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MAY, 1968

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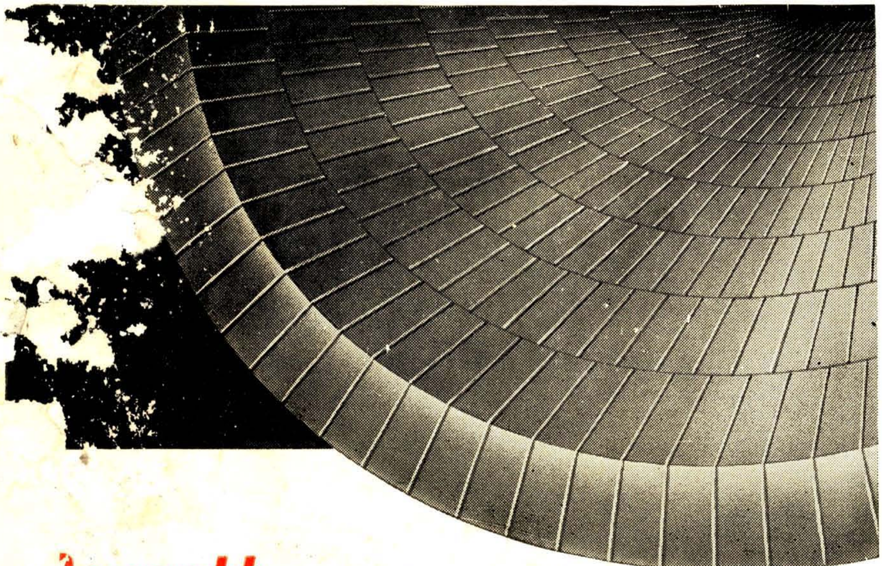

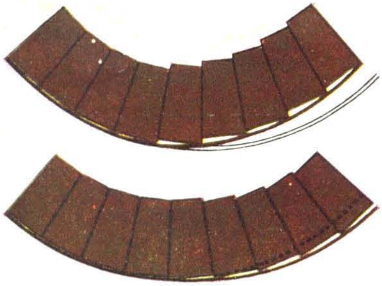

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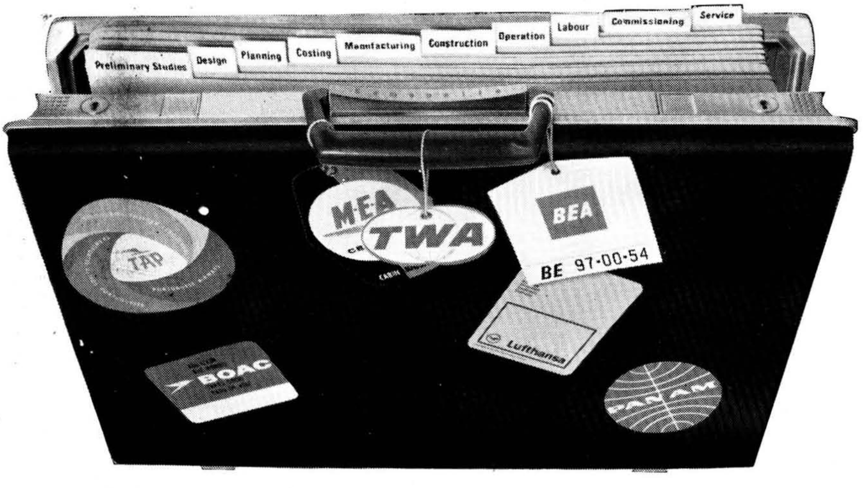

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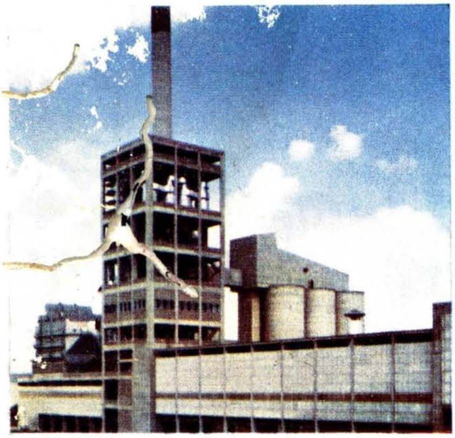

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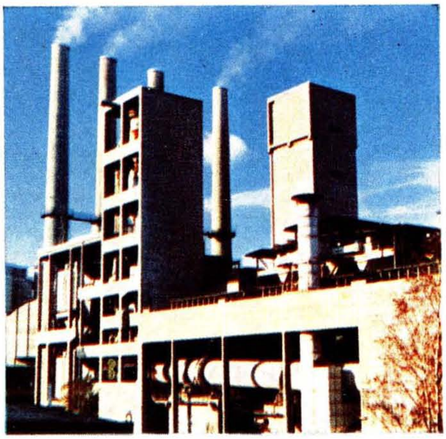

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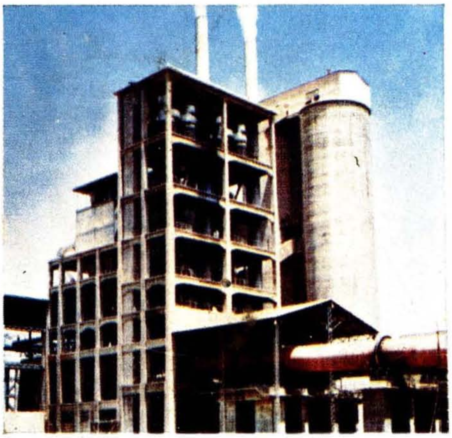

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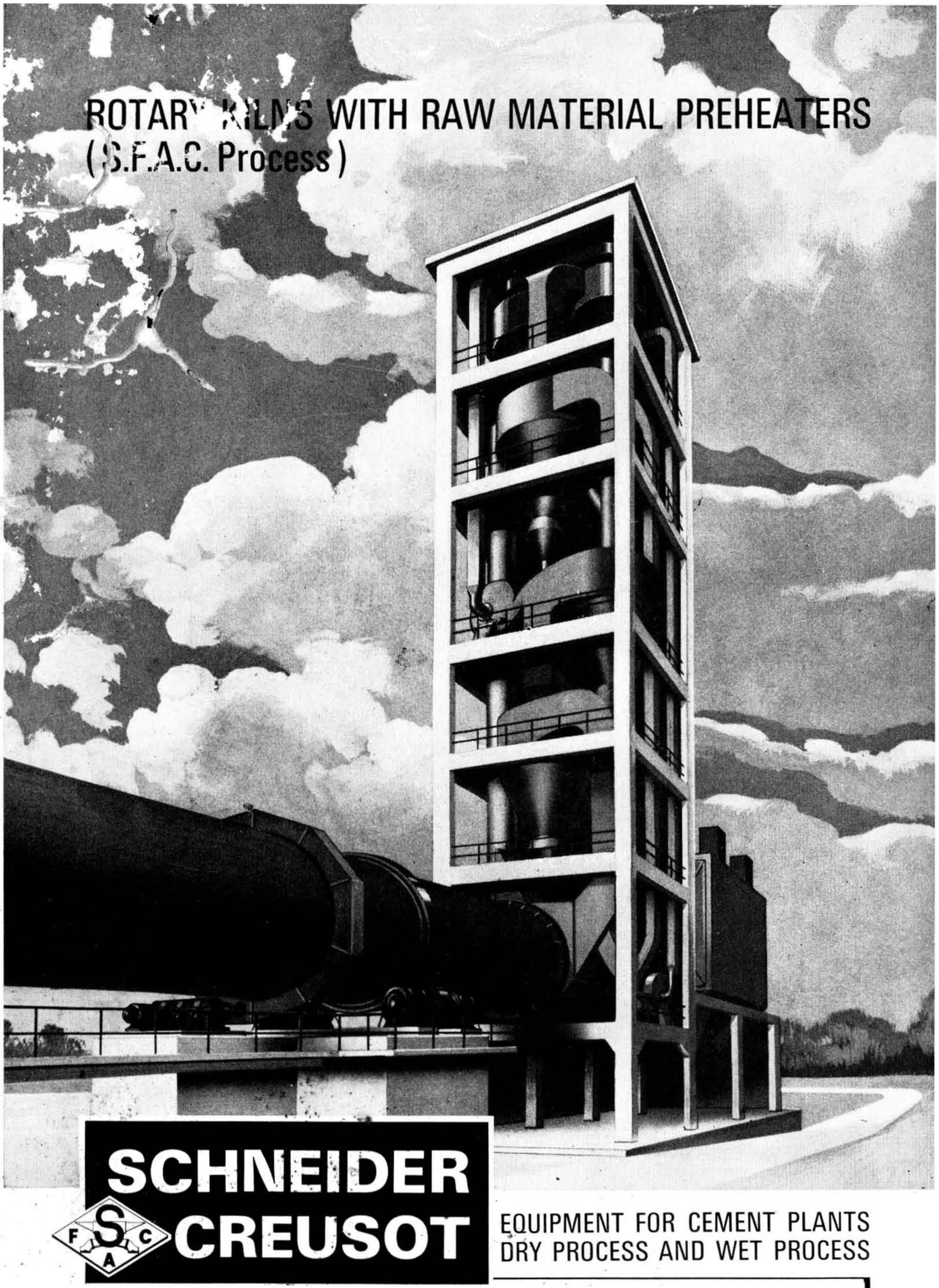

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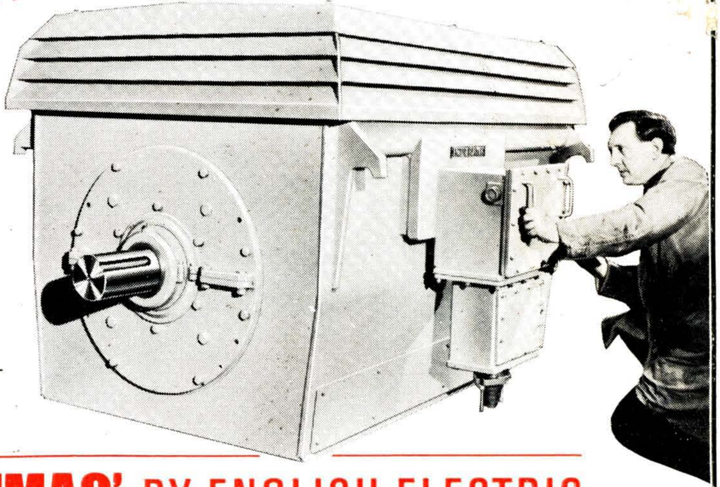

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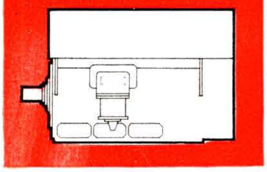

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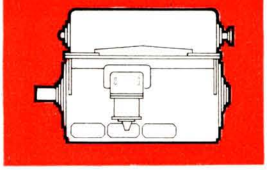

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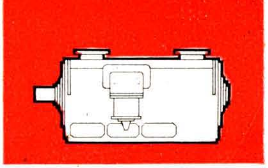

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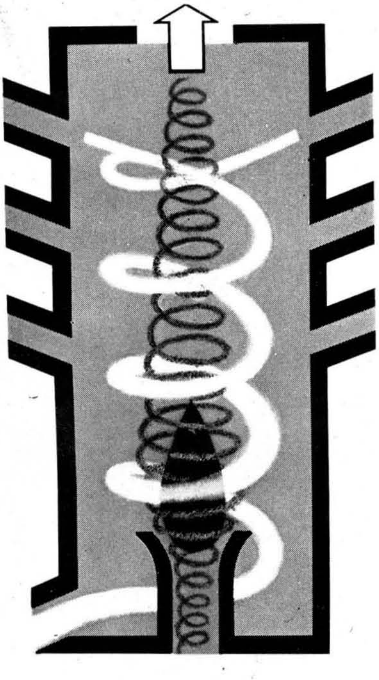

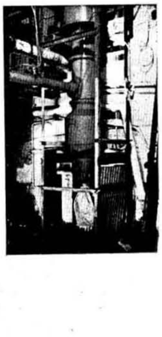

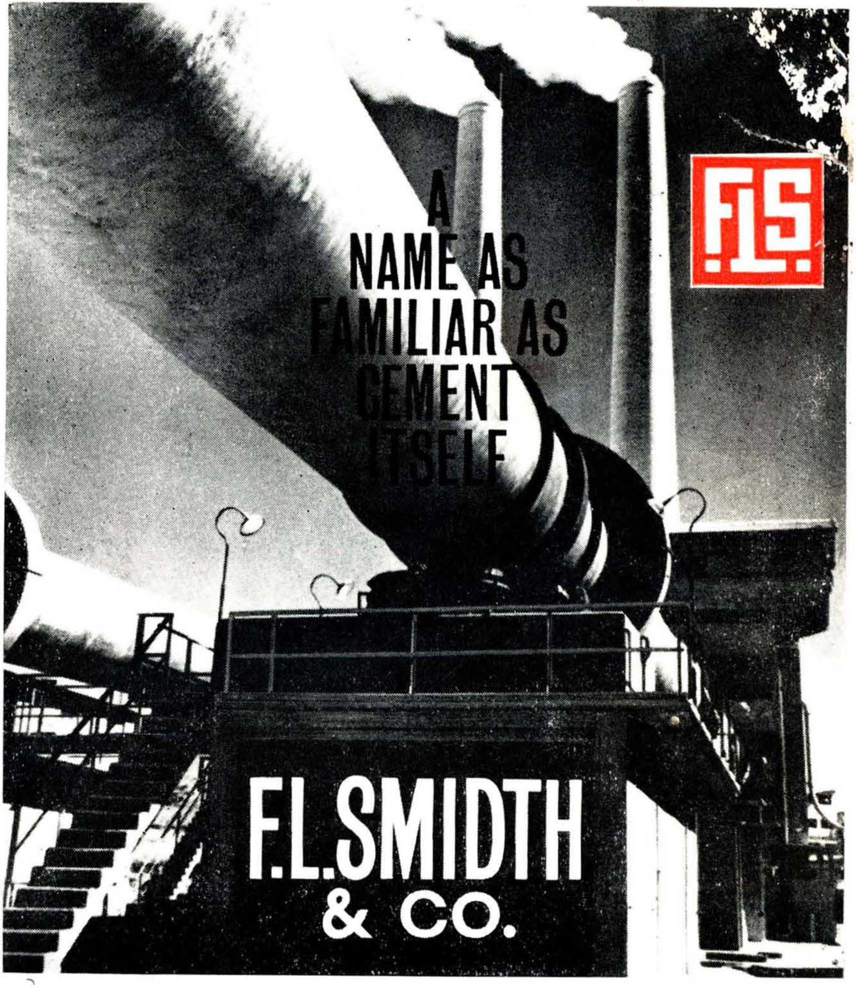
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VOLUME XLI NUMBER 3 MAY, 1968

Bed-blending of Raw Materials for the Dry Process

By K. C. BARRELL, M.A., C.Eng., F.I.Mech.E.

THE EARTH'S surface is rich in deposits of the calcium carbonate and argillacious and silicious materials needed for the production of Portland cement. Many of these materials are, however, far from being homogenous and, if they are to be used, present considerable problems of selection and blending to give the necessary composition of the raw material for burning. In the cradle of the cement industry, the Thames Estuary and the adjacent valley of the River Medway, the chalk and clay were popularly thought to possess some mysterious property that made them superior to any other. Any superiority of these products was, however, almost certainly due to their being particularly homogeneous and to the relative ease of wash-milling and blending these soft materials. The industry, in course of time, spread to areas where limestone and shale had to be used, the natural preference being for homogeneous deposits. Too great a variation in composition could raise problems of selection and blending too difficult and costly to solve with the equipment then available, and it would only be feasible to establish a cement works where the materials were better and to transport the cement to the market area.

New methods are now leading away from such a situation. The sizes of works are increasing rapidly and it is important to avoid adding heavy transport costs to a cheap commodity. The tremendous development in earth-moving machinery has made it possible to work deposits that were previously uneconomic. But, unless the materials are fairly homogeneous, the problems connected with the provision of separate storage of large quantities of materials of different grades and the operation of blending them by the conventional methods, that is weigher-feeders feeding the various components to the raw-mill and then blending the raw meal in air-agitated silos, can be formidable.

A new method, known as " bed-blending," is now coming into use in the cement industry. Some seventy years ago, it was developed in the U.S.A. for the refining of copper concentrates, iron ore and coal. Not until 1959 was an appli-

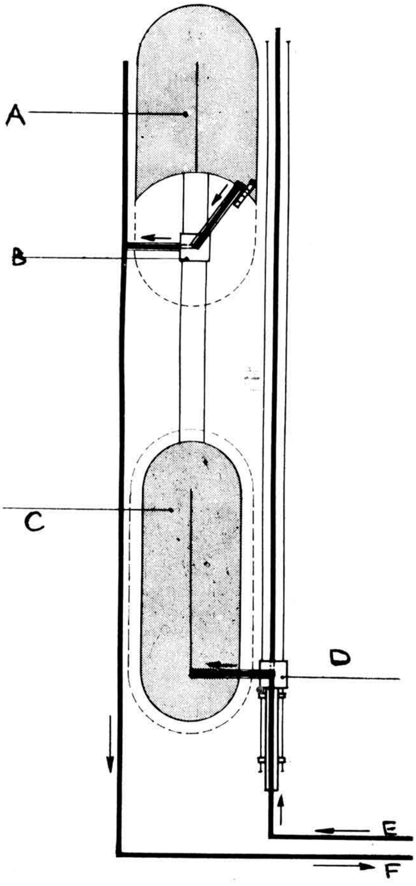

**Fig. 1.
Typical lay-out for bed-blending with two piles.
Fives Lille-Cail System.**

cation made to the cement industry, when an installation was established at Oro Grande, U.S.A., for the Riverside Cement Co. This was described in the January 1960 number of this journal. However, the cost of the heavy equipment then used, rendered the method uneconomical for general use in the cement industry. By modified design, this objection has now been overcome, and plants have been installed in France, Spain and Italy. A plant at Cordoba, Spain, was described briefly in the July 1967 number of this journal.

The basis of the bed-blending method is to build a pile of the material in evenly spread layers or " beds " and to reclaim the material from the completed pile by raking it down across the grain of the beds. This gives a very homogeneous product from the materials present in the pile, but it is of course also essential to the manufacturing process that this product be of a specific composition.

Therefore, an essential adjunct to bed-blending is a satisfactory method of continuous sampling and weighing of the feed to the pile, so that the mean composition of the pile is known at any moment during the building of the pile.

The usual size of a pile is about the minimum stock for five days' operation of the works. Two such piles are needed, one being built while the other is being consumed. Thus there would be about 8,000 tons in each pile for an output of 1,000 tons of clinker per day. The five-days' period of building the pile is available for sampling and analysis, so that there is plenty of time to direct the operations at the quarry to give the required composition.

The blending operation requires that the material be crushed to less than 25 mm. in order to avoid the risk of segregation while piling and to make the various handling operations easy. This grading also simplifies the automatic selection of a representative sample continuously.

The flow in the bed blending process is summarised as follows :

Dump the various materials from the quarry into the reception hopper at the crushing plant.

Crush to minus 25 mm.

Extract a continuous sample from the crusher product, by means of equipment which selects and prepares a mean hourly sample.

Ascertaining the weight of material delivered hourly by means of a continuous integrating weigher on the conveyor to the blending-bed pile.

Determine the mean composition of the pile by correlating the analysis of the hourly samples and the hourly weight of material.

Control the rate of dumping of the various components into the crusher to give the required mean composition of the pile as it comes to completion.

A result typical of the process is stated to be

Average $CaCO_3$:	As quarried	76% ± 10%
	Bed-blended	± 1%
	Raw meal (ground)	± 0·3%

With such, it would be practicable to feed to the kiln without further blending.

It is claimed that the capital cost of a bed-blending installation with covered storage would be about the same as that of a conventional plant with overhead grabbing cranes and with separate mill hoppers with proportioning feeder-weighers for several component materials. If silos for blending after milling can be omitted there would be a substantial gain.(1)

The method may also be very advantageous where one of the constituent materials is sticky and difficult to handle. By the provision of a separate feeder for it at the crusher reception point, such a material can be sandwiched with the other components, reducing the risk of choking the crusher and, being subsequently thoroughly blended with the more tractable components, does not have to pass through bunkers and weighers and feeders alone.

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[1] W. A. Bemelman ; see "Acknowledgements."

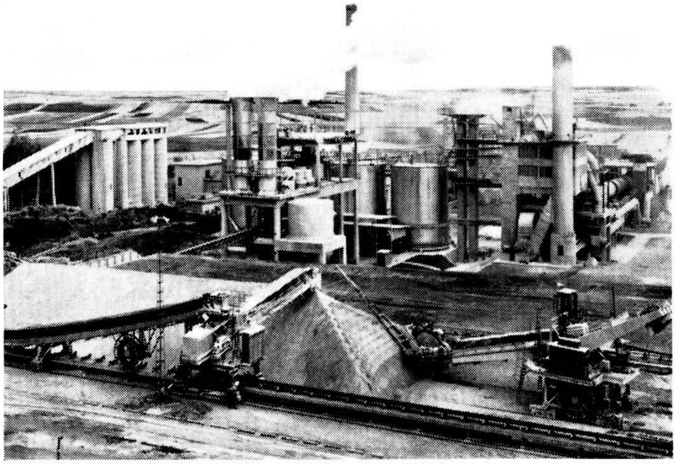

Fig. 2. Fives Lille-Cail equipment at Villaluenga, Spain. Stacking and reclaiming open piles at 150 tons per hour.

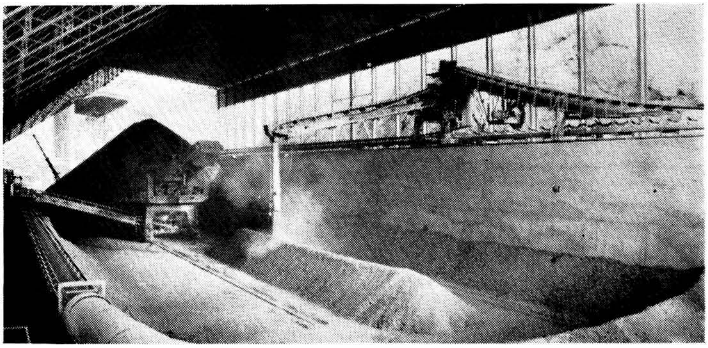

Fig. 3. Covered bed-blending piles at l'Estaque, Marseilles. Stacking at 450 tons per hour. Reclaiming at 300 tons per hour.

The general practice in the U.S.A. is for the installation to be in the open, but in Europe it has been considered desirable in some installations to provide a roof over the stockpile.

Building a Pile

Fig. 1 shows a typical layout of a plant with two piles using equipment developed by Fives Lille-Cail.

The crushed material is brought to the piles by the conveyor E. A stacker D picks it up from the conveyor and distributes it by means of a boom on to the pile C being built. The material is recovered from pile A, which had been previously constructed, by an unstacking machine B which discharges it on to conveyor F for delivery to the grinding plant.

Continued on page 41

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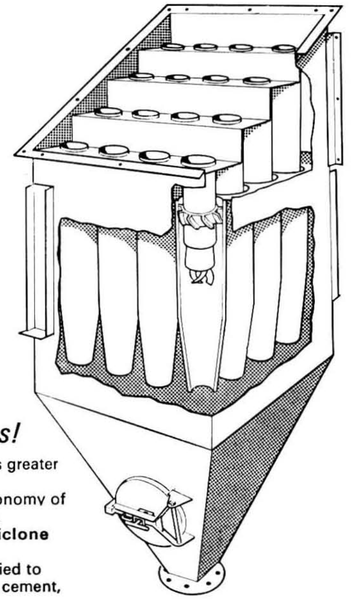

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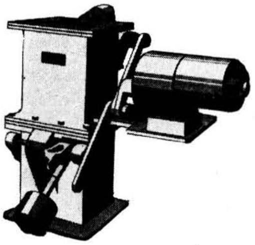

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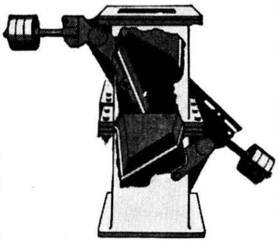

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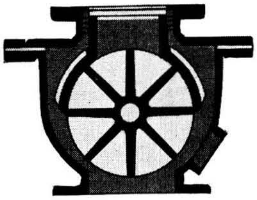

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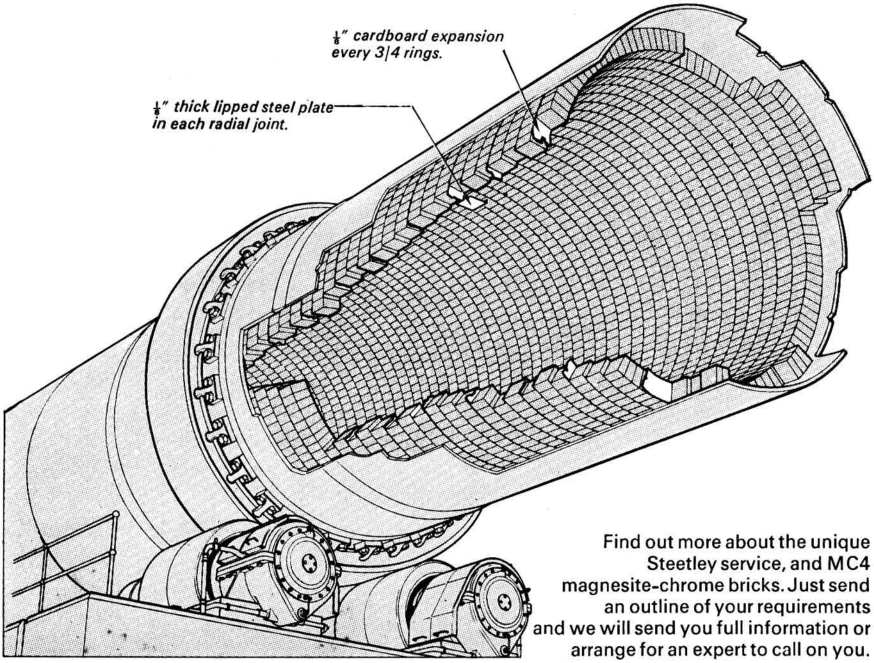
B	10′ 6″ (3.5m)	Wet	15 months	12 months
C	9′ 1″ (3.0m)	Wet	19 months	15 months
D	9′ 0″ (3.0m)	Wet	18 months	18 months
E	10′ 0″ (3.3m)	Wet	18 months	(No record, Steetley supplying first basic lining)
F	9′ 10″ (3.25m)	Wet	12 months	6 months
G	11′ 10″ (3.9m)	Wet	13 months	9 months



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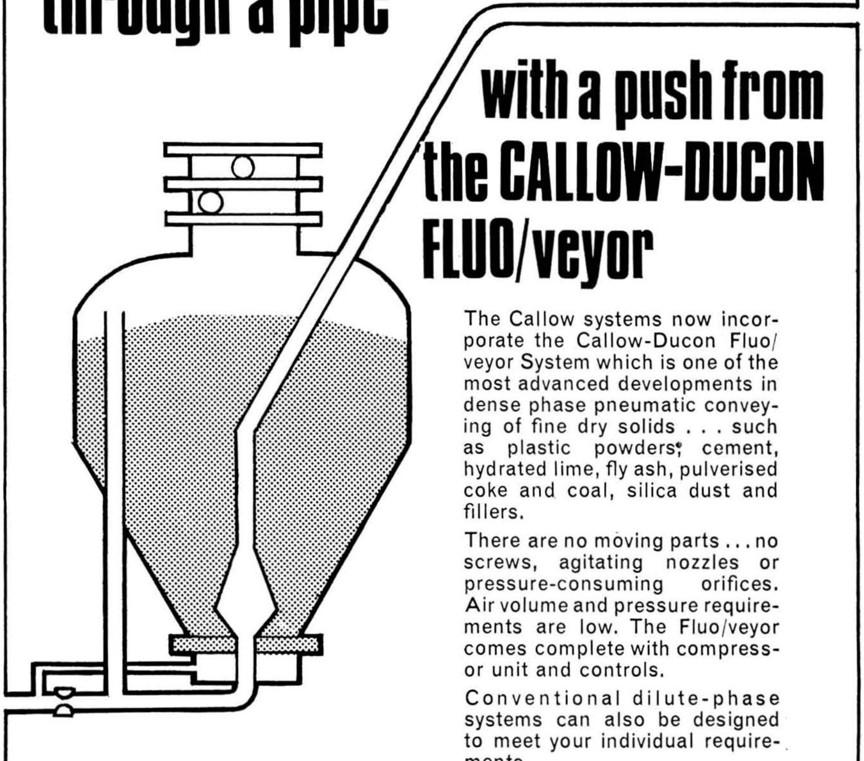


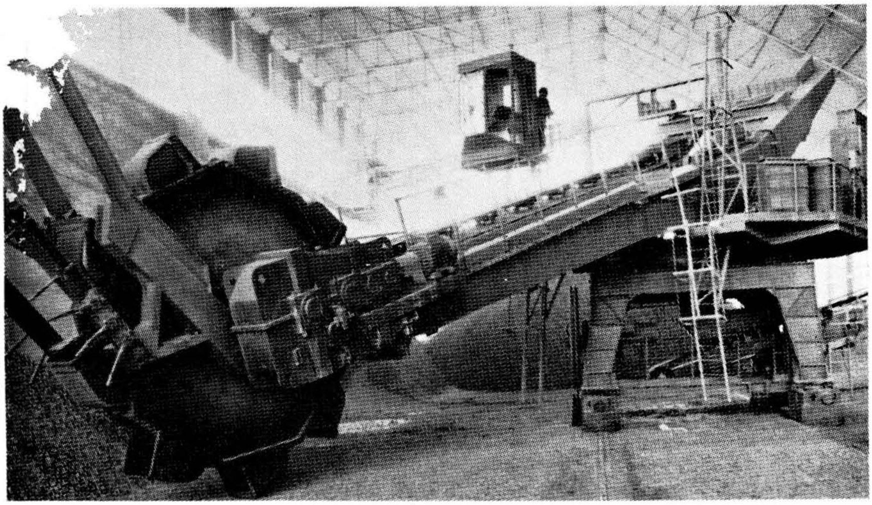


Fig. 4.—Fives Lille-Cail bucket-wheel reclaimer at cement works, l'Estaque, Marseilles.

This arrangement is illustrated in *Fig.* 2 for an open plant at Villaluenga, in Spain. Here, for convenience of photography, the stacker and recovery equipment are shown working on the same pile. *Figs.* 3 and 4 show similar equipment, but roofed over, at Cimenteries de l'Estaque-Marseille in France.

The stacker traverses up and down the length of the pile, the boom being raised as the crest of the pile progressively rises. Automatic controls correlate the traversing and elevation to give an even thickness of bed. The stacker travels faster when moving in the opposite direction to the longitudinal conveyor than when moving in the same direction so as to give an equal rate of deposition in each direction.

The strata produced in a pile are shown in *Figs.* 5 and 6, in which the thicknesses are much exaggerated. An alternative method can be adopted if pockets of variation are expected in the quarry. The boom on the stacker is longer and is arranged to swing so that it can cover the whole width of the bed. A pattern as in *Fig.* 7 is produced, with as many as a thousand " chevrons " in the pile.

Recovery from a Pile

The machine for reclaiming or recovery of the material is shown in the diagram in *Fig.* 8 and is illustrated in *Figs.* 2, 3 and 4. As it advances along the track on the centre-line of the pile, the boom carrying the bucket-wheel and rake oscillates about a vertical axis so that the rake sweeps across the end face of the pile in a circular arc. The rake is inclined at about the same angle as the angle of repose of the material. The advance between each sweep is only 2 cm. to 4 cm. so that a very thin slice of material is brought down, to be picked up and put on to the

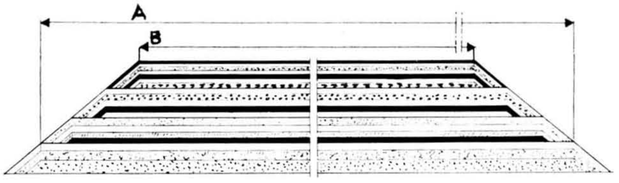


Fig. 5.
Longitudinal section of pile.
A = maximum travel of stacker.
B = minimum travel of stacker.

Fig. 6.—Cross-section of pile: Short-boom method.

Fig. 7.—Cross-section of pile: Long-boom method.

removal conveyor by the bucket-wheel. The control is automatic with a limiting control from the hopper of the grinding plant, when the hopper is full.

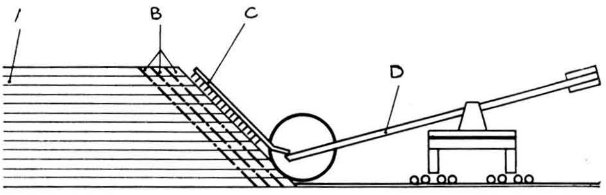
An installation at Rehon in France, with four beds and using the Hewitt-Robins system, is shown in *Fig.* 9. In this plant, the rake and bucket-wheel for reclaiming are mounted on a travelling gantry spanning the bed (*Fig.* 10).

Continuous Sampling

Equipment for automatically selecting samples continuously is, as already mentioned, essential to the successful operation of bed-blending. The production of a sample once an hour, representative of one hour's flow will probably be sufficient. The problem is to select a true sample of less than 1 kg. per hour from a flow of several hundreds of tons per hour.

Depending upon the clayey characteristics of the material, the sampling process adopted would be either wet or dry. In either of these methods, there would be two stages of sampling. In the first, a quantity of some 300 kg. per hour, truly representative of the main flow, has to be selected from which, in a second stage consisting of grinding and further selection, the final sample is obtained.

Typical flow-diagrams for both processes are shown in *Fig.* 11.



A = Beds being reclaimed.
B = Successive transverse cuts.
C = Rake.
D = Reclaiming machine.

Fig. 8.—Diagram showing operation of Fives Lille-Cail reclaiming machine.

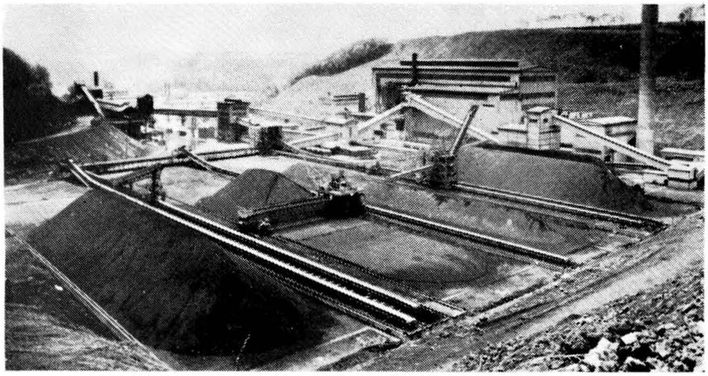


Fig. 9.—Hewitt-Robins plant on four piles, at Rehon, France.

FIRST STAGE.—The object of the first stage is to furnish for the second sta about 300 kg. per hour of material not exceeding 25 mm. in size. Should t main flow exceed this in size, a roll-crusher would have to be installed before t second stage. In the Fives Lille-Cail installations, the primary selection is ma by the " Dragon " selector (*Fig.* 12). In this plant, a small chute sandwich between two large chutes, is mounted on a frame which is seen in *Fig.* 12 as th part on which the man's hand is resting. The frame is reciprocated at consta speed across the stream of material falling from a feeder-conveyor above The material caught in, and discharged from, the pair of large chutes and from t

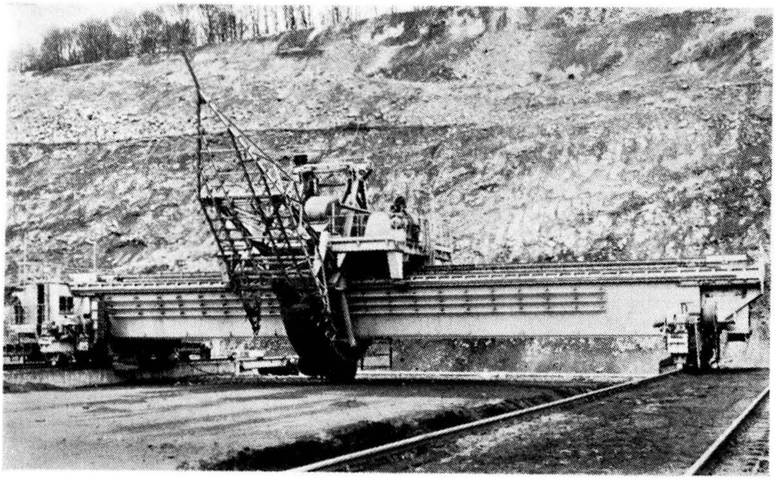


Fig. 10.—Hewitt-Robins reclaimer.

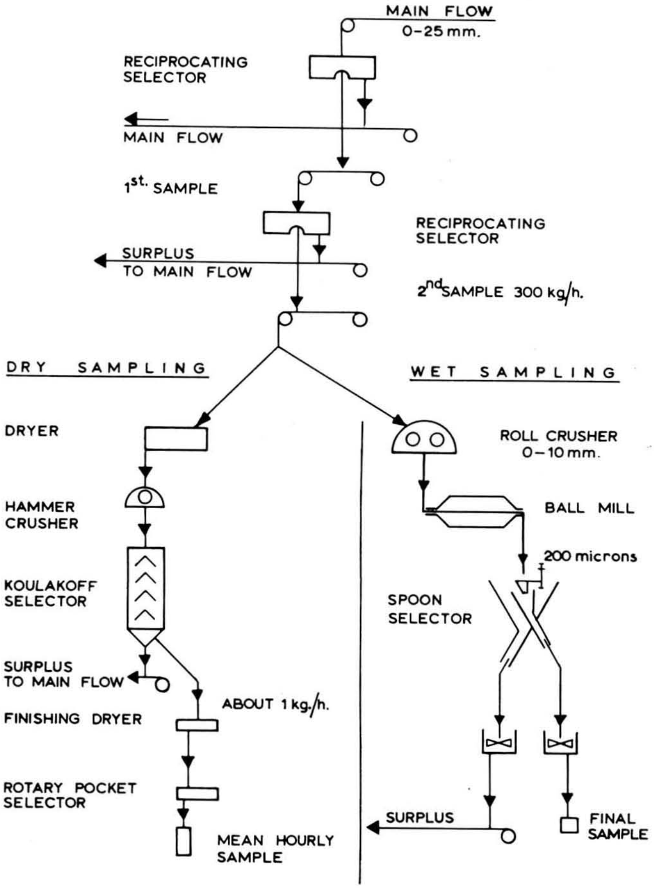


Fig. 11.—Flow-diagram for continuous sampling by dry and wet process.

small chute fall on to separate conveyors. The bulk, from the large chutes, is returned to the main flow to the works. Two selectors may be required in series, in which event, the second has to reciprocate three times as fast as the first in order to achieve a representative selection. The driving mechanism is controlled to give a constant speed of passage through the material.

SECOND STAGE

Dry sampling.—For the second stage, the material needs further reduction in size to a final powdered sample suitable for analysis in the laboratory. Sufficient drying is therefore necessary to permit grinding and avoid building-up in the various pieces of equipment. The chain of equipment is as follows:

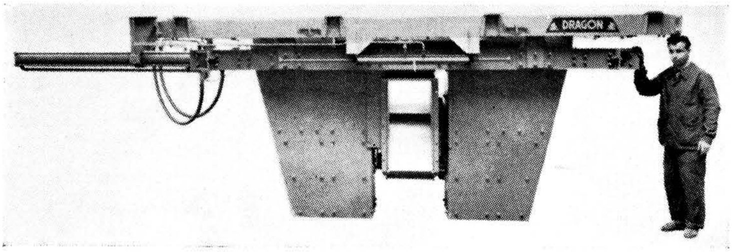


Fig. 12.—" Dragon " reciprocating selector.

A dryer (*Fig*. 13).
A hammer crusher.
A selector (*Fig*. 14).
A finishing dryer.
A disc crusher.
A rotary pocket selector.

The " Dragon " Koulakoff selector used by Fives Lille-Cail consists of a series of cones with slots. The material cascades over the first cone. The small proportion that falls through the slots is directed on to the cone beneath. The

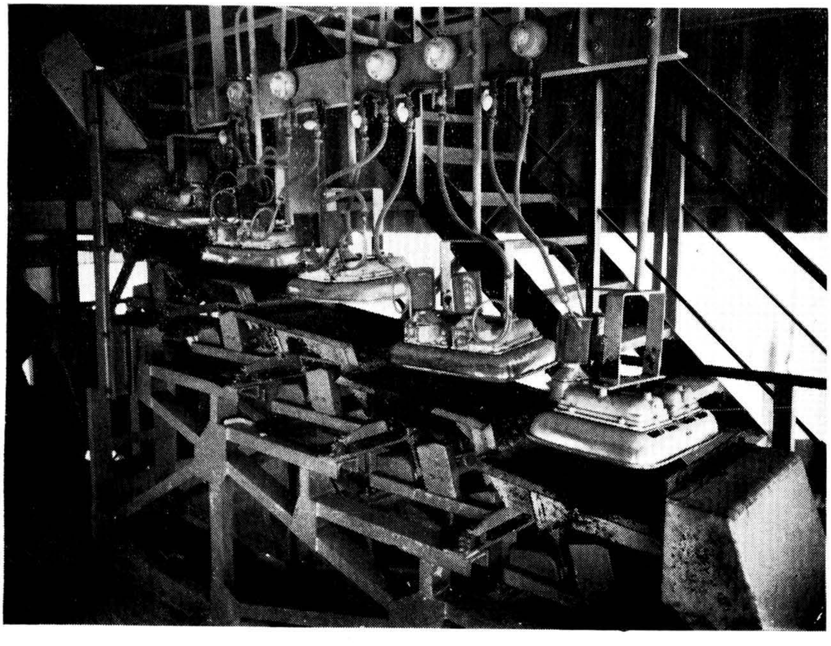


Fig. 13.—Gas-fired infra-red dryer.

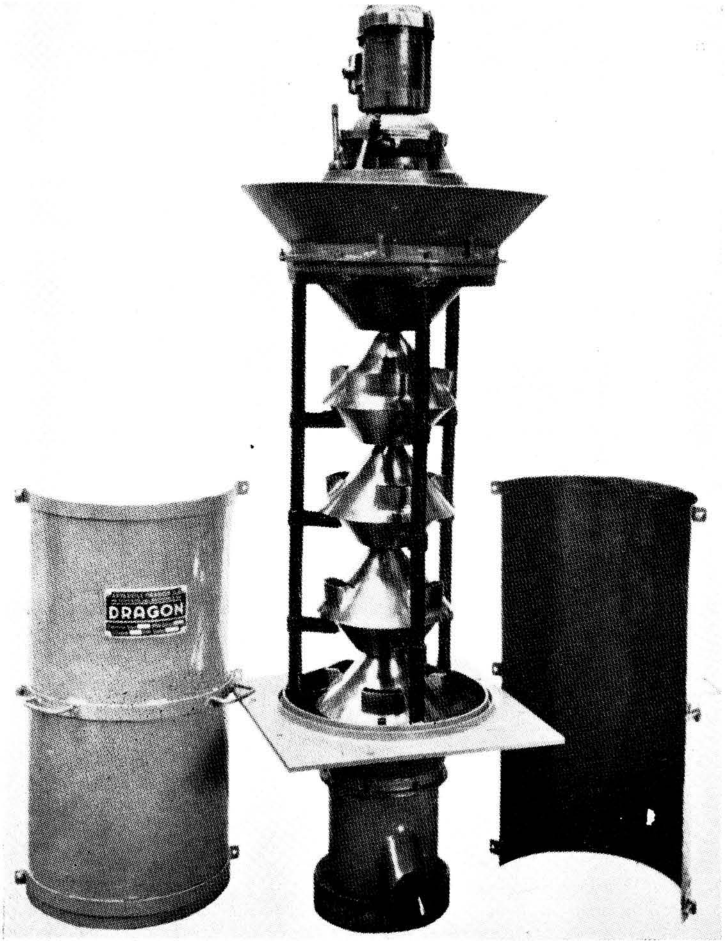


Fig. 14.—" Dragon " Koulakoff selector.

remainder falls to discharge over the bottom edge of the cone. The process is repeated past the subsequent cones. The final selection is about 1 kg. per hour of well-mixed material.

The permissible error of sampling is in the order of 0·25 per cent. of $CaCO_3$. To achieve such precision, it is essential that the equipment be so designed that there is no building-up and that the loss of dust, particularly in the dryers, should be negligible. The gas-fired infra-red tray dryer (*Fig.* 13) is used with this object in mind.

Wet sampling.—If, with very clayey material, there should be a risk of an unacceptable loss of fines as dust, it may prove necessary to resort to a wet-sampling process. The chain of equipment would then be as follows:

A roll crusher to give a product less than 10 mm. in size.

A ball-mill to grind 300 kg. per hour of the roll-crusher product with water to produce a slurry of about 30-per cent. water-content and fineness of 97 per cent. under 200 microns.

A spoon sampler.

A stirred reservoir from which the final sample is drawn at the required intervals.

With the wet process of sampling, it is also essential to take great precautions to prevent settlement or building-up which would upset the results.

Acknowledgements

Acknowledgement is made of information kindly supplied by S. A. Fives Lille-Cail of Paris, Appareils Dragon of Paris, Hewitt-Robins (Holland) N.V. of Amsterdam, and The Associated Portland Cement Manufacturers Ltd. Reference has also been made to papers by R. Lucas in " Revue des Materiaux de Construction, Ciments & Betons " No. 621, June 1967; and by W. A. Bemelman in " Zement-Kalk-Gyps " No. 7, 1966.

Modern Cement Plant in Japan

THE FOLLOWING information is abstracted from the number of the " IHI Bulletin " for February 1968.

IN 1961, Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI), of Tokyo, concluded with Klockner Humboldt Deutz A.G. (KHD), of West Germany, a technical licence agreement for the Humboldt suspension preheater. This action has played a prominent role in producing a technical revolution in the Japanese cement industry. Based on the techniques acquired, IHI made its own studies and improvements which were directed to enlarging the scale of the cement plant and eventually acquiring the knowledge to manufacture a plant having an annual productive capacity of 1,500,000 tons per kiln and, finally, establishing manufacturing facilities capable of turning out the massive equipment necessary for such large-scale plants.

IHI is currently manufacturing a dry-process cement plant of the IHI-Humboldt type with a suspension preheater, having a maximum capacity of 4,000 tons per day from one kiln. This is said to represent a kiln of the largest capacity currently in use anywhere in the world. IHI have manufactured kilns for wet-process

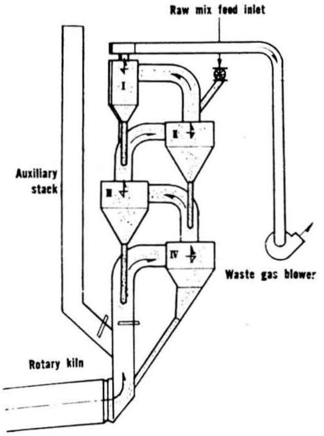


Fig. 1.
Humboldt
preheater
as
developed
in
Japan.

plants since 1956 and has also manufactured various equipment for cement works and, today, is exporting plants on a turnkey basis to many South-East Asian countries. The development of the IHI-Humboldt suspension preheater (*Fig.* 1) has achieved drastic reductions in fuel consumption.

The suspension preheater comprises a number of large cyclones and connecting ducts. Pulverised raw material, charged into the high-temperature kiln exhaust gas, is thus preheated. By this process some 40 per cent. of the $CaCO_3$ is calcined into CaO and CO_2 within the preheater. This converted raw material is charged into a kiln, which is much shorter in length than for that required for other dry-process plants of the same capacity, while a greater specific throughput is achieved and consequently lower unit cost of production becomes possible by the use of this type of plant.

A characteristic of dry-process plants equipped with IHI-Humboldt suspension preheaters is that the most suitable arrangement of preheater cyclones provides greater thermal efficiency with fuel consumption ranging from 750 to 800 Kcal. per kg. of clinker. Some of the IHI plants have actually operated at 710 Kcal. per kg. of clinker. Since the preheater exhaust gas contains the equivalent of a 150 Kcal. per kg. of clinker, which is sufficient heat to release 8 per cent. of the moisture contained in the raw material, the use of the waste heat serves to increase economy further.

In order to reduce the dust content of the exhaust gas discharged from the preheater, the diameter of the first cyclone is smaller thereby increasing the dust-collecting effect. In cases where this exhaust gas (at about 350 deg. C.) is not used for drying raw material, an IHI-Humboldt electrostatic dust collector is installed.

Effects of Temperature on High-alumina Cement Concretes

THE U.S.A. National Bureau of Standards recently carried out research on the effects of temperature on the composition and mechanical properties of hydrated high-alumina cement concretes. The temperatures at which the studies were made varied between room temperature and 1400 deg. C. The samples were cured, dried and heat-treated, and were then identified by X-ray diffraction and differential thermal analysis.

Measurements of transverse strength, modulus of elasticity, and changes in length with temperature were compared with the change in composition that occurred during hydration and dehydration. The studies revealed a correlation between changes in mechanical properties of hydrated high-alumina cements and the corresponding changes in their mineralogical composition as a result of heat treatment.

The investigation related to the preparation and properties of heat-resistant concretes, commonly known in the U.S.A. as " refractory castables," that are prepared from a mixture of high-alumina and heat-resistant aggregate.

At temperatures up to about 1100 deg. C., it is the high-alumina cement that determines the properties of a refractory castable. Although considerable information is available on the chemistry of high-alumina cement, the mechanisms involved in the hydration and dehydration are not yet fully understood.

An attempt was made to relate any changes in composition, following heat treatment of hydrated and dehydrated high-alumina cements, to changes in physical properties. The results in general show a significant correlation between changes in mechanical properties and compound composition.

Four commercial high-alumina cements, two of U.S.A. origin and two from other countries, were investigated. The cements provided material having a fairly wide range of silica and iron-oxide content. A water-cement ratio of 0·25 was used in the preparation of the test specimens, which were 1 in. square and of two lengths, namely, 7 in. and 12 in. The hydrated specimens were cured for twenty-eight days at 25 deg. C. to 27 deg. C. and between 95 and 100 per cent relative humidity prior to heat treatment. All heat treatments at 200 deg. C. and over were preformed in a furnace heated by silicon-carbide resistance elements at the rate of about 100 deg. C. per hour with a two-hour soaking period at the highest temperatures. For heat treatments below 200 deg. C., the specimens were placed directly in a conventional drying oven which was then maintained at the desired temperature for forty-eight hours.

X-ray diffraction and differential thermal analysis were used for identification of the compounds. X-ray patterns were made at room temperature before and after hydration of each cement and after heat treatment of the hydrated specimens. Differential thermal analysis was performed by placing a sample of cement and a reference material in a furnace and increasing the temperature at the rate of 8·5 deg. C. per minute. The temperature of the sample of cement and its deviation from that of the reference material were continuously recorded during the entire heating period.

The dehydration characteristics of three hydrates commonly found in hydrate high-alumina cement were also studied to facilitate the identification of the hydrated constituents of the cement specimens. These compounds were $CaO.Al_2O_3.10H_2O$, $3CaO.Al_2O_3.6H_2O$, and $Al_2O_3.3H_2O$. Differential thermal analysis patterns showed characteristic endothermic peaks for the three compounds as well as for the hydrated specimens prepared from the commercial cements. The number of peaks indicated that dehydration of the samples occurred in a stepwise process common to many types of clays.

The modulus of elasticity was determined for the 12-in. specimens before and after heat treatment. A sonic method was used in which the specimen was vibrated in flexure with frequencies up to 25,000 cycles per second. This vibration is sensed by a phonograph pickup and fed to an oscilloscope, where the resonant frequency is located by means of Lissajous figures. The resonant frequency is accurately determined from an electronic frequency counter and is used to calculate the elastic modulus.

Upon completion of the dynamic elasticity measurements, the specimens were placed in a transverse testing apparatus and loaded to failure.

Changes in length with temperature were measured with a dilatometer for hydrated specimens that had received no prior heat treatment. The specimens were placed in a furnace and data obtained for two separate heating and cooling cycles.

It was found that elasticity and strength decreased between room temperature and 50 deg. to 75 deg. C., because of the partial dehydration of $CaO.Al_2O_3.10H_2O$ and the formation of $3CaO.Al_2O_3.6H_2O$ and $Al_2O_3.3H_2O$. However, the specimens showed a high rate of expansion up to about 110 deg. C. Between 75 deg. C. and 110 deg. C., the strength increased because of increased crystallinity of $3CaO.Al_2O_3.6H_2O$ and $Al_2O_3.3H_2O$. At about 100 deg. C. to 300 deg. to 500 deg. C., the strength and the rate of expansion decreased because of complete dehydration of all three hydrates. The modulus of elasticity was relatively constant in the temperature range from 300 deg. to 500 deg. C., to 1100 deg. C., indicating that elasticity is less sensitive to changes in composition and structure. Above 700 deg. C., all cements exhibited decreased strengths. Above 800 deg. C., differences became apparent in the changes of length of the four cements because of differences in composition. Also, sintering occurred at these high temperatures, resulting in rapid contraction of the cement.

Thus, the laboratory studies showed that many changes in the mechanical properties of high-alumina cements are directly related to corresponding changes in compound composition. For example, the dehyration of $CaO.Al_2O_3.10H_2O$, $3CaO.Al_2O_3.6H_2O$ and $Al_2O_3.3H_2O$ produced an overall reduction in strength and modulus of elasticity as well as an appreciable contraction of the cements. Also, the grain size, crystallinity and sintering characteristics of each constituent compound and the solid state reactions between these compounds influenced the mechanical properties to varying degrees.

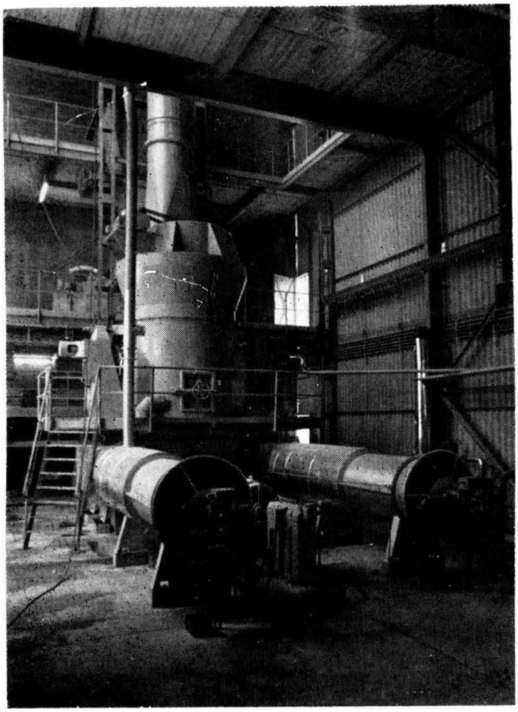
Cement Works in the U.K.

HE CEMENT mills for the new Cookstown (Northern Ireland) cement works (see page 13 of this journal for January 1968) were supplied by Vickers Ltd., which firm also made the shells for the kilns at this works for Polysius Ltd.

Vickers Ltd. also supplied the kilns for the Whitehaven works of Marchon Products Ltd. (see page 34 of this journal for March 1968).

Cement Mills of 3,000 h.p.

THE ILLUSTRATION in *Fig*. 5 in the article entitled " Cement Mills of 3,000 h.p.", which was published in the November 1967 number of this journal, was reproduced from a photograph supplied by S. A. Equipment Industriel Slegten, of Brussels. The illustration in *Fig*. 4 does not actually show Slegten type classifying liners in one of the six new 3,000-h.p. mills for A.P.C.M., but relates to a similar cement-grinding mill in Germany. These liners, which were made in Germany, are not of BF-253 material as are the corresponding liners in the Vickers-Armstrong Mill.



International Symposium on the Chemistry of Cement

IN the following are given the titles of the papers proposed to be presented at the Fifth International Symposium on the Chemistry of Cement, which is to be held in Tokyo from October 6 to 12, 1968.

Principal Papers

CHEMISTRY OF CEMENT CLINKER

"Structure of Portland Cement Minerals."
By Prof. Dr. A. Guinier and Mrs. M. Regourd (France).

"Phase Equilibria and Formation of Portland Cement Minerals."
By Dr. R. W. Nurse (U.K.).

"Analysis of Portland Cement Clinker."
By Dr. G. Yamaguchi (Japan).

"Chemistry of Calcium Aluminates and Their Relating Compounds."
By Dr. T. D. Robson (U.K.).

HYDRATION OF CEMENTS

"Crystal Structures and Properties of Cement Hydration Products (Calcium Silicate Hydrates)."
By Prof. Dr. H. F. W. Taylor (U.K.).

"Crystal Structures and Properties of Cement Hydration Products (Hydrated Calcium Aluminates and Ferrites)."
By Prof. Dr. H. E. Schwiete (Germany).

"Phase Equilibria of Cement-water."
By Dr. P. Seligmann and Mr. N. R. Greening (U.S.A.).

"Kinetics of Hydration of Cements."
By Dr. R. Kondo (Japan).

"Hydration of Portland Cement."
By Dr. L. E. Copeland and Dr. L. Kantro (U.S.A.).

PROPERTIES OF CEMENT PASTE AND CONCRETE

"Structures and Physical Properties of Cement Paste."
By Mr. G. J. Verbeck and Mr. R. A. Helmuth (U.S.A.).

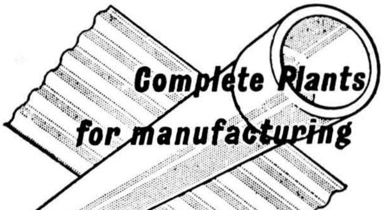
"Durability of Concrete."
By Prof. Dr. O. Valenta (Czechoslovakia).

"Carbonation of Concrete."
By Dr. M. Hamada (Japan).

"Hydration of Portland Cement Paste at High Temperature under Atmospheric Pressure."
By Mr. G. M. Idorn (Denmark).

"High-temperature Curing of Concrete under Atmospheric Pressure."
By Dr. Yurii M. Butt (U.S.S.R.).

"High-temperature Curing of Concrete under High Pressure."
By Dr. G. Kalousek (U.S.A.).



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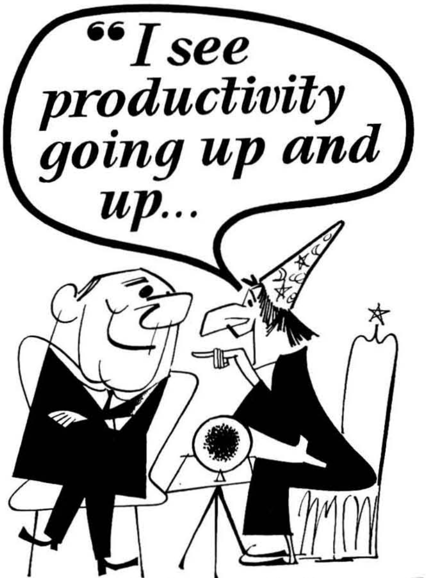

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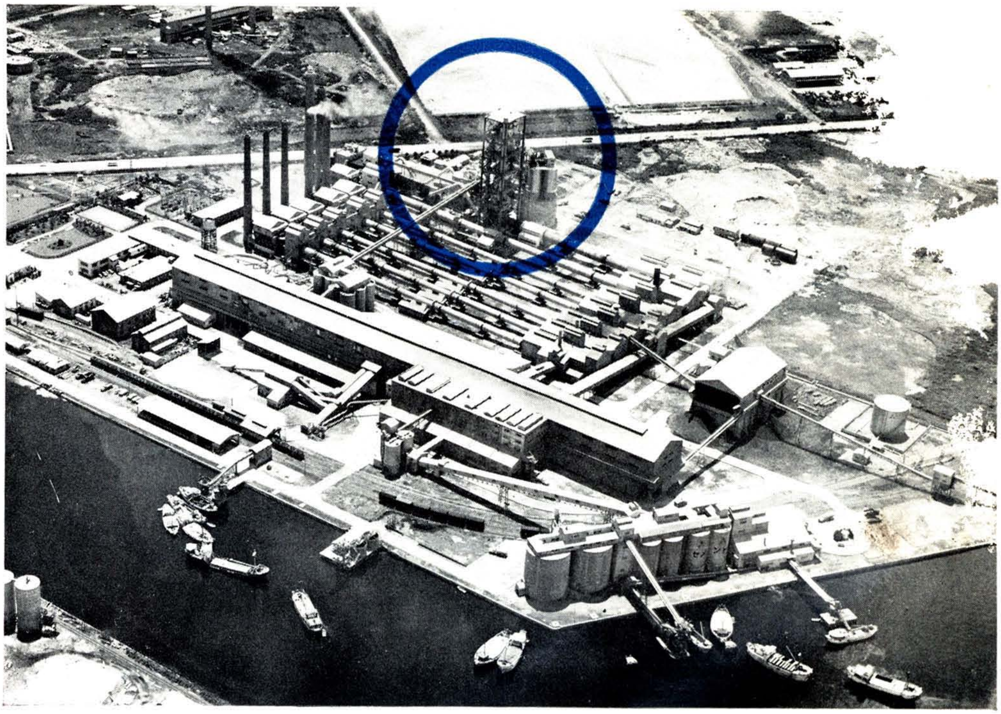
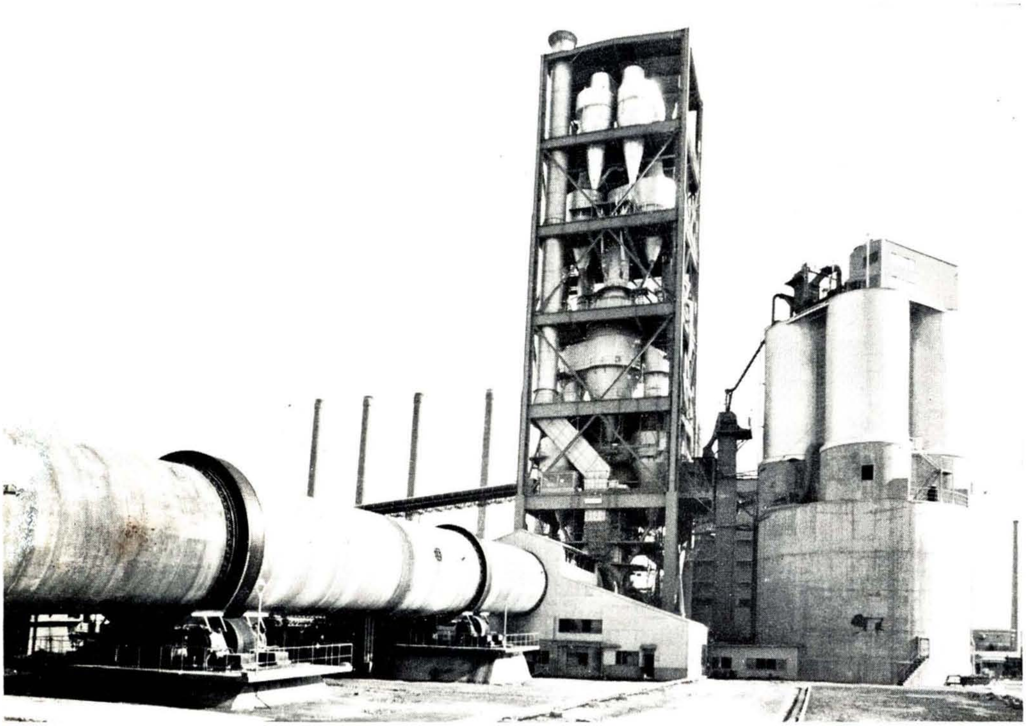


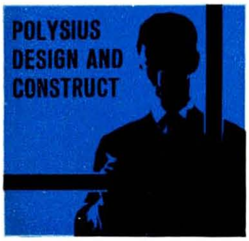
Here stood an almost new wet process kiln of 17′/16′/17′-6″ diameter, 615′ length, with an output of 1800 tons/day (with the high heat consumption associated with that system).
Greater kiln efficiency was required and the works engineers investigated the conversion of this kiln to the dry method.

There were two possibilities:-

1.) a long dry-process kiln with internal fittings. Guaranteed output: 2200 tons/day at 850 kcal/kg of clinker.

2.) a Polysius Dopol preheater with the existing rotary kiln shortened from 615′ to 310′ (the remaining length of the kiln to be used as a rotary dryer). Guaranteed output: 2500 tons/day.




POLYSIUS
DESIGN AND
CONSTRUCT

Admixtures and Special Cements

" Use of Surface Active Agents in Concrete."
By Dr. R. Mielenz (U.S.A.).

" Fly Ash and Fly Ash Cement."
By Dr. M. Kokubu (Japan).

" Slags and Slag Cements."
By Dr. F. Schroeder (Germany).

" Utility of Expansive Cement."
By Dr. P. P. Budnikov and Dr. I. M. Krawchenko (U.S.S.R.).

" By-product Gypsum from Various Chemical Industries, as a Retarder for the Setting of Cement."
By Dr. K. Murakami (Japan).

Supplementary Papers

A LARGE number of Supplementary Papers has been provisionally approved for presentation at the Symposium, and include five papers from Australia, five from Belgium, six from Canada, two from Czechoslovakia, two from Denmark, six from France, twenty from Germany, one from Hungary, four from India, two from Israel, six from Italy, thirty-seven from Japan, two from the Netherlands, two from New Zealand, two from Poland, two from South Africa, fifteen from U.S.A., and ten from U.S.S.R. The following Supplementary Papers are being contributed by authors from the United Kingdom.

" Manufacture of Portland Cement from Phosphatic Raw Materials."
By W. Guft.

" The Minor Elements in Alite (Tricalcium Silicate) and Belite (Dicalcium Silicate) from some Portland Cement Clinkers as Determined by Electron Probe X-ray Micro Analysis."
By H. G. Midgley and T. K. Ball.

" Calcium Aluminate Hydrates and Related Basic Salt Solid Solutions."
By M. H. Roberts.

" Crystal Structures and Reactions of $4CaO \cdot Al_2O_3 \cdot 13H_2O$ and Derived Basic Salts."
By S. J. Ahmed, L. S. Dent Glasser and H. F. W. Taylor.

" The Distribution of Alkalis in Portland Cement Clinker."
By H. W. W. Pollitt and A. W. Brown.

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"my daddy makes siment

in a grate big tube corld a kiln witch goes round and round. Inside their are a lot of speshul briks corld refractrees becors it gets very hot. My daddy says the best refractrees are made by a general who must be very clever nearly as clever as my daddy who makes siment"

There is much more than mere cleverness behind the excellence of GR products, like years of experience, extensive research, the selection and blending of the right raw materials, care, craftsmanship and other things too numerous to mention—but you can't expect a little girl to know all that, can you? And she has forgotten to mention

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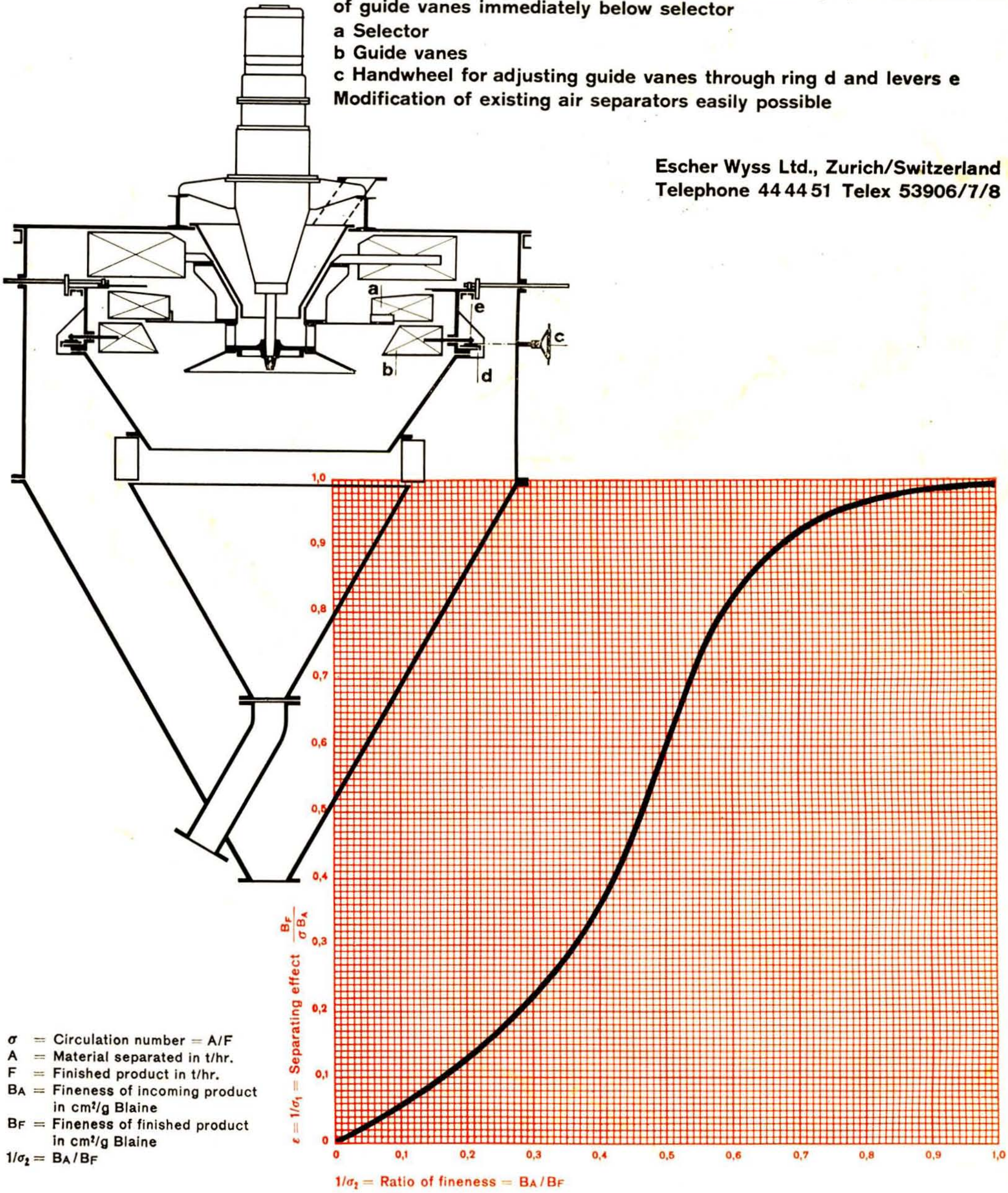
a
e
c
b
d
1,0
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
$\varepsilon = 1/\sigma_1$ = Separating effect $\frac{B_F}{\sigma B_A}$
0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1,0
$1/\sigma_2$ = Ratio of fineness = B_A/B_F