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TECHNOLOGY, INNOVATION AND TRANSFER OF TECHNOLOGY IN THE CEMENT INDUSTRY

Ruth Pearson

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Oficina de la CEPAL en Buenos Aires
Cerrito 264, 5° Piso
1010 Buenos Aires, Argentina

PREFACE

Increasing research attention has been devoted in recent years to the technological and economic evolution of the Latin American cement industry. Quantitative studies, such as that of Carlos Diaz Alejandro 1/ which seeks to explain observed productivity differences between Latin American and extra-regional cement plants using the idea that these two types of plants operate with different production functions, and studies such as that of Eduardo Guimaraes and L. Gomes dos Reis 2/ concerned with the diffusions of innovations in the Brazilian cement industry, show that the exploration of this field is continuing with renewed interest.

The IDB-ECLA Research Programme in Science and Technology has begun the technological and economic study of this particular sector in two of the Latin American countries: Mexico and Argentina. The work, which is already underway, is designed to generate information both about the development of the international "best-practice" frontier in cement-making technology as well as about the current technological situation of the cement producers in the two above-mentioned countries. The studies will explore the differences that exist between the two countries with regard to scale-of-plant, technology employed, extent of "in-house" capacity for operating and expanding plant capacity, etc., and will also seek to throw light upon the relative position of each country compared to the international best-practice frontier, and to trace how these relative positions have been evolving in recent years.

The present monograph is the first in a set of three which Ruth Pearson intends to publish in the course of the next few months. In the present case, her interest has been to examine in detail the alternative processes for producing cement, the different factor-combinations which these alternatives involve, and the flow of successive technological innovations which have been accumulating at the best-practice frontier in the industry. In the succeeding monographs, Ruth Pearson will be examining the Mexican and Argentine cement industries, respectively.

The three papers are part of the overall programme of research which the author is developing for her submission of a doctoral thesis in economics at the University of Sussex, England.

1/ Carlos Diaz Alejandro, Labour Productivity and Other Characteristics of Cement Plants. An International Comparison, Economic Growth Center, Discussion paper Nº 117, July 1971.

2/ Eduardo A. Guimaraes, Leonidia Gomes dos Reis, "O Processo de via seca na industria de cimento", IPEA, Difusao de inovacoes na industria brasileira: tres estudos de caso. Río de Janeiro, 1976.

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Part 1

TECHNOLOGY AND INNOVATION IN THE CEMENT INDUSTRY

1. Introduction

In analysing the development of the cement industry from a technological point of view it is necessary to clarify a number of points which have a direct bearing on the nature and source of technical innovation and on the diffusion of such innovations, especially within less developed countries.

Firstly, the growth of the use of cement as the basic building material, both for construction and civil engineering, is related to the general trend in mechanisation, complexity and increasing productivity in the construction industry. This trend began in Europe in the late nineteenth century and has continued up to the present day. The analysis of the use of cement and cemend-based products falls outside the scope of this paper; however, it is important to note that the kind of technical innovation on which the use of cement as a building product was based was qualitatively different from the development of large scale methods of manufacture which have occured in the industry producing cement. The adoption of cement as the basic component of concrete and the widespread displacement by concrete of more traditional building materials was the result of progress in engineering and construction design which demanded high-load bearing materials and consistent quality which were not available from the traditional building materials. Technical innovation in cement production was also the result of progress in engineering skills as well as the application of continuous production techniques to the production of cement; however, although contemporary developments, the kinds of innovation in the industry producing cement and the industry using cement were totally diferent and disconnected.

Secondly, the nature of innovation and technical progress in the cement industry has consistently followed a general trend: that of replacing the discrete parts of the process as it was initially undertaken at the end of the nineteenth century with a complete system which has transformed the cement factory into a continuous production line. A more recent extension of this trend has been the application of automation techniques to the production process. At the present time cement plants can be controlled automatically from the stage of extraction of raw materials, through the raw materials grinding and preparations stages to the burning, cooling, final grinding and packaging stages. This trend towards continuous production has had direct effects on the efficiency of the production process and in most cases the immediate objective of progressive innovations were seen precisely in relation to these improvements: namely the reduction of labour required per unit of production, the reduction of fuel consumption, the improvement in the control of the quality and homogeneity of the product and the increase in the productive capacity of a given plant, which implied the overall reduction of unit costs and the increase of the productivity of fixed capital investment.

The third important point for the analysis of technological innovation in the cement industry is the increasing separation of the production of machinery for cement production where the majority of process innovations have originated, from the industrial sector which produces cement. The machinery manufacturing sector forms a highly concentrated group of firms within the international heavy engineering sector which has virtually no organisational links with the cement industry. 1/ Cement machinery production has been traditionally dominated by German producers, currently under challenge from Japanese industry. These machinery producers operate on a world-wide scale selling cement plant either in turnkey contracts or by selling separate parts of the production line. They also operate as technical consultants to the industry, with or without formal technical assistance contracts and also act as finance institutions via the granting of suppliers' credit to their customers.

These firms have been the innovators in process technology for cement production during the twentieth century. In contrast the greater part of the research and development activities of the cement companies have been confirmed to "internal" aspects such as organisation of quality control within the plant, geological and chemical investigation, product innovation, and administrative and distribution methods.

The first part of this paper is therefore devoted to an analysis of the innovations in cement production, and the consequences of these innovations in terms of technical and economic parameters for the cement producing industry. The analysis of the economic structure of the cement industry and the cement machinery producing industry and the effects of this on the transfer of technology to cement industries in developing countries will be discussed in Part 2.

2. Description of the basic processes of cement production

(a) Cement

Traditionally "cements" refer to those adhesive substances which can unite masses or pieces of solid matter to produce a solid monolithic block, with compounds of lime and lime derivatives.

Cementitious materials have been known and used since time immemorial. Evidence of a product used mainly as a mortar to fix other building materials such as stone blocks or bricks has been found in the Assyrian and Babylonian civilisations, the pyramid-building Egyptians, the Greeks and Etruscans, and the Mayan civilisation of Central America.

1/ The exception to this is the cooperation between sectors of the heavy engineering industry and the cement industry in Japan which have managed to produce innovations on the basis of imported technology and close coordination of research and development activities.

Portland cements 2/ and modern derivatives of Portland cements 3/ dominate the contemporary use of cements for construction purposes. Portland cement is technically an active combination of silicates and aluminates of lime. Cement is obtained by the preliminary grinding and mixing of the requisite amounts of lime, silica and aluminums usually found in different compositions of limestone and clay. The mixture is then burnt to incipient vitrification (about 1 300°C) and cooled, at which stage it has the form of grey lumps, rather like pieces of solid coke. The material in this stage is called clinker. The clinker is then ground finely at which point it becomes cement. A small amount of gypsum is added at the grinding stage to retard the setting of the cement when it is activated by mixing it with water, aggregates such as sand, gravel and crushed stone. The solidified mixture of cement, water and aggregates is called concrete. The purpose of the gypsum is to make the hardening concrete mix more flexible, allowing a greater time period before it hardens. The transformation of raw materials to clinker and then cement, and the use of cement to make concrete is illustrated in figure 1.

3. Basic elements of the production process

The different stages which make up the production process of cement are as follows:

(1) The extraction and transportation of the raw materials from the quarries to the cement factory;

(2) The grinding of the raw material to the fineness necessary for burning;

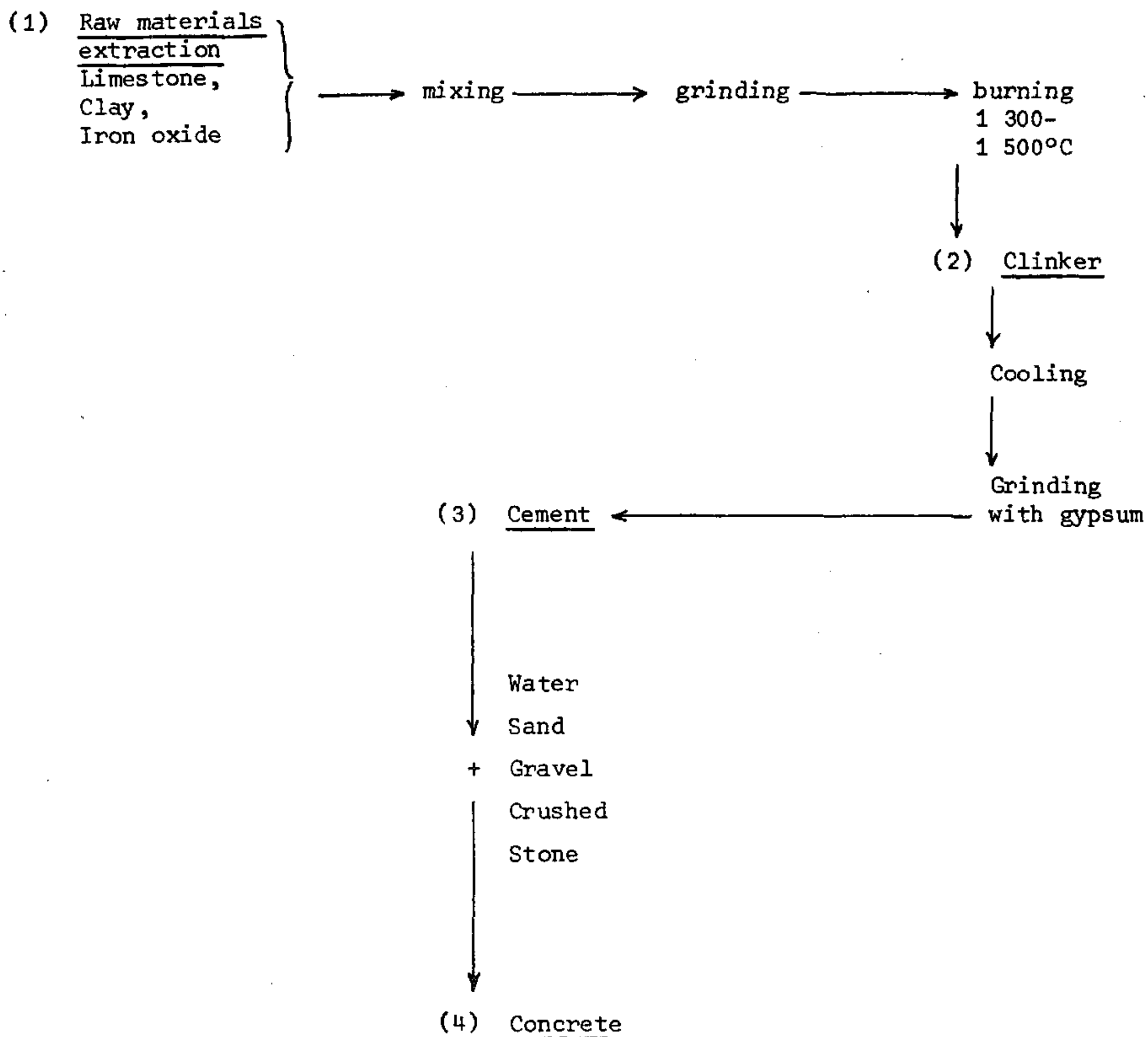
(3) Mixing of the ground raw materials to the required degree of homogenisation (grinding and mixing is often done together);

(4) Burning the mixture in the kiln by the addition and burning of solid fuel, petroleum or gas;

2/ Portland cement is a generic name for cement made by sintering in the way described in this paragraph. Portland was the name given to the cement developed by Aspin in 1821 in South East England, because of its similarity to the Portland stone on the South Coast of England. Although many cement manufacturers use the term "Portland" in their company names, and many writers use the term as though it has some technical significance (c.f. UNIDO: Industrial Branch reports: The Cement Industry. UNIDO ITD 156 9/11/72, p.18: "Portland cement is produced from Portland clinker (sic)"), "Portland" identifies neither a specific firm nor a specific product.

3/ Special cements have been developed by modern cement manufacturers for specific uses: e.g. oil well cements, rapid hardening cements, sulphus resistent cements. There are also non-portland cements being developed, some of which will have the same end use as the special portland cements, but as yet they have not gained great acceptance in the market. (See Rock Products, October 1976.)

Figure 1. Transformation of raw materials to cement and cement to concrete.



(5) Cooling of the clinker formed as the result of the burning process;

(6) Grinding the clinker with cement to form clinker.

The principal components of the machinery employed in the cement manufacturing process correspond to the discrete parts of the process outlined above. Considerable innovations have been made to the systems and machinery involved in all stages of the process, particularly those corresponding to the grinding and homogenisation of the raw materials before burning, and the kiln and associated equipment, and these are the dominant elements in the production equipment.

Cement was initially manufactured in various types of (vertical) stationary kilns which were fed and unloaded by hand. The technical obsolescence of this manufacturing technique and its supercedence by the (horizontal) rotary kiln was the revolutionary technical innovation which began the transformation of the nascent late nineteenth century cement industry into the modern large scale continuous process it has become today.

4. Different processes for manufacturing cement

There are basically two processes for manufacturing cement through the six stages of production described above. These are known as the wet process and the dry process. There are also variants of these processes, known as semi-wet and semi-dry, but these will be dealt with below under the discussion of technical innovations. 4/ The processes are illustrated in figure 2.

(a) Wet process

The principal feature of the wet process is the manner in which raw materials are ground and blended. The wet process is normally used with soft raw materials, which are washed and beaten up in water to form a slurry. The slurry is a paste made of water plus ground raw materials and has a water content of 30% to 40% when fed into the kiln. This method of mixing raw materials is extremely efficient and further precision can be achieved by blending slurries of different constituents. The mixture is fed directly into the kiln where the water content is removed by heating and the raw materials are calcinated into clinker. From the kiln the clinker passes through a cooler after which it is stored until ready to be ground into cement.

The main disadvantage of this method is its high fuel consumption (see figure 3), which increases unit costs substantially. 5/ However, when this method was first introduced it was the most efficient, since it achieved maximum blending and control of raw materials. It is less energy (power) intensive than the dry process methods since high speed grinding of hard raw materials is more power intensive than the slurry making process used in the wet process.

(b) Dry process

The dry process was developed initially to calcinate hard raw materials not amenable to dissolution into a slurry. The equipment was essentially similar except that the raw materials had to be dried to remove any natural water content, and ground to a powder before being fed into the kiln. However, until about the

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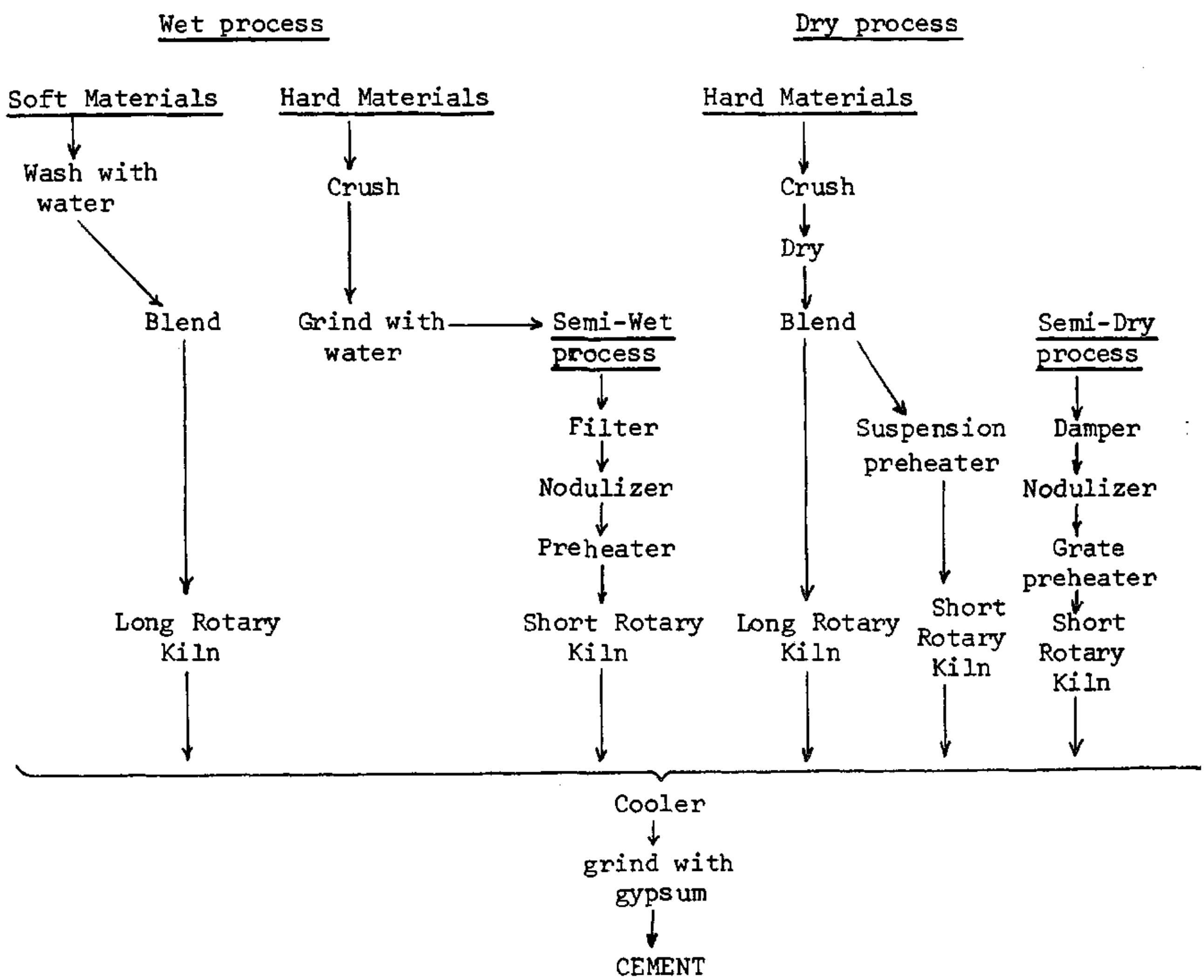
4/ The data in this section is based largely on the following publications: (a)K.C. Barrel, "The Manufacture of Portland Cements", five articles published in Cement Lime and Gravel, January-May, 1971, and (b) Blue Circle Group, Consultant Services, Publicity Department A.P.L.M., 1971.

5/ Fuel as a percentage of total manufacturing costs in cement production can vary between 20% and 40%. This of course depends not only on the process used

Figure 2. Different processes for manufacturing cement



Source: Adapted from K.E.Burrell, "The Manufacture of Portland Cement", Cement, Lime and Gravel, January 1971, p. 5, fig. 3.

5/ (cont'd)

and its relative efficiency with respect to fuel consumption but also on relative prices of fuel and other inputs.

Figure 3. Fuel consumption according to kind of process used

		Kcal/kg	
		1970 a/	1974 b/
1.	Wet	1 650	1 250
2.	Semiwet (preheater + short kiln)	1 000	975 c/
3.	Dry		
	Long kiln	1 300	950
	Preheater + short kiln	875	850 c/
4.	Semi dry		
	Lepol kiln	950 d/	875 c/
5.	Vertical kiln	1 150 e/	

a/ Table 1. Heat consumption of the various processes in K.G.Barrell, "The Manufacture of Portland Cement", Cement, Lime and Gravel, January 1971, p. 6.

b/ Pit and Quarry, July 1974, p. 122. fig.11.

c/ This is the figure given for a moisture content of 10%. At higher moisture contents the fuel consumption will be higher.

d/ Including 100 kcal/kg for drying raw material.

e/ Including 150 kcal/kg for drying raw material.

third decade of this century grinding machines were very cumbersome and inefficient, and although in theory intimate mixing could be obtained by grinding the different grades and kinds of raw materials together, the equipment then available made the control over the blending and handling of dry raw materials much less accurate and more difficult than mixing slurries.

However, the advantage of the dry process is that it is much less fuel intensive than the wet process (because of the absence of water in the raw mix). For this reason the majority of the important innovations in the cement industry consist of modifications to the dry process to take advantage of and improve this characteristic of fuel saving. The dry process was only adopted widely in the cement industry when innovation in various techniques of prehomogenisation, grinding, and dust collecting systems were perfected. These innovations are described in the next section.

(c) Vertical kilns

However, it is interesting to note that although the innovations in both wet and dry processes are based on the use of the rotary kiln, Vertical shaft kilns still remain as an alternative production method for cement manufacturers. These kilns have been developed from the stationary Schneider kiln used at the end of the nineteenth century before rotary kilns were widely adopted in Europe and North America. The Vertical kiln is now a semidry kiln for which the raw materials are dampened and nodulized. The nodules are fed continuously into the top of the kiln and the clinker is extracted cold from the botton of the kiln by a rotating grate. The kilns are limited to outputs of below 300 tpd and to low volatile fuels. 6/

5. Principal technical innovations

Since the introduction of the rotary kiln which opened the possibility of a continuous production line for cement there have been a number of important innovations in production techniques and machinery design, giving rise to a series of alternatives in the various parts of the production process. However, in describing these innovations which are all concerned with the way raw materials are ground, blended, heated and calcinated, i.e., on the design of the kiln process and associated equipment, we would not wish to make the error to suppose that these discrete innovations represent the totallity of technical innovation in cement production. It is also important to take into account complementary innovations concerned with increasing knowledge of the nature of the

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6/ Although this possibility of using small scale vertical kilns does exist, especially for production in outlying areas (taking into account the high freight cost of cement which has a very high weight/value ratio) there is no evidence that it is actually used. As figure 3 shows, its fuel consumption is reasonable and its capital cost per ton is considerably lower than that of rotary kilns. The OECD Manual of Project Evaluation, taking investment in cement production as an example concluded that the vertical kiln was the most rational decision. (See Little and Mirles, Manual of Industrial Project Analysis in Developing Countries, Vol. 2, Methodology and Case Studies, p. 289, OECD, Development Centre Studies, 1969). There are reports that the vertical kiln is used in China as part of the rural-industrial decentralisation policy. Research is being done at at least one institute in a developing country (The Planning Research and Action Institute Planning Department, Uttar Pradesh, India) to improve quality control and scale it down for village use. (See also Vertical Shaft Kilns for Cement Production (Feasibility Reports), Regional Research Laboratory, Jorhat India But most cement and machinery manufacturers alike quote 1 000 tpd as the minimum economic scale of production, and I have never seen nor read of a case where a manufacturer has quoted for the construction of a vertical kiln. The vertical kiln is also reported to be used in some areas of the United States to supply special construction projects which imply a determined and intense demand for cement over a definite limited time with the idea that the plant can then be abandoned with a minimum capital loss.

physical-chemical reactions which take place during the transformation of raw materials into clinker inside the kiln, improvements in the materials handling, grinding, prehomogenisation and dust-collecting techniques, advances in the heavy engineering sector which increased the range of physical variables and the degree of precision available to plant designers in terms of the specifications of individual pieces of equipment, the development of machine tools capable of producing large scale plant and the ability to control scientifically all stages of the production process. 7/

This stress on the role of scientific and engineering skills and of minor innovations is important for two reasons. Firstly, an analysis of innovation in cement production techniques outside the context of this complementary technical progress would be distorted and partial, and secondly, it enables us to understand the nature of technical progress in this sector and the reasons for the economic and geographic concentration in the sector producing cement machinery. Thus the high degree of specialization and its engineering and science base in this sector has removed it from the sphere of the cement producer per se and it has become concentrated in gigantic corporations with considerable engineering, scientific, research and financial capacity. For this reason the design and production cement machinery has remained outside the realm of the cement and capital goods industries in developing countries which lack the skills-science base that provide all the conditions necessary for such innovating/productive activities.

Innovations in cement production can be characterized under three headings:

(1) Fuel saving innovations

(2) Increases in the scale of production

(3) Automation and computerization

However, there are ploblems in separating innovations into distinct categories since, for example, those innovations which clearly have a fuel saving effect are also associated with increases in production scale. Moreover the application of automation techniques to cement production improves fuel consumption along with other components of unit costs, and because of the high investment implied by such equipment, are only installed in large scale plants.

Therefore, we shall discuss the innovations in accordance with the part of the process which they modified, treating separately the effects of increases in scale of production and automation.

7/ See A. P. Usher, "Technical Change and Capital Formation", in The Economics of Technical Change: Ed. Nathan Rosenberg, Penguin Economic Readings, Penguin Books Ltd., 1971, pp. 43 to 71, for a discussion of the importance of engineering and scientific skills in the transformation of inventions to innovations and the importance of secondary and tertiary innovations which allow primary innovations to be implemented.

6. Main innovations in cement production in the twentieth century

(a) Early innovations

The early innovations at the beginning of the century were concerned with improving the wet process of production which was the only one universally applicable at that time and with transforming the separate parts of the production process into a unified production line. In early plants where each piece of equipment was mechanically separate, one of the big problems was the transportation of materials between the different stages of production. This necessarily involved high labour costs for the handling of materials. However, in the modern cement plant the materials are transported by automatic conveyor belts and the plants have been designed to minimize as much as possible the problems and costs of the transportation of materials.

One of the first innovations in cement processing following the development of the Rotary Kiln was the development of a wet process system for hard raw materials. This was patented by the Danish Company F.L. Smidth in 1900. 8/ This system was developed on the basis of previous innovations by the same company in crushing and grinding machinery. Since the major disadvantage of dry grinding for hard materials at this time was the very high power consumption, this process was a progressive innovation since it represented a 10 to 20% power saving over dry grinding. It also represented some measure of fuel saving because it incorporated a system of recovering heat from the hot clinker thus reducing the temperature of the kiln exit gases. Also this method achieved a more accurate mixing of raw materials than dry grinding. In the new process slurries were made by suspending ground hard materials in water which could be blended together before calcination. This method was widely used for processing hard materials for 40 or 50 years until new techniques of prehomogenisation and dust collection were developed and incorporated into the dry process, making obsolete the wet process for dry raw materials.

Another early innovation by the same company was the UNAX kiln, developed in the 1920's. This consisted of a kiln which had a clinker cooler and heat recuperator as an integral part of the kiln. However, the application of this kiln was limited by technical constraints: heat resistant steel was not available and machine tools were too small to manufacture this system for any but the smallest kilns. 9/

8/ "The Development of F. L. Smidth & Co.", Cement Technology, January/February 1973, p. 16.

9/ See Rock Products, May 1973. FLS patented a new type of UNAX kiln in 1965 based on the same system but incorporating the suspension preheater which had been developed in the meantime. Integral coolers are also called satellite coolers and consist of a number of small diameter cylinders mounted on the outside of the kiln shell connected to the kiln by various channels thru which the clinker passes to the cooler.

During the 1930's there were a number of minor innovations to different parts of the cement process. The wet process kiln was improved by the introduction of a series of chains hung from the kiln shell inside the kiln. The idea behind this system is that the slurry will coagulate on the chain as the kiln rotates, thus offering a larger and more accesible surface to the gas streams. This implies more efficient heating and burning of the slurry and so reduces the fuel consumption of the system.

Since the introduction of chain systems a number of variations have been developed using different kinds and arrangement to heat-exchange bodies. A well-designed chain system can reduce the temperature of the gases leaving the chain zone from 240°C to 180°C, thus reducing the amount of fuel required in that part of the kiln.

(b) Innovations in crushing equipment

The equipment which breaks up the rock containg the raw materials into pieces small enough to be fed into the raw meal grinding machine has remained basically the same for many years. Normally primary and secondary crushers are used, though for wet materials these are replaced by a circuit consisting of wash-mills and crushers. 10/

The efficiency of the classic crushing machines - such as the jaw crusher, the roll crusher and the single and double rotor hammer machines have been steadily improved, especially through the use of materials which are more resistent to abrasion by hard raw materials. 10/

An innovation developed in the mining industry has been adopted for use in raw material preparation in the cement industry. This is the autogenous mill which is an airswept mill of very large diameter fed with large limps of stone which act as their own grinding media. These mills work in conjunction with the grinding mills and eliminate the necessity for secondary crushers, since they can take raw material in large lumps (larger than 1 m^3) and can pregrind such material down to less than 10 mm particle size. However, autogenous mills are not suitable for hard dry raw materials and are unlikely to replace conventional crushers in the near future. 11/

(c) Innovations in grinding equipment

Successive improvements have been made to the grinding equipment used for both raw meal and finish grinding.

There are basically two types of grinding mills available in the market for raw material grinding. The first is based in the ball and tube mills initially developed by FLS al the turn of the century. In these mills the grinding mechanism is operated by gravity with steel balls inserted into a rotating cylindrical mill. The ball and tube mill consists of 2 separate chambers; the ball mill was short with a large diameter, say 4 ft x 8 ft, charged with steel

10/ UNIDO op. cit., p. 73.

11/ Barrel op. cit., pp. 62, 73.

balls 3-5" in diameter which performed the primary grinding of pieces of raw material of up to 2" in size produced by the crushers of the period. From the ball mill the material passed through screens to the tube mill which was a long cylinder with a smaller diameter (e.g. 30'x6'). This mill was charged with balls of 5/8-1 inch diameter which performed finer grinding.

In about 1920 it became practicable for crushers to produce raw meal feed of about 1 inch. Therefore, the large balls in the ball mill were no longer necessarv and the functions of the two mills were combined into a compound mill. The compound mill was divided into chambers each of which was charged with balls of diminishing size. The screens separating the chambers allowed the passage of the graded raw materials but not of the balls.

The rod mill was a development of the ball mill, based on the same principle but with steel rods up to 10 feet long in the first chamber.

Roller mills are a more recent development though they may be traced back to the edge-runner mills used before the tube mills were developed. In roller mills the material is ground on a flat pan or table rotating around a verticle axis. The rollers are pressed down onto the material by spring or hydraulic pressure. The mill is airswept by hot gases from the kiln in order to remove humidity from the materials, and has a classifying system to separate fine ground material from material still in process.

The tube mill still remains the standard grinding mechanism especially for finish grind. It has been improved mainly through the use of more abrasion-resistant materials for liners and grinding balls and, to a certain extent, through increased knowledge of the effect or higher mill speeds. The replacement of the steel liners by rubber liners in wet mills has reduced wear, maintenance cost and noise. 12/

(d) Innovations in cooling equipment

Another innovation developed in the 1930's was the Fuller Grate Cooler, which remained a feature of modern cement production up until the end of the 1960's. The coolers initially used in cement production were Rotary Coolers, which were similar in construction to the Rotary Kiln. The first zone where the hot clinker enters was, like the Rotary Kiln, lined with refractory bricks, since as we noted above, heat-resistant steel was not available at this time. Although the rotary cooler is essentially a very simple mechanism with low maintenance costs, it was not very efficient because of the difficulties of bringing the cooling air adequately into contact with the clinker.

The planetary cooler, although designed in the 1920's was not a viable proposition at that stage. However, in about 1940, the United States company Fuller's developed the grate cooler in which the air is blown through a bed of clinker carried on a travelling grate designed to give an even distribution of the clinker and maximum exposure to the cooling air flows. This system which has been progressively improved from the original inclined

12/ UNIDO, 1972, op. cit., p. 73.

grate, now can be used with a horizontal grate, and a combination grate which contains air quenched cooling with heat recuperation and final cooling. 13/ Grate coolers have also been developed by F. L. Smidth and Polysius.

The new type of integrated cooler, redesigned by F.L. Smidth in 1965 has tended to displace the grate cooler in more recent plants, although the grate cooler remains the more standard equipment. 14/

(e) Innovations in core technology. Development of a dry and semi-dry process

The most significant innovations in the cement industry since 1930 were those associated with the development of the dry process the semi-dry process and the semi-wet process (see Fig. 2). These innovations which have a major fuel consumption advantage over the traditional wet process were based on reorganizing the functions of the rotary kiln, and removing from the kiln the pre-heating function which was transferred to a separate piece of equipment known as pre-heater.

The pure dry process, which consists of the dry grinding and blending of the raw materials, is essentially the same as the wet process, consisting of the raw materials preparation equipment and a long rotary kiln. These have been in use since the 1930's, and their use has become more efficient than the wet process for hard materials as improvements have been made in the grinding equipment described above.

However, the revolutionary innovation in the dry process was the development of the suspension pre-heater which is used in conjunction with a short rotary kiln for processing dry raw meal. In this system the blended dry meal passes through a special piece of equipment called the suspension pre-heater. This is a tall structure in which are arranged a number of cyclones 15/ in vertical series. The gases from the kiln are passed upwards through each cyclone. The raw meal feed is introduced through an air seal into the gases entering the highest cyclone to reduce the dust carried away by the exit gases. 16/ The meal caught in the gas screen is introduced to the circuit again by mixing it with the gases entering the next lower stage. As the raw meal proceds to the lowest part of the system it encounters progressively hotter gas streams which have been heated in the kiln and conducted directly into the pre-heater system. The material, as it leaves the last stage and enters the kiln is at a temperature approaching calcination 17/ (1 450°F).

13/ Cement Technology, 1972, No. 3.

14/ UNIDO, 1972, op. cit. pp. 74, 75. See also article by Fedderson, Rock Products, May 1974.

15/ Cyclones are conical vessels which separate dust by centrifugal action from the gases or materials moving through them.

16/ The highest stage of the system comprises two smaller parallel cyclones which maximize the dust recuperation before the gases escape altogether from the system.

17/ i.e. the removal of calcium dioxide from the limestone.

This kiln system reduces the necessary length of the kiln by up to a half since the precalcination function is removed from it. It is also much more efficient in heat consumption, as shown in fig. 3.

The first suspension pre-heater kiln was apparently patented in Czechoslovakia in 1933/4, 18/ but it was not developed for commercial operation at that time, largely, it is understood, because of lack of dust collecting systems which could dedust the hot exit gases emerging from the kiln at very high temperatures. 19/ F.L.Smidth also claim to have patented a propotype kiln with a 4-stage cyclone pre-heater as early as 1933, 20/ but again were unable to overcome the problems of dedusting the kiln gases. A further problem which delayed the commercial application of this system was the inadequacy of homogenization techniques. 21/

Instrumentation, process control and the dedusting problems were finally overcome by the development of electrostatic dedusting equipment after World War II.

Humboldt were the first company to launch the pre-heater on the market in the early 1950's, the system being patented by them in 1950, and this innovation gave them an important advantage in the world market. However, suspension systems have since been developed by Polysius and F.L. Smidth, and the secondary machinery manufacturers in Europe and the United States, as well as the Japanese companies are now manufacturing under license one of the systems developed by the big three. Each of the different systems uses different arrangements and combinations of cyclones and expansion chambers with the object of achieving more heat transfer and thus minimizing the fuel consumption of the process.

The Polysius system, known as the Dopol (from Double Stream Preheater) was first marketed in 1958, and derives its name from the fact that the exhaust gases are repeatedly divided into two streams to give a high grade of dust separation at a favorable pressure loss.

A new development of the Polysius system is the Prepol system which was put on the market in 1974. This system has the added advantages that all combustion air is drawn back through the kiln before entering the preheater so that no dust is carried from the cooler to the preheater. 22/

(f) Semi-dry process, Lepol kiln

The other pre-war innovation that had an important impact on cement mastering technology was the semi-dry process on the Lepol kiln, as it is usually known.

18/ K.G.Barrel, op.cit., p.6.

19/ Cement Technology, Vol. 3, May/June 1973, p. 102.

20/ K.G.Barrel, op.cit., p.6.

21/ In modern homogenisation systems, the raw material is fluidized by aeration and pumped through systems designed for proportioning and measuring inputs to achieve accurate blending.

22/ Rock Products, August 1975.

In this process dry raw materials are wetted to a moisture content of 12-14% to form a "cake". This cake is then made into pellets or modules which are fed onto a travelling grate through which the hot gases of the kiln are passed. In this way the pellets entering the kiln are preheated to a large extent allowing the reduction of the kiln length to about half, giving, with the grate, an overall length of about 70% of the equivalent long kilns. This process was first developed in about 1929 from the design of Dr. Otto Lellep, an Estonian emigrê in Germany. Polysius, which was by then fairly well established in the cement machinery field invested in the development of a pilot plant and produced a semi-wet kiln for the market by 1933. However, the widespread adoption of this process was inhibited by the world depression and although some Lepol kilns were sold before the outbreak of the war the firm was forced to abandon production. The firm reestablished itself in West Germany after the war and redeveloped the kiln for the world market in the late 1940's.

(g) Semi-wet process

The semi-wet process was also developed during the 1930-1950 period. This process seeks to obtain the advantages of the wet process without the high fuel consumption implied. As in the semi-dry process the raw materials are washed in water to form a slurry, but then filtered to expel the majority of the water content. The resulting cake has a moisture content of 18-20%. As in the semi-dry process it is converted into nodules which are then exposed to hot kiln gases in some kind of preheater. This removes some of the remaining water content before the nodules are fed into the kiln. This process theoretically results in considerable fuel saving (see fig. 3) but has never been widely adopted since the procedure for filtering the slurry to form the cake entails the use of cumbersome batch operated pressure filters which produce an intractable substance difficult to manouvre and pellitize. Some good results have been obtained using this method with various kinds of special non-suspension preheaters 23/ with particularly suitable raw materials but its use is not very widespread. Innovation has concentrated mainly on perfecting variations of the dry process which afford greater possibilities of fuel saving.

These major innovations implied various developments of ancillary machinery and of engineering, dosification and measuring techniques on the part of other branches of the engineering industry before they could be developed commercially; these are the techniques of production commonly available to the investor today. However, a new system for cement production - the Flash Calcinator - has been developed in Japan which, although in one way represents a logical development from the S.P.H., has introduced a totally new element in the available techniques. We separate in from the innovations discussed so far because as yet it is regarded with scepticism by cement producers, especially in developing countries, but the trends indicate that it will gain greater acceptance as it proves to be viable in ordinary commercial operations.

The basic concept of this new system is the addition of a separate combustion chamber like a stationary kiln at the base of the conventional S.P.H. system. Ahead of the rotary kiln following precalcination in the S.P.H., burning takes place

23/ See K.G.Barrel, op. cit., p. 13.

by multiple burners in the combustion chamber with preheated combustion supplied by the coolers. The precalcination that takes place in the chamber of the preheated suspended raw meal particles is up to 95% complete so that the material entering the kiln is ready for the sintering process of clinkerization. Thus 60% of total fuel demand is concentrated in the preheating and precalcination systems giving a much lower heat load for the sintering process within the kiln. 24/

The principal advantage of this system over the conventional processes is that it increases the capacity of the rotary kiln by up to 220% without increasing its size. This is because the burden of gases and thus their volume within the kiln is cut by over half, allowing a corresponding increase in the amount of raw meal, in its precalcinated state, to pass through the kiln in any given time. The thru-put time of the burning process within the kiln is also reduced. The importance of this fact lies principally in the constraints on kiln size imposed by the quality and nature of the refractory bricks which form the linings inside the steel shell of the kiln. As a kiln increases in size its diameter tends to become larger, and thus its degree of curvature diminishes. After a certain point it thus becomes very difficult to keep refractory bricks in place since the curvature of the kiln shell no longer provides the lateral tensions required. This fact, added to the variable quality of refractories produced, especially in less developed countries, means that the degeneration of refractories becomes a very costly item with the use of large scale kilns, making precision control of the process much more complicated, and imposing a longer down-time for the kiln in order to replace the bricks which no longer serve. However this new system implies that the size of the kiln can be increased from say 1000 tpd to 2000 tpd with no increase in the diameter of the kiln, and thus no corresponding increase in the cost and problems associated with refractors.

Other advantages claimed for this system are a marginal reduction in fuel consumption (5-10%), lower emissions of nitrogen oxide, and possibly lower construction costs per ton of installed capacity. 25/

There are at least three separate Japanese system which are being marketed world-wide through licenses and selling rights conceded to various European and American companies. At least one European company, Polysius, has developed its own calcinator system which it claims can be adapted to a conventional and some non-conventional fuels (such as oil shale), has a low alkali concentration, and can be used in conjunction with planetary coolers. Polysius claim to have several years operating experience of this system in conjunction with a West German Cement manufacturer (a full scale pilot plant) and are actively offering this system for commercial use in the United States where the problem of alkali content has prevented in many cases the adoption of the conventional SPH system, with its concomitant fuel savings.

Most of the plants reported in the trade press as having adopted this system are very large (up to 1600 tons a day), since the constraint on kiln size

24/ "Improving Kiln Thermal Efficiency", Rock Products, August 1974, p. 49, Designance Operation Considerations, Part. 4.

25/ These last two facts are apparently doubtful according to one informant who visited Ishikawajina Harima Industries' plants in Japan at the end of 1975.

was the incentive to develop these innovations. However, it can be used successfully for plants of much smaller size (2000 tpd) where the problem is quality of refractory bricks rather than size of kiln. 26/

Technical improvements in efficiency due to process innovations in Cement Production.

It is difficult to obtain reliable information about efficiency of different processes and innovations it terms of technical parameters. Fuel saving has been the main impetus behind many of the important innovations in the cement industry, and theoretically very low fuel utilization rates are attainable. Table 1 gives an indication of estimates of best practice ratios in 1974.

Total power utilization, at least in the United States cement industry has remained more or less stable over the past 25 years. The reason given for this is that additional power required for air pollution control equipment and for finer grinding techniques has been offset by larger prodution units and more compact design layouts. 27/

Traditionally United States energy and fuel requirements for cement production have been higher than those in Europe and Japan. In a study comparing wet and pre-heater installations it was shown that the United States used an average 1.5 million BTU/short tons more fuel than plants in Japan using similar processes. The total specific energy consumption of the United States plants (including fuel plus fuel equivalents of electric power) is approximately 25 millon BTU/short tons greater than the European plants operating either wet or pre-heated processes. 28/ Total energy requirements per ton in the United States industry is estimated to be about 50% of 1945 requirements. It is too early to have any definite data on improvements in labour, fuel and electricity utilization in the new flash calcinator kilns, since there has been little industrial experience of these plants.

Labour requirements in the United States have fallen substantially as the result of both technical innovations, increases in production scale, and automation. Labour requirements per (short) ton of cement produced in the United States are estimated at between 0.35 and 0.75 man-hours, depending on the type and size of the plant concerned. Plants of 500 000 tpy and below require 0.50-0.60 man-hours per ton. Those above 500 000 tpy should need less than 0.40 man-hours per ton. This is estimated to be about 50% of the 1970 requirements and only 17% of the 1965 requirements. 29/

26/ A Mexican manufacturer is reported to be considering such an investment for this reason.

27/ The average electrical energy consumption in several plants in the United States in 1974 was 130 KWh/ton (Rock Products, May 1976, pp. 77 and 126). This is fairly high especially compared to plants in developing countries. However, electricity consumption reflects the degree of automation and mechanization of the plant as well as the efficiency of the mechanical equipment employed.

28/ Study published by the U.S. Portland Cement Association. "Energy Conservation Potential in the Cement Industry". Quoted in Jay Warshowsky, "Challenge to the Cement Industry and its Suppliers", Fuller Engineer, Vol. 25 No.1.

29/ Rock Products, May 1976, p. 77.

Labour requirements in the United States cement industry have generally been below those in the European industry because of higher labour costs. However, the gap now appears to be closing. In 1965 West Germany utilized 1 man-hour per short ton of clinker while the United States utilize 0.6. By 1973 the differences had narrowed to 0.6 for Germany and 0.55 for the United States based on the same size of plant. 30/

(h) Automation of cement plants.

Although automation is not specific to cement plants it is essential to treat it in conjunction with other innovations, since the application of automation techniques determines the current technology in modern cement plants.

Automation of cement plants has various functions. Primarily technical in that automatic control of each stage of production, and in the last analysis, automatic coordination between stages of production allows for immediate correction of variables which alter the productivity of the process. In the raw material grinding, blending and preparation stage, greater and immediate control, by way of on-line X-ray analysis ensures that the raw material mix can be maintained between minute degrees of variation, previously calculated by computer in order to ensure the optimum mix determined by the constituents of the raw materials as the physical conditions of the plants. Since even within particular quarries covering small areas there can be enormous variations in the quality of raw materials, quality control at this stage of the process is essential.

Control of the raw material mix is also directly linked to control of the burning process itself, since failure to obtain the optimal blending of raw material will result in suboptimal burning and calcination within the kiln, implying higher fuel consumption, and a higher ratio between raw materials and clinker produced. A major consideration is the wearing of the refractory bricks lining the kiln shell, which can also be optimized both by control of raw materials mix and also control of the velocity of fuel feed and oxygen supply and burning of the fuel used, thus maintaining constant temperatures at different stages within the kiln.

Automatic control of the ancillary processes, excavation of raw materials, material transportation and handling, packaging and loading of ground cement is aimed at economic rather than directly technical efficiency. 31/ Automation of these processes reduces the labour-output ratio considerably thus reducing the general production costs of the plant. Reduction of the total labour force also implies management benefits for the plant, since the fewer operators involved, the less production can be threatened by organized action on the part of the workers. This is an important consideration in an industry where continuous production for at least 330 days of the year (24 hour a day) is considered the norm against which productive capacity of the plant is measured. Moreover, because of the physical nature of the process involving the maintenance of high temperatures, interruption of production caused by human error or sabotage represents high fuel losses from cooling and reheating the kiln as well as the

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30/ J.Warshowsky, op.cit., p.3.

31/ Though obviously technical efficiency has its pay-off in cost terms.

physical damage for the equipment caused by such brusque temperature variations.

Automation in cement plants ranges between closed circuit control of distinct stages to a fully-integrated computerized system encompassing the whole plant. Closed circuit control of stages of production, principally the grinding, blending and burning stages is now fairly standard in cement plants. In this system all the instruments which present readings of the different variables related to each process are grouped together in a control room. If the system is to be controlled manually, the burner has to rely on his experience and the guidelines he receives from the technical department to interpret instrument readings and make the appropriate corrections. While it is relatively simple to apply automatic control to combustion so that the burner may obtain more or less heat by operating a simple control, the linking of all the factors to maintain the burning zone automatically is not practicable without resort to a computer which can programme these variables, control the degree of permitted variation of each one and the reciprocal corrections necessary.

However, the production of a satisfactory computer programme is complex, requiring long experimental work on-site with each kiln to adjust it to the characteristics of raw materials, fuel, temperature, etc. Such programmes have been installed in some large kilns, not only in industrialized countries but in Latin America as well. However, they need to be backed up by a competent team of analysts, programmers and electronic engineers to be a usable investment in the long run.

The integration of the whole plant operations under computer control is even more complex than that of control of kiln burning, and consequently requires extreme precision and measurement at all stages of the process in addition to the technical back-up of programming, analyzing and electronic capacity. Few plants in Latin America have such a system and its advisability is extremely doubtful without the necessary technical backing.

Another element of the process amenable to automation is the quality control system which effects continuous analyses on samples extracted from all stages of the raw material preparation processed. Although most modern plants have X-ray analysis equipment installed, there is room for a large amount of variation in the degree of automation of the procedure for effecting such analysis. The X-ray analysis equipment can consist of nothing more than the equipment for analysing raw materials and producing very quickly the required analysis of proportional constituents. However, depending on the degree of automation existing in the rest of the plant a system of automatic sampling can be installed whereby instead of the sample being transported normally to the laboratory, it is automatically transported and fed into the machine. A further sophistication of this process is that the machine is connected to a mini-computer which receives the chemical and physical analyses, and compares them to the programmed variations for each factor, and calculates necessary corrections; these can also be communicated directly to the plant. Clearly the more automated is this process of quality control the more quickly corrections can be effected to the plant, and thus the more efficient is the whole process. 32/ But also it is

32/ In the course of field work in Mexico and Argentina variations in the time taken to obtain results from X-ray analysis varied from 1 minute to 30 minutes. For traditional laboratory analyses the process took 3 hours.

clear that the implementation of such a program depends on a considerable technical infrastructure either within the firm or accessible to it.

Another of the aspects of technical skills which is a prerequisite of the successful implementation of computerization to cement plants, is electronic and mechanical maintenance. Since automation requires precision measurement and control it depends on all elements of the machinery and equipment working at their expected efficiency. However, since automation also implies continuous production, shut-down of plant to effect maintenance procedures is counter productive. Therefore, in order to maintain the equipment functioning as expected capacity plants which are fully automated have to introduce a system of preventive maintenance which implies programming the maintenance of each element of the equipment as often as is necessary (which can be every day for some elements of sensitive electronic machinery) without interfering with the productive process. Although maintenance system are necessary for all plants whether they are automated or not, the investment in electronic engineers and trained personnel to effect preventive maintenance in automatic plants is very costly and adds to the total investment required to successfully apply automation techniques to cement production.

(i) Scale of production

From the published information available as well as from empirical investigation it is clear that there has been a sustained tendency for the scale of cement production to increase over time. This is true in terms of plant size, and also in terms of the capacity of individual kilns. 33/

At the begining of this century, kilns were constructed with a capacity of 30 tons a day. Between the two world wars the average size of new kilns increased from 60 000 tons per year to 100 000 tons per year. 34/ Since the 1950's the size of kilns has been continuously increasing. By 1973 average size of new kilns ranged from 300 000 tpy to 500 000 tpy. Of 110 new kilns delivered by Polysius from 1908 to 1973, 25 were between 600 000 and 1 400 000 tpy. 35/ At the upper end of the scale kilns have been produced with capacity of up to 1 700 000 tons per year. 36/

Plant sizes have also increased. New plants today are not built smaller than 300 000 tpy and many manufacturers consider 600 000 tpy to be the operating minimum. The largest United Kingdom plant has a productive capacity of 4 000 000 tpy and plants in Japan of up to 8 500 000 tpy are reported in the construction stage. 37/

33/ Since capacity of plants/kilns can be increased by the use of flash calcinators, it is somewhat ambiguous to talk of size of kiln.

34/ Svenilson, Study of Trends in the European Industrial Production, 1915-1950. Draft chapter on cement, Mimeo, No date, Table 2. "Rotary Kilns Delivered from Four European Manufacturers, 1900-1950".

35/ "Polysius Equipment in the Cement Industry", Cement Technology, March/April 1974.

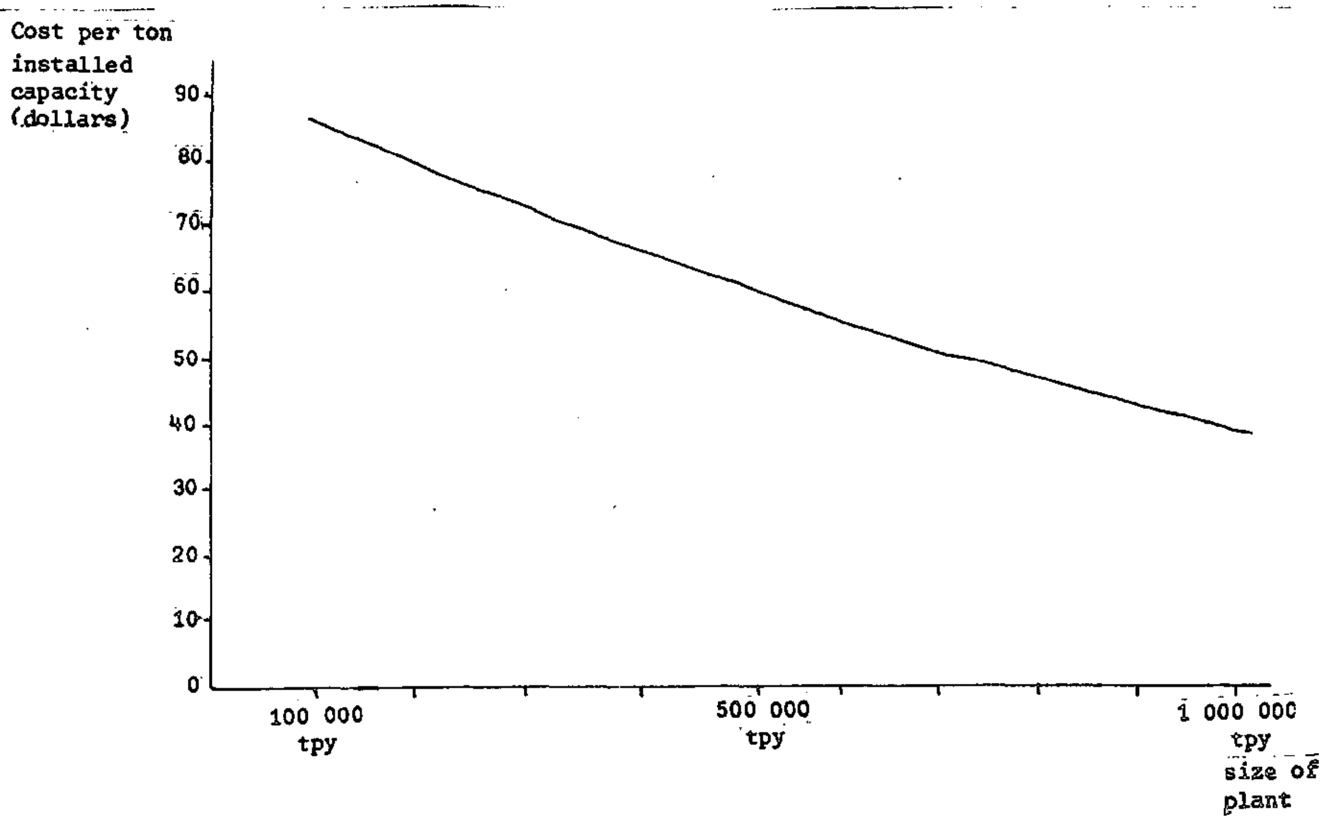
36/ "The World's Largest Cement Kilns", Rock Products, May 1973, pp.112, 113.

37/ Pitt and Quarry, January 1975.

Various studies have been carried out demonstrating economies of scale for larger plants in cement production, both from the point of view of the initial investment cost and also on the basis of all round operating cost.

Estimates of economies of scale in investment cost are shown in table 2. Where the figures in the different columns are clearly not comparable since they relate to different time periods, different investing countries and situations the table indicates that the cost per ton of installed capacity is less, the greater the size of the plant. 38/

The same sources indicate how this investment is distributed between the various item which make up the total investment cost, i.e. mechanical equipment, electrical equipment, spare parts, insurance, transportation, erection, automation and administration, start-up costs and civil engineering (see table 3). From this information, it is clear that some cost items are more affected by the scale factor than others; mainly ancillary operations linked to the cost of transport, plant erection, civil engineering, etc. However, the cost of equipment and spare parts, which represents 70% of the total cost for the 100 000 tpy plant, 60% of the 500 000 tpy plant and 45% of the 1 000 tpy plant, declines by almost half in terms of cost per ton of installed capacity with the increase in scale. The graph below shows the investment cost curve derived from this information.



Source: See table 3.

38/ These estimates are made on the basis of investment in new plants, rather than for expansions of the existing plant.

Studies on economies of scale also indicate that there is considerable saving in terms of unit operating costs directly proportionate to increase in scale of production. Table 4 reproduces the result of the UNIDO analysis of variations in fixed and variable cost items in cement manufacturing. This calculation is based on a number of assumptions regarding the cost of different inputs which may be totally different from the situation in particular cases. However, it can be taken to represent the orders of magnitude of economies of scale for 'the average situation' in the cement industry in the early 1970's. The economies of scale in the various parts of the process can be represented in form of index numbers, taking a 250 000 ton per year plant as 100 (table 5).

However, without detracting from the validity of these studies it is important to point out their limitations, and confusions, before they are accepted as the bases for policy decisions, especially for investment by cement producers in developing contries.

Firstly there exists a confusion between economies of scale with respect to the size of the kiln, plant and firm. In the studies quoted above, a "new plant" was taken as the unit for analysis. However no distinction was made as to whether the new plant consisted of a single production line (with one kiln) or of a single production line based on 2 kilns, 39/ more than one production line. Furthermore established companies often construct a "new plant" on the same site as an old plant, with all production facilities separate, but nevertheless are able to overlap certain labour inputs, supply, functions, etc.

Secondly there is no distinction made between economies of size of production line/kiln and economies resulting from multi-plant firms (and thus of firm size), since these studies are based on information supplied outside the competitive context of the investor and, moreover are based on technical coefficients which may or may not represent best-practice ratios. It is important not to confuse lower unit investment or operating costs obtainable or obtained at larger scales of production from economies deriving from multi-plant firms, whose size and experience inplies that they are in a stronger bargaining position vis-a-vis the cost of the investment (i.e. cost of m/c, equipment and other services bought from suppliers) and the cost of finance for that investment. Moreover, the existence of large firms with more than one plant implies also that they possess experience and a technical infrastructure within the firm which makes it more probable that they will be able to achieve the theoretically attainable cost reductions derivable from large-scale productions. Equally it is possible that a small new firm in a developing country, with the same equipment, will produce at higher unit costs, partly because his negotiating position with machinery and finance suppliers is weaker, partly because with only one small plant the unit costs of fuels, electricity and water is higher and partly because his lack of experience and technical base impedes him from attaining the theoretical maximum efficiency from the plant he has bought.

Nevertheless there is obviously a learning factor involved here, that a new

39/The UNIDO report makes the observation that it is more sensible to design a plant with two kilns thus allowing for the possibility of continuing production if one should break down or be stopped for maintenance.

firm may experience higher unit costs to begin with and these will decrease as his abiblity to run the plant increases. Whether this learning is achieved depends on the technical capacity and policy of the firm as discussed in the second half of this paper.

A further factor which makes it difficult to interpret concretely these estimations of economies of scale is the fact that the type of technology used and the degree of automation of the plant is not specified as discussed in the previous section, different techniques in the various stages can result in different technical coefficients in terms of unit fuel, power and labour utilisation. Although these are also affected by scale of production, it is nevertheless important to specify exactly what kind of plant is being bought since this will affect the unit cost of investment and impose technical parameters of efficiency on the operating cost which will intervene in the calculations of scale economies.

Table 1. Fuel consumption ratios attainable for dry, semi dry and suspension preheater kilns in 1974

Kiln type	Btu/short ton.	Kcal/Kg.	% of Dry
Long dry	4,200,000	520.8	100
Lepol	3,600,000	446.4	85
Suspension Preheater	3,000,000	372,0	71

Source: "Improving Kiln thermal efficiency". Part 4, Fig. 19. A. Rock Products, August 1974, p. 58

Note: This table gives information on "typical fuel consumption (excluding raw-material drying) for large, well designed and well-maintained semidry and dry process kilns in the United States".

Conversion factors: 1 short ton = 907.1847 kg.
Kcal/kg. = 1.8 BTU/16

Table 2. Various estimations of cost per ton of installed capacity

Capacity in tons per year	Dollar cost per ton of installed capacity 1960 a/	1970 b/	1970 c/	1976 d/
30,000		168		
50,000		116		
100,000	120	80	72	
200,000	100			
250,000		60		
300,000			60	
400,000	83			
500,000	80	55		
550,000				103
600,000			48	
1,000,000	56	42		
1,100,000				78
1,200,000			43.2	
1,400,000				

Source: See footnotes below.

a/ Data elaborated from case histories of 18 new plants in the United States 1956-60. Based on information published in Rock Products, May 1958 and 1959. Adjusted to 1960 prices quoted in Studies in the Economics of Industry I. Cement Nitrogeneous Fertilizers. United Nations, New York, 1963 (ST. ECA/75), p.3

b/ Data on investment cost in the cement industry reflecting the average situation in early 1970's. Taken from UNIDO: Industrial Branch Reports: The Cement Industry (UNIDO/ LTD 156. 9/II/72).

c/ Quoted in C.P. Pratt, Economies of Scale in Manufacturing Industry, University of Cambridge, Department of Applied Economics, Occasional Papers No. 28, C.U.P. 1972. p.92.

d/ Figures supplied by the Gerencia de Programación Industrial: Proyecto de Bienes de Capital, Nacional Financiera, S.A. México. Figures relate to new investment in the cement industry for approximately February 1976.

Table 3. Distribution of investment costs for various sized plants

Cost Item	(a) 100,000 typ cost per ton Dlls. inst.cap.	(b) 500,000 typ cost per ton Dlls. inst.cap.	b as % of a	(c) 1,000,000 typ cost per ton Dlls. inst.cap.	c as % of a
Mechanical equipt.	26	19	73	14	54
Electrical equipt.	4.5	3.6	80	3.0	66
Spare parts	3	2	66	1.5	50
Insurance and transport	4	1.8	45	1.0	25
Erectron and Start-up costs	10	5.2	52	3.4	34
Civil Engineering	30	18	60	13.0	43
Automation and instrumentation		7.2		4.0	
Other costs	7.5	4.2	56	2.1	53
	85	61	72	42	49

Source: Data contained in Tables 9, 10, 11 of UNIDO, Industrial Branch Reports op. cit. pp. 39, 40. Elaboration by author.

Table 4. Variation of total manufacturing cost with size of cement plant (United States dollars per year per ton of cement)

Cost item	Plant size in tons a year					
	30,000	50,000	100,000	250,000	500,000	1,000,000
Variable costs						
Fuel	4.07	3.58	3.13	2.70	2.36	2.14
Electricity (variable)	1.45	1.41	1.27	1.16	1.04	0.94
Production surplus and maintenance materials	2.05	2.05	2.05	2.05	2.05	2.05
Subtotal	7.57	7.04	6.45	5.91	5.45	5.13
Fixed costs at 100% capacity utilisation						
Labour	12.13	7.28	4.64	2.32	1.61	1.09
Electricity (fixed)	0.72	0.69	0.64	0.58	0.53	0.49
General plant expenses	2.13	1.28	0.64	0.32	0.26	0.17
Depreciation	18.48	12.76	8.80	6.60	6.05	4.62
Subtotal	33.46	22.01	14.72	9.82	8.45	6.37
Total cost of bulk cement	41.03	29.05	21.17	15.73	13.90	11.50
Addition for packing in 50 kg cement bags	2.20	2.20	2.00	2.00	1.90	1.90
Total cost of cement in bags	43.23	31.25	23.17	17.73	15.80	13.40

Source: UNIDO, 1972, op. cit, Table 16

Table 5. Economies of scale in the cement industry

Annual capacity of plant (tons)	Variable cost	Fixed cost	Total manufacturing cost of bagged cement
30,000	128	340	221
50,000	119	224	176
100,000	109	150	130
250,000	100	100	100
500,000	92	86	89
1,000,000	87	65	76

Source: Calculated from data contained in UNIDO, Industrial Branch Reports, The Cement Industry, op. cit., p. 55, Table 16.

Part 2

TRANSFER OF TECHNOLOGY IN THE CEMENT INDUSTRY

1. Introduction

Part 1 of this paper described the technological developments that have taken place in cement production technology during the present century, pointing out the economic implications of such innovations in terms of reducing unit costs. The other important effects of technological innovation were the possibilities of achieving greater control over the production process and the quality of the product manufactures and the continual tendency towards larger scale production.

In part 2 of the paper we shall discuss the process of the transfer of technology within the cement sector, especially the transfer of such technology to cement producers in developing countries.

To understand the mechanisms of technology transfer in any industrial branch it is necessary to understand the economic structures comprising both sides of the market for technology, as well as the nature of the technology and innovation concerned. Therefore the first two sections of this part of the paper are devoted to examining the structure of the cement machinery sector, and of the cement producing industry in various parts of the world. Once the structure of the demand and supply sides of the technology market have been analysed we can go on to discuss the actual mechanisms for technology transfer in the cement industry and their implications for cement producers in developing countries.

2. History of the industrial sector producing machinery and equipment for the cement sector

The production of machinery and equipment for cement production has, in the course of this century, become almost totally divorced from the cement producing sector. As a result of this separation the majority of technical innovations incorporated into modern cement production were developed in the machinery sector which has evolved into a highly specialised part of the heavy engineering sector on a world scale.

Production of cement machinery is today concentrated among very few producers which between them divide the (non-communist) world market. 40/ There are two German companies and one Danish company which together share the greater part of the world market. There are also a couple of small German companies, two French and two United States firms which supply ancillary technology and core technology

40/ While it is known that there are East European companies, especially in Czechoslovakia, producing cement machinery for the COMECON market, their participation in the rest of the world market in minimal.

produced under license from the major producers. In addition there are three Japanese groups which have been responsible for the development of the Flash Calcinator system and appear to be increasing their intervention on the world market, although it is important to note that they developed the Flash Calcinator systems on the basis of licences from the major European companies for the production of the suspension pre-heater systems.

The major European companies are firms which began as manufacturers of foundry parts and brick kilns during the nineteenth century and have expanded by specialisation into machinery for process industries and by diversification in the sense of corporate links with other branches of the heavy engineering industry. Today their command of the cement machinery market rests on a vast infrastructure of investment in heavy engineering facilities, plus extensive research and financial resources.

The best known of these companies is the German company Polysius which, as discussed in Part 1, was responsible for some of the major technical innovations in cement production. This company made its name in cement by the development of the Lepol (semi-dry) kiln. Although it did not develop its own version of the Suspension Preheater until 1958 (five years after Humboldt patented the system) Polysius has in recent years gained an increasing part of the world market, and is developing its own version of the Flash Calcinator. 41/ Moreover, considerable financial as well as heavy engineering strength has been gained by Polysius by its incorporation into the Krupp group in about 1969/1970. 42/ Polysius has its own subsidiary in the United States and appears also to have taken over the United States production and marketing facilities of Krupp. Polysius has production facilities in Great Britain, France, Canada and South Africa in addition to its United States facilities. The sales of Polysius in cement machinery have been increasing in recent years although no accurate data is available to indicate the exact proportion of total market enjoyed by each company. Table 5 indicates the rapid growth of Polysius' sales of suspension pre-heater kilns. In 1974 Polysius announced its best-ever year with a total volume of 390 million dollars. 43/

The Danish company F.L. Smidth & Co. is the second of the big European producers. As noted in Part 1, this firm has been producing cement machinery since the beginning of the century. Traditionally it concentrated on wet process kilns and its early important innovations were concerned with the improvement of wet process kilns and their ancilliary machinery. However, since the introduction of its own version of the suspension pre-heater in 1955 FLS has become known as a dry process supplier as well, and has maintained an important

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41/ Rock Products, Improving Kiln Thermal Efficiency, Part 5, September 1974, pp. 88, 89.

42/ Rock Products, August 1975, p. 59. Krupp was a minor producer of cement machinery but did not have the world renown that Polysius has in this branch. Polysius still continues to work entirely autonomously as far as the market is concerned and few people, even within the cement industry, are aware that Polysius is now part of the Krupp group.

43/ Pitt and Quarry, July 1975.

share of the market. In the early 1970's FLS machinery was estimated to be responsible for 40% of the existing world capacity. 44/ Whilst no merger of this company with any other group in the heavy engineering sector is known of, it is possible that it may be supported by the Danish government in terms of facilitating suppliers' credits to FLS's customers. 45/

The other important German company is Humboldt, which was first responsible for the commercial development of the suspension pre-heater. This company also started as a manufacturer of foundry parts in the mid-nineteenth century and has grown on the basis of mergers with various other companies in the engineering sector. In 1930 Humboldt merged with Motorenfabrik Deutz to form the company Humboldt Deutz Motoren A.G. Later in the 1930's it merged with the Magirus truck factory and in 1938 established itself as Klockner-Humboldt Deutz A.G. In 1969 it bought the engineering firm of Wedag, which had also been a minor manufacturer of cement machinery, and its full company name now is Klockner-Humboldt Deutz Industrieanlagen A.G. with Humboldt-Wedag being the cement machinery division. Humboldt licenses the suspension preheater for manufacture by the United States company Fuller, which is responsible for the sales of the Humboldt process in the United States. 46/ It has also concluded a technical license agreement for the preheater with the Japanese firm Ishikawajima-Harima Heavy Industries of Tokio (IHI) from which the Japanese firm developed their own suspension pre-heater system 47/ and later the Flash Calcinator. 48/

The two French companies referred to are Five Lille Cail and Creusot-Loire. Five Lille Cail was formed by a series of mergers between various companies involved in different branches of the engineering industry. Five Lille was originally a manufacturer of machinery for processing beet sugar. In 1923 it took over the operations of Dalbouse et Brachet which were then specialists in the production of ancilliary equipment for cement works. In 1963 the group acquired Societé Appelvage, a producer of cranes, conveyor belts and other heavy equipment in the materials handling sector. 49/ In the 1950's and 1960's FLC manufactured the suspension preheater under license from Humboldt 50/ but in 1972 announced the development of its own patented cyclone type preheater.

44/ "The Development of F.L. Smidth & Co", Cement Technology, Jan/Feb. 1973, pp. 14-19.

45/ The article quoted above comments "It is hardly an exaggeration to say that FLS constitutes an important factor in the Danish economy" talking of its role as foreign exchange earner and major exporter. Other firms in the cement sector complain of the fact that FLS is able to offer very favourable credit terms although the German companies are also in some circumstances supported by Government guaranteed credit.

46/ Rock Products, August 74, p. 59

47/ Cement Lime and Gravel, May 1968

48/ Cement Technology, 1972, No. 5

49/ Cement Technology, "History and Development of Five Lille Cail" 1972-1973, Jan./Feb. 1974, pp. 268.

50/ Cement Technology, March/April 1972, p. 35.

In 1973 the company merged with Babcock Atlantique, a subsidiary of the US-UK Babcock Wilcox group. FLC's main market has been former French North and West Africa, and Asia and Southern Europe and parts of South America but it is understood that much of the machinary it manufactures is made under license from Humboldt.

The other French company Creusot-Loire is much less well known. It recently announced a marketing agreement with Kawasaki Heavy Industry (KHI) of Japan to market their reinforced suspension preheater system (similar to the Flash Calcinator). Recent contracts announced by Creusot-Loire have all been in North Africa.

Until the mid 1960's there existed a cement machinery division of Vickers Armstrong, the UK aircraft manufacturer. However, this division has now been discontinued as a separate organisation within the firm although it appears that Vickers continues to manufacture rotary kilns and other parts of cement machinery under license from the European manufactures. 51/

The two United States companies are Fuller and Allis Chalmers. Both these companies work with licenses from the German manufacturers (see table 6), but account for a fair proportion of world sales, especially for those sales linked to United States credit.

Fuller is a subsidiary of the General American Transportation Corporation, a large engineering group concerned with transport and other equipment. The cement equipment division has been maintained as a separate entity and has been best known for the production of the Fuller Grate Cooler which for many years was considered to be the most efficient equipment of its kind. As discussed above, the Humboldt suspension preheater system is manufactured and marketed by Fuller in the United States. Fuller has its own affiliated companies in France, Great Britain, Spain, Mexico, Australia, Canada and South Africa. 52/ It has recently acquired the sole North American licesing rights from IHI of Japan, 53/ and is reported to be working on a new fluidized bed system of clinkerisation which it would bring on to the market independently.

Allis Chalmers is the other established producer in the United States, but this company too has traditionally worked on the basis of licenses from the

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51/ Cement Lime and Gravel, May 1968. Vickers announces a joint agreement with Wedag (now part of Humboldt) to "integrate the activities of the two firms in design and manufacture of cement manufacturing plants". In 1975 the General Engineering Department of Vickers Mechanical Engineering Division announced a contract to make £1.4 million of cement equipment (grinding mills and kiln shells) for FLS and Polysius. (See Cement Technology, March/April 1975).

52/ Rock Products, January 1974.

53/ Cement Technology, July/August 1972.

European producers. It holds a license for the manufacture of the MIAG suspension preheater 54/ and for the various equipments developed by FLS. 55/ It also has a licensing agreement to market world-wide the reinforced suspension preheater developed by the Japanese firms Kawasaki and Onada Cement. 56/ It was announced recently that Allis Chalmers was entering into a joint venture with Fiat, the vehicle and motor manufacturer, to make construction machinery. Whether this agreement affects the manufacture of cement machinery is not known. Most of Allis Chalmers sales of cement machinery are to South America, and more recently to the Middle East.

Another United States manufacturer which makes some items of cement machinery is Kennedy Van Saun, a subsidiary of McNally Inc. Pittsburg.

The United States machinery manufacturers have never been in the forefront of technical innovation for various reasons. The relatively smaller size of United States plants and the availability of cheap fuel until the early 1970's meant that they had neither the pace of investment demand nor the economic incentive to develop technological improvements. Another factor which slowed down the pace of technological innovation in the United States was the problem of alkali content which made the suspension preheaters unusable for many United States plants. However the market for US-made machinery was maintained largely on the basis of tied aid agreements 57/ using foreign licenses to manufacture the core machinery. Recently there appears to have been a renewed interest on the part of the United States firms to develop new technology especially in the face of the energy crisis.

The Japanese firms which have developed the precalcinating systems described in Part 1 are not yet an active part of the world market since the new systems have not had enough time to be industrially tested. However, it appears that as the systems receive wider acceptance, the Japanese firms will adopt the marketing strategy of licensing the well-known European and United States firms to sell their technology rather than trying to break into the very closed market under their own names. To this end a number of license agreements have already been celebrated: Ishikawajima Harima Heavy Industries, together with the Japanese cement firm Chichibu Cement Corporation have licensed Fuller Co. to market their system; 58/ Kawasaki Heavy Industries, with the Onada Cement Company, have licensed Allis Chalmers and Creusot-Loire to market their precalcinating system. On the other hand, both Polysius and FLS are reported to be developing their own precalcinating system so it remains to be seen to what extent the Japanese companies will penetrate the world market.

54/ MIAG is other smaller German manufacturer. It too appears to be losing its share of the world market although as yet there is no evidence of a merger/take-over move.

55/ Cement Technology, November/December 1972.

56/ Rock Products, July 1974.

57/ However, the Fuller cooler has been recognised as United States technology in its own right.

58/ Cement Technology, July/August 1972.

3. Analysis of the international cement industry

The result of the increase in minimum production scale and the cost of investment in the cement industry has been a trend towards increasing technical and economic concentration in the industry. As shown in Part 1, the average size of cement plants has increased substantially and the size of new plants shows an even greater tendency to increase in size. Concurrently, in both developed and developing countries there has been increased economic concentration, i.e. the national markets are increasingly being controlled by fewer and fewer firms.

In developed countries this concentration took place earlier than in developing countries. In the United Kingdom 65% of the capacity is controlled by one group (APCM Ltd.) 59/ while the largest three groups have control of 91% of installed capacity; 60/ this market structure has been more or less stable since the second world war. In France the three largest companies, Ciments Lafarge, Ciments Francais and Ciments Viart, produced in 1972 70% of the total domestic consumption and this figure increases to 90% "if their participation in smaller companies is included." 61/

In other European markets the same concentration is manifested. In 1974 S.A. Cimenteries C.B.R. supplied 40% of the Belgian market; 62/ in Denmark **Arkeselkabathalberg Portland Cement** Fabrik owned nearly 90% of the installed capacity in the country. 63/

In the United States the degree of economic concentration has been somewhat mitigated by the size of the United States market and its division into discrete regional markets. Also the application of the anti-trust laws inhibited the nationwide growth of United States firms. However, by 1966 analysis showed that in only 3 of 51 regions did the four largest suppliers account for less than 40% of sales; in 14 areas the largest 4 firms accounted for between 50 and 70% and in the remaining 34 areas 75% of sales was shared between four or less suppliers. In terms of the whole national industry cement is reported to be amongst the most highly concentrated sectors with the largest companies measured on a nation-wide basis frequently being the leading firms in regional markets. 64/

59/ APCM has been the leading manufacturer since 1900 when it was formed from an amalgamation of over 38 independent producers.

60/ Zoete and Gordeon, Stock Exchange London, The Cement Industry, 1969.

61/ "Cement and Lime in France", Cement, Lime and Gravel, February 1973.

62/ Informations Internationals DAFSA.

63/ CEMBUREAU World Cement Directory, 1970.

64/ U.S. Federal Trade Commission, Staff Report, "Economic Report on Mergers and Vertical Integration in the Cement Industry", April 1966.

A further tendency in the cement industry in developed countries is the tendency towards vertical integration into cement using sectors, especially the ready mixed concrete industry and the concrete products manufacture sector. In Canada the percentage of sales going to the Ready Mixed sector was over 70% in 1975; 65/ in Japan the proportion was 40% by 1972 66/ and in the United Kingdom it had grown from 10% in 1963 to 40% in 1972. 67/ In the United States the same tendency was apparent by the mid sixties. The Federal Trade Commission Report was of the opinion that there had been a virtual fusion between the Cement Industry and the Ready Mixed Concrete Industry. By 1965, 40 RMC firms had been acquired by leading cement companies while several RMC companies had gone into the manufacture of cement. The sales to the Ready-Mix sector (60% of total sales) are dominated by sales from cement producers to fully owned integrated Ready Mixed Concrete facilities. 68/

Other aspects of vertical integration include the expansion of cement firms into concrete product facilities and into prefabricated building components and ultimately into real estate construction companies. 69/ Since the oil crisis the United States cement industry has also been integrating backwards into coal and other fuel products. 70/

These trends are being repeated in other countries, especially in developing countries which have long been self-sufficient in cement production. Since the home market can only grow to the extent that the derived demand for cement increases (and this is directly dependent on the growth of Fixed Capital Investment in the economy) competition between producers to increase their market takes the form of extra cement production activities designed to achieve a greater control over the final market for cement and also control over the basic inputs.

The form and extent of economic concentration in the Latin American cement industry will be discussed in the country monographs on Mexico and Argentina.

Another important aspect of the world cement industry is the substantial degree of internationalisation within the industry. Firstly there has always been a certain amount of trade in cement and this is accentuated by periodic shortages

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65/ Berald Aranoff, "Canadian Cement Industry Expanding into the US Market", Pitt and Quarry, July 1975.

66/ C.E. Reynolds, "The Cement Industry in Japan", Cement Technology, September/October 1970.

67/ Financial Times, "Survey of Concrete", 15 February 1973.

68/ Federal Trade Commission, op. cit. chapter 5, p. 92.

69/ Lone Star, Inc., one of the major United States cement manufacturers operates National Building Centres and Home Care Centres, which sell building materials and modular housing. The company also invested heavily in land and housing development although this is seen as diversification rather than vertical integration. (See Lone Star Inc., Annual Report, 1971.)

70/ Ideal Basic Industries has formed a Joint Venture with the Rocky Mountain Energy Co. to reopen and expand underground coal mining. Pitt and Quarry, April 1974, p. 12.

in various parts of the world, the most notable one being the United States in the early 1970's. 71/ The other aspect of internalisation has taken the form of foreign investment by cement producers of industrialised countries in both other developed and underdeveloped countries.

In the European market there is a substantial degree of cross investment with Swiss investment in the German industry, Belgian investments in the Dutch industry and various European investments in Spain, Portugal and Greece. The most notable feature of the North American industry in recent years has been the growing role of foreign (European) investment. The most active investor is Holderbank, the Swiss group, but the French company Lafarge has also made important investments in both the United States and Canada.

In the Canadian cement industry 3 of the 4 publically owned companies have substantial foreign investment. These three companies comprise 76% of total installed capacity: Ciments Lafarge has a 54% participation in Canada Ciments Lafarge; Societé General de Belgique has 22.4% participation in Genstar and APCM owns another 11% in the same company; the Holderbank group holds a 35% share of the St. Lawrence Cement Company. 72/

About 10% of total installed capacity in the United States cement industry is now controlled by foreign investment. Holderbank bought a million ton a year plant in Dundee, Michigan, in 1958 and opened a 1.25 million ton plant at Clarksville, Missouri, in 1967. Holderbank also markets cement produced by the St. Lawrence Cement Company, Canada, via another subsidiary in Chicago. 73/ The French company Lafarge formed a joint venture with Lone Star Inc. called the Ditadel Cement Co. Citadel has invested some 5 million dollars in cement capacity in the United States. Another French firm, Ciments Vicart of Grenoble bought the National Cement Company of Alabama in 1974. The National Portland Cement Plant at Broadhead, Pennsylvania, has been owned by Danish capital since the 1930's.

On the other hand the large United States producers have themselves a certain amount of foreign investment abroad, mainly in developing countries. Lone Star has three fully owned subsidiaries and one majority-controlled subsidiary in Latin America with a total overseas capacity of 2.1 million tons. Kaiser Cement and Gypsum has interests in two Thai plants and one Indonesian plant with a total capacity of 940 000 tons. Kaiser also had a share in a Japanese firm (capacity 440 000 tons) but is reported to have sold that interest in 1975. Universal Atlas owns an 850 000 ton plant in the Bahamas and was involved in plants in Greece and Majorca, but these latter interests have now been sold.

71/ US imports of cement grew from 0.7 million tons in 1963 to 3.6 million tons in 1973, which represented 8% of total production. Foreign trade formed less than 5% of total world production in 1970. (See CEMBUREAU, World Cement Directory, 1970)

72/ G. Aranoff, "Canadian Cement Industry Expanding into the US Market", op. cit.

73/ Cement Technology, September/October 1973.

In addition to these direct investments by United States cement companies, General Portland tried to buy a 49% interest in a Mexican cement firm. This was thwarted by the Mexican Government but it is reported that a long-term export contract between the Mexican firm and General Portland was substituted. 74/

The leading European producers also have extensive direct foreign investment in developing and developed countries. The British APCM group has interest in 40 cement and clinker grinding plants abroad: in Australia, New Zealand, Bahamas, Malaysia, South Africa, Nigeria, Rhodesia, Kenya, Canada, Mexico and Singapore. In 1973 cement deliveries from the overseas companies in which APCM held interests reached 14.6 million tons, compared to the 12.5 million tons produced in the United Kingdom. The French company Lafarge has interests in 25 cement and clinker grinding factories abroad which have a combined capacity of 10 million tons (compared to the 15 million in France). Lafarge controls 40% of both the French and Canadian markets, 80% of the Moroccan market and substantial parts of the markets in Senegal, Antilles, Brazil, the Camerouns, Gabon and the Ivory Coast. Societé de Ciments Francais has investments in cement factories in Morocco, Luxembourg and Spain. 75/

The Swiss Group Holderbank is a very large conglomerate of financial and industrial interests and it is difficult to ascertain the exact extent of its investments in foreign cement producing facilities. However, by its own admission, it controls 30 companies in 17 countries though the total is probably higher. Most of its overseas investment is in East and Southern Africa, although it has recently increased its investment in cement production in Latin America, especially Mexico and Brazil. The company claims to control an annual cement capacity of 30 million tons with direct control of 20 million, which would make it the biggest cement multinational company in the world. In addition it has technical and management contracts with other cement plants in developing countries and controls many other enterprises connected with building materials and construction. 76/

Japanese cement companies have also started to invest overseas, basically in Southern Asia. Onada Cement is reported to be entering a joint venture with an Indonesian company to establish a new cement factory in Indonesia. 77/ Onada are also apparently entering a joint venture for the establishment of a plant in Singapore. 78/ Since Japanese cement firms have tie-ups with the leading Japanese machinery producers with whom they effect turnkey contracts and other

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74/ US cement manufacturers have made similar export contracts with other Latin American producers. Because of the decapitalisation of the United States industry and the high cost of investment made even steeper by the strict application of ani-pollution legislation, plus the fuel shortage, it is often cheaper to import than to invest in new production facilities in the United States.

75/ Information in this section comes from various international business directories and from the trade press.

76/ For rarely published information on Holderbank see Rock Products, May 1973.

77/ Rock Products, January 1974.

78/ Cement Lime and Gravel, May 1969.

joint ventures, there may well be other Japanese foreign investments in the cement industry.

Although cement is not considered as a sector in which multinationals are dominant, there is a considerable degree of internationalisation within the world industry. The Fortune directory (1974) lists six cement groups in its list of the 300 largest non-US companies: Lafarge, Holderbank, APCM, Genstar and the Japanese companies Ube Industries and Miubishi Mining and Cement Co. 79/

In addition to direct investments there are a number of other ways in which foreign capital is involved in overseas production, especially in developing countries. These range from technical and managerial contracts, suppliers' credit, long-term export contracts and licenses and patents for the use of process technology or special cement production. These will be discussed in the next section.

4. Channels of technology transfer in the cement industry

The transfer of technology to the cement industry in developing countries is conditioned by the structure of the technology producing sector as well as by the nature of the links between local cement industries and foreign capital.

The variations of organisational forms of cement producers in developing countries are listed below:

(a) Fully-owned subsidiary
(b) Local company with various degrees of foreign participation
(c) Joint ventures between local (state or private) and foreign capital
(d) Fully-owned State company
(e) Private, locally-owned company

All these forms exist in the cement industry in developing countries. As discussed in the previous section, the major European and to a lesser extent the United States producers have substantial investments in cement companies overseas. The form which the association with foreign capital takes, depends partly on the historical circumstances of industrialisation in individual countries and partly on the development strategy adopted by those countries with reference to foreign investment and State participation in the industrial sector. The concentration of British and French investments in cement is found primarily in their former colonial territories. United States foreign investments are found primarily in the Far East and in parts of Latin America where US capital has played a historically important role. 80/

79/ The Fortune ratings are on the basis of world sales. Although this does not necessarily indicate that these companies have high international activities, the limitations of the cement markets in their home countries, especially the European companies, implies that a large proportion of their activities must take place abroad.

80/ However, United States capital has never played a dominant role in cement production in any of these countries.

In Latin America the cement industry is, in its major part, owned by independent local capital. Fully-owned subsidiaries do exist, for example in Argentina and Uruguay (and formerly in Mexico). However, these investments date back to the beginning of the century and al least in Argentina and Uruguay do not play a leading role in the cement industries of these countries. In Mexico foreign investment (minority controlled) accounts for about a third of total production capacity. However, in most of Latin America national capital accounts for the larger proportion of market shares.

In West and East Africa the more usual form of organisation of cement firms is State companies with either direct foreign participation or management and technical contracts with foreign cement producers or machinery suppliers. In the case of joint ventures with cement producers the latter are generally nationals of the former colonial power which controlled the import market before local production was initiated. In these cases the role of the State has been to prevent total foreign control by substituting for the lack of local capital which is inexistent after long periods of colonial administration. The fact that many West African countries initiated cement production relatively late (in the 1950's as compared with the beginning of the century in many Latin American countries) implies that they were faced with much more technically complex production possibilities, which forced them to collaborate technically as well as financially with foreign capital. The long history of cement production by local capital in Latin America on the other hand has implied that local capital has had a long learning process and has been able to incorporate new technology into new investment as the technology has evolved over time.

The role of the State in centrally planned economies of North Africa is clearly less passive but these companies also rely to a certain extent on technical if not financial aid from foreign firms.

In Asia the situation depends on the history of the individual country. India's cement industry enjoys a considerable degree of State participation and the role of foreign capital although present, is strictly controlled. Shri Lanka also has a large degree of State participations in the cement industry but is totally dependent on machinery suppliers and foreign consultants for technical assistance. In South Korea, Malaysia, Singapore and Indonesia, the cement industry is largely in the hands of private capital although State participation and foreign investment are both present.

5. Influence of organisational form on the transfer of technology in the cement industry

The intervention of foreign capital in the cement producing sector as well as the concentration in the sector producing machinery and equipment influences the possibilities of effective transfer of technical knowledge within the cement industry, and limits the possibilities of building up local technical capacity on the part of cement producers in developing countries. While each case depends on its particular circumstances we are able to make some general observations about the way in which organisational form and association with foreign capital influences the transfer of technology. 81/

(a) Fully-owned subsidiary: these companies are generally reliant on their parent company which acts both as negotiator (with machinery and credit suppliers) and technical consultant on behalf of the subsidiary. The local company has no control over investment decisions and often all the investment planning is done at company headquarters so that local personnel have no opportunity to participate in the various stages of the investment. The parent company usually makes a technical contract with the subsidiary in theory to pay for their technical services though in practice these contracts also help the parent company to repatriate profits. In addition special contracts are made both with the parent company and also with consultants and machinery suppliers for particular services, usually connected with new investments.

However, the fact that the local company has no control over the investment process does not necessarily mean that the cost of the investment is higher than the prices prevailing on the world market. A well-known international company is in a much stronger bargaining position vis-a-vis machinery suppliers than a small company from a developing country. But the benefits of low prices are recouped by the parent company rather than by the subsidiary.

(b) Minority-owned subsidiaries: In principle these companies are in the same position as fully-owned subsidiaries and generally have technical contracts with the foreign investor in return for his technical services. In practice however the existence of local participation makes it necessary for many of the technical positions to be filled by local nationals. Hence the foreign investor is forced to train local personnel who therefore have a greater participation in the investment process. While the local company may be involved in the planning stage, the foreign investor has the final decision on all investments and usually negotiates directly with the suppliers. The parent company's technical capacity in terms of plant design, computer programming and quality control techniques is also used though local personnel may be trained to utilise the data banks held by the parent company. In general there is much more room for negotiation of local technical participation in this situation than in the case of the fully-owned subsidiary, although the exact degree of local autonomy depends on the reasons why foreign participation exists and how it is controlled by the local government.

(c) Joint ventures with State capital: In these cases the nature of the State participation is important. In certain investments in West Africa, where Federal and State government have put up capital to build a cement plant jointly with European companies, the State cedes all rights over technical and investment decisions precisely because it does not possess the technical capacity, in the

81/ These general observations are based on 10 case studies made in cement firms in Argentina and Mexico, as well as more general research on the relationship between cement multinationals and their subsidiary companies, and on the role of machinery suppliers in the transfer process. Detailed information of the Argentine and Mexican cases will be found in the corresponding country monographs.

form of trained and experienced high level technical manpower to intervene, even though training and counterpart programmes are generally stipulated in the contracts. On the other hand, a Mexican firm which has received financial investment from a parastatal financial institution precisely to avoid foreign investment in a firm which has considered selling out to United States capital is in much the same position as a totally private-owned local firm.

(d) Fully-owned State companies: there are few companies which are totally State-owned outside centrally planned economies and those that exist are set up precisely because neither local nor foreign capital consider them an on-going commercial venture. They are usually situated in badly communicated, distant parts of the country where they are able to operate at high unit cost without any competition from the rest of the industry. State companies of this nature usually employ machinery suppliers to manage their investment decisions and procedures and the suppliers take on the role of consultants as well as machinery suppliers.

(e) Private local companies: these companies are those that are in a position of most freedom with regards to control of their investment activities. However, the degree of freedom they are actually able to maintain depends on the technical capacity of the individual firm. Some local firms are large and growing concerns which over time, and with the help of a conscious policy, have been able to build up their internal technical capacity and are able to negotiate good terms with machinery suppliers and financial institutions and can dispense with most, if not all, of the services offered by technical consultants (machinery suppliers and others). On the other hand, some local firms are entirely dependent on the assistance of those elements within the international industry which offer technical services necessary to implement new investments. These firms are normally small firms with no technical base within the firms. Consequently, they are in some ways worse off than the fully-owned subsidiaries. Although they make their own investment decisions in the sense that they decide whether or not to invest in new capacity and the size of the new investment, that is as far as their participation in the investment process goes. The machinery suppliers design the whole project and very often take responsibility for the execution of that project, subcontracting themselves the companies responsible for civil works, erection and the minor local suppliers. The investing firm loses the opportunity for future learning since the machinery suppliers can stipulate that they will not hand over the detail plans of the machinery they are supplying. Moreover, the small firm lacks the bargaining power in terms of price and credit terms available to the subsidiary via the parent company and the cost per ton of installed capacity to such firms can exceed by up to 100% the cost available on the world market to a firm with more bargaining power. Small firms are also at a disadvantage in negotiating for technical assistance contracts, if only because they have no means of assessing the indispensibility and the quality of the services they are being offered. Sometimes both financial credit and technical assistance contracts are negotiated jointly especially for firms in developing countries with no technical base, in which case the two aspects are interrelated and there is no other choice but to accept the credit conditions and the consulting package offered.

It has been known that the same firm supplies the bulk of the capital goods necessary for the investment at the same time as acting as a major credit supplier and celebrating a separate technical assistance contract with the investing firm; on other occasions the consultant firm is different from the machinery supplier, but has close links with the financing institution.

The firms observed in the case studies in Argentina and Mexico include both extremes described here. Some local firms, especially those which have captured the greater part of the local market, have a relatively advanced technical base and are able to unpackage contracts, negotiate on reasonable terms with different suppliers, obtain finance directly on the international market, and dispense with all additional technical assistance. Others are entirely dependent on the technological package supplied by the machinery suppliers/consultants, and have great difficulty obtaining investment finance even for small projects.

6. Elements involved in the transfer of technology in the cement industry

As in many other industries, transfer of technology in cement is primarily realised via new investment in production facilities, i.e. via the acquisition of machinery and equipment either to construct a new plant or to extend or modernise the capacity of existing plants. However, there are also elements of process technology mainly concerned with plant management which can be acquired separately from major new investments and which can come from different sources.

The typology of technical elements involved in the transfer of industrial technology has been described by various authors, 82/ and includes the following stages:

(1) Feasibility studies
(2) Design of plant
(3) Tenders and estimates
(4) Contracts
(5) Civil works
(6) Erection of plant
(7) Putting the plant on stream
(8) Achieving guaranteed production
(9) Quality control
(10) Automation
(11) General plant management

These elements will be discussed below with reference to their importance for technology transfer in the cement industry.

(a) Elements of technology directly related to new investments

Feasibility studies imply a two-fold investigation: Firstly a geological study must be made of the raw materials to be used for cement production: their degree of purity, in terms of the required chemical composition

82/ For example C. Cooper and F. Sercovich, The Channels and Mechanisms for the Transfer of Technology from Developed to Developing Countires, UNCTAD, Genova 1971.

and the difficulties involved in eliminating impurities, or the degree to which certain elements contained in the raw materials will affect the production of cement. Secondly, an economic study must be made in terms of the cost of materials, the market for the product, the cost of investment (including the cost of finance and the production and distribution cost).

On the basis of the feasibility study the decision to (or not) invest is made. Once that is taken the next step is to design the productive facilities. It is here that the greatest divergence is found between different firms with different internal technical capacities. One possibility is to hand the whole project over to a consultant/machinery supplier stating only the production capacities required and the nature and characteristics of the raw materials available. This is known as a turn-key contract since the contracted firm takes charge of the whole project, handing it over to the investing firm only when the plant is on site and functioning.

However, if the firm is able to specify what type of process it desires and the specifications of each piece of equipment, as well as the plant layout, etc., it is in a much stronger position to negotiate prices and conditions and to ensure that the equipment it is buying will fulfill the requisites of the firm.

At this stage a number of tenders can be submitted by suppliers for consideration and the relative technical and economic merits of each can be assessed. This is an important aspect of the investment since although there are so few major suppliers, each one has a reputation for different parts of the process and different pieces of specialised core and ancillary machinery. If the firm is able to negotiate a separate contract for each part of the production line it is likely to get better results in terms of financial cost, technical efficiency and in terms of its own control over the investment which has an implied learning effect. It is also important that the investing firm is able to participate in the detailed planning of the investment and to have open discussions with each supplier on the detailed specification of the equipment. In this way the firm is able to ensure that they are buying a product which will give the required technical performance rather than ending up with a piece of obsolete equipment or one which has given problems in the past, but which the machinery suppliers are anxious to sell in order to recoup their own development costs.

The other elements in the investment process, the erection of the plant and the civil works necessary can be contracted out to different local or foreign contractors; the fact that the investing firm is able to retain the over-all management over these elements implies that they are in a position to control the costs and standards of these activities and that the experience in doing so will improve their capacity for such activities in the future. The main machinery supplier is often willing to assume responsibility for these activities, subcontracting directly to other companies, but clearly will charge for these services.

It is generally implicit in most contracts that the machinery supplier has the responsibility to put the production line on-stream and to ensure that it reaches the guaranteed output stipulated in the contract. However unless otherwise stated, the responsibility of the machinery supplier ends at this point and subsequent production problems are the responsibility of the investing firms. If a long-term technical contract with the machinery supplier, or other technical consultant exists, they may undertake the problems of trouble shooting but this again implies a heavy cost to the investor both financial and in terms of loosing the opportunity to master the technical details of the process and to effectively control the plant from a technical point of view.

However, some problems with plant are due to defects in design and construction which are ultimately the responsibility of the supplier. A machinery supplier is much more likely to admit responsibility in the case of a well-known/large/technically competent firm than in the case of a small firm with no technical base if only for the reason that the large firm represents future business which they cannot afford to risk loosing. And secondly of course, the firm with technical capacity is in a better position to demostrate that the error originates in faulty plant design or construction rather than in problems with plant operation.

(b) <u>Elements of technology concerned with production and plant management</u>

The elements of technology in cement production which are not necessarily linked to new investment are those concerned with general plant management, maintenance, quality control and automation. As discussed in Part 1 of this paper, new techniques of quality control and automation of the productive process have been applied very recently to cement plants. While these techniques imply considerable technical advantages which can be translated into economic advantages over competitors in the form of increased productivity and reduced unit costs, they also bring the producer into a new sphere of potential technological dependence, and require considerable investment in new kinds of technical skills.

Firms interviewed which have adopted such systems are of two types: firstly the minority subsidiaries of multinational companies which specialise in the application of such techniques to cement production. These firms are employing to great advantage programmed maintenance systems, automatic quality control and process control. However, although considerable investment has been made in terms of training local personnel to operate these systems they are entirely reliant on the data and programme banks of the foreign company to produce the programmes, install the computer and cope with any variations to normal conditions of operation. It seems likely that the withdrawal of foreign personnel and especially the restriction of access to the foreign data/programme banks would make the equipment non-functional at least in the immediate future.

On the other hand two national firms were interviewed which were applying to a lesser degree the techniques of automation and programmed maintenance. One firm having installed a computer to operate the kiln found that it had in fact bought a "black box". The programmes were supplied on computer tape without the programmes containing the data so that the moment the variables differed, in the course of normal operation, from those contained in the tapes, the computer was unusable for kiln operation. In addition the same firm had contracted one of the major machinery manufacturers to provide it with a system of programmed preventive maintenance. The contract was of five years duration, involving the clasification and programming of each element of the machinery in the plant, and was expected to be put into operation after three years of preliminary study.

Another national firm which had bought a computerised system from a machinery supplier some few years ago when the particular system was still in the experimental stage was using specialised personnel to write new programmes with the purpose of using the computer to control the calcination process, to carry out all quality control procedures and, eventually, to automise the complete production line once the operational problems had been solved by the internal technical capacity of the firm itself.

These examples are discussed in detail because they illustrate the dangers of installing advanced technology without understanding its uses and limitations and without simultaneously expanding the firm's technical capacity to cope with such specialised production techniques. Clearly however, if the adoption of new technologies of automation etc. is left entirely to market forces, with no institutional control, there will be a two-fold tendency: firstly the firms in developing countries with access to technical know-how from their foreign investors will introduce these techniques at relatively low costs and force their competitors to follow suit, or to lose their share of the market. And secondly, that the unrestricted application of automatic techniques, apart from leading to an even lower enployment-absorption in the cement industry will result in a further dependency on imported technology, both in terms of the specialised equipment required, and also the specialised manpower and information needed to run them. Since, in these kinds of operations it is possible to import the hardware while retaining the information contained in the software outside the country it is possible that the degree of dependency will not only increase but will become self-perpetuating in a way which conventional government policies designed to counteract such technological dependence may find it difficult to alter.

7. Factors which affect the firm's ability to unpackage contracts

In the previous section we illustrated the fact that the local investing firm is faced with a series of options between two extreme limits: that of a turnkey contract for the design and construction of a plant, and at the other extreme, the possibility of direct negotiation with suppliers, the unpackaging of the various elements of technical knowledge and services required and the retaining of control over the whole investment process.

The ability of the local firm to unpackage its technology purchases depends partly, as we have seen, on its links with foreign capital. Here we will analyse in more depth the intervening factors which encourage or restrict the ability of the local firm to develop the capacity to adopt an independent position vis-a-vis its imports of technology.

There are three kinds of actors which intervene: technical, financial and institutional.

(a) Technical factors

The technical factors we have to some extent discussed above in terms of the elements involved in transfer of technology to the cement industry. But it is necessary to separate them out in detail. One way of unravelling them is to counterpose the concept of technical capacity to the concept of technological dependence. The technical capacity of a cement firm can be defined in 5 stages:

(1) The ability to maintain production with the existing equipment, with no outside technical assistance;

(2) The ability to effect small and medium modifications to increase productivity without installing new equipment (i.e. marginal improvements in fuel consumption and capacity utilisation due to more exact control over raw materials mixing, and quality control;

(3) The ability to carry out the studies and designs necessary to expand existing equipment;

(4) The ability to design and carry out projects for entirely new plants without outside technical assistance (from suppliers or consultants);

(5) The ability to effect innovations in equipment and to carry out innovations in the production process (here is included the application of new techniques of automation and process control).

To each of these stages corresponds a development of manpower such that the internal resources of the firms are sufficient to manage whatever project the firm undertakes without relying on external technical assistance. The first two stages are clear, and refer to firms which are established, which have already invested in what has now become semi-obsolete equipment but which are able to improve the performance of the equipment in order to maintain their competitive position, perhaps while they are studying and effecting new investment. In terms of developing countries the observations made earlier about the different timing of investment in cement capacity in different historical and geographical situations is relevant. A Latin American firm with 40 or 50 years of experience in the industry has had time to develop an internal technical capacity to match the nature of the equipment it is using. On the basis of that existing capacity it is a strong position to organise itself to develop the skills necessary to effect new investments and to familiarise itself with new technical options as they become available on the world market. On the other hand, the new firm, established for example in the oil emirates of the Middle East, although equipped with the most modern (and expensive)equipment, with large scale plant and automation techniques, is unlikely to possess the internal technical capacity either to become self-sufficient (in the short run) in the management of their existing equipment nor to participate in, let alone control the investment process connected with the installation of new productive capacity.

The second important factor which becomes relevant when discussing the expansion of existing plants and the investment for new plants is the knowledge of the new technical options available. This again is related to the existing technical capacity of the investing firm. However, it is not only the knowledge of options available which is important, but also the ability to obtain them on the world market on the terms most convenient to the firm seeking to expand its internal technical capacity and to adapt innovations available to its own particualr productive situation. 83/

Clearly one way of ensuring this is to buy technology in the process of development and to participate in the application of the new technology to the firm's own production situation (the case of the computer system mentioned above). However, this implies that the firm is already organised in such a way as to be able to absorb, manage and take advantage of the new technology, rather than allowing it to become a burden on its technical resources which have not foreseen the necessity to prepare new management/control systems to internalise the new techniques.

Thus the firm which is able to maintain the greatest degree of freedom regarding the negotiation and management of imported technology is the one with experience in the field, with knowledge of technical developments in the industry and which is internally organised to cope with and utilise the new technology it is buying. The individual history of the firm will determine whether it is in a position to develop this capacity, and its relations with foreign capital will also be instrumental. However, the absence of restrictions from foreign investors and the antiquity of a firm are not sufficient conditions to ensure that a particular firm is able to develop the technical capacity referred to. The country monographs will attempt to analyse in more detail the explanatory variables limiting the development of technical capacity in individual cement firms in Argentina and Mexico.

(b) Financial factors

The second group of factors involved are financial. A pre-requisite for any investment is the availability of finance; there are various alternative forms of financing investment available to cement companies, each of which may have a different effect on the freedom the firm has in negotiating its technology imports:

The first form is the internal finance of the firm itself which clearly implies no restriction on its negotiating position (except in the obvious case where self-financing implies finance from the parent company). However, given the indivisibilities of cement investment and the large sums involved, it is extremely unlikely that many firms in developing countries are able to finance

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83/ For example, many firms believe that the new flash calcination system necessarily has to be used with extremely large kilns, and in a fully automatic plant. However, according to an employee of one of the leading consultant firms, the system can be applied to medium sized kilns and does not require an automated plant to be made operational.

this kind of investment in foreign exchange. 84/

The form of self-financing used in developed countries - raising capital by new stock issues - is not available in most developing countries because of the peculiarities and restrictions of the local capital markets.

If self-finance is not available either from accumulated reserves or from new capital issues, the firm has to resort to outside finance which is the most common case in the cement industry in developing countries. The forms of outside finance are varied, and the financing of any investment is usually a mixture of all the alternatives.

Suppliers credit plays an extremely important part in financing new cement investments. As discussed in Section 2.1 the major machinery suppliers are part of immense industrial enterprises which have strong financial interests behind them. Most new investments in developing countries contain a large amount of credit obtained directly from the major machinery supplier. This form of credit commonly accounts for 1/3 to 1/2 of the total foreign exchange cost of the project. Therefore a firm faced with two or more different tenders will necessarily be influenced in its choice of supplier by the fact that a particular firm is able to offer more credit, and/or better credit terms than its competitors. However, the acceptance of a particular line of credit may restrict the firm's ability to unpackage the contract in the sense that it may be obliged to buy the whole line of equipment from one supplier which offers credit, when it may prefer for technical reasons to purchase parts of the line from various different suppliers.

National banking credit is generally not very active in financing private investment projects in the cement industry, at least in Latin America where most of the research has been done. In these countries the role of the national banks is generally to guarantee loans contracted abroad in foreign exchange, though the local content of the contract may be financed directly by local banks. National non-banking institutions on the other hand have been known to participate actively in local cement industries. Like national banks they guarantee foreign loans, but also finance part of the investment projects and have occasionally bought out part of the share ownership of national companies which were in danger of going bankrupt or of selling out to foreign capital.

Foreign banks are much more important in cement investment financing because of the fact that the majority of the investment contract has to be paid for in foreign exchange. Cement companies from developing countries seeking finance on the international market generally contract loans with consortia of banks rather than with individual institutions, and sometimes prefer to spread their risks of exchange fluctuations by contracting loans from banks in a number of different European and North American countries. However, with the increasing fusion of

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84/ An exception, at least until recently, were the cooperative cement firms in Mexico which have special tax arrangements which allow them to dedicate a large proportion of gross profits to investments. However these firms too have recently had to resort to outside finance and have found that this has restricted their freedom of choice of suppliers.

industrial and financial capital on the international market, loans to cement producers from individual banks or consortia often tie the investor if not to one particular supplier, to suppliers from one particular country.

Table 6. World and United States sales of suspension preheaters

Developer and manufacturer	United States representative	Year developed	World sales 1966	World sales 1971	United States sales, 1971
Humboldt a/	Fuller	1950	180		16
Wedag	-	1962	15	267	0
F.L.Smidth	F.L.Smidth	1955	24	75	1
Polysius	Polysius	1958	55	132	0
Krupp b/ Germany	Krupp	1964	11	26	3
Miag Germany	Allis Chalmers	1968	0	5	2
TOTAL			285	505	22

Source: Rock Products, August 1974, fig. 22, p. 59.

a/ Humboldt Purchased Wedag about 1969.

b/ Krupp purchased Polysius about 1970.

Official banking institutions set up by developed countries to provide investment finance to developing countries offer an alternative source of credit. However, these loans are definitely tied to the purchase of capital goods in the country concerned although the terms of credit are unusually more advantageous than those obtainable on the commercial market. The most common example of this is the Export Import Bank of the United States which has made available several lines of credit to Latin America countries which have been utilised for cement investments. 85/

Another example is the FRG's Kreditanstalt fuer Wiederaufbau which has also given credit to finance investments in cement capacity in Latin America: however these loans have to be used to buy equipment in the country concerned - the United States in the former case and the Federal Republic of Germany in the latter.

85/ In terms of the fact that loans from the Export Import Bank of the United States are tied it should be remembered that the restrictions are only geographical. Thus a loan from EXIMBANK can be used to purchase machinery and equipment from European manufacturers which have production facilities in the United States, although such contracts most often go to one of the United States suppliers.

International financial institutions have also been active in financing cement investments, especially the International Finance Corporation, which has financed some 15 different projects in Latin America and elsewhere. However it is not clear what degree of control the IFC exercises over the companies to which it gives credits since the loans from the IFC are always announced jointly with the announcements of which firm has the major equipment contract, and if different, to whom the technical assistance contract has beeen awarded.

The necessity to raise finance and the limitations of local capital markets thus tend to impose restrictions on the choice of technology supplier, and hence on the ability of the firm to unpackage contracts in the way it wishes. However the ability to obtain finance, internal or external, is linked to the size of the firm concerned, its market share and its growth possibilities, all of which are measures of its credit worthiness. Technical capacity is also often related to the size of the firm, since a large and growing firm will be more likely to invest in the skills and organisational systems necessary to maintain their technical capacity at the level dictated by the pace of technical change in the industry. Therefore the restrictions imposed by tied loans are probably felt most by those firms whose technical capacity is insufficient to provide them with the elements with which they could exercise complete freedom of negotiation and choice of technology suppliers.

(c) Institutional factors

Various types of government policies affect the ability of firms to unpackage technology and build up their internal technical capacity.

Control of imports of capital goods together with the promotion of local capital goods industry can be important and positive if such policies are realistic and efficiently implemented. A common kind of policy measure is that which prohibits the importing of items which can be produced within the country. If the local capital goods industry is developed to the extent that certain items of cement equipment, even those items general to other industry, can be manufactured in the country, the firm and the government are forced to detail the parts and equipment comprising each investment project in order to distinguish the locally producible component.

However, there are limitations and problems with this kind of policy. Firstly, although some ancillary equipment and general parts may be produced locally, the major supplier may refuse to guarantee his equipment if the plant has to incorporate local material. Secondly, the response of equipment suppliers at least in some Latin American countries to such policy measures has been to set up local offices in those countries which are responsible for the production of the local component of the plant. In such cases the promotion of the capital goods industry does not have the secondary effect of encouraging the growth of technical capacity within the client firms of the capital goods industry whatever general multiplier and foreign exchange savings effects it might have on the economy as a whole. And thirdly, there is real danger that items which local producers convince the government are available in the country are actually not obtainable either in the quantity or to the specifications required. In this case the policies tend to back-fire since the client firms put pressure on the government to open the frontier to the imports they require and have no faith in the production of local parts and equipment. This in turn has a negative effect on the whole policy of encouraging the growth of local capital goods industry since the industrialists do not support the policy measure and make every attempt to avoid buying locally.

Other government policies can also be instrumental. Control of foreign investment and technology contracts has been implemented in many developing countries as governments have realised that such contracts are a means by which foreign companies can avoid restrictions on profit repatriation. In addition governments are also now more careful to screen the content of technology imported under such contracts to ensure that the techniques of production and the products resulting from the employment of such know-how are advantageous for the development strategy of the importing country. However in the case of technology imported for cement production control by such measures is ineffective since the majority of the technology is embodied in the machinery and equipment bought. To effect control over such import contracts would require specialised personnel with knowledge both of the cement sector and of the international market for the capital goods concerned in order to formulate norms against which procedures for control of the import of technology can be designed. Such policies and procedures, if correctly formulated and applied, could also be used to stimulate the growth of local technical capacity and encourage the technical development of the industry in accordance with the development objetives of the country. In addition the danger foreseen earlier of increasing technological dependence by importing hardware without adequate information systems to make it functional could be avoided by carefully formulated and implemented policies.

The availability of skilled personnel for employment by local cement firms is also crucially important. Most cement firms have trained their own personnel but there is an obvious shortage of chemical, electrical and mechanical engineers available for recruitment. This subject falls outside the scope of this paper since it enters into the whole area of national policy on science and technology. Nevertheless it is important to mention that in the assessment of industrial demand for skilled manpower and technical specialists account should be taken not only of the demand on the basis of current techniques of production and future growth projections, but an assessment should be made of the tendencies of technical innovations within the industrial processes and the changes they imply for the composition of future demand for specialist personnel.