSTRY

1. Introduction

The technology incorporated into the Mexican cement industry includes not just the machinery utilised but the know-how and systems necessary to operate that machinery and control the production process. The channels of acquisition of technology are various; clearly the machinery suppliers are the ultimate source of the machinery or hardware used in the plants. However the process which leads to the planning of investment capacity, and choice of machinery and processes can involve many agents other than the sellers of machinery. Moreover machinery suppliers are able to influence investment decisions by aftersales service, information, supplies of spare parts and credit facilities. These are discussed in Monograph One. The role of the parent company of a foreign subsidiary is also vitally important especially when the foreign firm concerned has a highly developed technical capacity which is available - at a price - to the local subsidiary.

As we observed in section I of this paper, two of the plants studied belonged to firms with 48% foreign ownership; a further two are owned by Mexican capital - either totally by private capital or with part public ownership in the form of participation by a parastatal financial institution; the remaining plant belongs to a cooperative. The influence of this ownership patter on technical capacity and local innovation will be discussed at length in the followign section on technical capacity. However, ownership is also relevant to the present discussion of technology acquisition and channels of technology transfer.

In this section we will discuss the channels of technology acquisition utilised by each of the plants visited, generally in connection with the most recent investment project carried out. At the end of the section we will analyse in more general terms the implications of these observation obtained from plant visits and company interviews.

2. Technology acquisition policies of the individual firms studied

Plant A

Plant A was found to be fairly reliant on its major technology supplier for the basic choice of plant equipment and processes although design 'in situ' and detailed plant planning and engineering design was carried out by the firm's own engineering department. To some extent credit sources had limited the choice of machinery supplier for the latest expansion project currently in progress. Although there was no technical assistance contract between the supplier and the firm, nor is there any suggestion that the loan from the United States Export-Import Bank was conditional on any form of outside technical assistance, the source of this line of credit restricted the firm to United States-made equipment and to certain expenditure limits.

As we have seen this plant is not being automated and therefore is not dependent on outside sources for computer technology and the software to run computerised systems. The standard closed circuit control systems used in this plant, particularly the instrumentation panels, have been adapted by the firm to the particular needs of the factory.

Technical information is obtained by the firm's technical staff from the usual sources of open information available - i.e. trade journals, conferences, information direct from machinery manufacturers and from visits to plants in industrialised countries. One visit made recently was to a Japanese plant in order to observe the precalcination technique of cement production in action. This visit was arranged by the major supplier for the new expansion project to a plant owned by the Japanese firm for which the United States firm has a distribution license.

Although this firm has a lively technical capacity, as we will discuss in the next section, there is a sense in which the investment situation in which it finds itself has made it more dependent on machinery suppliers if not for the source of all general information on technical alternatives, then at least for the specific technical information needed to plan in detail and execute their current expansion project. The firm admitted that the selection of equipment made for the latest project was dictated by financial considerations in the sense that they could not afford to pay for the superior engineerign supplied by the European firms, especially Polysius, in comparison with the United States supplied equipment. However it would be incorrect to give the impression that this firm really operates with tied hands; the information regarding alternatives from the different suppliers is available, especially since several of the manufacturers have offices in Mexico. The choice of supplier is made on a combination of financial, credit and technical considerations with the firm being fully aware of the implications of the choice it is making. Once a machinery supplier has been selected there is then room for a great deal of negotiation regarding the division of labour between the supplier and the technical departments of the client firm and about the type and specifications of the machinery to be supplied.

Plant B

The technology acquisition of Plant B has to be analysed in a double context. Firstly the nature of the technical links between the firm and its foreign parent company have a definite influence on channels of technology acquisition and the technological choices made by the firm. And secondly it must be borne in mind that the reorganisation of the company which began in 1971 has led to an increasing development of technical capacity within the Mexican firm which to a great extent has mitigated the influence of the foreign parent company. 34/

The newest production line at Plant B went on stream in 1972. The machinery was purchased from three major machinery suppliers - Polysius, Fullers and FLS in addition to the prehomogenisation unit supplied by Hewett Robbins. The firm has in fact used single supplier turnkey contracts in the past but found them unsatisfactory. This firm claims that none of the manufacturers is able to produce

34/ For more on this point see footnote Nº 54, in Section IV.

the most efficient machinery for each and every part of the process. This is particularly illustrated by the fact that many plants had Fuller coolers while all other machinery was European. Fuller's grate cooler has been the universally preferred cooler until the resurgence of the Satellite cooler in recent years, whereas European machinery was preferred for other parts of the process, especially the kiln-preheater complex.

The group's Technical department is responsible for the design of the new plant and the supervision of its construction, although much of the detailed engineering work is carried out by the machinery suppliers in the design and preparation of drawings for each part of the equipment. The foreign parent company retains the right of final decision or veto over all major capital expenditure and often takes an active part in the negotiation with the suppliers. The reason given for this involvement in the purchasing and specification process is that the foreign firm is internationally known and therefore has a larger bargaining power with the suppliers than a little known local firm. 35/

While the firm has access to the usual channels of technical information -trade journals, seminars, etc. - the parent company is also instrumental in supplying the local firm with technical information, especially about innovations in process technology and new methods of process control. However a new department was being set up to apply this information to cost control, efficiency and productivity within the group's Mexican plants and this department was being trained and monitored by staff from the parent company's headquarters.

Technical assistance contract. Much of the technical information and assistance obtained from the parent company is covered by the technical assistance contract which exists between the Mexican firm and its foreign parent company. The terms of the contract includes the rights and obligations of both signataries in the fields of technical information, assistance, innovation and other developments. Whilst the contract is registered on a declining cost basis i.e. payments are fixed in terms of Mexican pesos per ton of cement produced while the price of a ton of cement increases constantly because of inflation, the parent company is well protected from the relative fall in the value of its technology contracts by the fact that specific services performed on behalf of the subsidiary are charged separate consultance, service or training fees which are determined at the discretion of the parent company.

35/ While on the one hand such a claim is true, it has to be seen in its context. This firm has experienced problems in trying to order ancilliary equipment from United States suppliers and has had to ask the parent company to intercede on its behalf. It is also claimed that the investment cost per ton is lower if the parent company does the bargaining. Since the parent company has world-wide interests it is logical that the suppliers are anxious to retain its orders. On the other hand, locally owned companies can also attain significant bargaining power, such as in the case of a large local cement producer in Argentina who achieved significant bargaining power with machinery suppliers because of (1) its large and growing importance in the local market and (2) the fact that it was known to be the technological leader in the Argentine market and thus influenced technology decisions of other firms.

Under the terms of the technology contract the local company is entitled to receive technical information about products and processes; it is also entitled to use the services of the parent company's engineers and other technical staff and to receive technical assistance on training and other technical matters. In return for these services the local company undertakes not to manufacture any product without the parent company's consent and to submit to the parent company's judgement about quality of product. The parent company is to give training and assistance on all aspects of project planning, design engineering, stock control, repairs and maintenance, security systems and process control and to make available to the subsidiary all relevant information, specifications, drawings, etc., relevant to the subsidiary's production necessities. These services are paid for separately, as commented above, and the local firm has no control over the level of payment for these individual technical services.

In the context of this technical assistance contract it is difficult to judge how far the channels of technology acquisition utilised by this firm are dominated by the parent company. It is clear that the parent company has the right to make final judgements on decisions regarding technological policy; on the other hand, it seems to be the case that the local company carries out most of the ground work regarding new project planning and design and the parent company is only brought in to give final approval. Since the reorganisation of the firm and the creation of technical departments with clear and delimited responsibilities the role of the local company has become more active and defined. The area where the effect of the parent company is probably most marked is that of research and development on new products. In response to several questions on the subject the engineers at this plant maintained that there was no need to carry out such activities since they were done on a larger scale and with more and better equipment and personnel at the company's foreign headquarters. This is discussed in more detail in the following section of this paper.

Plant C

Plant C belongs to a group in which there is no significant foreign participation. Nor is there any formal technology contract which ties the group to a single supplier or consultancy for technical assistance. However in addition to the normal channels of acquisition of technical information the group has come to rely on one single supplier (FLS) both for equipment and for much of the technical information necessary to make investment decisions and execute investment projects. In addition the group has had recourse to other consultants in the field for specific assistance on automation and on plant design and specification.

The reliance of this firm on its major suppliers is to a large extent pragmatic. The firm claims that they have very good relations with the suppliers and that there are various economies to be obtained from dealing with the same manufacturer. While in the nature of this research it was not possible to investigate meaningly comparative costs of new investment 36/ the kinds of

36/ Preliminary figures indicate that the price of this firm's new investment is neither significantly above nor below average prices in Mexico. But such comparison is meaningless without comparing in detail the kind of plant and services bought, the cost and terms of suppliers' and other credit, and the quality of engineering services embodied in the plant.

advantages obviously accruing to this kind of relationship are standarisation of parts which lead to economies both in construction of new machinery, drawings and specifications, maintenance costs and spare parts and training of operators. In a firm which does not enjoy the protection of the international reputation of the multinational firm like Plants B and D in this sample, it is perhaps rational for a firm to build up a relationship with a single supplier.

The process of technology acquisition by the firm from their suppliers illustrates the degree to which they are dependant for technical assistance on the machinery manufacturers. The firm specifies to the suppliers the output characteristics of the required investment and the machinery suppliers will then furnish alternative specifications to fulfil the output requirements. These alternatives are vetted by the firm's Engineering department which is then responsible for designing the plant on the basis of the information and drawings supplied by the manufacturers. In the case of smaller plants belonging to the group in various parts of the country, the Engineering department has carried out practically all the design engineering required. In the case of the plant visited, which was the largest plant of the group, the assistance of a foreign consultant had been hired in order to carry out the design of the investment project currently under construction as well as the previous project now in production.

However, the technical departments of the firm have recently been reorganised (see Section IV) and it is anticipated that the need to employ foreign consultants for these functions will diminish as the technical internal capacity of the firm in these areas is developed.

As we discussed in the section on technology, foreign assistance was hired by this firm in two other technical areas; automation and programmed preventive maintenance. The history of the project which involved the purchase of a mini computer to run the kiln automatically is not clear. However it is known that the software to run the computer was purchased from the same consultant used for the basic design engineering of the last two kilns at the plant. As we saw in the previous section the project was not very successful and was certainly not conceived as part of an ongoing programme to automate the whole plant. The firm was not reorganised to make the maximum use of this computer and the lack of success of the project has led the whole area of automation to be quietly dropped.

The preventive maintenance programme at this plant is being carried out with the help of technical assistance from the major machinery supplier. Unlike the computer project, this project is seen in a long term context and the learning opportunity offered by the implementation of the project at this plant is to be repeated at the group's other plants. The impetus to install the preventive maintenance system appears to have originated from the suppliers rather than from the firm itself though the exact channels of information are uncertain. Certainly the suppliers are heavily involved in the implementation of the project. (See Section II) 37/

37/ No data is available about the terms of these contracts which are not registered as technology contracts in the same way as those between subsidiary and parent company are. The main reason why they are not registered as such is that these contracts with foreign consultants cover specific services rather than the range of technical assistance covered in the other type of contract.

The channels of technology acquisition used by this firm are varied and include all the normal channels discussed in Monograph One. The machinery suppliers play a very important role in the acquisition process complementing the relatively underdeveloped design engineering departments of the firm itself. As we shall see in Section IV the innovatory activities of this firm are concentrated in new product development and quality control procedures.

Plant D

Plant D is the other firm in our sample which is controlled by a foreign cement multinational company and, in the same way as for Plant B, the relationghip with the parent company has a very important influence on the channels of technology acquisition.

Plant D's technology contract. Like Plant B this company is covered by a technology contract between the parent company and the subsidiary. The terms of the contract are along similar lines, although in some respect the provisions are more far reaching. Under the terms of the contract the parent company agreed to make available to the subsidiary the results of its technical, economic and chemical studies, its experience in production of ordinary and special cements, its experience in planning and organisation of cement plants and in the technology of cement production on control of costs. Mentioned specifically is the good relationship which the parent company has with the suppliers of machinery. The content of these technical areas is specified in much more detail than the other contract analysed. Specific assistance is to be given in expansion projects, and their requirements, quality and cost control procedures, training, raw materials consumption, geological research, quarry exploitation, project planning and execution including drawings and other design necessities and advice in the selection of new machinery and the introduction of new production techniques. The terms of the contract also cover training of local personnel in the parent company's plants all over the world and assistance on commercialisation and administrative matters.

In fact there is little connected with technology or any other matters which is not funnelled through the parent company. In the words of one (Swiss) engineer at the local company 'There is no difference between ourselves and the parent company'. The influence of the parent company is detected in all operations. The whole process of negotiating with the suppliers of machinery, as well as the plant design and basic engineering, is carried out on behalf of the local firm by the parent company. The fact that the design team might include technical staff belonging to the subsidiary and that parts of the design process takes place at the Mexican company headquarters does not alter the fact that the parent company is the technical force that is important. The parent company seeks and evaluates tenders and designs the layout of the Mexican plant. The local engineering staff participates in these and other studies and activities carried out. The project and investment planning activities are backed up by the data bank compiled as the result of the international group's many years of experience in many production situations which in fact, according to one informant, managed to reduce the per ton investment cost of the latest expansion at the plant to a group record. 38/

38/ While this may be entirely true there is no information on how the technical input to the project by the group in terms of computer and in formation back up is costed for each project.

In the planning and design of the local plants, designs used by the group in other parts of the world, are made available for use by the local company. In addition norms of efficiency, productivity and cost control are supplied by the foreign company and constant staff training both in Mexico and abroad help to ensure that local technicians and engineers are competent to operate the plant effectively.

In such a situation the channels of technology acquisition of the local company cannot be separated from the generation of technical know-how carried out by the parent company and made available to the local subsidiary. This is not to say that local internal technical capacity is not developed - the extent of this development will be discussed in the next section. And clearly this firm uses the machinery suppliers for the source of its production technology since the firm itself does not manufacture cement process machinery nor carries out innovatory developments to such machinery. The strong area of this firm is the applications of systems management to all aspects of cement production and in particular the application of automatic techniques and it is clear that in this instance, the automation installed at the plant is entirely derived from previous development by the parent company to the Mexican operation.

Plant E

Plant E has a totally different policy towards technology acquisition from the other plants in the sample. The latest expansion project carried out by the firm was a complete turnkey project awarded to Polysius. The reason given for using a turnkey option was that it was considered cheaper than buying the machinery from different manufacturers. However no data was produced to support this believe and it is likely that the lack of internal technical capacity in the firm which could enable it to carry out its own process and machinery selection and plant design and basic engineering made the choice a limited one between a turnkey contract with a machinery supplier and a contract with a foreign consultant to carry out the basic engineering functions.

The engineers at this firm, however, are still convinced that the extra cost of a turnkey contract is less than the expense of maintaining an engineering team which would be idle in the intervals between expansion projects. 39/

The firm claimed that its sources of technical information were the normal ones for the sector though it placed a heavy reliance on the information made available by the machinery suppliers with whom it made turnkey contracts. The engineering and technical staff at the plant were capable of carrying out the

39/ This is a hard statement to support or reject since we have no precise information on the charges made by suppliers for their turnkey services nor do we have them for the cost of maintaining a design team. However it is interesting to note that Plant A, which has a much lower capacity than this plant, has been able to maintain an engineering design team permanently occupied. This reason for not developing internal technical capacities denies the importance of the opportunity of learning from innovation and experiences which marks th major difference between Plant A and this one.

feasibility and pre investment studies needed before new projects got underway although these studies were conceived of very much as marketing and distribution studies.

One of the sources of information on new developments in cement production which kept the firm relatively up to date with new innovations were plant visits to factories in the Unites States and especially in Europe. The company appeared to have particularly strong information links with the French cement industry.

Because of their reliance on a single machinery supplier no outside consultants were used for new investment planning or implementation. Nor were consultants used for other technical matters. In Section II we described the firm's pragmatic approach to programmed preventive maintenance and many technical problems in the factory were treated in the same empirical manner.

Section IV

TECHNICAL CAPACITY IN FIVE MEXICAN CEMENT PLANTS

1. Introduction: concept of technical capacity

The present section analyses the technical capacity in the five cement plants which were visited in the course of the research described in this paper. Although visits were made to only one plant of each company or group, detailed interviews were also carried out at the headquarters of most of them. The analysis will therefore attempt as far as possible to assess the technical capacity of the company as a whole.

The concept of technical capacity was discussed in Monograph One in relation to the ability of a firm to manage its technology, investment projects and to carry out innovations at different levels. While using this schematic analysis of technical capacity we have found it necessary to adjust the level of the analysis in terms of the kind of technology employed by different firms and the interaction between local firms and outside sources of technical inputs, be they foreign firms with direct participation in the local subsidiary, or foreign firms whose services and know-how are purchased on the market. 40/

In order to assess technical capacity we will use the following factors as indicators:

a) organisation of the firm from the technical point of view;

b) number of engineers and other trained personnel per unit of capacity output;

c) tasks performed by the technical departments of the firm in relation to design and implementation of new plants and expansion projects;

d) research and development and other innovative activities undertaken by the technical departments of the firms;

e) access to and general attitude towards technical innovation in the cement sector.

40/ The main reason why the schematic assessment of technical capacity drawn up in Monograph One is not entirely satisfactory is because in its staged analysis it assumes that there is no difference in the requirements of internal technical capacity between one kind of technology and another. The research carried out for this paper indicated that the capacity to run an automated plant is quite different from that required to run a more standard plant; thus, a firm able to carry out all the necessary functions in connection with the latter will not necessarily be able to cope with the former. Similarly a fully automated plant run with the assistance of imported technical know-how does not in itself indicate that the internal technical capacity of the plant's staff is greater than that of the staff of a plant which operates less sophisticated equipment autonomously.

In discussing these factors it will become obvious that they are not exclusive of each other and the discussion of one will inevitably cover aspects of others. It will also be apparent that, due to the nature of the field work undertaken much of the analysis is on the basis of subjective judgements rather than quantitative relationships. 41/ Nevertheless we feel that the assessment is of definite value be it only to point up the areas of more detailed research on the subject which would give more reliable results and to bring out broad explanatory hypotheses regarding the connection between technical capacity and innovatory activity in the firms, and the ownership and market structure of each firm in the sector. The explanatory hypotheses will be contained in the final section of this paper.

In the previous discussion of channels of technology transfer we emphasized the influence of foreign firms on the access of their Mexican subsidiaries to technology, innovation and know-how and on the kind of technology they incorporate into their plants. The problem in this section is to find some means of separating the internal technical capacity of the Mexican firm, as we have defined it above, from the technical factors which make up that capacity which are directly supplied by the foreign firms. By wanting to make this distinction we are not arguing that technical transfer between subsidiary and parent company is not a real and effective transfer; clearly the access to technical information about new techniques of production and process control and the training provided by the foreign firm both at its metropolitan headquarters and by visiting engineers at the plants of the subsidiaries in Mexico has a positive effect on the internal technical capacity of the firm. Nevertheless it is also clear that the activities of the foreign firm removes from the sphere of operation of the subsidiary a number of decisions about choice of technology and process control. This in itself has a negative effect on the firm's technical capacity. 42/ In these circumstances there appears to be no exact method of separating the two components of technical capacity in the case of subsidiary firms and the methodology adopted will be rather subjective.

2. Technical capacity in Plant A

Plant A is not the most technically advanced cement plant in Mexico in terms of the kind of equipment and process control employed (see Section II).

41/ By the term "subjective judgement" we refer to the interpretation of the information obtained by interviews and questionnaires. In order to test accurately an assessment of technical capacity it would be necessary to observe and cost each technical department over a large time period, for instance, the planning and execution of an investment project - task which has been outside the reach of the present study.

42/ It should be remembered that technical transfer do not necessarily always take place between subsidiary and parent company. For example, the United States cement firm operating in Argentina had a policy of opposing any technical development in its local plants, and all technical activity was directed by the parent company without any training or staff development programmes being organized for local personnel.

Nevertheless we found that the company has an integrated and rational internal technical organisation which is aimed at maintaining its technical capacity at a level capable of fulfilling the technical functions required by the firm's overall production strategy.

Organisation of technical departments

The technical direction of the two plants within this group is organised from Head Office in Mexico City. The Technical department at Head Office consists of the Industrial Manager and the following staff: Sub-head of the Technical Department, Head of Construction and Installations, Head of Civil Engineering, Head of Electronical Projects and Head of Factory Production, a total of six qualified senior engineers in the relevant disciplines. In addition one of the members of the central Technical department also acts as head of the New Expansions (Ampliaciones) department, which is located organisationally between the Head Office and the plants, and comprises a staff of four civil engineers, one technician and seven draughtsmen.

The New Expansions Department is a department which does not exist in any other cement firm in Mexico. This team is responsible for the execution of all new investment projects within the group, acting in a sense as project planning group in charge of all civil works and construction activity. The group has been kept continuously occupied since its formation some ten years ago since it functions not just for the erection of new lines of equipment but also for the replacement of individual items of equipment. It also supervises construction activity of the group which is not connected with the production facilities at the cement plants. 43/

At the factory level there are three technical departments. The Production department comprises a Chief of Production (engineer) plus three engineers who supervise each of the three production shifts; in addition there is a staff of three trained technicians who act as aides to the shift engineers.

The Maintenance department is split into four parts - mechanical,with a staff of two mechanical engineers; electrical, with one electronic engieer; electronic (two electronic engineers) and civil (one engineer plus staff). The maintenance of the refractory bricks which form the kiln lining are the responsibility of the Production department since it is that department whose activities directly regulate the life span of the refractories.

The Quality Control department has a staff of five chemical engineers and this is supplemented by fifteen trained technicians who work on shifts.

There is a further technical department at the plant which, strictly, is part of the Production department. This is the Department of Operations Research, which consists of a small staff of one (civil) engineer, one statistician and one draughtsman.

43/ Since this is a cooperative plant, the social activities of the cooperative include a variety of construction projects.

The organisational structure and number of engineers in the plant and at head office is shown in fig. 5.

Aspects of technical capacity

The technical strategy of this firm as we have seen is not to incorporate the most sophisticated and automated machinery but rather to increase the efficiency of the conventional equipment they have and, in parallel, to improve the technical capacity of their staff. In this way the group has managed to retain their market competitivity with the other firms serving the metropolitan market. Nevertheless as we discussed in the previous section the engineers at this firm are fully cognisant of technical innovations in production technology elsewhere and have taken steps to incorporate certain innovatory elements of new process and process control where these are compatible with their overall strategy. 44/

The degree of autonomy of the firm with respect to new investment management was largely dealt with in the previous discussion of the channels of technology transfer. Once the equipment is selected from the suppliers the firm receives standard drawings for standardised basic equipment from the suppliers. The Technical department of the firm which is situated at the Mexico City Head Office then carries out the detailed plant design and the engineering required to transform individual items of equipment into an on-line production unit. The decisions about what kind of technology to use are, as we discussed earlier, somewhat limited by the restriction on choice of suppliers caused by the necessity to raise foreign exchange loans to finance the investment project. However within these limitations the firm possesses sufficient technical knowledge to define the production specifications it requires and to make choices between alternatives. 45/

Innovatory activity/research and development

Within these limitations the firm undertakes a certain amount of innovatory activity some of which can be described as Product Research and Development. The laboratory at the plant has developed a special cement (EAT: Exempt from Aluminium Tricalcinate) which has a large application in Mexico for drainage pipes. The laboratory has an ongoing research programme to improve the qualities of the other cement manufactured at the plant and to develop new variants. As well as ordinary portland cement (Type I in the Mexican classification) this plant produces Type II, which is a modified ordinary portland cement; Type III, quick high resistence, Type IV, low hidration temperature; Type V, the special EAT cement mentioned above.

44/ I refer here to the introduction of the prehomogenisation unit in 1973, and to the adoption of a preventive maintenance routine.

45/ This is not intended as a gratuitous patronising comment. The ability to make appropriate choices between alternative processes and items of equipment is an essential factor in investment management, and the realisation of expected profits from any investment obviously requires avoiding possible mistakes.

The small scale digital computer used for analysing the results of the X-Ray analysis of raw materials and materials in process was programmed and is operated by the plant's own engineers in accordance with the production needs of the plant. While this is not in itself innovatory it does indicate a fairly high level of technical knowledge of the part of the department.

The Operations Research department, which is part of the production department has been set up within the last few years in order to suggest ways in which productivity and efficiency can be improved. Although its staff is extremely small it does in fact work in close contact with the other departments. To date it has been fairly successful in diagnosing areas where the performance of machinery can be improved or the process control can be made more effective. For instance: the efficiency of the raw grinding mills at the plant have been increased by 40% in terms of throughput per hour. This was achieved by altering the size of the raw meal particles fed in from the secondary grinding equipment and the sizes of the grinding balls until an optimum combination was found which resulted in this substantial increase in capacity. The experimental work was carried out with the spectrometer for which the firm's engineers had been trained by attending a Polysius training course.

Whilst not strictly relevant to efficiency of production there are two other aspects in which the firm can be said to be innovatory. The first is the whole area of working conditions and internal communications. Noise levels, in particular noisy departments such as raw grinding and cement mills, have been minimised and operators are housed in sound proof offices with microphones which enable them to monitor the process without being subjected to high and continuous noise levels. Moreover the operators of the grinding mills, in common with all other operators in the plant have direct telephone links with the control room and production department.

Another aspect of improved working conditions and communications is the special operator manuals produced by the firm for the operators of each stage of production. The issuing of operator instruction manuals is of course standard practice; most cement firms however use the manuals provided by the machinery suppliers, suitably translated. The manuals produced at Plant A however were written specially to inform the operator not only how to perform his specific functions but also how his tasks and equipment are related to the rest of the production process and thus the importance of his control for other processes and subprocesses. The object of such manuals are two fold; on the one hand the operator is formally integrated into the overal plant activity which is beneficial in terms of cooperation to meet production targets etc. On the other hand the operator is provided with information which helps him diagnose and solve problems in his sphere of operations - a kind of on-the-spot "trouble shooter". In addition he is able to more effectively implement quality control and potentially to suggest ways in which process control and productivity can be improved.

Clearly these 'innovations' stem from the particular organisation of this firm as a cooperative and there is no data to indicate a real and measurable return from such activities, other than pleasanter working conditions. Nor is there any guarantee that this ad hoc approach to improving technical capacity of operators will in the long run prove successful in comparison with more standard forms of operators' training and incentives 46/. However it does present an interesting possibility in terms of maximising the potential technical learning possibilities in a situation where skilled, experienced and formally educated technical staff are at a premium.

A further aspect of this firm's R&D innovatory activity concerns not cement production but agriculture. Again because it is a cooperative the objectives of the plant are formulated differently from the normal profit/growth maximising objectives of other firms 47/, the agricultural venture is still at a pilot stage. Its logic is to use raw materials reserves for the factory, combined with by/waste products of cement production to develop agricultural techniques suitable for the kind of soil and climatic types found in the region, and to absorb local labour not employed by the plant. To date some interesting results have been obtained by growing standard food crops (wheat, beans) using sulphur and phosphorous fertilisers with carefully elaborated planting and harvesting schedules. The firm's laboratories and technical staff are used for the necessary laboratory research and the cooperative defrays the cost of the two agronomists running the agricultural research programme. 48/ Whether the results of this experiment will ever be viable depends on what kind of cost effectiveness it achieves and also on the problematic land tenure and agricultural productive system in Mexico. However what makes it interesting from the point of view of this analysis is that the concept of scientific and technical knowledge in this particular productive unit is not strictly limited to the production of cement. Technical knowledge and physical facilities are being shared with other productive activities with a potential benefit for both cement production and agricultural production. 49/

The existance of the New Expansions department at the plant is another example of the way in which technical problems are rationally approached and internal technical capacity of the firm is systematically developed. By keeping a coherent group together the firm has built up a considerable amount of experience in installation of equipment as well as in construction activities. The growth period of the firm began in the early 1960's, since when the department has participated in the erection and civil works connected with 5 new kilns, 3 grinding plants and the prehomogenisation plant. Currently it is involved in the new production prehomogenising unit. This has given the firm considerable advantages

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46/ Formal training courses are also run at the plant, and union wage equivalents are paid.

47/ The firm is of course interested in minimising costs and increasing its market shares, but has other concerns as well.

48/ Cooperatives in Mexico operate under a separate tax regime which enables them to deduct such expenditure from their taxable surplus.

49/ The benefits for cement production in this instance appear to be fairly limited. They are of some significance in relation to the identification of the plant workers with the region and the avoidance of conflict between those employed at the plant and those living in the area. Yet another interesting alternative has developed: a chemical engineer from another plant while looking for suitable raw materials in a region which had not been ecologically surveyed, was aided fortuitiously by a botanist who was able to point out what flora was normally associated with the particular form of calcium carbonate available in that area.

in various ways; firstly it is able to reduce the supervisory functions of the machinery suppliers to a minimum. This brought a considerable reduction in costs. Secondly, the existance of the group obviates the need to contract out the construction and supervision of civil works activities to outside consultants or engineering firms. 50/ Thirdly, there seems to be an advantage in being able to judge as to the specific technical advice provided by equipment suppliers. 51/ Finally, if the firm's internal departments have been responsible for setting up the plant, designing the layout and monitoring the quality of the engineering works, they will probably have accumulated considerable detailed knowledge of the mechanics of the equipment they are using which assists them in diagnising and rectifying faults and failures. This knowledge is also important not only to keep the plant functioning but to make the suppliers accept responsibility for problems caused by faulty engineering and machinery. 52/

An overall assessment of the firms technical capacity must take into account its peculiar objectives as well as the level of technology used and the organisation of technical resources within it. Nor is there any quantitative way in which technical capacity can be measured for the purpose of comparison with other firms in the sector. This firm as we have seen is not at present attempting to employ the most up to date methods of quality and process control although the machinery it uses is modern by conventional industry standards. However the evidence presented in this sector illustrates that the firm has set up a rational organisation of technical departments which enable it to carry out the following functions which correspond to the first three stages of the model of technical capacity drawn up in Monograph One:

1) to maintain production with existing equipment with no outside technical assistance;

2) to effect small/medium modifications to the equipment to increase productivity without new investment;

3) to design and carry out projects necessary to expand capacity by increasing capacity of equipment at an existing plant.

Whether the firm has the capacity to carry out the design and implementation of an entirely new plant is not clear. The current project being undretaken is the construction of a new and separate production line which can be considered to represent a mid point between expansion of an existing plant and establishment of

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50/ In Mexico mechanical construction and civil works are normally contracted to Mexican specialist firms, while the machinery suppliers often play a supervisory role.

51/ Several firms complained that there was a danger in, for example, buying a whole production line from one manufacturer with the exception of the cooling system. There is the chance that the major supplier could take such opportunity to undermine the performance of the competitor's machinery.

52/ This was one of the problems which subsidiaries of foreign firms are happy to have solved by their parent companies since the latter have better negotiating strength to use against suppliers.

a new plant. This project was supplied by a single supplier mainly because of credit restrictions. However it cannot be considered as a turnkey project since it was clear that the local firm participated to a great extent in the plant design which was implemented according to the firm's own specifications.

However this schematic model does not entirely cover the analystic needs of assessing technical capacity in cement firms. The dependence of this plant on machinery suppliers for new technology both that incorporated into machinery and equipment and for elements of process and quality control necessary to increase productivity and efficiency is obvious. On the other hand we have seen how the firm has been organised to incorporate and internalise technological information and techniques acquired from outside sources into the rational control of production in the plant.

3. Technical capacity in Plant B

The technical capacity of the cement group which owned Plant B was found to have developed considerably in recent years as the result of the reorganisation of the firm. The consequence of this reorganisation has been that technical functions are rationally distributed between departments and technical staff and engineers have been recruited to serve these newly defined and expanded technical roles. In the course of this development and rationalisation the firm has also achieved substantial distance and independence from the parent company in technical matters. This is so to the extent that it can no longer be said that the foreign firm imposes direct restrictions upon the development of local technical capacity.

Organisation of technical departments

The technical departments of the group are organised according to the scheme shown in fig. 6. There is a central Technical Services department which answers to the Board of Directors and sets technical policy and makes technical decisions for the whole of the firm. 53/ At the present time the Technical Services department is headed by a Civil Engineer who has overall authority. Under him are two sub-heads of department who direct the Engineering department and the Quality Control department respectively.

The Engineering department has four sub-sections: Civil, Mechanical, Electrical and Instrumentation; each department has a staff of one or two specialised engineers plus two or three draughtsment. The total staff of the Engineering department consists of 10 qualified engineers.

The Technical Services department is responsible for planning, designing and monitoring the execution of new projects; day to day production problems are

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53/ Before the reorganisation which was caused by the Mexican government forcing the parent company to reduce its interests to less than 50%, the Board of Directors, which comprised mainly engineers, were directly responsible for the formulation of the technical policy of this firm.

left to the technical departments at the plants, though Head Office personnel may be used to give specific assistance and to organise and participate in inter/intra plant technical seminars and training programmes. The central Technical department also sets maintenance policy for the plants; execution is left to the relevant plant staff although its satisfactory execution is monitored by the central Technical department.

The Technical Services department's responsibility for new projects is at present undergoing modification. With the realisation that production experience and detailed knowledge of local conditions is necessary for the successful design, start-up and maintenance of new plant in situ, it is intended to decentralise the functions of the Technical department. The new expansion project at one of the group's smaller plants is being carried out under a modified structure. Instead of the Head Office staff doing all the project planning and design, and then handing it over to the plant staff once all decisions have been done, local staff are to be brought in during the initial stages. A special Project Task Force is being set up which will be headed by the Plant Superintendant at the plant where the project is taking place. The Plant Superintendant will participate with the headquarters staff in the planning and design and also purchasing the equipment demanded by the project. He will then have complete responsibility for the execution of the project as Head of the Project Task Force, only calling on the services of the central Technical department for assistance when specifically required. 54/

This decentralisation of investment planning and execution is an important measure for a firm with a large number of plants spread over a fairly wide geographical area. The reason that prompted the organisational changes was the realisation that technical staff at Head Office had little experience of working at a plant and rarely any at the particular plant where the investment was taking place. Since problems only become manifested once a plant is in operation, which is often too late for modification of the original design, local participation at all stages by people with intimate knowledge of plant conditions and local peculiarities is clearly advantageous. The move also reflects a growing confidence in the ability and experience of the local plant's technical departments.

The Quality Control section of the central Technical Services department has a parallel function to the Engineering department vis-a-vis the functioning of the plant's quality control laboratories. The Quality Control department is staffed by 5 chemical engineers and one geologist plus technicians. Its responsibility is to set the policies for quality control procedures and standards in the plants and to monitor their execution. It is also responsible for non-routine analysis of new raw materials. This investigatory activity takes place within the context of the technical assistance contract between the firm and the foreign parent company; problems requiring computer analysis or sensitivity analysis are sent to the parent's Head Quarters for analysis.

54/ This project has in fact been postponed since the devaluation of the Mexican peso in August 1976. However the organisational changes are expected to be adopted as a permanent feature of the firm's organisational strategy.

Technical departments at the plant level

At the plant level technical departments are mainly concerned with on-going production problems. At the plant visited there was a total of 15 qualified engineers spread between four departments. The Production department which is responsible for the running of the plant and supervision of production personnel has three qualified engineers and various technicians. The laboratory is staffed by three chemical engineers and various technicians.

The Maintenance department comprises a staff of two engineers from each of the four major engineering disciplines: electrical, electronic, civil and mechanical. The department carries out a full programme of corrective maintenance. Fully programmed preventive maintenance has not as yet been implemented at this plant though its future implementation is soon to be decided by the central Technical Services department rather than the plant's Maintenance department.

Technical Department

The organisational innovation at this plant was the establishment at the end of 1975 of a Technical department which is responsible for carrying out ongoing studies to increase productivity and efficiency in the plant. The local staff at this initial stage comprises a Superintendant chemical engineer, an assistant (technician) and a statistician; however it was anticipated that a large and qualified staff would be required as the work of the department gets underway. Two chemical engineers from the parent company had been sent to the plant for a period of two years to set up the department and to train the local personnel in the relevant planning and analysis techniques and procedures. The parent company set up a Technical Services department some six years ago mainly to offer consultancy services to subsidiaries and other cement companies overseas. Technical assistance of the kind represented by the setting up of the Technical department at the plant comes within the terms of the technical assistance contract discussed in Section II of this paper, but is costed separately.

Innovation and research activity

This company clearly does rely very directly on technical assistance from the parent company. In terms of any kind of new product development or process innovation the local firm is completely passive, accepting patents and tested process innovations, however minor, from the parent company. No new process research is carried out even at the central laboratories of the Technical Services department; two special cements which have been manufactured recently by the company - a sulphur resistant cement, and a coloured cement, are both being produced on the basis of purchased patents.

In spite of the establishment of the new Technical department specific problems in production are still solved with the assistance of the parent company. The problems with the newest kiln at Plant B is being analysed by the Research department of the parent company, this being defended on the grounds that the parent company has the computer, information and experience which is lacking in Mexico. The installation of the prehomogenisation unit at the plant was a solution which was generated by the parent company's Technical Services division; in fact the prehomogenisation unit has failed in the specific function of solving the production problems associated with the kiln, though its overall benefits are not denied.

Potential process innovations and modifications - for instance the conversion of the company's Wet Process kilns to dry process operations, or the installation of a Flash Calcinator in one of the plantas have been studied in conjunction with the parent company; while the parent company has the final decision in such technical matters the local technical staff carry out much of the research necessary to reach that decision in the context of the Mexican plants. What is not clear is how far such decisions take into account the potential learning and technical development opportunities inherent in carrying out process innovations or modifications.

To attempt an assessment of the overal technical capacity at this plant, and in general of this firm, the role of the parent company must be taken into account. Although clearly the highly qualified technical staff have the capacity to maintain production with existing equipment with no outside technical assistance and to carry out modifications to such equipment, nevertheless it remains true that the potential assistance from the parent company should non-routine technical problems occur, cushions the firm in attaining complete technical independence.

4. Technical capacity in Plant C

Organisation of technical departments

The technical departments of this firm were, together with the whole organisational structure of the company, reorganised some two years ago. The current situation in this respect is depicted in fig. 7. The reason for the reorganisation was the recognition of the tremendous growth that the group had undergone over the last ten-year period (see Section I). The group's technical departments are located at the group's Headquarters which is in fact the same location as the plant visited for this research. The discussion in Section III of the channels of technology acquistion revealed that this firm relies to a large extent on the technical support from machinery suppliers and international consultants. Part of the reason why this is so is again the very fast rate of growth of this group which has involved the establishment of two completely new plants and the acquisition of four plants, plus the continuous expansion of all but one of their existing plants. The organisation of the firm now represents a more realistic appraisement of the technical resources of the firm and an attempt to develop those areas which are rather weak at present in order to be able to keep abreast of future technical developments in the industry.

The central Technical Services department is divided into three sections: Chemical, Engineering and Purchasing. Each section is headed by a qualified engineer in the relevant discipline. The Chemical section has a staff of three chemical engineers, one geologist and one topographer, with two "perforacionists". The Engineering department comprises a chief (mechanical) engineer and two each of mechanical, electrical and civil engineers plus draughtsmen. The purchasing department has a staff of two mechanical engineers.

These departments and staff are in the central Technical department and serve all the plants in the group. They are supplemented by the technical staff at each plant, which is concerned with routine production tasks and is much smaller than the central technical departments. The plant's technical departments at this and other plants in the group, have the same technical groupings as in other firms: Quality Control, Production, Mechanical, Engineering and Maintenance, with a total of twelve qualified engineers in the various departments. The functions of these departments will be discussed later in this section.

Functions of technical departments

The central technical departments set the technical policy for the whole group and are responsible for all new investment and trouble-shooting activities - in fact anything beyond the normal production routine at the plants. The firm owns a fleet of small aircraft and the central technical staff can spend up to three or four days a week visiting one of the group's eight plants to monitor the production at the plants, or to solve specific problems or carry out training activities amongst local staff.

The central Chemical or Quality Control department acts in the same kind of auditory and policy setting functions as the Quality Control department described at Firm B. However in addition to setting control norms and monitoring their adherence in the various plants, que quality control department at this company also has a large research function which was absent in the department of firm B mainly because of the role the parent company plays in this respect in the case of Firm B.

The Head of the Quality Control department at Company C described the functions of his department as follows:

1) localisation of new raw materials;

2) quarry exploitation policy and programming;

3) auditing of quality control procedures in the plants;

4) research of new raw materials and new types of cement, and research into new processes of cement production. Also research into the interaction of different raw materials in the calcination process.

In fact the Quality Control department in this group appears to be carrying out many of the research and diagnostic functions which in the other plants hereby described are carried out by specially appointed research departments. 55/ The reason that research activity beyond the expected product development research is concentrated in the Quality Control department is not clear. One possible explanation is that the recent reorganisation of the group was based on the previous organisational divisions and has not been completely adapted to the new technical functions of the departments brought about by the more up-to-date

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55/ It should be noted that this firm has no department responsible for analysis and process innovation, unlike Plants A and B (see diagrams of technical organisation, figs. 5, 6, 7).

technology being used, and by the pace of competition for markets within the national industry. Another explanation is that the Chief of the Quality Control department is the most able and forward looking technical person in the company and has expanded the functions of his department on his own initiative beyond the laboratory work normally associated with quality control activities to meet problems of efficiency, technical productivity and new materials development as he has considered them necessary.

The results of the R&D activities undertaken by the Quality Control department are varied. Particularly in the area of new product development and the use of new raw materials the department is actively developing non-portland cements, especially Puzzolanic cements. Although the firms interests in Puzzolanic cements stems from its recent take over of a previously independent firm which has traditionally manufactured them, it is actively seeking to establish certain properties of these cements which would make them a more economic alternative to special cements in certain specific uses. Blast Furnace cements have traditionally been manufactured by one of the group's plants and the Quality Control department has in recent years begun to expand the commercial market for this product, although in the face of much opposition. 56/

This emphasis on the development of new cements, particularly non-Portland cements, was not encountered anywhere else in the Mexican cement industry and is significant because it represents a very far sighted R&D strategy both in the context of the Mexican market and in relation to the possibility of exporting this product to the United States. Moreover, it is an independent strategy not dictated by imported norms of technical efficiency, and based on an acute appraisal of market developments in Mexico and the direction these are likely to take in the near future.

The Engineering department shows no such advanced thinking or innovatory activity. The department is responsible for the design of new projects and the installation of new machinery. 57/ The level of knowledge of alternative technologies and experience of negotiation with suppliers appeared to be narrower than at other plants visited, possibly because the staff of this department had not been many years with the firm. The procedure for technology acquisition was described earlier in this paper - namely specifying production requirements to a single supplier and selecting between the alternatives offered. The Engineering department finds it necessary to supplement its own capacity by assistance from consultants and suppliers; the last two expansion projects as well as the kiln currently being installed at the plant visited were designed by the Swiss consultancy firm Holderbank, which as we noted in Section I has a controlling

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56/ On one occasion a tender to use Blast Furnace cement in the construction of a nuclear energy plant, which would have meant a substantial reduction in construction costs, was turned down on the advice of United States advisors to the project. Since Blast Furnace cement is little used or known in the United States its use in Mexico was similarly curtailed.

57/ The Head of the Engineering department volunteered that he shared this responsibility with the Head of the Quality Control department, confirming that the chemical engineer in charge of quality control has technical functions beyond those normally associated with such a department.

interest in two plants in Mexico. The same company also supplied the software for the computer which, as we discussed in Section II, was far from behaving in an entirely satisfactory way.

The majority of the execution work connected with new investment projects are contracted out to outside firms because the Engineering department lacks the personnel to mount a design team or to supervise the montage, civil works, etc. Putting the plant on stream and much of the plant design was left to the machinery suppliers. According to members of the Engineering department the role of outside technical assistance will diminish as the department develops its own skills and experience; however in the foreseeable future external dependence is likely to continue.

Technical departments at plant level

The technical departments at the plant, as opposed to the company, are depicted in fig. 7. The staffing structure of these departments was enumerated earlier in this section. As we noted earlier, this plant is run as two separate plants and the production depatment is split into two separate sections with both technical staff and shift workers being assigned to one or other of the plants. In contrast to other plants where the engineers in charge of the production departments are mechanical engineers both the superintendants in the Production department at this plant were chemical engineers, perhaps reflecting the supremacy of the Chemical/Quality Control department at this firm.

Maintenance department. An interesting aspect of the technical departments at this plant is the expanded maintenance department which has been set up within the last three years. The department consists of seven engineers and twenty two "officials" who are responsible for the implementation of the preventive maintenance system described in Section II. The whole preventive maintenance programme was suggested to the firm by their major machinery suppliers FLS and the firm has a four-year contract with the Danish firm for assistance with the design and implementation of the preventive maintenance programme. This contract covers all aspects of the maintenance programme from recording the information about the machinery and equipment installed at the plant, to analysing the relevant programming and planning the execution of the programme with conventional planning techniques such as flow diagrammes, Critical Path, etc. The contract also covers the necessary training of the technical staff. However it is intended that the maintenance programme being implemented at this plant will be a pilot project and that at a later stage it is intended that similar programmes be applied in other plants in the group using the expertise and know-how accumulated in the pilot project without further technical assistance.

Innovation

At the plant level there was no evidence of interest in innovations - either product or process innovations - apart from the concern with the maintenance programme and the conviction that the maintenance programme would be an economic advantage to the plant.

Technical capacity in Firm C

This firm is apparently at a transitional stage in developing its internal technical capacity, largely because of the rapid rate of growth it has undergone in recent years and the subsequent reorganisation it had to suffer to adapt itself to the new plants and capacity it has acquired. At present the technical level of the various departments is very uneven. In the engineering departments there was a clear admission that much of the engineering tasks connected with new investment design and execution was not even attempted by the firm. The same departments demonstrated an uncritical faith in their major machinery suppliers which may have been based on satisfactory past experience, though the hypothesis cannot be rejected that it is based on lack of knowledge or sufficient interest in investigating alternatives.

On the other hand in terms of long term policy there were certain clear policy decisions which indicated that the firm intends to develop its technical capacity to meet its requirements in the future. The Quality Control department was concerned with the development of special cements and the introduction of non-portland cements in the Mexican market and elsewhere which would result in considerable fuel and raw materials savings. All the major areas where the firm was currently seeking to improve the level of its technology with outside technical assistance were seen very much as pilot projects. Consultancy assistance in design of new projects at the firm's largest and most up-to-date plant were contracted in the hope that the expertise gained is due to serve the group's other plants with no additional outside assistance. The same policy was apparently behind the contract to implement the maintenance programme at the plant, as we discuss above.

It is therefore difficult to assess Firm C's technical capacity in terms of the five stage categories outlined in Monograph One. Existing equipment is clearly operated without outside technical assistance; however there was no evidence at the plant visited of any minor innovations or modifications being introduced to expand existing capacity on the basis of already installed equipment. New lines of production are not installed by the firm without assistance, which is required both from machinery suppliers and from foreign consultants although the Head Office's Technical department insists that lines of production at the smaller plants are designed without outside cooperation.

The attitude of this firm towards the idea of independence from technical assistance of any kind is in marked contrast to that of the two other firms in the sector discussed so far. The reliance on the machinery suppliers was not questioned; nor was the lack of design capacity in the Engineering departments. The experiment with automation of the kiln which had been largely a failure, was not being followed up by a more in-depth study of automation of the plant and interest in the latest process innovation - precalcination was limited on the grounds that it was not as yet a commercial proposition.

One of the reasons for this apparent disregard for the importance in terms of competitivity of technical innovations and the continuing reliance on one supplier is that until recently this firm had a near-monopoly in the North-Eastern region of the country and did not compete in other important national markets. However since the recent spate of mergers, take overs and plant expansions the firm now competes in almost all the nationally important markets. Nevertheless the termination of its protected position will take some time to influence its technical policy.

5. Technical capacity in Plant D

In discussing the technical capacity in Firm D there is a problem of separating the local technical capacity from that supplied directly or, al least made possible, by the parent company. In the discussion of Section II we have seen that the technology employed at this plant is the most sophisticated and technically efficient of all the cement plants visited in the course of this investigation. However the discussion in Section III of the channels of technology acquisition makes it quite clear the extent of the firm's dependence on the parent company for the technology - both process technology and control methods - employed at the plant.

Technical organisation of the firm

The technical organisation of the firm reflects the intimate intervention of the parent company in the running of the local subsidiary. The influence of the parent company in this respect is underlined when it is noted that

a) the senior technical personnel are Swiss; and
b) none of the technical staff working for the company when the Swiss company purchased its 48% share in 1963, are still employed at the plant.

The technical departments are organised under a (Swiss) Technical Director located at the Mexico City Headquarters of the firm (see fig. 8). Although he is legally an employee of the Mexican company his appointment was made by the parent company and his identification with the parent company is very strong. The Technical Services department at the Mexico City office coordinated the relations between the Mexican company and the parent company. Its direct responsibilities include the design and implementation of new projects and the establishment of control policies - quality control, automation procedures and maintenance procedures for the plant. There are only five members of the Technical department who are based in Mexico City, the rest of the engineers are based at the plant in the State of Mexico. Only a minimum engineering staff - civil and mechanical engineers who are employed in designing and modifying the plant under installation are retained at the Mexico City office for the purpose of collaboration with the machinery suppliers and with the Technical Services departments of the parent company.

The technical departments at the plant, while under the ultimate hierarchical control of the Mexico City office, are grouped under a Superintendant of Production who has control over all the production departments at the plant. The Production Superintendant, which is the most important technical post at the plant is filled by a Mexican engineer who was trained for twelve months at the parent company's headquarters in Switzerland.

The departments grouped under the Production Superintendant are Process, Quality Control, Instrumentation and Maintenance. The Process department is equivalent to the production department in other plants. It is staffed by four Production Chiefs who are chemical engineers as well as the three Shift Superintendants and the employees. The Quality Control department whose functions were described in Section 2 has a staff of two chemical engineers and three analysts in addition to the non-qualified workers. The Instrumentation department is in charge of the automation system and in particular its maintenance. It is headed by two electronic engineers who have a staff of eight. The other Maintenance departments - Mechanical and Electrical have a staff of two engineers each in the relevant disciplines, plus technicians and non-qualified employees.

All the staff in the Instrumentation department had been trained by the parent company at their Canadian Technical Department which is their centre for all activities on the American Continent. The Quality Control department had been set up by Swiss engineers and at the time of the plant visit there was an engineer from the company's Head Office training local staff in the use of the X-Ray analysis equipment. Before such equipment and the necessary analysis had been carried out on behalf of the Mexican company at the Canadian Headquarters. However the Mexican staff have now all undergone sufficient training, apart from the training programmes currently in progress and are competent to carry out the required procedures.

Role of parent company

Because of the interdependence with the parent company it is not possible to asses the technical capacity of the local company in the same way as with other plants. The efficiency of the plant, and the level of technology employed, is beyond doubt one of the highest in the Mexican cement industry (see Section II). But this technical efficiency was achieved with the aid of a large infusion of assistance from the Swiss parent company which is one of the world leaders in cement process technology. In the previous section we discussed the dependency of the Mexican plant in terms of the supply of data and programmes necessary to make effective the automatic control system installed at the plant. A similar dependency exists in terms of the relevant training of Mexican manpower to operate these systems. While high level technical training is available in Mexico, specific in-plant training is necessary to supplement the general disciplines and make the operative familiar with the machinery and processes he is required to operate and monitor. Nor would it be realistic to assume that once the first round of training personnel is completed the Mexican subsidiary will be self-sufficient in the provision of suitable engineers to run the installations. If the group continues to expand in order to maintain and increase their market share, more trained personnel will be required. Moreover this plant is likely to adopt process innovations in advance of its competitors and such innovatory action will come at the instigation of the parent company and will most probably involve a further influx of trained and experienced personnel

Innovation and research

Innovatory activity, some of which comes under the heading of Research and Development, is undertaken at this plant, although as in previous cases the capacity to carry out such activities is clearly derived from the parent company. As far as new cements and new uses of cements is concerned the reliance on the parent company is complete. A patent has just been bought which will enable the

Mexican subsidiary to manufacture Oil Well cement and it is considered more economic to acquire the patent from the parent company than to finance any autonomous research activity in the Mexican laboratories. Some problems which are specific to the fact that the plant operates in Mexico are tackled by the Mexican staff. One of these problems is the unsatisfactory nature of locally produced refractory bricks and the impossibility of importing them due to government regulation. In order to overcome these problems the firm has analysed a variety of imported bricks and cooperated with the refractory manufacturers in developing a local imitation of the imported ones.

Other minor innovations include the conversion of the original raw meal mills to finish mills in order to conform with the recently issued anti-polution legislation. The combination of more efficient dust reclamation and accurate process control has resulted in the actual capacity of plant being increased above the theoretical capacity by up to 20%.

Such minor innovations are a direct response to the Mexican manufacturing situation, and as such have to be carried out at the plant level even if the expertise originates abroad. Without doubt such innovatory activities yield a learning by-product for the Mexican staff involved and adds to the indigenous technical capacity in this respect. However, any assessment of the internal technical capacity of the Mexican subsidiary must conclude that to date such capacity is dependent on external stimulus and assistance in the selection of technical problems it chooses to solve, as well as in the nature of the innovatory activities carried out at the Mexican plant.

Other technical tasks implying certain degrees of technical capacity are similarly modified by the interaction with the parent company. The firm carries out its own pre-investment studies for new projects and negotiates directly with the suppliers the division of technical duties between the machinery manufacturers and the clients in the execution of the project. A substantial amount of the design engineering is carried out by the Mexican firm whose engineering staff are well trained, experienced and capable. However the parent company reserves the right to make the final decision on all investment expenditure and, under the terms of the technical assistance contract, the parent company can participate actively in the project design and negotiations with suppliers. In terms of innovation in the production process and process control the firm is apparently very dependent on the assistance of the parent company. The Technical department at the plant visited required the full time input of two engineers from Head Office for at least two years to set up the department and train local staff in the procedures necessary to monitor production, analyse bottlenecks, and identify the causes of low efficiency and of less-than-expected productivity.

Product research was virtually non-existent at the plant visited and an interview with the Laboratory department at the Mexican Head office indicated that new product development was not considered an economic proposition by the local firm, since they received patents for new cements from the parent company. This contrasts with the development activities carried out at one of the firms previously described (Firm A) which with inferior equipment carries out an ongoing Research and Development project to develop new cements for the Mexican market.

6. Plant E

The information obtained regarding Plant E was insufficient to carry out an analysis of technical capacity in the manner of the other plants visited. From the information at hand and that contained in the previous sections we are able to note that to a large extent this plant relies on machinery suppliers especially for the design and implementation of new investment projects. Installed equipment can be run by the firm's own staff without outside assistance though it must be remembered that the level of technology embodied in that equipment is not as advanced as in some other plants in the Mexican cement industry. Little interest was manifested in any kind of research or innovatory activity and what activities there were which were designed to maintain and increase the plant's market share were concentrated on sales and marketing techniques. The chemical engineer who is in charge of all plant operations (Gerente de Operaciones) has only been with the company some two years - he was brought in to revitalise the company and increase its influence in the national market following the administrative separation of this plant from other plants in the same group. The previous experience of this engineer has not been in the cement but in the chemical industry and he tends to approach technical problems with a pragmatic viewpoint not often seen in the cement industry. Nevertheless his knowledge of technical innovations in the sector in general is very up-to-date and the decisions not to adopt certain process innovations - such as automation or pre-calcination are based on a rational assessment of the plant's operations and staff.

7. Summary and interpretation of information regarding internal technical capacity of the five plants/companies visited

The information we obtained regarding various factors which we included in our assessment of internal technical capacity enables us to make some relative assessments of the nature of technical capacity in each firm and the relationship between that capacity and explanatory factors like ownership structure, participation of foreign consultants, technical organisation, etc.

However, the information also points up the intense difficulties of making quantitative assessments of technical capacity. One measure of technical capacity would be to calculate the number of qualified engineers employed by the plant and weight this according to its size. The first problem here is how to compute the technical staff which are located at the group's Head Office and which serve other plants in the group as well,even though their efforts in many places may well be concentrated on the largest plant in the group. Disregarding this and calculating the entire engineering staff at the plant plus headquarters in relation to the productive capacity of the largest plant in the group we find that Plant A has one engineer per 32,450 tpy capacity; Plant B one per 36,666 tpy; Plant C one per 46,200; and Plant D one engineer for 64,200. If we use these ratios as a measurement of technical capacity we find that there is the highest concentration of technical capacity in Plant A and the lowest in Plant D.

However we have to consider the possibility of there being economies of scale which enable the internal technical capacity of a firm/plant to be maintained with no increase in technical staff over a larger productive capacity.

Since Plant A's capacity in 1976 was lower than that of any of the other plants for which this ratio has been calculated we could assume that, following the increase in capacity at Plant A currently under construction, the engineer/ capacity ratio will drop considerable since few extra engineers will need to be recruited to run the expanded plant.

Another reason for the apparent discrepancy in these ratios is that Plant D is the only one in the sample for which the engineering staff serves just this individual facility and no other in the group. In this situation it is reasonable to assume that extra engineering staff at the other plants' headquarters are occupied at least some of the time in technical matters concerning other plants in the group. Also there is the problem of "quality" of technical staff. Fig. 4 (Section II) shows that in terms of technical efficiency Plant D is in most respects more advanced than the other plants in the sample. The subsequent analysis in Section III and IV shows that much of Plant D's technical capability has been trained by its foreign parent company and that the foreign firm provides many technical services which have greatly assisted the plant to reach the standards of technical efficiency indicated by these figures. Furthermore there is also the question of different technology being employed at the different plants, some of which is more efficient in terms of unit output than others.

A more fruitful approach and one which is in accordance with the main directions of the ECLA/IDB overall research project is to try to assess technical capacity in terms of the ability of the firm to assimilate major innovations generated elsewhere and their ability to generate local innovations in the form of minor modifications to process equipment and control and of new product research and development for the local market. In the context of this study it became clear that the nature of innovation in cement producing technology has been such that local Mexican producers have found it necessary to consciously organise their technical departments in order to manage complex systems of process and quality control, automation, maintenance systems and new product development. Not all firms have approached this problems in a direct manner. Firm A, in spite of its relatively small size and less advanced technology (see Section II), has evolved an organisational structure which is aimed at maximising the internal technical capacity on two important aspects: firstly, the whole area of new investment management including design, procurement, construction, supervision and putting on stream of new plants has been for some years coordinated by the New Expansions department which is a technical group not seen in any other plant visited. The existence of this department, as well as being a rational response to the obvious problems of investment management and implementation in the face of increasingly complex and costly investment procedures, also demonstrates a realisation of the importance of "learning-by-doing" and thus the need to systematise the learning procedures in order to maximise the benefits for the firm and minimise the costs of acquiring such learning.

The Operations department recently set up at the Plant A has a more specific function: that of devising minor innovations into the production procedures of the plant in order to increase the technical efficiency of the installed machinery and thus to increase its productivity. In addition to the work of this department which as we have seen has already resulted in important productivity increases, the laboratory attached to the Quality Control department has developed new products for the Mexican market without the aid of purchased foreign know-how or extremely sophisticated equipment.

Plant B, together with the whole group to which it belongs is also engaged in reorganisation to maximise the performance of its technical resources. The autonomy of this firm is to some extent limited by its association - formal and informal - with its foreign parent company. For this reason no new product research is undertaken in Mexico and the parent company's agreement is necessary for major items of policy or equipment acquisition. Nevertheless there has recently been a recognition within this firm of the importance of the two aspects of technical capacity mentioned with reference to Plant A - namely, new investment management and productivity of the existing facilities. With reference to the former aspect the firm has come to realise that the learning experience involved in setting up new plants cannot be obtained outside the context of the operating conditions of the plant, although the knowledge of new techniques and experience in negotiating with clients and management of the planning and implementation aspects of new projects is also important. The setting up of a Task Force to manage the new investment proposed in the North is intended to be an experiment to find the appropriate organisational form which will combine both technical knowledge on the part of the Head Office staff and the experience of operating conditions and problems held by the local staff. Significantly the new plant manager is to head up the Task Force and to be involved in the project management from the planning stages.

Plant B's concern with productivity and process control is shown by the establishment of the Technical department. Although this appears to have been instigated by the parent company and the staff of the Technical department are being trained by personnel from the foreign firm, it nevertheless represents a rational approach to the problems of improving productivity at the plant and of training the local engineers in techniques of process control prior to the introduction of more sophisticated automation.

Plant C is part of a group which has undergone extraordinary growth in recent years and is still in the process of reorganisation in order to manage both its expanded productive capacity and the sophisticated machinery and control systems it is purchasing from its machinery suppliers. As yet the organisation of the firm does not reflect a conscious attempt to separate out research, control and innovatory activity from operational production departments and there was no evidence to suggest that studies to improve productivity and efficiency (other than new maintenance systems) nor to improve control and learning from new investment management was a direct part of the firm's technical strategy. There was still a substantial reliance on foreign technical assistance both from the machinery suppliers and international consultants to solve technical problems and make good the firm's shortfall in technical capacity for design and implementation of new productive capacity and new systems of production control. However there was considerable, and in the Mexican context, unusual emphasis on new product development and the functions of the quality control laboratories had been extended from the operational functions common to the other plants to include a substantial amount of research and development activity for new product development.

Plant D, which is the most up-to-date plant in terms of technology and process control systems employed, relies to a very large extent on the technical resources of its parent company. The firm has no overt strategy of systematic learning through autonomous activities in investment management, productivity innovations and new product developments. All technical know-how and experience in these matters is obtained from the international group which owns this plant. In spite of this the firm's local staff receives intense training both at the parent company's headquarters and at the plant itself. Such training is related with the management of the modern equipment and control systems, all of which results in a net increase in the technical capacity of the personnel concerned.

Section V

LEVEL OF TECHNOLOGY AND INTERNAL TECHNICAL CAPACITY IN THE MEXICAN CEMENT INDUSTRY

In this paper we have examined the structure of the Mexican cement industry, the level of technology and the channels of technology transfer to the industry and have discussed various indicators of technical capacity within each firm. We have found that the level of technology incorporated into the industry did not diverge from the standard process technology used by the industry at an international level, with the exception of innovations such as the Japanese-developed precalcination system which has not as yet won universal acceptance in the cement producing field. The greatest differences in technology between the different Mexican producers relates not to core technology but to process control techniques such as automation systems and quality control and maintenance systems. In this respect we found that there was considerable reluctance in the Mexican industry to adopt process control systems, - especially automation and, to some extent, programmed preventive maintenance systems - with the exception of those firms which were strongly linked with foreign firms whose activities in the cement field were centred on sophisticated process control techniques.

Although the core technology used in cement production (see Monograph One) and incorporated into the Mexican industry is clearly exclusive to the cement industry, many methods of process control and quality control are common to different branches of industry. Nevertheless the case study at an industry level enables us to see how such innovations which have been developed in the context of the international industry, together with innovations in cement-related process technology, are incorporated into the local industry, and what limitations these impose on the possibility of domestic innovatory and research activity.

The analysis contained in this paper illustrates the predominance of imported technology in the cement sector, as well as the external origin of both, core technology and the application of control systems. However within these structural limitations we have seen that there are areas in which local innovation is not only possible but in a sense essential if local producers are to be able to make their imported production systems effective in their actual locations in Mexico. In at least two firms we saw evidence of how systematic monitoring and studying of the operation of major and minor parts of the process machinery has led to an increase in the productivity of different machines, and ultimately to an improvement in the efficiency and in the effective output capacity of the plant as a whole. It is important to stress that this kind of innovatory activity, which differentiates the passive importer of technical systems and equipment from the active integrator of technology, is not dependent upon the geographical source of the equipment or know-how utilised. 58/

58/ In Mexico, as in other Latin American countries, serious consideration is at present being given to the domestic production of capital goods. Among them those demanded by the cement industry (this industry is being studied as part of a wider program sponsored by UNIDO, and being carried out in conjunction with various research departments of Nacional Financiera S.A.). Such

Throughout this paper we have used various indicators to assess technical capacity in local cement firms. Innovatory activity in various aspects of production control and product development was just one of these indicators. Others included the organisation of technical departments within the firm and their rationality with reference to the technical functions demanded by production, the number of qualified technical staff serving the technical departments, and the relative autonomy of the firm vis-a-vis the machinery supplier and outside consultants in the selection of new investment capacity and the organisation of new investment projects. We also stressed that the technical capacity of a firm should be assessed in relation to the situation of that firm - i.e. the kind of technology and process control employed by the firm, the rate of growth and thus the frequency of new investments and the particular objectives of the firm at any period in time with regards to competition, its new product development and long tern technical strategy, etc. In the context of these factors which can alter the kind of technical capacity relevant to a particular firm at a particular time we can abstract an aspect of technical capacity which in a sense redefines the meaning of innovation and technical learning in the Mexican context: what we are trying to assess in this situation is the ability to maximise the technical learning opportunity provided by the acquisition of imported technology in order to maximise control and thus productivity derivable from any set of capital goods.

The concept of technical capacity we have built up in relation to Mexican cement firms is a far cry from the crude idea of Latin American firms being passive receptors of imported technology. However we have also observed substantial differences between firms and can therefore generate some tentative hypotheses regarding the kinds of situations which are conducive to the development of local technical capacity and those which tend to restrict or at any rate not to stimulate such developments.

One of the factors which has evidently had a great effect upon the Mexican cement firms hereby studied is the role of the foreign parent companies and, to

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policy option has its own merits in terms of balance of payments effects, as well as in terms of the learning opportunity and the linkages with the steelmaking and heavy engineering sector. Also, and regardless of how the technology for the cement capital goods production is acquired, the net effect of such policy option on the technical capacity of the capital goods sector must be positive.

However in terms of the kinds of innovatory activities we have been concerned with here -which consist of relevant knowledge and technical know-how necessary to plan investment projects, select technology, manage and control the project through the whole construction phase and operate that series of capital goods in the manner most productive in the particular situation of the plant,such innovation and technical capacity is not affected by the possibility of local manufacture of capital goods. If all core technology were fabricated in Mexico the same problems of investment management, plant control and productivity improvement would be posed at plant level to the individual cement producer.

a lesser extent, of foreign consultants. In the case of the two firms, B and D in our sample - both subsidiaries of foreign firms - we observed that the presence of foreign participation does not necessarily have a similar effect in all cases. Both Mexican firms had a formal technical assistance contract with their parent companies and both had considerable communication and guidance from headquarters. However, in the case of firm D the role of the parent company was much more active and direct; none of the former technical staff at the plant before the foreign firm took over had been retained, and the plant, together with its technology and management methods, had been entirely re-designed according to the practice of the parent company. All technical problems which were outside routine operational circumstances were referred to the parent company and there was a constant interchange of personnel for advice/training between the two firms. Whatever development of technical capacity there was in terms of training and experience of the local personnel, came as a by-product of the main functions of the organisation of the firm and plant. Plant B, on the other hand, has been in existance since the beginning of the century and has always coexisted with its British parent company. This firm too has a formalised technical assistance contract with the parent company and relies on the parent company for non-routine technical analysis and for certain laboratory and testing facilities which do not exist in the firm's laboratories in Mexico. There is also considerable interchange of personnel for training and consultancy purposes. However the change in the company's ownership structure - i.e. the reduction of the British company's holdings to less than fifty percent, together with the amalgamation with one of Mexico's largest construction conglomerates - has given an impetus towards the rational development of the firm's own technical capacity and the organisation of its technical departments, with the explicit purpose of increasing the sphere of technical independence. All this illustrates how the firm has been able to develop its own technical capacity in spite of its close links and technical assistance contract with its parent company.

In order to understand more clearly the difference between the situation of these two subsidiaries we need to understand quite a lot more about the nature of the respective parent companies. As we mentioned earlier in this paper the company which partially owns Plant D is a Swiss multinational whose activities in the cement field are characterised by the application of sophisticated process control and automation techniques. Traditionally this company has been operating mainly in South and East Africa and in Europe but during the last ten years it has made a substantial inroad into Latin America. Apart from a number of technical assistance contracts with firms in which it has no capital participatory relationship, this company has investments in cement plants in Costa Rica, Peru, Brazil, and Colombia, as well as in Mexico. These investments are comparatively recent, and the pattern of intervention nearly always follows the path taken at Mexico's Firm D - namely,once participation has been bought the firm is expanded and completely modernised very often abandonning the old productive capacity in favour of a totally sophisticated and integrated modern plant.

The British company on the other hand, though traditionally one of the market leaders in the international cement industry does not have the dynamic technical profile that the Swiss company has. The British company has much production experience in East and West Africa and in the former Asian colonies, and more recently has invested in the Middle East. However the process control and automation systems used at its plants are largely purchased from other companies rather than developed directly by the firm itself. Moreover its long association with the Mexican firm gave way to a most special relationship. The Mexican firm has established certain areas of autonomy over the years, particularly in earlier periods where the firm was the market leader in Mexico with little competition from other companies threatening either its market share or its reputation for quality of product. The intensification of competition in the late 1960's and the 1970's has altered that situation and made it necessary for the Mexican firm to revise its technical standards and seek ways to improve its efficiency. This has been done partly with the assistance of the parent company - hence the technical assistance contract - and partly on the basis of the firm's preexisting technical departments. In this situation it just could not happen that the foreign firm found itself free to completely reorganise the plants or replace all existing technical staff, as happened in Firm D.

There is also variation between technical capacity of firms not connected with foreign capital. In this study we observed how the firm which was organised as a cooperative not only developed an extremely independent and self-reliant attitude towards minor innovations, new product development and investment management, but was also less concerned with the substitution of labour by sophisticated control methods, and more interested in improving the productivity of labour by improving working conditions and workers' motivations towards efficiency of the plant.

Government policy towards technology transfers and acquisitions in many Latin American countries is mainly concerned with the regulation of payments for technical assistance contracts, patents and licences which has been a major source of profit repatriation for multinational companies in the past. While this is a necessary area for government action it is also necessary for national technology policies to go beyond negative restrictive measures to create legislation and operative norms which positively stimulate the development of indigenous technical capacity both in the private sector as well as in government-sponsored research institutions. One aspect of this would be to ensure that those civil servants employed to monitor imports of technology and know-how and their relevant payments should have sufficient knowledge of the sector and processes involved to be able to assess whether the technology being acquired, the manner in which it is to be used, etc., will stimulate the development of internal technical capacity of the importing firm. This is particularly important with reference to the purchasing of automation systems or other systems for which not only the hardware (computer) but also the software (programmes) are purchased from external sources. In such a situation there is a danger that the software would turn to be inappropriate to the production situation of the purchasing firm which does not possess sufficient internal technical capacity to make good the discrepancy (the case of Firm C in our sample). There is also another kind of problem attached to the importing of systems for which the data and software is supplied externally. This is the case when the importing firm is so dependant on the foreign supplier for the continuing provision of information, programmes and technical assistance to make the system operative that there is little indication that an effective technology transfer is taking place in the sense that local national technical personnel are acquiring the skills and experience necessary to dispense, in a reasonable time period, with the external technical assistance.

The Mexican legislation on the transfer of technology, although representing an important step forward in an attempt to devise a relevant policy on regulating technology transfer to Mexican industry fails to take note of a major issue in this field; that is the transfer of know-how and skills implicit in a purchase of productive equipment from a machinery supplier. According to the legislation only technology which is paid for separately from an equipment purchasing contract is under the terms of reference of the law so that the whole area of investment planning and management is excluded from consideration. By analogy, the installation of control systems - maintenance and automation - are also excluded from the terms of the legislation. Such a hiatus in the control of importing of technology should be rectified but can only be effectively controlled when the personnel with sufficient knowledge of industrial sectors and industrial control processes are available to the government.

Table 1: The Mexican cement industry:
distribution of installed capacity, market shares and production, 1975

Companies and plant locations	Name of factory/firm	Installed capacity Tons a/	Installed capacity % b/	Production Tons a/	Production % b/
	I. Tolteca group				
1) Atontonilco, Hgo.	Div. Atontonilco de Tula	1,320,000	10.1	880,007	7.7
2) Tolteca, Hgo.	Div. Tolteca	669,900	5.1	504,941	4.4
3) Zapotiltic, Jal.	Div. Jalisco	495,000	3.8	535,251	4.7
4) El Fuerte, Sin.	Cementos Sinaloa S.A.	330,000	2.5	380,274	3.3
5) Mixcoac, D.F.	Div. Mixcoac	313,500	2.4	235,050	2.1
6) Marmol, Sin.	Cementos del Pacífico S.A.	165,000	1.3	152,084	1.3
7) Puebla, Pue.	Cementos Atoyac S.A.	132,000	1.0	154,860	1.4
8) Hermosillo, Son.	Cementos Portland Nacional S.A.	112,200	0.9	104,121	0.9
	TOTAL	3,537,600	27.2	2,946,588	25.8
	II. Cementos Mexicanos group				
1) Monterrey, N.L.	Unidad Monterrey	1,386,000	10.7	845,695	7.4
2) León, Gto.	Cementos Maya S.A., Div. Cementos Portland	495,000	3.8	496,056	4.3
3) Torreón, Coah.	Unidad Torreón	330,000	2.5	340,120	3.0
4) Mérida, Yuc.	Div. Mérida	207,900	1.6	218,015	1.9
5) Valles, S.L.P.	Unidad Valles	165,000	1.3	173,457	1.5
6) Tlaquepaque	Cementos Guadalajara S.A.	660,000	5.1	560,374	4.9
7) Ensenada B.C.	Cementos Guadalajara, Div. Cementos California c/	189,750	1.5	355,227	3.1
8) Monterrey, N.L.	Cementos del Norte	-	-	-	-
	TOTAL	3,433,650	26.5	2,988,944	26.1
	III. Anahuac group				
1) Barrientos, Mex.	Cementos Anahuac S.A.	1,914,000	14.7	1,371,220	12.0
2) Tamuín, S.L.P.	Cementos Anahuac del Golfo S.A. d/	660,000	5.1	691,615	6.0
	TOTAL	2,571,000	19.8	2,062,835	18.0
	IV. Cruz Azul group				
1) Cruz Azul, Hgo.	Cruz Azul S.C.L. Hgo.	973,500	7.5	920,830	8.0
2) Lagunas, Oax.	Cruz Azul S.C.A. Oax.	495,000	3.8	477,788	4.2
	TOTAL	1,468,500	11.3	1,398,618	12.2
	V. Apasco group				
1) Apasco, Mex.	Cementos Apasco S.A.	680,460 d/	5.2	807,991	7.1
2) Orizaba, Ver.	Cementos Veracruz S.A.	297,000 d/	2.3	296,720	2.6
	TOTAL	977,460	7.5	1,104,711	9.7
	VI. Chihuahua group				
1) Chihuahua, Chi.	Cementos Chihuahua	297,000	2.3	212,917	1.9
2) Ciudad Juárez, Chi.	Cementos Chihuahua	115,500	0.9	89,671	0.8
	TOTAL	412,500	3.2	302,588	2.6
	VII. Independents				
1) Hidalgo, N.L.	Cementos Hidalgo S.C.L.	264,000	2.0	282,596	2.5
2) Acapulco, Gto.	Cementos de Acapulco	198,000	1.5	167,289	1.5
3) Cuernavaca, Mor.	Cemento Portland	145,200	1.1	166.083	1.4
	TOTAL	607,200	4.7	615,968	5.4
WHOLE COUNTRY		13,010,910	100	11,430,252	100

Sources: Capacity: Calculated from Table 6 p. 28, El Mercado de Valores, Suplemento al Nº 11, 1976, "Aspectos básicos para la programación de la industria del cemento". Production: Calculated from figures published by the Camara Nacional del Cemento, Producción de Cemento Portland Gris, Mexico D.F., 1975.

a/ Tons: all measurements in this paper are in terms of metric tons (tonnes). b/ %: all in this table are calculated as % of Total industry capacity or production. c/ This plant, although part of the Cementos Mexicanos group is excluded because it produces mainly blast furnace slag cement using clinker produced at the Monterrey plant of Cementos Mexicanos. Total installed capacity at Cementos del Norte is 264,000 tpy. d/ Denotes plants in the process of expansion and near completion at December 1975.

Table 2: Demand for cement in Mexico: total consumption. 1940-1975

(metric tons)

Year	National domestic production	Imports	Exports	Total apparent consumption
1940	484,992	4,476	949	488,519
1945	808,318	108,958	-	917,276
1950	1,387,544	2,956	21,325	1,369,175
1955	2,085,652	873	49,610	2,036,915
1960	3,086,162	314	920	3,085,520
1965	4,198,546	52	1	4,198,597
1970	7,179,981	3,449	97,837	7,085,593
1971	7,362,419	3,896	158,708	7,207,607
1972	8,602,196	2,609	267,070	8,337,735
1973	9,787,269	1,370	168,668	9,616,971
1974	10,594,918	3,249	196,096	10,402,071
1975	11,611,956	n.a.	n.a.	n.a.

Source: Cámara Nacional del Cemento: Datos estadísticos sobre producción, importación, exportación y consumo de cemento gris en la República Mexicana 1935-68.

Table 3: Growth of productive capacity. 1940-1974
(metric tons and percentages)

Year	Total installed capacity a/	Total production	Capacity utilisation %
1940	564,300	484,992	85.9
1945	1,156,650	808,316	69.9
1950	1,999,800	1,387,544	69.4
1955	2,768,700	2,085,652	75.3
1960	3,908,850	3,086,126	79.0
1965	5,136,450	4,198,546	81.7
1970	8,837,400	7,179,981	81.2
1971	9,764,700	7,362,419	75.4
1972	10,647,450	8,602,196	80.8
1973	12,858,450	9,743,175	75.8
1974	13,254,450	10,594,918	79.2

Source: See Table 2.

a/ To be consistent we have recalculated all capacity estimates on the basis of 330 working days per year which is the standard measurement nos used. However such a standard is unrealistic up to the 1960's and consequently capacity utilisation is underestimated for the earlier years.

Table 4: Relative changes in market shares of major cement groups and other companies 1965-1975 according to production

(metric tons and percentages)

Groups	1965 Tons	% of total	1970 Tons	% of total	1975 Tons	% of total
1. Tolteca	1,112,912	26.8	1,795,419	25.2	2,946,588	25.7
2. Cementos Mexicanos	357,925	8.6	858,727	12.1	2,988,944	26.1
3. Anahuac	512,053	12.3	1,000,692	14.1	2,062,835	18.0
4. Apasco	386,862	9.3	597,055	8.4	1,104,711	9.6
5. Cruz Azul	460,085	11.5	797,193	11.2	1,398,618	12.2
6. Others a/	1,321,196	31.8	2,071,147	29.1	948,028	8.2
WHOLE INDUSTRY	4,151,033	100	7,120,233	100	11,449,724	100

Source: See tables 1 and 2.

a/ The relative loss of markets by the firms not part of any of the five main groups is partly explained by the faster growth of the main groups and partly by the fact that many previously independent companies were absorbed by the major groups during the decade under analysis.

Table 5: Relative changes in market shares of major cement groups and other companies 1965-1975 according to installed capacity

(metric tons and percentages)

Groups	1965 Installed capacity: Tons	% of total	1970 Installed capacity: Tons	% of total	1975 Installed capacity: Tons	% of total
1. Tolteca	1,407,450	29.3	2,247,300	26.5	3,537,600	27.2
2. Cementos Mexicanos	429,000	8.9	966,900	11.4	3,433,650	26.4
3. Anahuac	594,000	12.4	1,171,500	13.8	2,571,000	19.8
4. Apasco	470,250	9.8	833,250	9.8	977,460	7.5
5. Cruz Azul	488,400	10.2	907,500	10.7	1,488,500	11.3
6. Others	1,417,350	29.5	2,364,450	27.8	1,022,700	7.9
WHOLE INDUSTRY	4,806,450	100	8,490,900	100	13,030,910	100

Source and notes: See table 4.

Table 6: Annual rates of growth of major cement groups 1965-1975

(percentages)

Groups	Production a/ 1965-1975 %	Production a/ 1965-1970 %	Production a/ 1970-1975 %	Installed capacity a/ 1965-1975 %	Installed capacity a/ 1965-1970 %	Installed capacity a/ 1970-1975 %
1. Tolteca	10.2	10.0	10.4	9.6	9.8	9.5
2. Cementos Mexicanos	24.0	19.1	28.0	23.0	17.7	29.0
3. Anahuac	16.0	14.3	15.6	15.8	14.5	17.0
4. Apasco	11.0	9.1	13.1	7.5	11.3	6.9
5. Cruz Azul	11.7	11.6	11.8	11.7	13.2	10.1
6. Others	-3.3	9.4	-14.7	-3.2	10.8	-15.4
WHOLE INDUSTRY	10.9	11.4	9.9	10.5	12.0	8.9

Source: See tables 4 and 5.

a/ Growth rates are average anual cumulative growth rates.

Table 7: Mexican cement industry: regional distribution of production 1975

(metric tons and percentages)

Region, group and plant		Production tons	Capacity tons	Production as % of regional production	Capacity as % of regional capacity
I. CENTRAL REGION		5,537,078	6,643,560	100.0	100.0
1. Tolteca	SUB-TOTAL	1,774,858	2,435,400	32.0	36.7
Atontonilco		880,007	1,320,000	15.9	19.9
Tolteca, Hgo.		504,941	669,900	9.1	10.1
Mixcoac, D.F.		235,050	313,500	4.2	4.7
Puebla		154,860	132,000	2.8	2.0
2. Cementos Mexicanos	SUB-TOTAL	496,096	495,000	9.0	7.4
León, Gto.		496,096	495,000	9.0	7.4
3. Anahuac	SUB-TOTAL	1,371,220	1,914,000	24.8	28.8
Barrientos, Mex.		1,371,220	1,914,000	24.8	28.8
4. Cruz Azul	SUB-TOTAL	920,830	973,500	16.6	14.7
Jasso, Hgo.		920,830	973,500	16.6	14.7
5. Apasco	SUB-TOTAL	807,991	680,460	14.6	10.2
Apasco, Mex.		807,991	680,460	14.6	10.2
7. Independents	SUB-TOTAL	166,083	145,200	3.0	2.2
Cuernavaca, Mor.		166,083	145,200	3.0	2.2
II. INTERMEDIATE CENTRAL REGION		865,072	825,000	100.0	100.0
2. Cementos Mexicanos	SUB-TOTAL	173,457	165,000	20.0	20.0
Valles, S.L.P.		173,457	165,000	20.0	20.0
3. Anahuac	SUB-TOTAL	691,615	660,000	80.0	80.0
Tamuin, S.L.P.		691,615	660,000	80.0	80.0
III. CENTRAL NORTHERN REGION		307,390	412,500	100.0	100.0
6. Grupo Chihuahua	SUB-TOTAL	307,390	412,500	100.0	100.0
Chihuahua, Chi.		217,719	297,000	70.8	72.0
Ciudad Juarez, Chi.		89,671	115,500	29.2	28.0
IV. N.E. REGION		1,468,411	1,980,000	100.0	100.0
2. Cementos Mexicanos	SUB-TOTAL	1,185,815	1,716,000	80.8	86.7
Monterrey, N.L.		845,695	1,386,000	57.6	86.7
Torreón, Coah.		340,120	330,000	23.2	16.7
7. Independents	SUB-TOTAL	282,596	264,000	19.2	13.3
Hidalgo, N.L.		282,596	264,000	19.2	13.3
V. N.W. REGION		826,202	796,950	100.0	100.0
1. Tolteca	SUB-TOTAL	636,452	607,200	77.0	76.2
El Fuerte, Sin.		380,247	330,000	46.0	41.4
Mármol, Sin.		152,084	165,000	18.4	20.7
Hermosillo, Son.		104,121	112,200	12.6	14.1
2. Cementos Mexicanos	SUB-TOTAL	189,750	189,750 a/	23.0	23.8
Ensenada, B.C.		189,750	189,750	23.0	23.8
VI. S.W. REGION		1,262,914	1,353,000	100.0	100.0
1. Tolteca	SUB-TOTAL	535,251	495,000	42.4	36.6
Zapotiltic, Jal.		535,251	495,000	42.4	36.6
2. Cementos Mexicanos	SUB-TOTAL	560,374	660,000	44.4	48.8
Tlaquepaque, Jal.		560,374	660,000	44.4	48.8
7. Independents	SUB-TOTAL	167,289	198,000	13.2	14.6
Acapulco Gto.		167.289	198,000	13.2	14.6
VII. SOUTHERN REGION		477,788	495,000	100.0	100.0
3. Cruz Azul	SUB-TOTAL	477,788	495,000	100.0	100.0
Lagunas, Oax.		477,788	495,000	100.0	100.0
VIII. GULF REGION		296,720	297,000	100.0	100.0
5. Apasco	SUB-TOTAL	296,720	297,000	100.0	100.0
Orizaba, Ver.		296,720	297,000	100.0	100.0
IX. PENNINSULAR		218,015	207,900	100.0	100.0
2. Cementos Mexicanos	SUB-TOTAL	218,015	207,900	100.0	100.0
Mérida, Yuc.		218,015	207,900	100.0	100.0
WHOLE COUNTRY: T O T A L		11,259,590	13,010,910		

Source: Calculated from "Aspectos básicos para la programación de la industria del cemento"; *El Mercado de Valores*, año XXXVI, Suplemento al N° 11 de 1976.

a/ Exact production figures for this plant are not known.

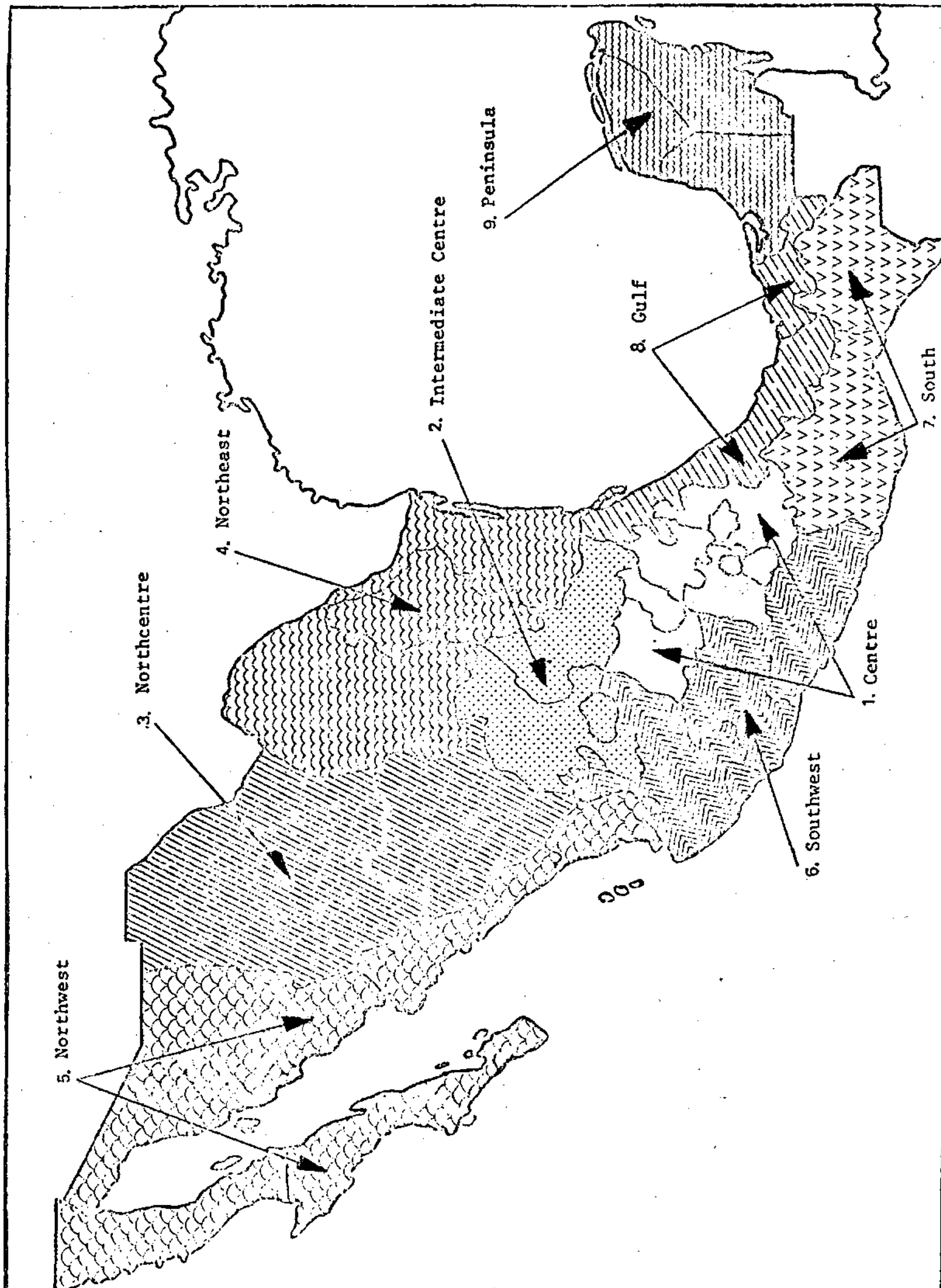
Table 8: Regional structure of production, consumption and installed capacity of Mexican cement industry 1975

(percentages)

Regions and states	Production % of total	Installed capacity %	Average consumption 1970-1975 %
1. Central	48.4	51.3	45.7
Distrito Federal	2.1	2.4	24.9
Mexico	19.0	19.8	8.0
Morelos	1.5	1.1	1.8
Guanajuato	4.3	3.8	3.5
Querétaro	-	-	1.6
Hidalgo	20.1	23.2	1.8
Puebla	1.4	1.0	3.4
Tlacala	-	-	0.7
2. Intermediate Central	7.6	6.3	3.3
Zácatecas	-	-	0.8
San Luis Potosí	7.6	6.3	1.6
Aguascalientes	-	-	0.9
3. North Central	2.6	3.2	4.2
Chihuahua	2.6	3.2	2.9
Durango	-	-	1.3
4. North East	12.9	15.1	12.4
Nuevo León	9.9	12.6	6.5
Coahuila	3.0	2.5	2.2
Tamaulipas	-	-	3.7
5. North West	7.7	6.0	9.0
Baja California	3.1	1.4	2.6
Baja California S.	-	-	0.5
Sonora	0.9	0.8	2.4
Sinaloa	4.7	3.8	2.8
Nayarit	-	-	0.7
6. South West	11.1	10.4	13.1
Jalisco	9.6	8.0	5.8
Colima	-	-	0.8
Mihoacan	-	-	3.8
Guerrero	1.5	1.5	2.7
7. South	4.2	3.8	3.9
Oaxaca	4.2	3.8	2.2
Chiapas	-	-	1.7
8. Gulf	2.6	2.3	6.7
Veracruz	2.6	2.3	5.4
Tabasco	-	-	1.3
9. Penninsular	1.9	1.6	1.7
Campeche	-	-	0.3
Yucatán	1.9	1.6	1.2
Quintana Roo	-	-	0.2

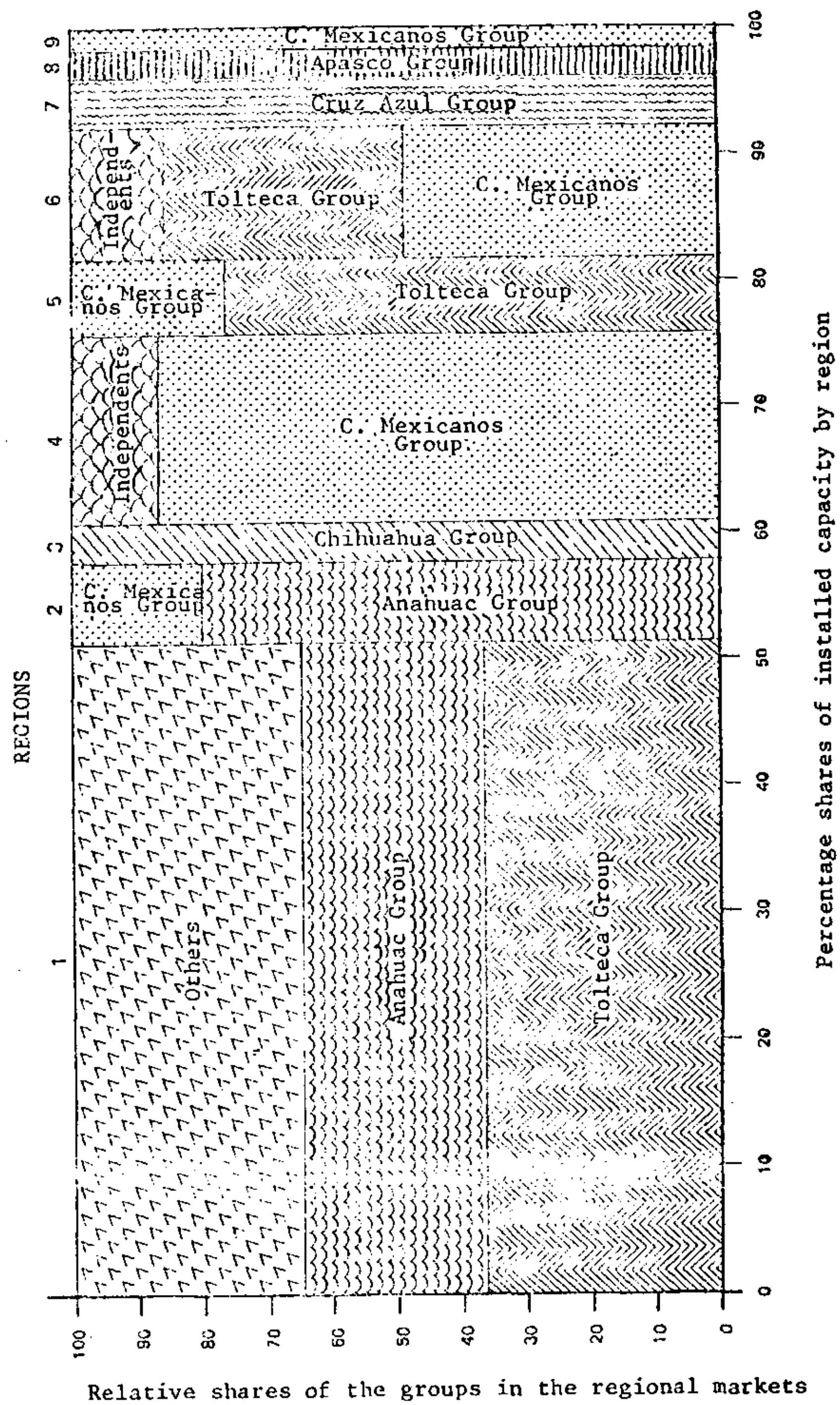
Source: Calculated from "Aspectos básicos para la programación de la industria del cemento"; El Mercado de Valores, Año XXXVI, Suplemento al Nº 11 de 1976, Table 7, p. 31 and Table 6, pp. 28-30.

Figure 1: Regional market division



Source: El mercado de valores, Año XXXVI, Suplemento al N° 11, Mexico, marzo 15 de 1976.

Figure 2: Market diferentiation



Source: El Mercado de Valores, Año XXXVI, Suplemento al N° 11, Marzo 15, 1976.

Figure 3: Technical parameters of five cement plants in Mexico

	Unit of measurement	Plant A	Plant B	Plant C	Plant D	Plant E
Fuel utilisation						
Whole plant:	Keal/kg.	930	1,028	975	889	1,040
Largest kiln:	Clinker	-	837	863	-	-
Electricity utilisation	Kwtt/ton cement	120	135 a/	125	112	110
Labour utilisation	Man hours/ ton cement	1.2	1.38	0.88	0.7	0.8
Raw materials utilisation	Raw materials/ ton cement produced	1.65	1.75	1.6	1.62	1.6

Source: Information given at company interviews.

Note: These figures, although given in good faith are not strictly comparable because of differences in production conditions and definitions, i.e. some of the labour utilisation figures include maintenance and quarry labour while others include only one of these activities. Differences in distribution methods also affect labour utilisation. In addition some firms include non-contract labour in their calculations of labour utilisation whilst others only use those on the permanent payroll. Further research would be necessary to eliminate these discrepancies and make the figures strictly comparable. Nevertheless they do give a good idea of orders of magnitude of the different technical parameters and in spite of interfirm differences in definitions etc., they also indicate which plants are the most efficient, which is useful in relation to the rest of the analysis on technical capacity and level of technology.

a/ The high power utilisation at this plant is partly explained by the changeover from one frequency to another during the period for which figures were obtained. Also the relatively low capacity utilisation at this plant increases this and other indicators of technical efficiency, in spite of the large scale of production at the plant.

Figure 4: Summary of newest technology used by five of the largest cement plants in Mexico 1976

Equipment	Plant A	Plant B	Plant C	Plant D	Plant E
Crushing equipment	Hazemag	Allis Chalmers	FLS	Moblie AC primary crushers & Hazemag	Hazemag
Raw Meal equipment	FLS	Polysius	FLS	Polysius	Polysius
Preheater/ kiln	Polysius	Polysius	FLS	Polysius Dopol	Polysius Dopol
Cooler	Fuller grate cooler	Fuller grate cooler	FLS Satellite	Satellite	Fuller/ Polysius Recupol
Cement grinding	FLS	FLS	FLS	Polysius	Polysius
Plant capacity tpy a/	975,000	1,320,000	1,386,500	990,000	1,914,000
Capacity of newest kiln tpd b/	700 c/	2,000	1,350	2,500	1,850

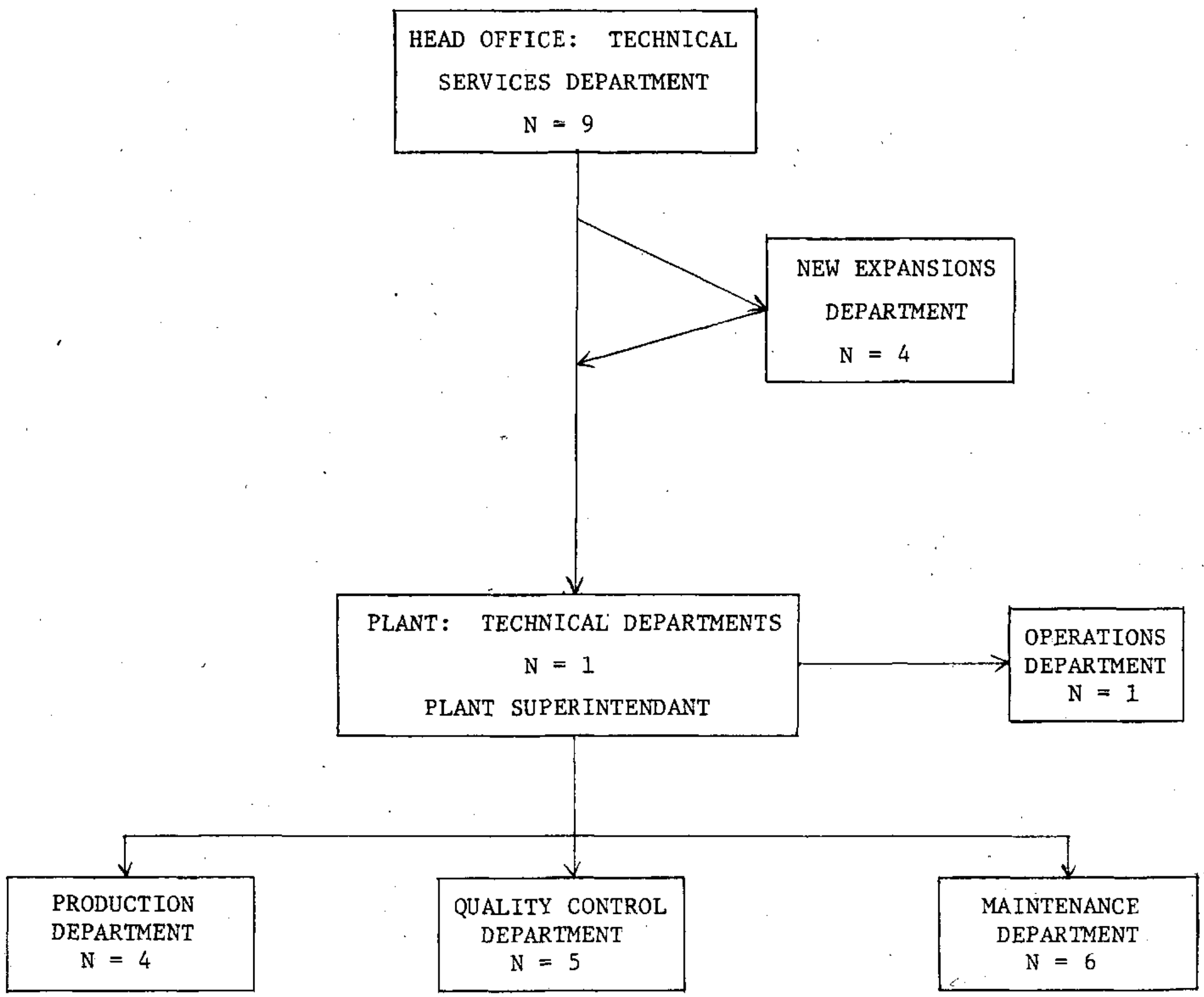
Source: Company interviews and El Mercado de Valores, Año XXXVI, Suplemento al Nº 11, Marzo 15, 1976, Table 4, pp. 24-26.

a/ Tpy = tons per year.

b/ Tpd = tons per day.

c/ New kiln of 2,400 currently being installed.

Figure 5: Organisation of technical departments. Firm A



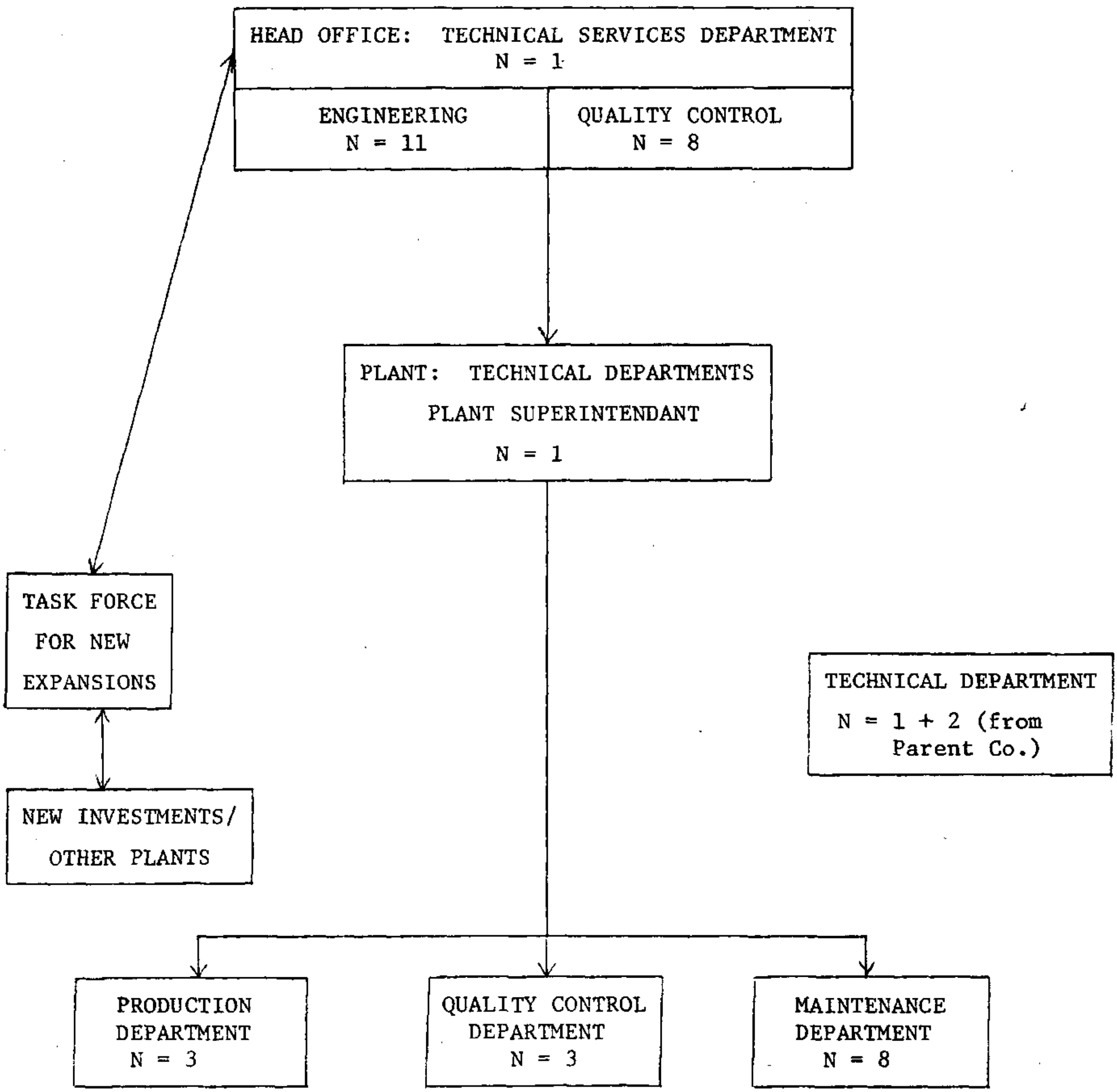
N = Number of qualified engineers in each department.

Total number of engineers: 30

Capacity of plant: 973,500 tpy.

Ratio of engineers to plant capacity: 1 engineer per 32,450 tpy.

Figure 6: Organisation of technical departments. Firm B



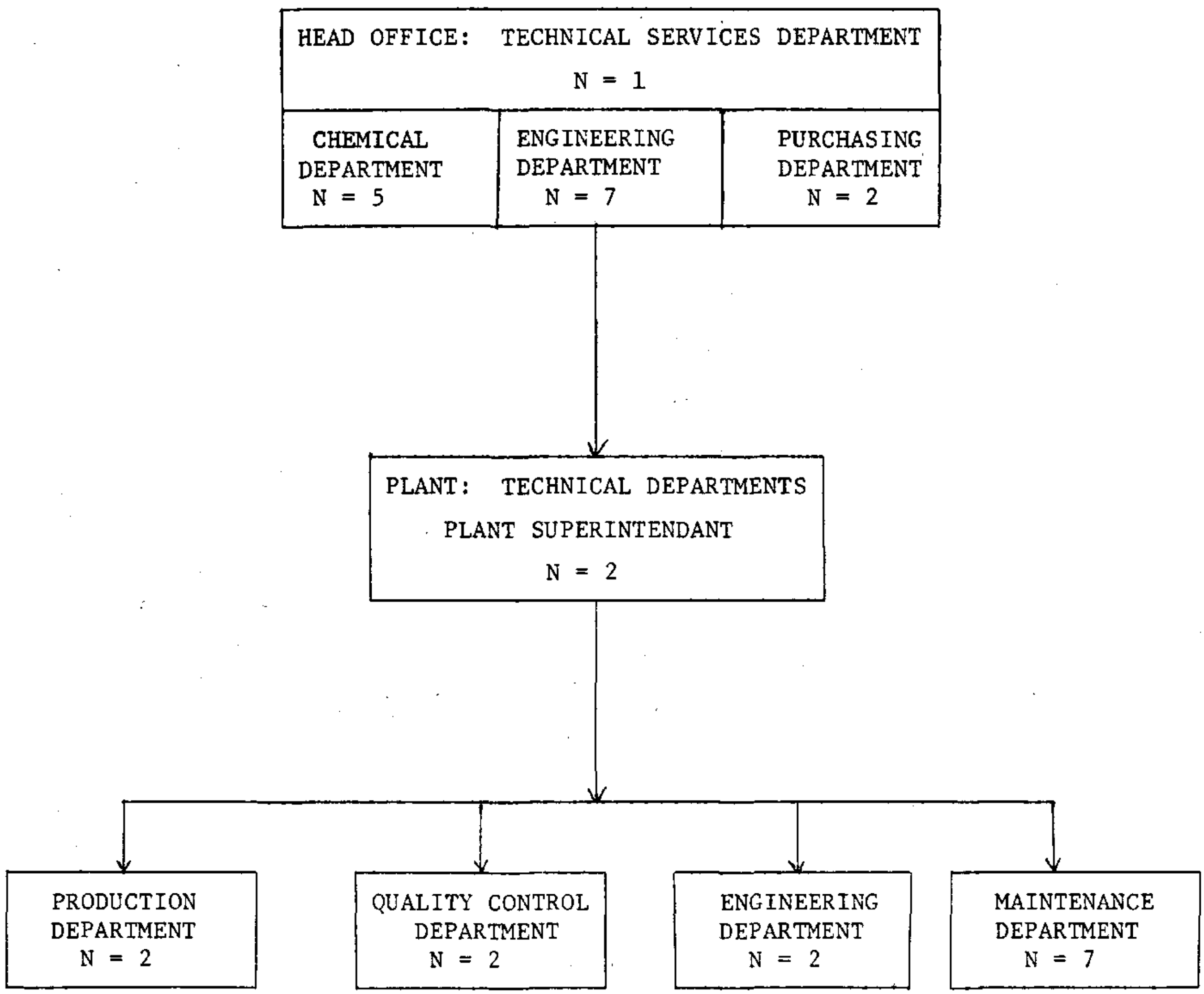
N = Number of qualified engineers in each department.

Total number of engineers: 36

Capacity of plant: 1,320,000 tpy.

Ratio of engineers to capacity: 1 per 36,660 tpy.

Figure 7: Organisation of technical departments. Firm C



N = Number of qualified engineers in each department.

Total number of engineers: 30.

Capacity: 1,386,000 tpy.

Ratio of engineers to plant capacity: 1 per 46,200 tpy.