CEMENT & LIME MANUFACTURE

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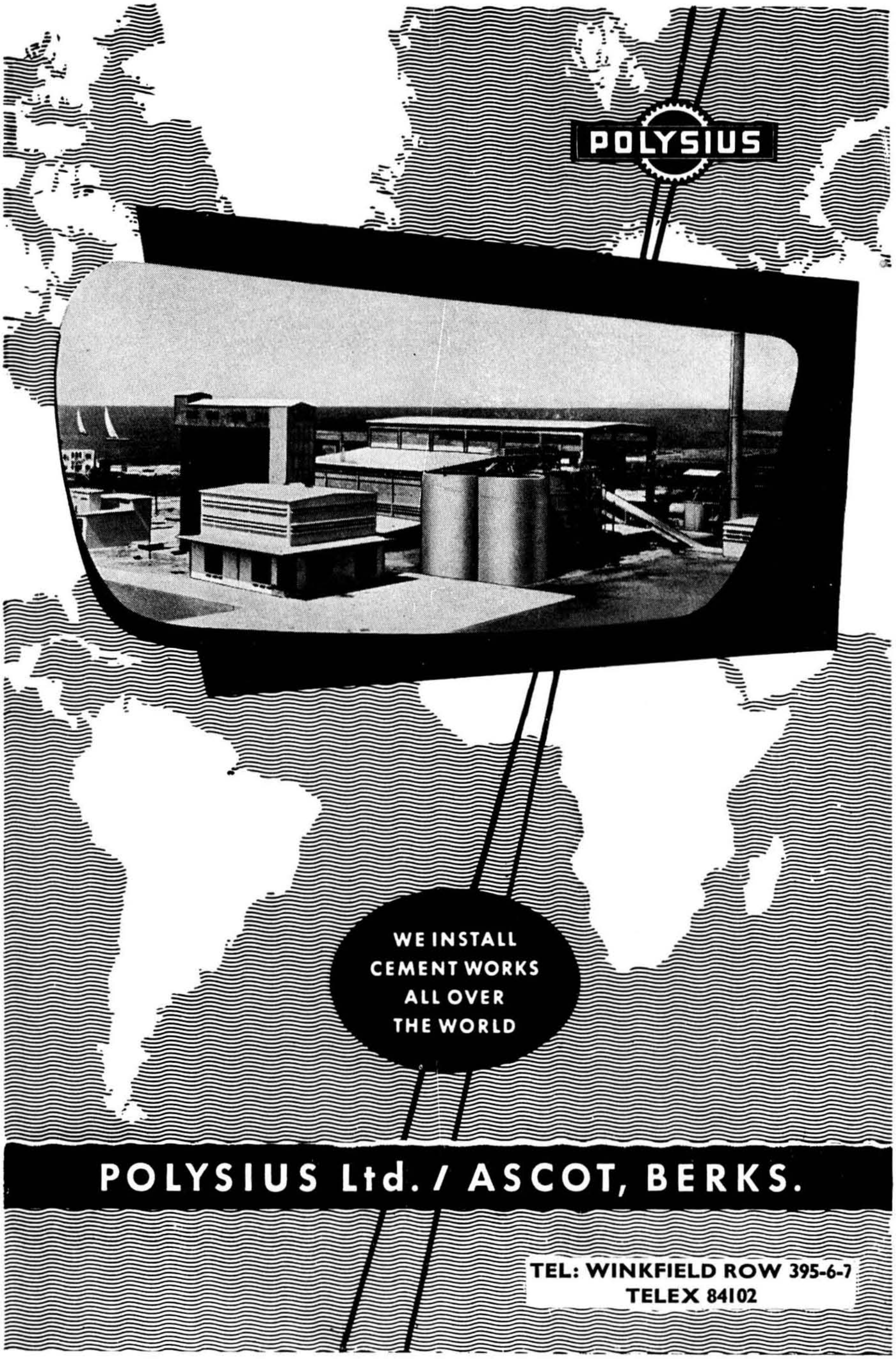
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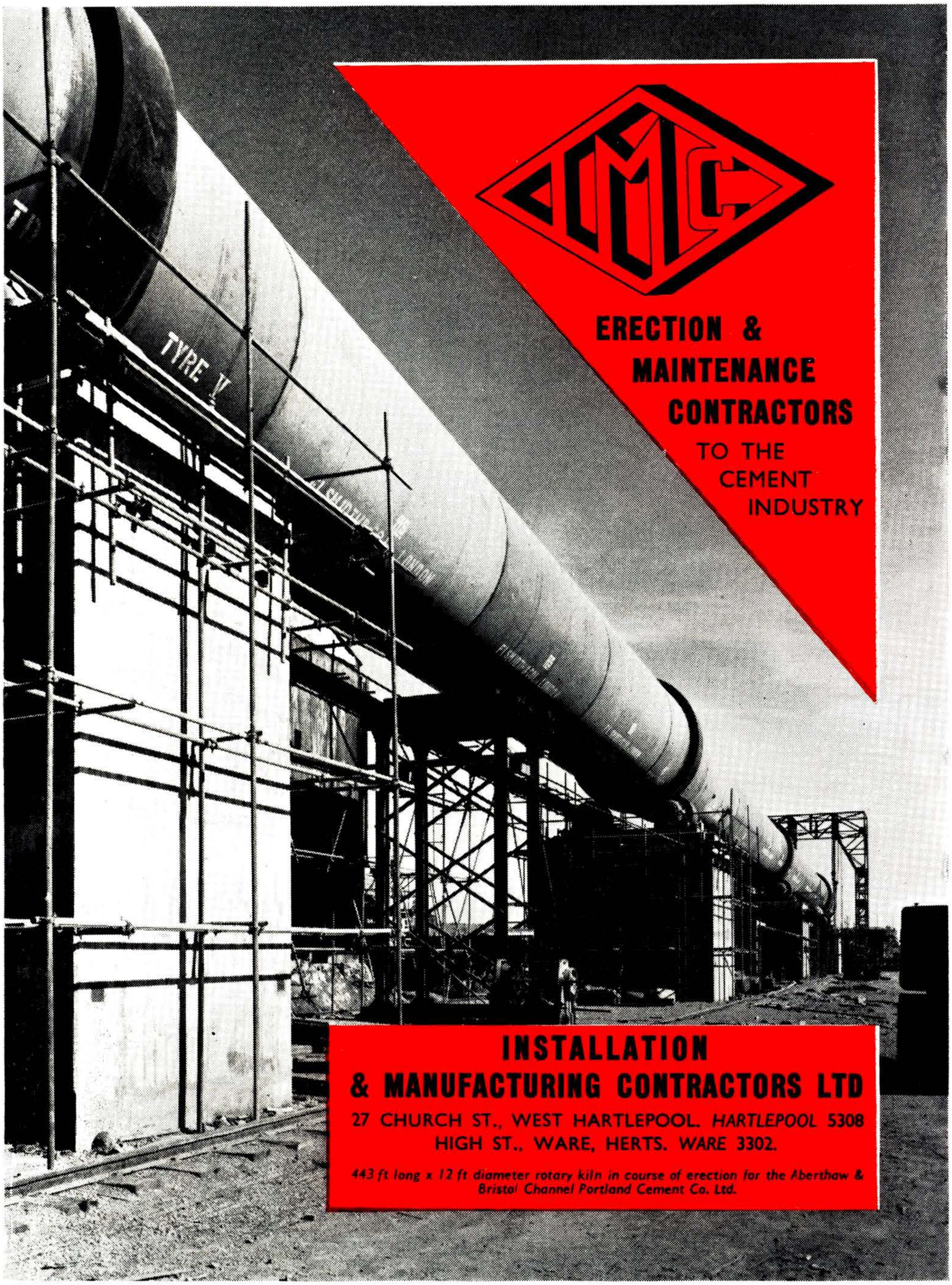
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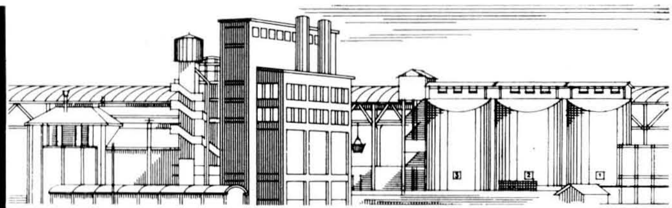

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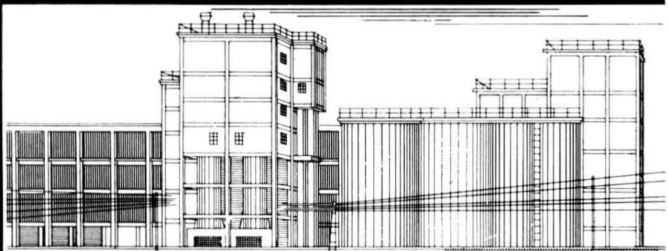

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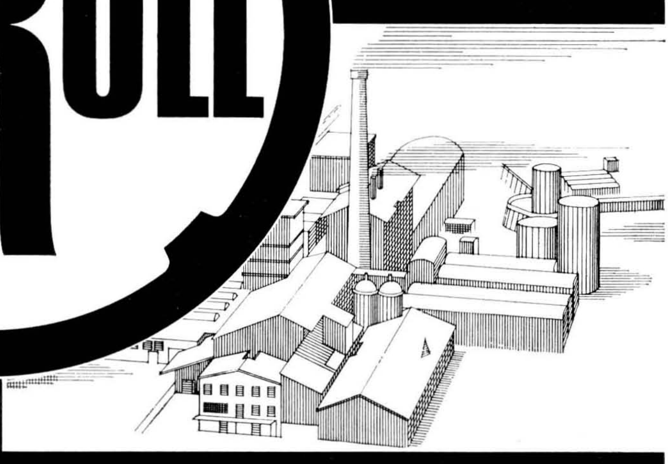

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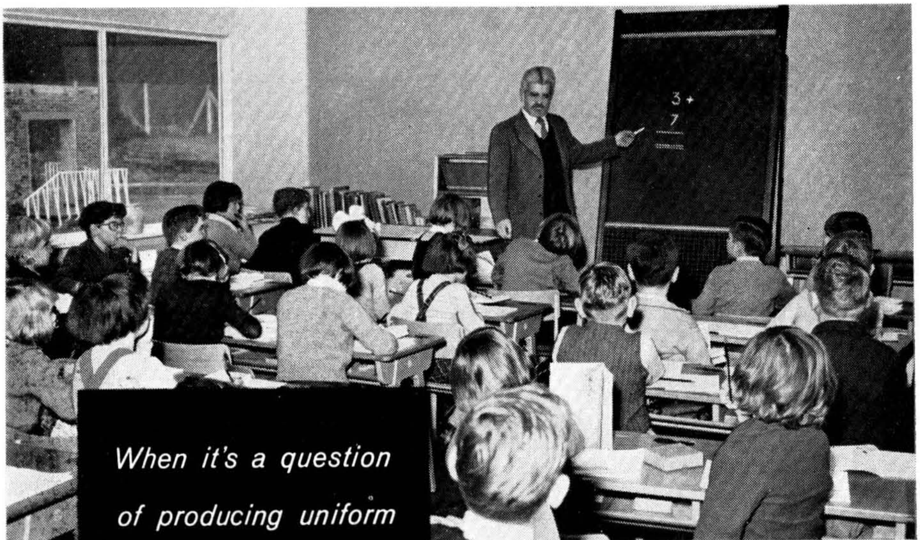

CEMENT AND LIME
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Modern Vertical Kilns For Cement Manufacture.

By S. R. DEVLIN, M.I.Mech.E.

Intensive research in recent years has resulted in important improvements in cement manufacturing processes based on vertical kilns. Some recent developments are described in this article.

Vertical Kilns in Operation in Austria.

At the end of March 1961, production commenced at the new cement works of Steirische Montanwerke von Franz Meyr-Melnhof at Paggau, Austria. The plant includes a vertical kiln and is the first works in the world designed from the outset to incorporate the patented Interground fuel process.

The raw materials, limestone and clay, are available close to the works, the ratio of limestone to clay being about 4 : 1, with a small percentage of pyrites and quartz sand. The four raw materials and fuel, which are accurately proportioned by means of electronic weigh-feeders (*Fig.* 1), are fed into a Loesche mill (*Fig.* 2) having a capacity of 32 tons per hour. The fineness of the raw meal is such that 90 per cent. passes a 200-mesh (6 per cent. +DIN 0·09). The mill, being of the air-swept type, permits drying simultaneously with grinding, the

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Fig. 1.

hot gases for drying being supplied by two Loma furnaces fired with bunker C oil.

The prepared raw meal is conveyed pneumatically to silos in which homogenisation is carried out also pneumatically. The homogenised raw meal is then stored in two large silos, discharge from which is by means of pneumatic dischargers. From these silos, the raw meal is conveyed to the kilns by elevators and drag-link conveyors and is finally fed into nodulisers (*Fig.* 3) by belt-conveyors.

The two vertical kilns are fully automatic in operation and incorporate the features described subsequently in this article. The average output is 190 tons per day from each kiln and peak outputs of more than 200 tons per day have been achieved. The cement produced from the clinker is rapid-hardening and has an average compressive strength of 550 k. per sq. cm. at twenty-eight days. The total power consumption is 82 kw.-h. per ton, and the fuel consumption is 880 k.-cal. per kg. of clinker. The cement is ground relatively finely so that nearly half of the total power consumption is used in the grinding. The cement is delivered by a pneumatic conveyor to the storage and packing plant from which it is despatched by rail and road in sacks or in bulk.

The works, which are designed to facilitate the installation of two more kilns without requiring additional handling equipment or buildings, had been in operation for just one year at the date of the fiftieth anniversary of the introduction of

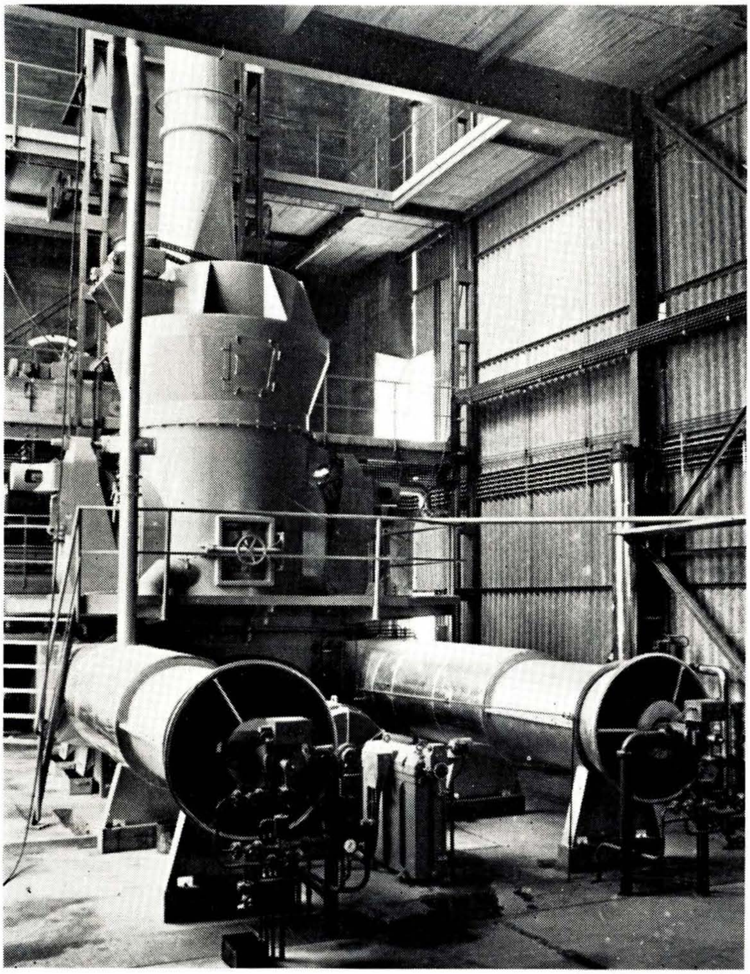


Fig. 2.

vertical kilns with automatic discharge, and exemplifies the full development of the process to date.

Operation of Vertical Kilns.

In general, the operating cost of a vertical kiln is less than that of a rotary kiln, mainly because cheaper fuel can be used and the thermal efficiency is higher. For an equivalent output, a vertical kiln can be accommodated in about one third of the space required by a rotary kiln and the initial cost is lower. Small works can be established economically at centres of developing demand. For the production of up to 275,000 tons per year, which would require four kilns, the instal-

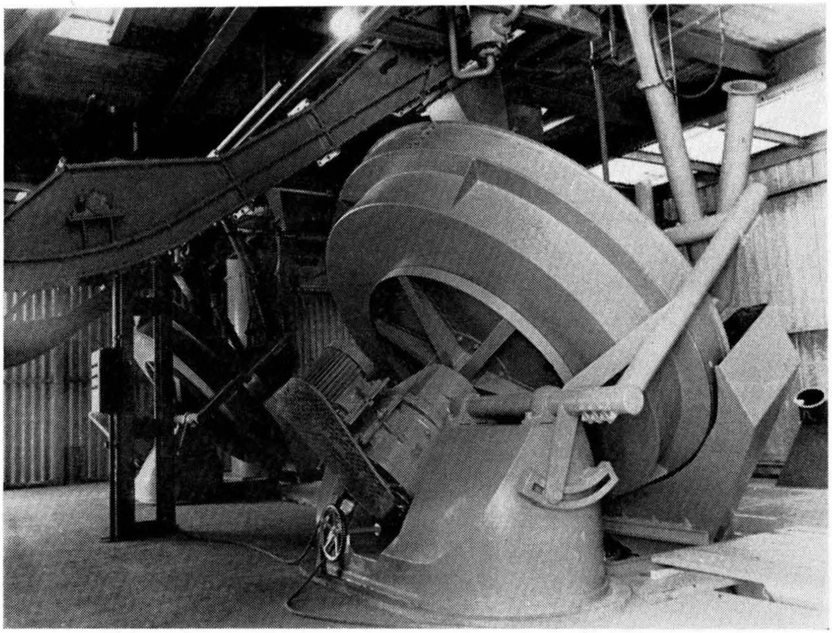


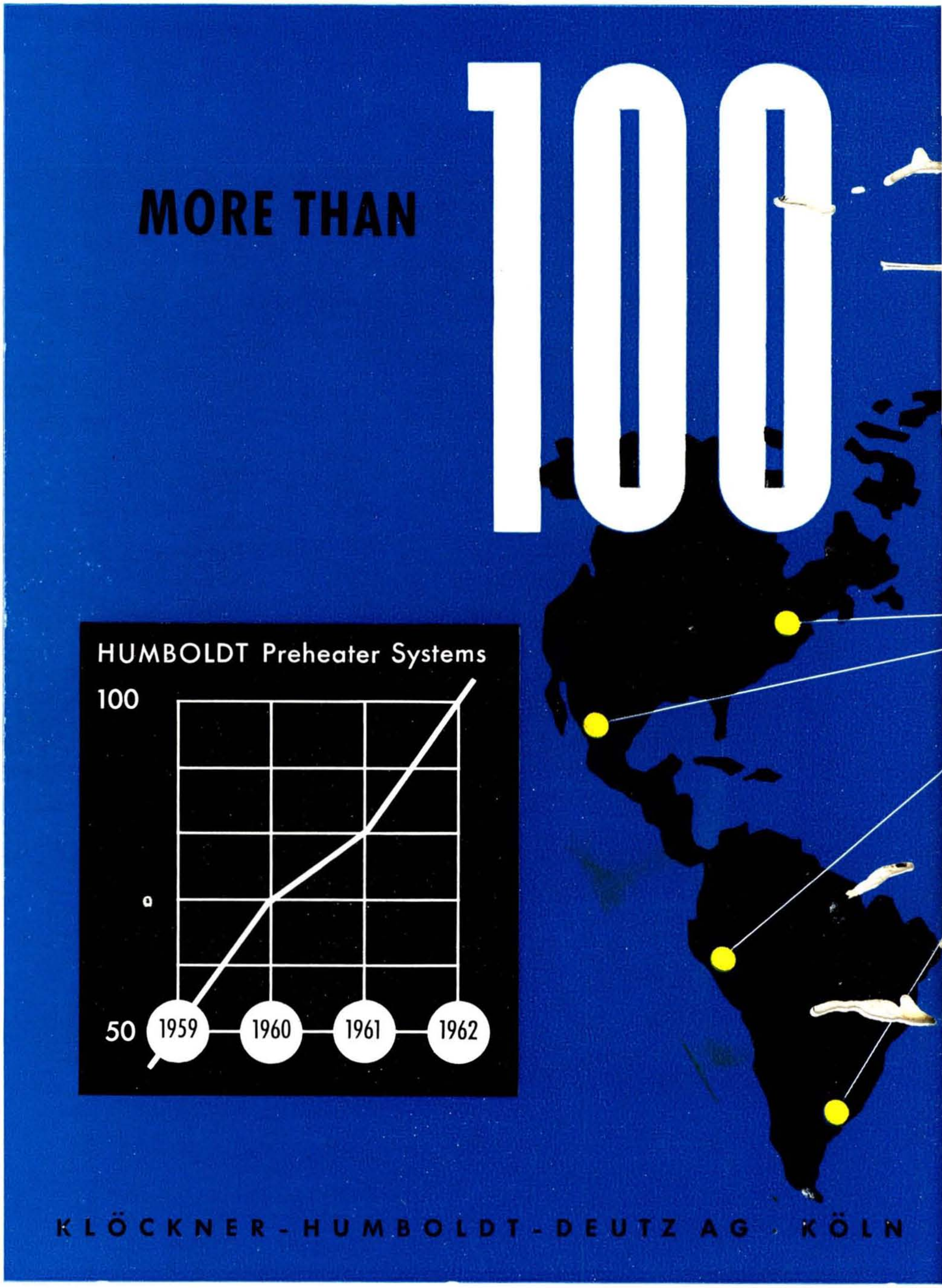
Fig. 3.

lation of vertical kilns provides an economical solution. Since the various parts of the kiln are comparatively small and light in weight, there are few transport difficulties even in territories where rail and road communications are poor. In a cement works where the grinding plant is in excess of the productive capacity of the rotary kilns installed, the output can be increased cheaply and expeditiously by adding vertical kilns, as has been done in some cement works in Europe.

The fuels most suitable include anthracite, coke, low-volatile coal and other materials with a high reactivity, such as charcoal and brown coal, while mixtures of anthracite and coke or of coals may be used. Although the best fuel is naturally that with the highest heat content, it is also possible to use coal of lower quality but with some loss of efficiency. Little water is needed for pelletising the raw meal, and need not be fresh but may be sea-water or brackish water since all alkalis are burned off in the calcining process.

The kiln is continuously full of pellets, about ½-in. in diameter, which after being calcined in a shallow burning zone at the top of the kiln progress downwards until they are discharged through a rotary grate and air-lock gates (*Fig.* 5). In passing downwards the nodules are cooled rapidly by the blast of air rising through the spaces between the pellets. The rising air is heated by the descending pellets and pre-heats the charge above the burning zone.

(*Continued on page 5.*)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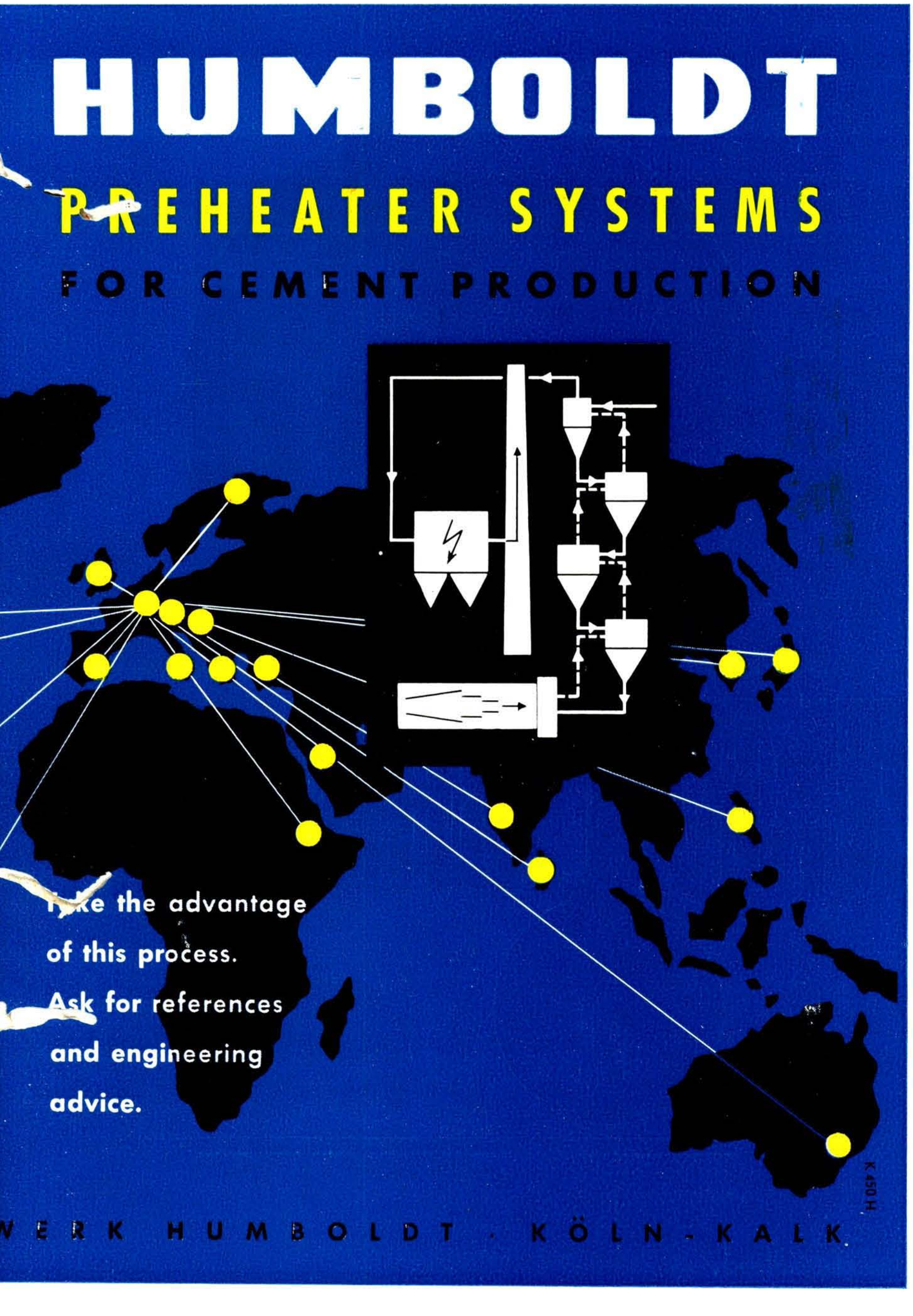
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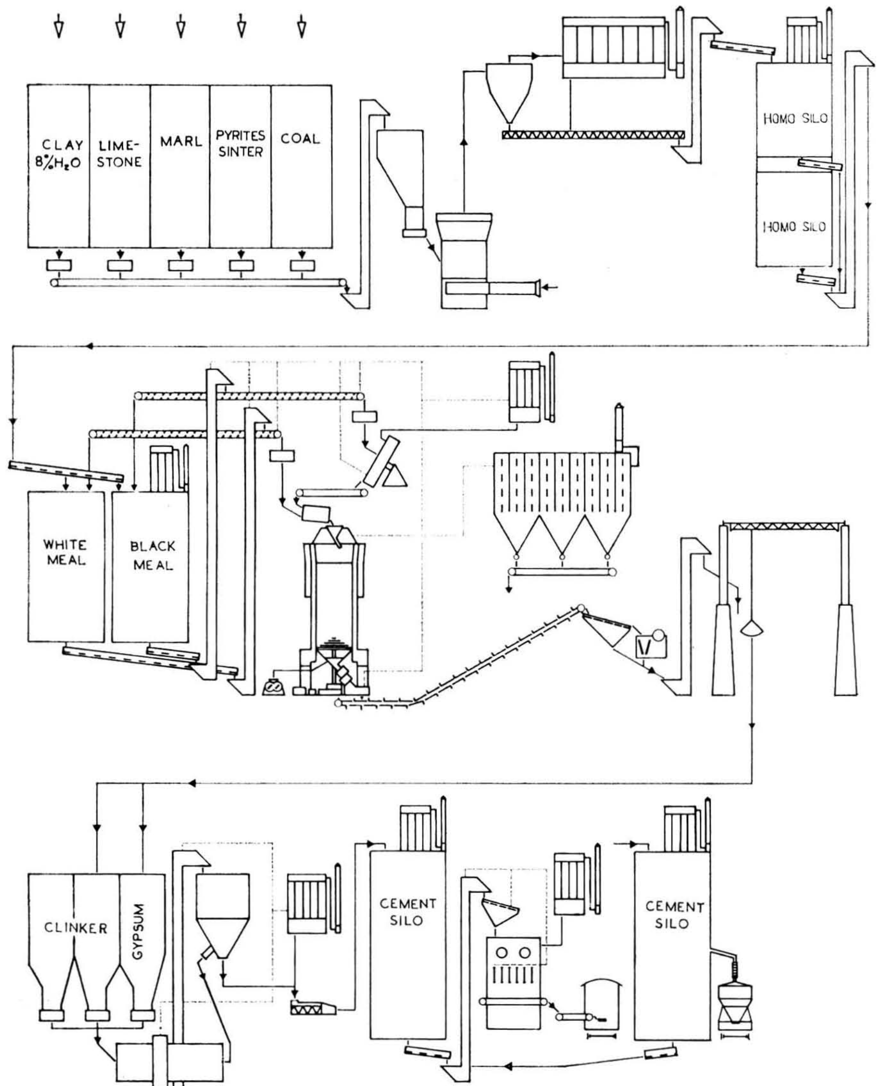

Fig. 4.—Flow-chart of Cement Works with Vertical Kiln.

To charge a vertical kiln to the greatest economic advantage, accurate quantity control of the raw materials and fuel is necessary and may be carried out by bulk weighing machines or preferably by weigh-feeders. For materials of a constant weight in bulk, drag-chain conveyors may be used and the feed can be adjusted

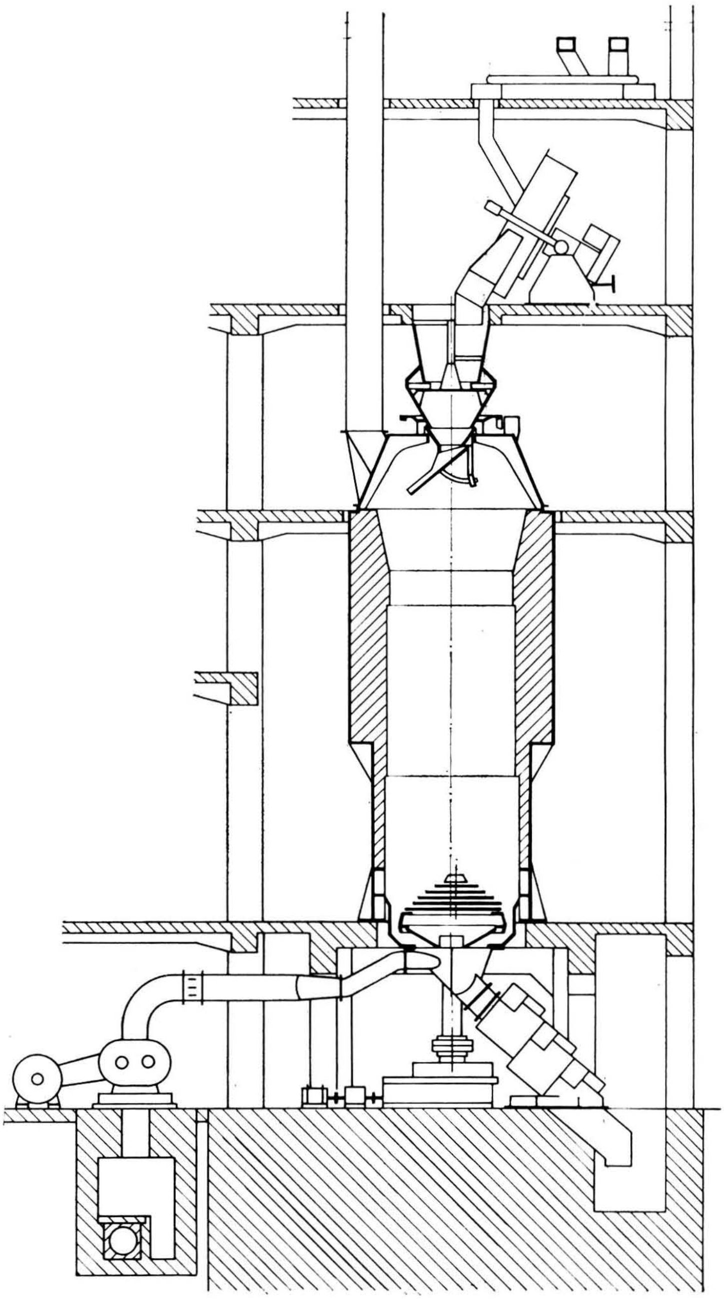

Fig. 5.—Cross-section of Vertical Kiln.

once the conveyors have been calibrated. There are several methods of forming the raw meal into pellets. Extrusion machines and subsequently roller presses or briquetting presses have been used but have proved expensive in power and maintenance. In modern works pan nodulisers are used since they have the advantages of low power consumption, little maintenance, and uniformity of product. In an ordinary vertical kiln, the fuel is supplied to the noduliser and added to the raw meal in the form of particles 1 to 8 mm. in size, but this process has some disadvantages, and close attention on the part of the chemist and kiln operator is essential.

A New Fuel-preparation Process.

A recent development in the operation of vertical kilns is the introduction to full-scale and continuous production of the Interground fuel process invented by Dr. E. Spohn*. The raw materials and fuel are accurately proportioned prior to grinding and are then ground together in the raw mill. When coal or coke breeze of up to 8 mm. in size is used as in the previous process, the clinker is contaminated by large particles of ash around which C_2S is locally enriched and there is a tendency to dusting, the material around large particles of coal being frequently " reduced " and white. There is much less reduction when the fuel is finely interground with the raw meal, and no contamination by ash can occur. The raw meal so obtained is then homogenised by a process called the "black meal process" (*Fig.* **4**) which makes it possible to produce clinker of the highest quality. The advantages claimed for this process, compared with the conventional vertical kiln process, are reduced consumption of fuel, consistent quality of the clinker, increased output, automatic operation enabling one operator to control several kilns, and automatic control of the flue-gas temperature permitting the use of electrostatic precipitators.

Quality of Clinker.

Three qualities of clinker are typical of the product from vertical kilns, namely under-burned, well-burned porous clinker, and over-burned, all three being often produced at the same time in varying proportions. Under-burned clinker is relatively harmless and quantities up to 2 to 3 per cent. may even improve plasticity and initial strength; larger quantities indicate, however, that the kiln is out of order or soon will be. Dense over-burned clinker is highly undesirable, and some of the factors causing such slowly-cooled clinker are burning shrinkage, poor insulation of the kiln and unsuitable sizes of fuel and pellets; these factors are considered in the following.

Burning Shrinkage.

Burning shrinkage forms an annular gap at the kiln lining. Air escapes through this gap causing a lack of air in the central area. Thus the periphery of the burning zone is hotter and less in depth than the centre, which moves downwards and

*E. Spohn: Der Zementschachtofen Heute. (" Zement-Kalk-Gips", Vol. 7, 1958).
E. Spohn and E. Woermann: New Grate Boosts Quality of Shaft Kiln Cement. ("Rock Products," February 1959).

becomes elongated. As a result, the clinker there is compressed by its own weight and still less air will be able to pass through it. If increasing flow of air results in the fire at the periphery being blown out, it is difficult to re-establish normal operation. A conical sintering zone at the top of the kiln helps to avoid formation of a peripheral gap, but the shape of the cone must be adapted properly to the shrinkage of the material and the depth of the sintering zone. Once the lining is built to the right shape, the depth of the sintering zone must be adapted to that shape and maintained properly.

Insulation of Kiln.

Heat losses take place at the periphery of the charge in a poorly insulated kiln, but the amount is negligible compared with the total. The charge at the periphery of the burning zone needs more fuel, however, to prevent it being underburned and, since no extra coal can be added at the periphery, the whole charge must be enriched with fuel. This results in excess fuel at the centre and in a fire that is too long and too hot and a clinker that is densely burned, reduced and poorly cooled. In practice the result is the same as that of shrinkage, and each result complements the other.

The alternative of adding extra fuel at the periphery has proved effective with ordinary kilns, but continuous operation could not be so maintained, since the clinker became so porous and friable that an ordinary grate could not retain it, the gates were flooded, and the short sintering zone disrupted. These defects result when " black-meal " is used with ordinary grates.

Size of Fuel and Raw-meal Pellets.

The sizes of the fuel and of the pellets of raw meal are important because they determine the reactivity and depth of the burning zone. The amount of fuel also exerts a minor influence. In many older installations, these factors are not fully under control. The fuel, especially, has no constant properties, and is rarely classified for uniformity of size and the thermal value varies considerably.

Fine pulverised coal reacts differently to coarse coal, which requires oxygen to effect the reaction. Sometimes oxygen is not present in the upper part of a kiln and combustion can only be completed in the lower part. Finely ground coal can react, however, with the raw meal even without oxygen; according to Hauenschild

$$CaCO_3 + C = CaO + 2CO \text{ (simplified).}$$

A deficiency of air does not result in a drawing down of the burning zone. The fire remains shallow and surplus coal in zones of air deficiency will disappear as CO in the upper part of the kiln.

With pulverised coal interground with the raw meal, the depth of the fire depends mainly on the size of pellet and so it can be easily controlled and kept uniform. A shallow fire in the upper part of the kiln does not produce a dense clinker, but the material remains porous; the pellets do not fuse but stay loose or are only slightly fritted together. It is easy to adapt the depth of the fire to the cone-shaped lining by changing the size of the pellets, and proper action of the cone can be maintained. Also the clinker does not shrink so much, and the burned pellets have a shell-like structure. The cone need not be tapered so much and uniform distribution of air throughout the kiln is facilitated.

It is understandable how improvement of quality is related to better heat economy. With a properly shaped cone, good insulation, interground coal and raw meal, and an improved grate, 860 k.-cal. per kg. of clinker is obtained, an improvement of some 200 k.-cal. per kg. compared with that of an installation with a conventional grate, medium insulation and coal graded from 0 to 3 mm. This fuel consumption is considerably less than that of a typical rotary kiln.

The Grate.

A short sintering zone and a porous clinker cannot be obtained by a grate of ordinary design, since such grates break up the masses of clinker and the broken pieces fall through the grate. If all the material were loose, it would flood uncontrolled through the grate; boreholes and craters would develop on the surface and the fire would collapse. With an ordinary grate, therefore, the burner must produce a compact clinker to ensure steady operation. The resultant densely burned and slowly cooled clinker is the cause of the less consistent quality of cement produced in the earlier type of vertical kiln.

The improved form of grate results in better quality clinker, regulates the discharge closely, prevents flooding and cratering, and would break up dense clinker if such were produced. Loose clinker is discharged at a regular rate.

Result of Combined Factors.

The combination of improved grate, cone-shaped sintering zone, good insulation and Interground fuel results in a great improvement in the quality of the clinker. The reduction rate is 0·2 mg. of oxygen per gramme of clinker compared with 0·6 mg. or more in an ordinary vertical kiln combined with a low rate of fuel consumption, increase of output and simplification of operation of the kiln. The feed to the kiln is fully automatic and this helps stabilization. In tests with ordinary grates, continuous success with automatic feed was not obtained. A kiln which is successfully fed automatically has a uniform flue-gas temperature and, since there is no danger of condensation, electric static precipitators can be used efficiently. The use of mechanical dust collectors or of electrostatic precipitators makes it necessary to keep the waste-gas temperature above dew-point; this presented some difficulty because of the good heat economy of a vertical kiln, until a new design of kiln hood was introduced which, by preventing leakage of air into the kiln hood, avoids lowering the waste-gas temperature.

Since the improved grate handles larger quantities of clinker, it requires more power to drive, so a new drive was developed with double the efficiency of the old drive and therefore no extra power is required. New air-lock discharge gates were designed to deal with the larger output of clinker, and these have much larger channels than the previous type. The gates are actuated by an hydraulic doublepiston system and close safely against a kiln pressure of 2,500 mm. (water gauge).

The outputs quoted, the uniform burning, and the restricted sintering zone are attained by the use of Roots blowers of standard design, for pressures up to 80 in. (water gauge) and air volumes up to 7,200 cu. ft. per minute.

Development continues. At the cement works of Gebr. Spohn, A.G., Blaubeuren, Germany, a new " coating process " has been introduced which results in further savings in fuel, since in this process, fuel consumption is below 800 k.-cal. per kg. of clinker.

Variations of Test Results.

THE two papers described in the following deal in a concise manner with the causes and effects of the variation of results obtained when testing cements with different samples of the same or similar cements.

CAUSES OF VARIATION IN CHEMICAL ANALYSES and PHYSICAL TESTS OF PORTLAND CEMENT, by B. L. Bean and J. R. Dise. [National Bureau of Standards (U.S.A.) Monograph 28 (1961).]—Variations in testing that could lead to the rejection of a cement fully conforming to specification requirements, or the acceptance of a material with undesirable chemical or physical properties, are apparent in the results reported by laboratories participating in comparative tests of Portland cement. Many of the causes for variation in chemical analyses and physical test results are considered, and remedies for some of the deficiencies more frequently encountered in apparatus and methods are suggested. Consideration is given to problems which do not seem to have been dealt with sufficiently in previous discussions.

VARIATIONS IN PORTLAND CEMENT, PART 2, by Stanton Walker and D. L. Bloem. [Reprinted from " Proceedings 1961," American Society for Testing and Materials, and issued by National Ready Mixed Concrete Association (U.S.A.).] Fourteen different non-air-entraining cements were sampled monthly for one year and the samples tested for compressive strength at ages of 7, 28, and 91 days. For each period, tests were made concurrently with a control cement. The samples were also tested for air-entraining capacity. (This work is similar to that reported upon previously.) Cement from all sources varied in strength from sample to sample, the degree of variability being greater for some than others and, in many cases, was sufficient to make it difficult to comply with specified concrete strengths without uneconomical over-design. The air content also varied but was always substantially below the maximum of 12 per cent. specified for non-air-entraining cements. Tests of samples from various positions in railway wagons of two cements were highly uniform. Comparisons of the results obtained by two operators showed mortar strengths to be almost identical in magnitude and uniformity. These supplementary data provide assurance that variations of strength were actual and were not caused by vagaries in testing.

The Absorption of Carbon Dioxide by Lime Mortars.

The Influence of Additives and Temperature.

THE continuous measurement of the absorption of carbon dioxide by means of an infra-red absorption recorder makes it possible to follow the process of carbonation of lime mortar without decomposition of the specimen. In a recent number of "Zement-Kalk-Gips" F. HENKEL describes the use of this method to record the absorption of carbon dioxide by lime plaster containing additives which are used as water-repellents, hardeners, densifiers, and for protection against frost. The effects of temperature and humidity are also studied. The frost-protectors were calcium chloride, and mixtures of sodium chloride and calcium or barium chloride, all of which had similar influence on the absorption of carbon dioxide.

The investigations were made under constant ambient conditions with control of loss of moisture giving measurements of absorption of carbon dioxide under reproducible conditions. White and dolomitic limes containing more than 97 per cent. of CaO and CaO + MgO respectively in the ignited state were used. The hydraulic limes were made from a natural lime containing marl.

Tests were carried out on prisms made in moulds coated thinly with a silicone oil which was found to have no influence on the amount of carbon dioxide absorbed. Measurement of the absorption was started immediately after de-moulding two days after making the specimens.

The carbonation of white and hydraulic limes in general decreased with increasing amount of the frost-protector, but in the case of dolomitic lime the admixture in many cases caused no reduction in absorption. The development of strength was favourably influenced by the addition of the frost-protectors,

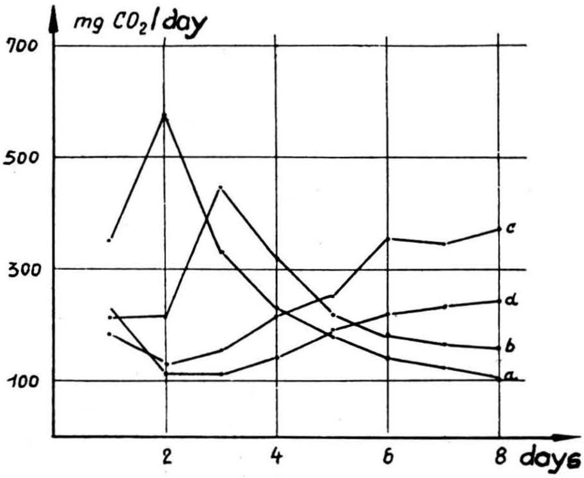

Fig. 1.

especially in the case of hydraulic lime, but there were a few exceptions in the case of white lime.

The absorption of carbon dioxide was not significantly influenced by external treatment of the specimens with a silicone preparation nor by the addition of lime soaps or solutions of salts of silicofluoric acid to the mortar.

The influence of temperature and humidity of the air was studied with air-hardening lime mortars. The curves in *Fig.* 1 show the rate of absorption of carbon dioxide in milligrammes per day for the first eight days by a mortar of 1 : 3 white lime and standard sand at different temperatures and relative humidities. At 30 and 40 deg. C., the amount of carbon dioxide absorbed falls sharply after two or three days; at lower temperatures it rises slowly and at five days it exceeds the values for the higher temperatures. This result is caused by the fact that the air had a constant total moisture content so that at higher temperatures the relative humidity was lower, and when the mortar was too dry it was unable to take up carbon dioxide.

Relating the thickness of the carbonated layer in the case of white lime with the bending and compressive strengths it was observed that greater strengths were produced where carbonation progressed more slowly. The initial formation of the layer of carbonate results in internal stresses which reduce the strength during the early part of hardening. It was also observed that after two weeks the bending strengths exceeded the compressive strength and this was attributed to the " stiff-tube " effect of the layer of carbonate.

Symposium on Calcareous Materials.

A TWO-DAY Symposium on the Analysis of Calcareous Materials is to be held under the auspices of the Road and Building Materials group of the Society of the Chemical Industry, on 18 and 19 April 1963, at the Imperial College of Technology, South Kensington, London. The symposium will deal with methods of sampling and analysis of limestone, chalk and other calcareous rocks; gypsum and gypsum plasters; hydraulic cements, lime, whiting, slags; calcareous ceramic products; calcareous building products such as concrete, mortar, and calcium-silicate (sand-lime) bricks; and asbestos-cement products. The sessions will be in four sections: (1) Sampling. (2) Gravimetric, volumetric and colorimetric methods of analysis. (3) Physical methods of determination of content of elements and radicals. (4) Methods of determination of compound content.

Enquiries regarding the Symposium should be addressed to the Secretary, Mr. H. N. Lee, The Chalk, Lime & Allied Industries Research Association, Church Street, Welwyn, Herts.

The Shrinking of Concrete with Finely-ground Cement.

Some views on the effect of the fineness of cement on the shrinkage of concrete were included in a paper entitled "Shrinkage and Creep in Concrete," which was read in November 1961 to the Reinforced Concrete Association by Mr. A. M. Neville, M.C., M.Sc. (Eng.), Ph.D., A.M.I.C.E.

It is stated in the paper that the properties of cement have little influence on the shrinkage of concrete. Mr. Swayze[1] has shown recently that a higher shrinkage of neat cement paste does not necessarily mean a higher shrinkage of concrete made with a particular cement. The fineness of the cement is a factor only in so far that particles coarser than, say, No. 200 sieve, which hydrate only little, have a restraining effect similar to aggregate. Otherwise, contrary to some earlier suggestions, finer cement does not increase shrinkage[1]. The chemical composition of cement is now believed not to affect shrinkage except that cements deficient in gypsum exhibit a greatly increased shrinkage since the initial framework established in setting determines the subsequent structure of the hydrated paste[2], and thus influences also the gel space ratio, strength, and creep. Inadequate retardation results in a more open framework and a higher shrinkage. An optimum gypsum content from the standpoint of retardation of cement is also one that leads to least shrinkage[3].

Shrinkage of concrete made with high-alumina cement is of the same magnitude but takes place much more rapidly than when Portland cement is used[4]. Entrainment of air has no effect on shrinkage[5]. The addition of calcium chloride increases shrinkage by varying amounts generally between 10 and 50 per cent.[6], possibly because a finer cement gel is produced.

In the discussion following the reading of the paper, the author stated that greater fineness meant more rapid hydration of the cement and hence greater strength. Thus it could resist cracking better, but it also had a lower creep so that it could relieve the cracking less easily. Hence it was right to distinguish between shrinking and cracking. It was possible to have cracking and at the same time measure comparatively little shrinkage because cracking took place around the pieces of aggregate. It had been doubted for some time whether the statement that finer cement led to greater shrinkage was true. Results of tests made by Mr. M. A. Swayze, and reported at the International Symposium on the Chemistry of Cement in 1960, show that in the case of neat cement, and partly also in mortar, there was definitely greater shrinkage accompanying the finer cement but, in the case of *concrete*, the tests showed that there was no sensible difference, and certainly no regular pattern of the variation of shrinkage.

In a written contribution to the discussion, Mr. A. Goldstein referred to the statement that fineness is a factor only in so far that particles coarser than No. 200 sieve hydrate only little and have a restraining effect similar to aggregate; otherwise finer cement does not increase shrinkage. He stated that he supported the practical opinion that increased specific surface increases shrinkage and the possibility of shrinkage cracking. Rapid-hardening cement made in Britain is often ordinary Portland cement ground more finely. If the prevention of shrinkage cracks is to be taken seriously when casting concrete, it is desirable that (inter alia) cement of a limited specific surface be used.

Shrinkage increases with fineness when other factors such as chemical composition, clinker, mixes, and water content are identical. The report by Mr. Swayze does not state whether the various cements used were identical, apart from specific surface, and whether all other factors were identical. M. L'Hermite expresses a view contrary to that given by Mr. Swayze, and supports the view that increased specific surface increases shrinkage, by reference to various workers in this field. Apart from practical views, there is a considerable opinion amongst research workers that increased specific surface does increase shrinkage. There is the difficulty in that conclusions drawn from tests on mortars may not apply to large-scale concrete construction. The answer will not be obtained until very large-scale tests on concrete are carried out under site conditions ranging from no curing to full curing. For example, it may be that the increase of shrinkage and shrinkage cracking which takes place on a site where finer cements are used, is manifested only under imperfect curing; if this is so, it is sufficient reason for using cement of lower specific surface.

In reply, Dr. Neville stressed the point that the authorities mentioned had tested neat cement pastes. The influence of fineness of cement on the shrinkage of neat paste is well established but it does not follow that the same influence exists in the case of concrete. Further, it is not stated whether the gypsum content was varied with the fineness of cement or not, this factor being of considerable importance. The finer the cement the higher the gypsum requirement for proper retardation. Thus, regrinding a specific cement without the addition of gypsum, yields results which have limited practical significance; under such circumstances shrinkage appears to increase with the fineness of cement. However, using cements ground from one clinker to different fineness, but each with the appropriate optimum gypsum content, concrete of fixed proportions exhibits practically the same shrinkage in all cases. The influence of fineness for the same and for different gypsum contents is illustrated in *Table* I, all results

TABLE I

Specific surface (Wagner) sq. cm./g.	SO_3 content %	Shrinkage (10^{-6}) for specimens water-cured for	
		7 days	28 days
1500	1·9	550	487
1800	1·9	574	493
2100	1·9	610	508
1500	1·5	603	516
	1·9	550	487
1800	1·9	574	493
2100	2·4	565	482

referring to 1 : 2·43 : 2·97 concretes with a water-cement ratio of 0·49 and made with cement ground from the same clinker; all specimens were cured in water for seven or twenty-eight days prior to exposure to a relative humidity of 50 per cent. for 300 days. *Table* 1 is an extract from a report[7] on the shrinkage of concrete, but it illustrates the pattern of behaviour. There is an optimum gypsum content for minimum shrinkage at any fineness, but in practice it may often not be possible to use such a high amount of gypsum because of the danger of false set. It is thus possible that some commercial fine cements have a gypsum content conducive to rather high shrinkage.

Mr. Pickett's results show that the increase in shrinkage with fineness of cement at a constant gypsum content is greater with a shorter period of water-curing. It seems logical that the effects of fineness of cement disappear on prolonged wet curing: by then the cement is hydrated to an appreciable extent and the size of particles that no longer exist is immaterial. If the period of wet curing is short there is a large difference in the degree of hydration of fine and coarse cements; as a consequence, the volume of restraining unhydrated material differs and so does the ability of the cement paste to creep and thus to relieve shrinkage. By a similar reasoning any difference in shrinkage when cements of different fineness are used occurs during the early stages of drying only. The rates of shrinkage beyond ten days' drying are the same, whatever the fineness of cement.

The influence of gypsum, as is apparent from *Table* 1, illustrates the difficulty of comparative studies when, apart from specific surface all other factors are identical. In the case of concrete it is not possible for all factors to remain constant. Of the three quantities, cement content, workability, and strength, only two can be unaltered when the fineness of cement is appreciably changed. In practice, the use of finer cement is often accompanied by a reduction of the cement content, and this affects the magnitude of shrinkage. Thus discussions of influences on shrinkage need qualification.

Commercial cements generally vary both in fineness and compound composition. In Great Britain and Europe rapid-hardening Portland cements often have the same compound composition as ordinary Portland cements, so that the conditions are not strictly comparable with those under which Mr. Swayze's tests were made in which each cement had an appropriate gypsum content as well as a different degree of fineness.

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Developments in the Cement Industry Abroad.

IN the papers contributed to the Second C.I.B. (International Council for Building Research, Studies and Documentation) Congress, which was held at Cambridge in September last, there are accounts of the state of the cement industry in several countries. Abstracts from some of these papers, the full text of which are given in " Innovation in Building " (Elsevier Publishing Co., Amsterdam), are given in the following.

U.S.S.R. and Eastern Europe.

The construction of concrete structures in the U.S.S.R. and associated countries in Eastern Europe is developing rapidly and consequently the consumption of cement has likewise increased and new types of cement have been developed. The output of cement for the period 1950 to 1960 is shown in *Table I.*

TABLE I.—PRODUCTION OF CEMENT (in millions of tons).

Country	1950	1955	1960	1960 *as percentage of* 1955	1960 *as percentage of* 1950
Bulgaria	0·60	0·81	1·59	196	265
Hungary	0·80	1·17	1·57	134	196
German Democratic Republic	1·41	2·98	5·03	169	357
Poland	2·54	3·82	6·59	173	259
Rumania	1·03	1·93	3·05	158	290
U.S.S.R	10·2	22·5	45·5	202	446
Czechoslovakia	2	2·89	5·05	175	253
Total	18·58	36·10	68·38	189	368

The increase in the production of cement is accompanied by improvement of the quality and widening of the range of cements.

In the U.S.S.R. the average strength of cement increased from 353 kg. per sq. cm. in 1950 to 429 kg. per sq. cm. in 1960, the average strength of Portland cement amounting to 482 kg. per sq. cm. in 1960. In 1950, cements, having strengths of 500 kg. per sq. cm. and higher accounted for 17 per cent. of the total output of cement, while in 1960 this increased to 37 per cent. Cement with a strength of 700 kg. per sq. cm. is being produced and production of cement having a strength of 800 kg. per sq. cm. is about to be started. The quality of cement is steadily improving also in all East European countries.

In 1925, Portland cement was almost the only type of cement produced in the U.S.S.R. In the following years, and especially during the last decade, production was started of new types, namely, pozzolanic and slag Portland cement, oil and gas-well cement, plasticised and water-repellent, quick-hardening, sulphate-resistant, magnesia Portland cement and low-heat (belite) cement. High-alumina, expanding, white and coloured, acid-resistant and other kinds of cements

are also produced. The production of quick-hardening slag Portland cement has been started.

In the U.S.S.R. and associated countries of Eastern Europe, the total output of cement in 1965, compared with 1960, is expected to increase by about 82 per cent. In 1965 the production of cement in the U.S.S.R. is likely to exceed 80 million tons.

Other Asiatic Countries.

In 1960, the production of cement in Burma was 44,300 tons, all of which was produced at a works at Thayetmyo. The amount imported was 23,350 tons.

A works in Bangkok, Thailand, produced 445,000 tons of cement in 1960. The importation of cement into this country is gradually decreasing.

The cement factory at Padang, Indonesia, has an annual productive capacity of 150,000 tons. In 1959 the government constructed a cement works at Gesik having an annual capacity of 250,000 tons and this may be expanded to 375,000 tons in the future.

The annual production of cement in 1960 from six companies in the Philippines was 1,030,000 tons, which is more than three times that in 1952. The amount imported in 1958 was 26,800 tons. Because of the rapid increase in demand, however, the cost of cement is still high.

The output of cement in Taiwan is increasing rapidly; it was 445,600 tons in 1952, but was 1,183,000 tons in 1960, and some is now exported.

Production of blast-furnace cement in Japan has increased rapidly since World War II because of the prevailing demand to cut down the cost of cement. A new manufacturing process has made it possible to increase the ratio of slag up to 75 per cent. without reducing the strength. Companies producing blast-furnace cement increased in number from five in 1955 to ten in 1960. Consequently the annual output of the blast-furnace cement reached 1,677,562 tons in 1960, almost twenty times as much as that in 1950.

Slag Cement in South Africa.

The steel industry in the Republic of South Africa produces, as a by-product, about 600,000 tons of blast-furnace slag per year. The fact that the local slags contain from 14 to 20 per cent. of magnesia led to doubts as to whether cements made therefrom would either have the necessary hydraulicity or be completely free from unsoundness. The fact that the geographical location of the steel industry was favourable, that the tonnage of slag involved represented some 20 per cent. of the annual production of Portland cement of the country, and that the cost of the waste product was low, made the possibility of its use attractive. As a result of discussions with the steel industry during 1947, extensive investigations were undertaken to establish whether local slags were suitable for cement manufacture. The first conclusions were that, while the project was sufficiently promising to justify more detailed attention, a good deal of basic research work on the slag was necessary, including a study of the quaternary system CaO—

Al_2O_3—SiO_2—MgO using quench and differential thermal analyses. During 1950, it was established that there was no risk of unsoundness, and pilot production and limited field trials of the slag cement were undertaken in co-operation with the steel industry and selected consumers. Laboratory studies of the performance of the slag cement in concrete and other cement products were concurrently undertaken, and by 1954 it became apparent that this work made possible new industrial development. From 1955 onwards, the National Building Research Institute, the Portland cement industry and other industrial interests commenced production respectively of Portland-blast-furnace slag cement and finely ground granulated blast-furnace slag for admixture on the building site with Portland cement. Standard specifications for both these products are being prepared by the South African Bureau of Standards. The demand for what was formerly a waste product is now increasing to a point where it absorbs virtually the entire quantity available. The product is widely used in concrete and masonry.

[An article dealing with the estimation of the slag contents of mixtures of unhydrated Portland cement and South African granulated blast-furnace slag is given in this journal for November 1962.—ED.]

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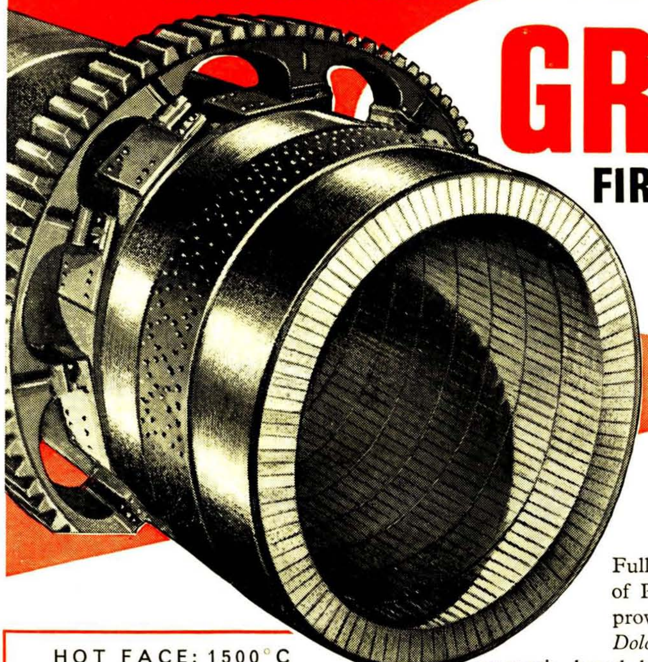

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