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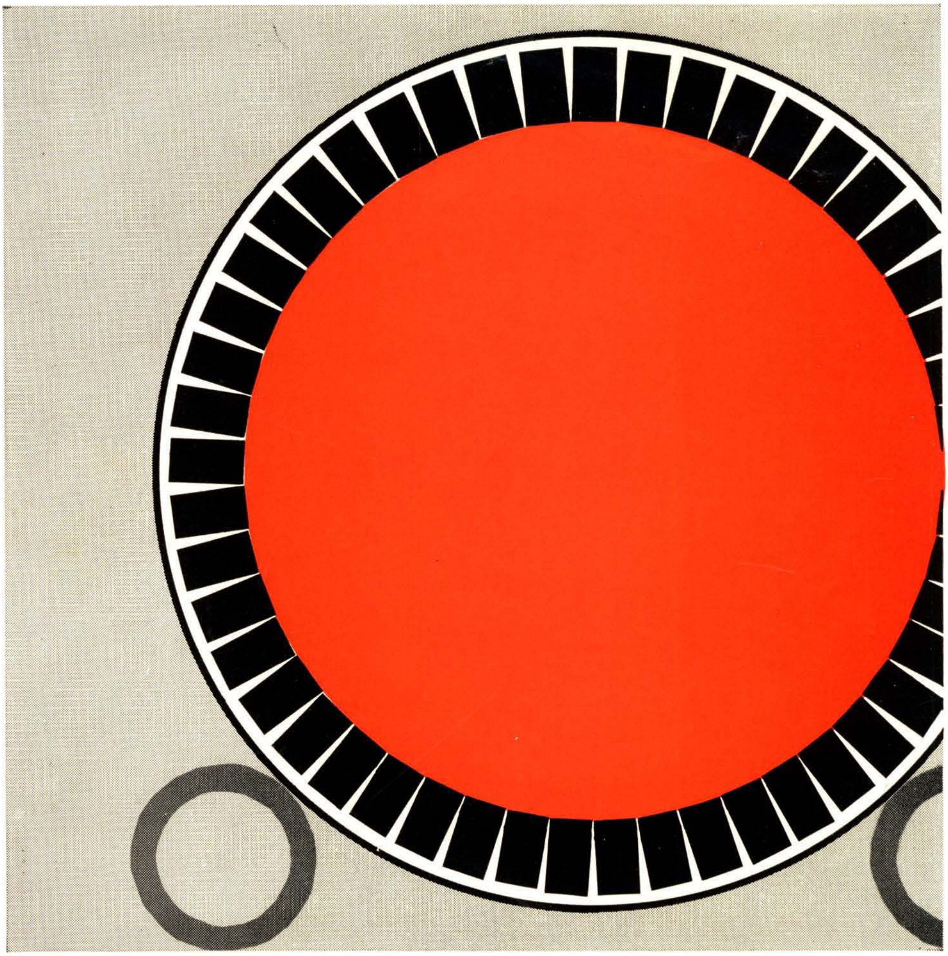

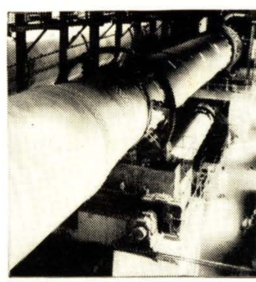

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Ships for Transporting Cement in Bulk.

BY L. S. HOLT, A.C.G.I., B.SC., D.I.C.

THE transport of cement in bulk by sea is increasing, especially where road or rail communication with the cement works is difficult. This is particularly the case in New Zealand and Norway where coastal ships serve various depots from which local distribution is made by road or rail. One such ship, M.V. " Ligar Bay," is described in the following. The use of a ship extends the sales area of a cement works, but the economical distance from the works to the centre of distribution is limited as these special ships must return empty. Other cargoes are not usually carried on the return trip as the holds of the vessels would have to be cleaned out completely to prevent contamination of any other material carried in bulk. A possibility in the future is to carry cargo packed to be proof against cement dust and stowed on a removable floor above the pneumatic handling equipment in the bottom of the hold.

M.V. "LIGAR BAY."

The M.V. " Ligar Bay " (*Fig.* 1) is a twin-screw diesel-electric ship designed to carry 1200 tons of cement in New Zealand waters at a service speed of 11 knots. The principal particulars of this vessel are given in *Table* 1.

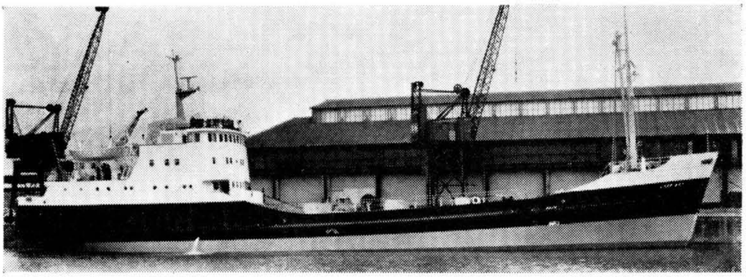


Fig. 1.—M.V. " Ligar Bay."

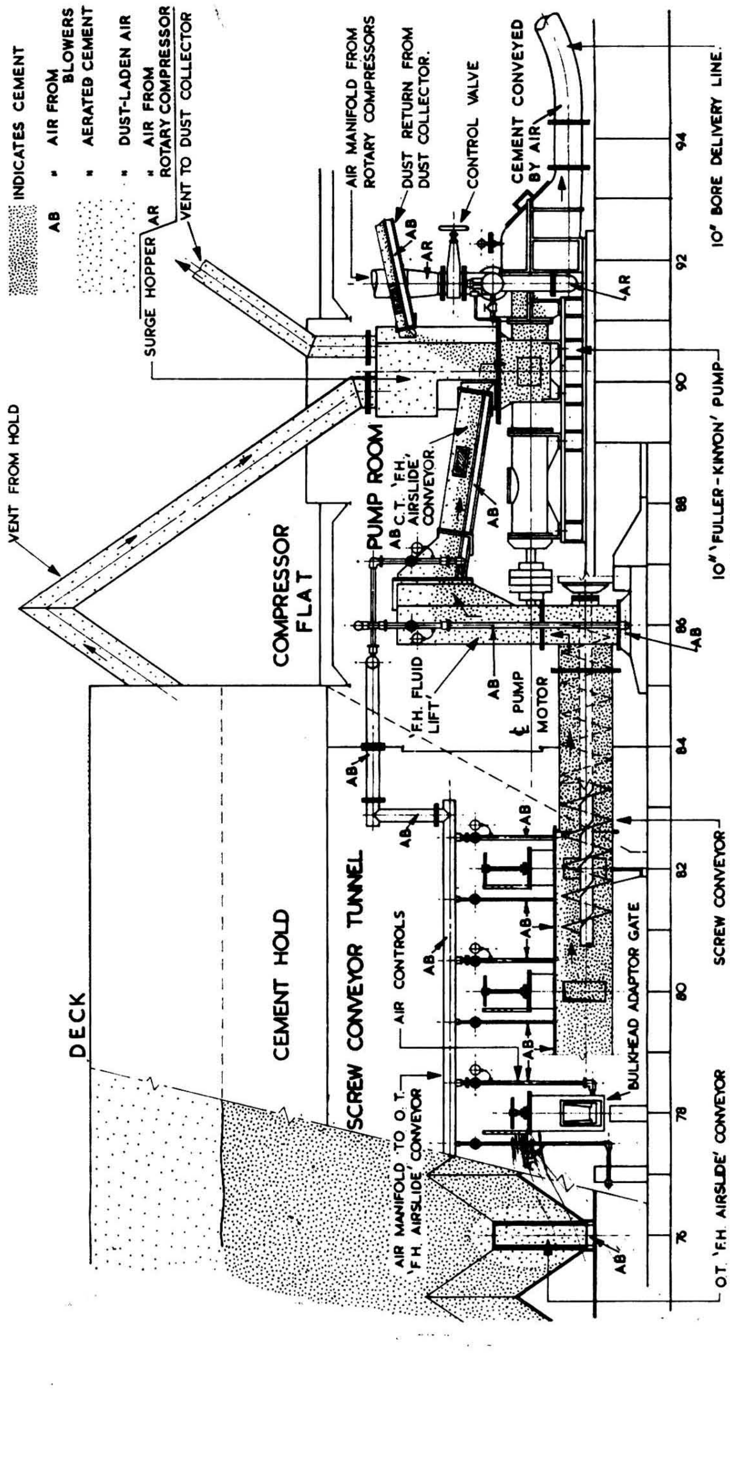


Fig. 2.—Extracting System.

The single cement pump and its associated compressors are installed forward in a pump-room below the main deck, the entrance being below the forecastle deck. The cargo hold extends 100 ft. aft to the engine-room bulkhead which coincides with the forward end of the accommodation. A longitudinal tunnel on the ship's centre-line runs the entire length of the hold and a central longitudinal bulkhead extends from the tunnel top to the underside of the trunk above the main deck (*Fig.* 3). On the port side of the trunk are three lateral casings with attachments for three telescopic loading hoses from the existing loading services at the Tarakoha works of the Golden Bay Cement Co., Ltd.

Principle of Operation.

The chief components of the system are a Fuller-Kinyon pump with associated air compressors, and " F-H Airslide " conveyors, which consist essentially of an air chamber covered with a porous membrane of rot-proofed cotton fabric woven with a controlled permeability. The tightness of the weave ensures that air emerges uniformly over the entire area of the fabric thus fluidising the cement in contact with it by infiltration of air between the particles. Inclination of the fabric membrane at a small angle to the horizontal causes the cement to flow down

TABLE I.—PRINCIPAL DIMENSIONS AND OTHER LEADING PARTICULARS.

	M.V. " LIGAR BAY "	M.V. " JOHN WILSON "
	ft. in.	ft. in.
Length overall	226 10½	270 0
Length between perpendiculars.. ..	210 0	246 0
Breadth moulded..	38 0	42 0
Depth moulded	16 0	18 6
Load draught	14 0½	15 9½
	tons	tons
Corresponding deadweight	1426	2107
Cement cargo capacity	1200	1750
Gross tonnage	1330	1675
Shaft horse power	1260	1600
Corresponding r.p.m.	250	220
Service speed	11 knots	11½ knots
Main generator capacity..	1 No. required for discharging 2 No. at 525 kW.	2 No. required for discharging 3 No. at 490 kW. at 440 v.
	tons per hour	tons per hour
Loading rate	Over 550	340
Discharge rate	130	280
Maximum conveying distance .. .. (including lift)	1500 ft. (60-ft. lift)	600 ft. (60-ft. lift)
Installed H.P.—discharging equipment excluding stand-by machines ..	795	910

M.V. "Ligar Bay."

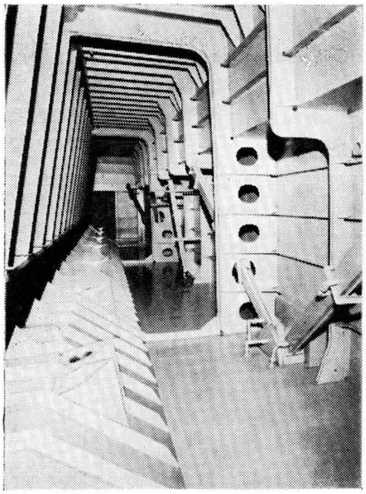


Fig. 3.

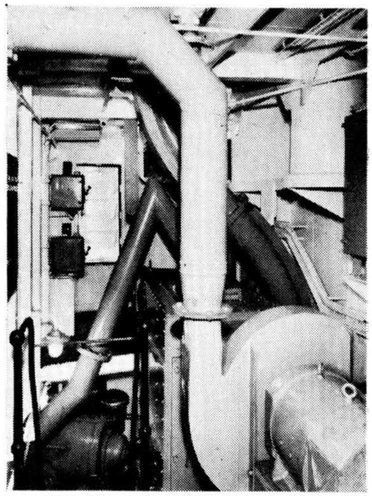


Fig. 4.

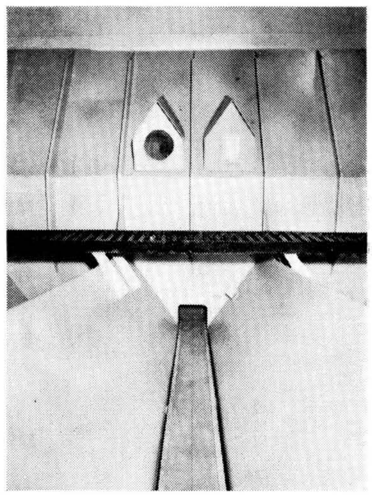


Fig. 5.

the slope. Cement settling from the bulk cargo above the fabric or arriving from an external source is immediately fluidised on contact with the fabric and thus a continuous flow is maintained.

The Fuller-Kinyon pump comprises a screw-shaft in a closely fitting barrel with a non-return valve at the discharge end. Cement reaching the pump hopper is fed into, and advanced along, the barrel by the screw-shaft which is directly driven at 960 r.p.m. by an electric motor, the pitch of the screw flights reducing at the discharge end to compact the cement and form a seal against the back pressure in the conveying line which is attached to the outlet flange of the pump mixing chamber. Cement discharged by the screw-shaft meets the conveying air in the mixing chamber and is transported through the conveying line to storage silos at some distance from the quayside. The compressors must have sufficient output to prevent settlement in the conveying line. The pressure in the line determines the power absorbed by the pump and compressors and is influenced by the rate of handling and distance conveyed.

Loading.

The three telescopic loading chutes previously mentioned are attached to the entry flanges on the port side of the trunk, and these accommodate changes of draught and tidal variations during loading; universal joints at each end of the chutes allow for rolling and slight fore-and-aft movements of the ship.

From the loading points, three " F-H Airslide " fluidising conveyors, inclined inboard, carry the cement to three distribution points installed at cut-outs in the central longitudinal bulkhead. From here, similar open-type conveyors with 2-in. side plates distribute the cement evenly over the hold, finally filling up to the level of the main deck with a surface which is practically horizontal. A heel indicator on the deck ensures the ship is kept on an even keel by varying the proportion of cement fed to port and starboard of the central bulkhead; controls for this are provided at the distribution points.

The trunk above the level of the main deck acts as an air space and the dust-laden air is withdrawn by a fan-assisted dust collector, which is a Dalamatic 1/2/60 FT plant with reverse jet cleaning. The dust-laden air consists of air displaced by the incoming cargo and air supplied by fans to the air chambers of the " F-H Airslide " conveyor system through header pipes. Most of the dust settles in the hold and the remaining airborne dust is drawn by the dust collector fan through a 12-in. duct from the trunk to the Fuller-Kinyon pump hopper as shown in *Fig.* 2. More dust settles here and the remainder continues with the air to the dust collector in *Fig.* 4. Here the dust is filtered and the fan discharges clean air outside the pump room, while the collected dust is returned via a 5-in. Fuller feeder and 6-in. " F-H Airslide " conveyor to the Fuller-Kinyon pump hopper, where it remains until the ship is discharged.

The motors driving the loading fans and associated dust-collector equipment are supplied from the auxiliary generator at 220 volts and only 22 h.p. is absorbed during loading.

Discharging.

The motors driving the discharging equipment are supplied at 440 volts from one of the two main generator sets, each of which has a capacity of 525 kW., the motors absorbing 660 h.p. when discharging at 130 tons per hour over a distance of 1,500 ft.; however, at the unloading depot, 1·7 kW.-hr. per ton are absorbed.

Cement is extracted from the hold and by means of a longitudinal screw-conveyor is conveyed forward to the Fuller-Kinyon pump and discharged to storage ashore. *Fig.* 2 shows the flow of material during discharging. A series of " F-H Airslide " fluidising conveyors inclined inboard at 9 deg. to the horizontal are installed at 4-ft. centres between mild steel sheets sloping at 55 deg. to the horizontal so that they are self-cleaning. One such conveyor is shown in *Fig.* 5 in which the control gate at the end of the conveyor can be seen in the closed position. An observation port and bulkhead light are also visible. To unload the hold two conveyors on each side are supplied with air from Roots blowers. Considering the conveyor in *Fig.* 2, the cement in its immediate neighbourhood is fluidised and flows down the slope when the control gate is opened and discharges into the screw-conveyor. Cement sinks to take the place of the material extracted and will flow down the self-cleaning steel sloping sheets until the trough is cleared. It will be appreciated that it is not possible to remove a strip of cement 4-ft. wide across the hold as after some extraction has taken place, the material over adjacent conveyors will avalanche in a fore-and-aft direction over the extraction element in use. Cement is therefore extracted using the conveyors in turn along the length of the hold until it is seen that the level is just above the peaks of the sloping sheets at the ship's side, at which stage it is possible to clear individual troughs quickly.

After passing the control gates the cement enters a 20-in. diameter screw-conveyor in the longitudinal tunnel. *Fig.* 6 shows the tunnel with control gates at each entry to the screw from the " F-H Airslide " conveyors in the hold. Headers of 4-in. diameter from the Roots blowers in the pump-room carry the air which is

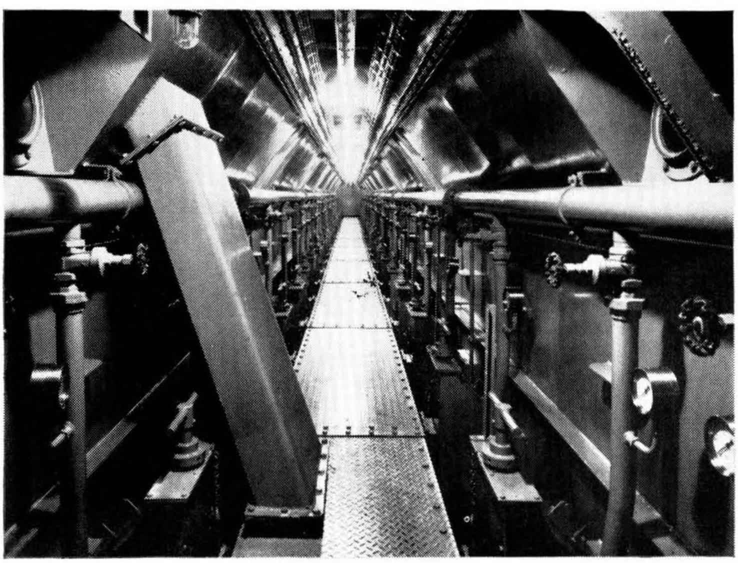
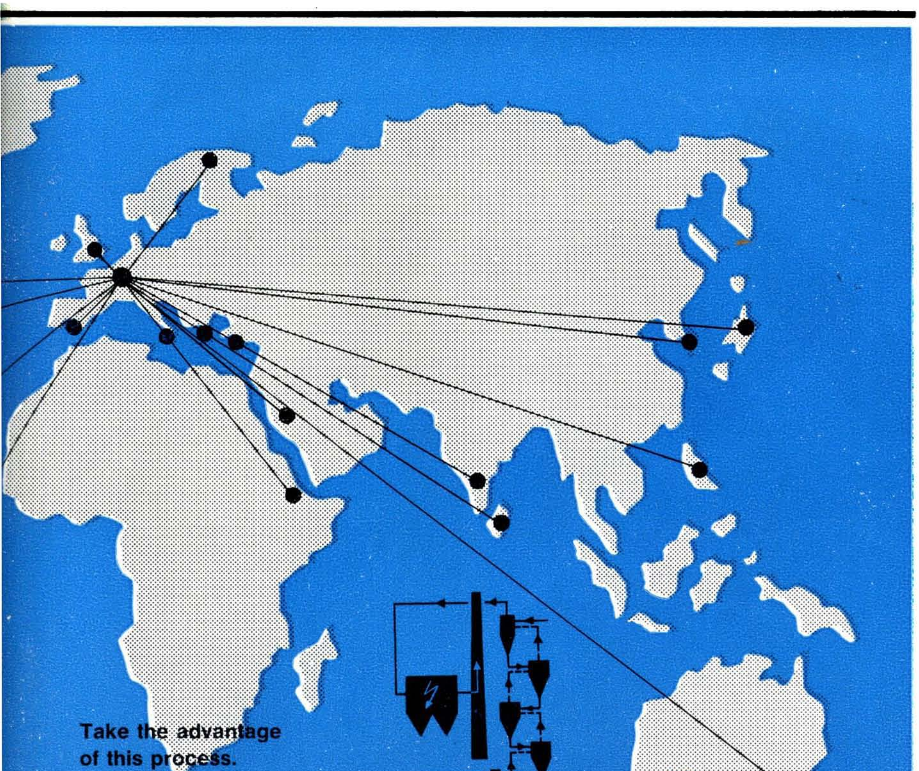


Fig. 6.

HUMBOLDT



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admitted to the various fluidising conveyors by 2-in. gate valves. Observation windows are provided at about eye-level and these are spaced so that the fields of vision overlap. Particular care is taken to ensure that all joints are tight since aerated cement is very "searching." The screw-conveyor is run about three-quarters full so that the fluidising air entrained during extraction from the hold can be vented from the top of the screw conveyor casing through ducting up the central bulkhead to the trunk air space above the hold.

A heel indicator in the tunnel warns when uneven extraction has induced a list and this is corrected by extracting temporarily only from the lower side. The opening of the gates controls the rate of feed to the screw-conveyor and thence to the pump. Further control of the rate of feed is possible by altering the speed of the screw-conveyor drive which has a 2 : 1 variation, although by running the screw at its maximum speed and controlling the feed on the gates, the screw will convey with the shallowest possible depth of cement.

The screw-conveyor is driven by a 65-h.p. (at 1,450 r.p.m.) motor with variation to 720 r.p.m. A worm-reduction gear drives the screw-conveyor through a flexible coupling and a thrust bearing is provided at the drive end (*Fig.* 7).

The rectangular casing of the screw-conveyor changes at its discharge end to a closely fitting cylindrical portion about 5 ft. 6 in. long, so as to provide a seal against the head of cement in the fluid lift into which the screw discharges. *Fig.* 2 shows the fluid lift, which is a vertical duct supplied with air by a Roots blower. This duct is fitted with a porous fabric base similar to an "F-H Airslide" conveyor. Cement discharged by the screw-conveyor is fluidised and displaced up

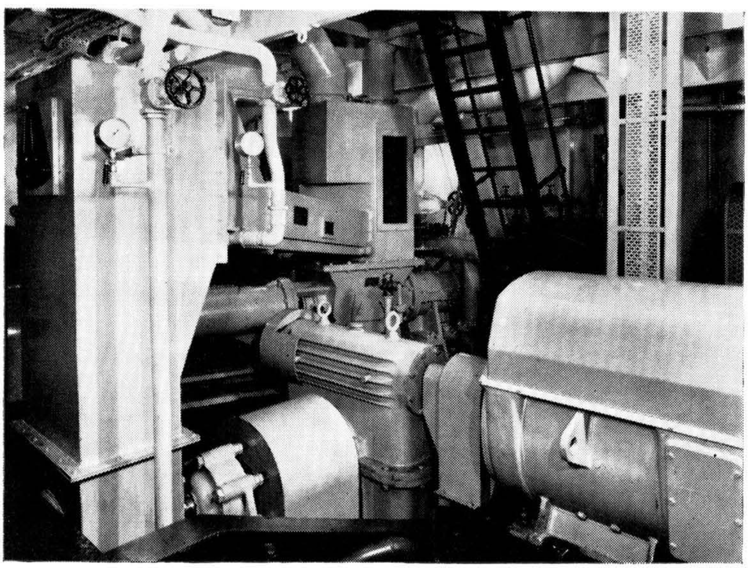

Fig. 7.

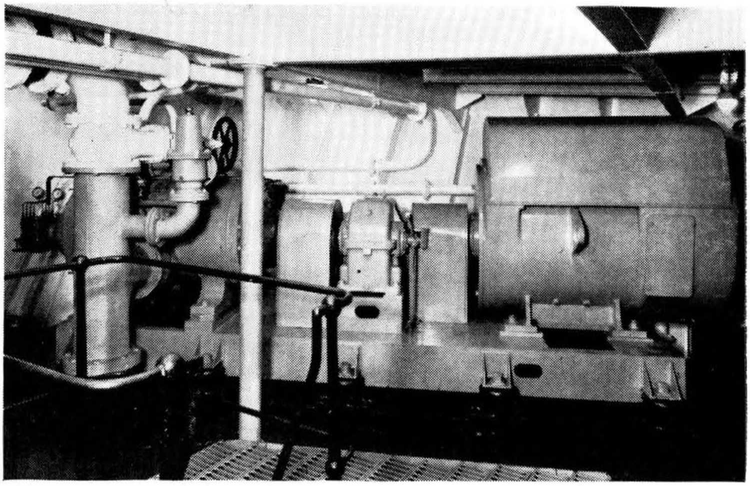

Fig. 8.

the duct by further cement advancing through the seal section of the screw-conveyor. At the top of the fluid lift, the cement spills into a closed type "F-H Airslide" conveyor connecting to the Fuller-Kinyon pump hopper, then falls into the pump and advances through the barrel as previously described. The dust-laden air is drawn off to the dust collector.

Fig. 2 also shows how air from the Hick Hargreaves RC.16 rotary compressors is added to the cement and transports it through the conveying line which can be seen in *Fig.* 4 rising to the forecastle deck between the dust collector and the forward bulkhead of the pump-room. In this view, one of the compressors can be seen on the flat below and in *Fig.* 8 this compressor is shown on a combined bed-plate fitted with flexible mountings. It is necessary for a flexible connection to be inserted in the air-delivery piping. The driving motor has the same size of frame as the pump motor and is rated at 225 h.p. at 1,450 r.p.m.; it drives the compressor at 485 r.p.m. through a spur reduction gear.

A 10-in. bore 120-deg. steel bend is slung from a derrick and flexible hoses are attached to the bend to connect the conveying line to shore, with provision to discharge to either side of the ship.

All motors are marine type and are interlocked as follows: RC.16 compressors, 10-in. Fuller-Kinyon pump, K.B. 400 "Fluid Lift" blower, 20-in. screw-conveyor, and L.675 "F-H Airslide" blower. A water-failure alarm is installed in the cooling-water circuit of each compressor to trip the above interlock system if the cooling water in either circuit falls below 70 per cent. of the required volume. Provision is made to remove one compressor from the interlock system when discharging over a distance of less than 300-ft., one compressor supplying sufficient air for this.

The "Ligar Bay" was designed and built by Messrs. Henry Robb Ltd., of

Leith. Sir J. H. Biles and Co., of London, acted as the owners' consultants. The project was engineered by The Associated Portland Cement Manufacturers Ltd., and the pneumatic handling equipment was supplied by Constantin (Engineers) Ltd., which firm also advised on the design of the hold to accommodate the cement-handling equipment. The motors were supplied by the English Electric Co., Ltd.

The " Ligar Bay " was brought from Leith to the Thames and set sail from there on October last on her voyage via the Panama Canal to Wellington, New Zealand. She reached Wellington in December. While in the Thames, loading and unloading tests were made at the Greenhithe works of The Associated Portland Cement Manufacturers Ltd. The new vessel, which is claimed to be the most advanced ship of her kind in the world, cost more than £350,000.

M.V. " John Wilson."

In 1961, Constantin (Engineers), Ltd., supplied similar pneumatic handling equipment for M.V. "John Wilson," which was also designed and built by Messrs. Henry Robb Ltd., for Wilson's (NZ) Portland Cement Co. The leading particulars of this ship are compared with those of M.V. " Ligar Bay " in *Table* 1.

The load carried, the length of voyage, the required service speed and rate of handling cement influenced the design of these ships. The " John Wilson " is designed for a discharge rate of 280 tons per hour over a distance of 600-ft., including a 60-ft. lift, and is fitted with two 10-in. Fuller-Kinyon pumps, while a single 10-in. Fuller-Kinyon pump in the " Ligar Bay " is designed to discharge at 130 tons per hour over a distance of 1,500-ft., including a 60-ft. lift. The pumps in the " John Wilson " have therefore been installed in a spacious pump-room amidships and receive cement from a fore-and-aft hold through two 18-in. diameter screws, one being 64-ft. 8-in. long and the other 58-ft. 7-in.; provision is made for one pump to handle in turn the output from both screws. Naval architectural requirements resulted in the pump-room in the " Ligar Bay " being located forward where conditions are cramped, but better weight distribution was obtained for the 1,200-ton cargo in the smallest possible ship. This resulted in a 100-ft. screw of 20-in. diameter with a stiffer shaft to allow for the extra length.

The " Ligar Bay " has less than half the discharge rate of the " John Wilson " but has more installed power per ton of cement conveyed per hour; this is due to the 1,500-ft. conveying distance requiring larger compressors and greater pump-motor power. The " John Wilson " appears to be generously provided with generator power but the criterion here was that three generator sets would be used for propulsion, requiring 1,600 s.h.p. for the single screw, while two sets with one stand-by would supply the cargo discharging equipment for which 910 h.p. is installed. The " Ligar Bay," as a twin-screw vessel, requires 630 s.h.p. at each screw and, since the power absorbed by the discharge equipment at the 1,500-ft. conveying distance is 660 h.p., propulsion and conveying requirements with one generator are closely matched.

M.V. "Golden Bay."

An earlier ship, M.V. "Golden Bay," has carried more than a million tons of cement since going into service in New Zealand waters about ten years ago; it was also built by Henry Robb Ltd.

Cement by Sea to Indonesia.

The Soviet M.V. "Tashkent" arrived recently in the port of Jakarta with a cargo of 8,000 tons of cement for Indonesia.

Book Review.

"Principles of Comminution." By Béla Beke. (Budapest; Publishing House of the Hungarian Academy of Sciences, 1964. 4 U.S.A. dollars; or from Maclaren & Sons Ltd., London; price 35s.)

THIS book, in the English language, is a revised edition of the original Hungarian work. The principal subjects dealt with include particle-size distribution produced by grinding, with a critical treatment of the laws of Schuhmann, Rosin-Rammler, Kolnogorov and others; the energy demand of comminution, with the laws of Rittinger, Kick, Bond and Charles-Holmes critically surveyed; a new law proposed by the author; the kinetics of grinding, the change of size during grinding, the development of granulometry, the phenomenon of agglomeration and its effect upon particle-size distribution and the equilibrium phase of grinding; grinding in closed circuit, with the method of calculation of the output and circulating load; the development of particle-size distribution in closed-circuit grinding and the methods influencing it. Much of the subject matter is based on the results of the author's own research.

Extensions at Westbury Cement Works.

THE Associated Portland Cement Manufacturers Ltd., which company is extending its works at Westbury, Wiltshire, as reported in this journal for November last, has placed an order of the construction of a second kiln-house with Messrs. A. C. Barvis Ltd. An order has also been placed with Messrs. A. E. Farr Ltd., for the construction of four reinforced concrete silos, each about 90 ft. high and 30 ft. in diameter, and each having a capacity of 2,000 tons.

The Use of a Magnetic Separator and Sulphide Determination in the Determination of the Slag Content of Portland Blastfurnace Cement.

BY R. E. CROMARTY*

SYNOPSIS

THE use of a magnetic separator and sulphide-content determination in the determination of the slag content of mixtures of Portland cement and blastfurnace slag is described. The analytical method is detailed and results of sixty determinations are presented with their statistical analyses for accuracy.

INTRODUCTION.

THE importance of determining the slag content of mixtures of Portland cement and blastfurnace slag initiated an investigation of the suitability of a variety of available methods.[1, 2, 2, 3, 4, 6, 7.] Difficulties that have been experienced with these methods led to the development of the method described in this report. The method is based on the principle that a reference component present in either the Portland cement or blastfurnace slag, or both, may be determined in the mixture and the proportion of each of the two main constituents calculated. A reference component present in only one constituent of the mixture simplifies the determination. Sulphides are present in blastfurnace slag, but seldom in clinker, and sulphide has therefore been used as a reference component [4]. The method described depends ultimately on an estimation of sulphides.

Where the pure slag is not available, a separation of the slag from the mixture must be effected. Such separations have been carried out by using heavy liquids[2] but this method was not successful with the mixtures used in this investigation. This difficulty was overcome by carrying out the separation in a magnetic separator. The effectiveness of this separation is determined quantitatively by a microscopic count of the slag particles in the separated slag-rich fraction. The sulphide content of this slag-rich fraction is determined and the sulphide content of the pure slag is then calculated. In the present investigation the proportion of slag in the mixture was then calculated from the sulphide content of the pure slag and that of the mixture. If, however, the cement contains sulphides the calculation must be modified.

A disadvantage common to most methods based on physical separation alone is that only the fraction of the mixture coarser than 40μ can be successfully separated. Only a small proportion of the Portland cement and blastfurnace slag mixtures for which the present method was developed and to which it has proved particularly applicable is coarser than 40μ and hence an estimate of the concentration of slag in such slag cements cannot be successfully accomplished by physical separation alone.

*Technical Officer; National Building Research Institute. South African Council for Scientific and Industrial Research.

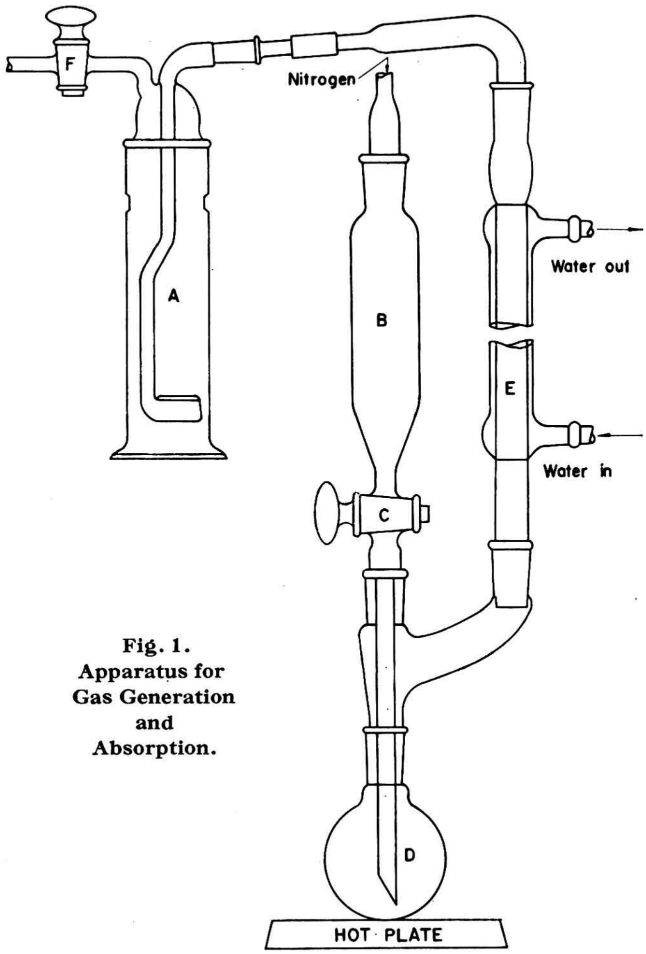

Fig. 1.
Apparatus for Gas Generation and Absorption.

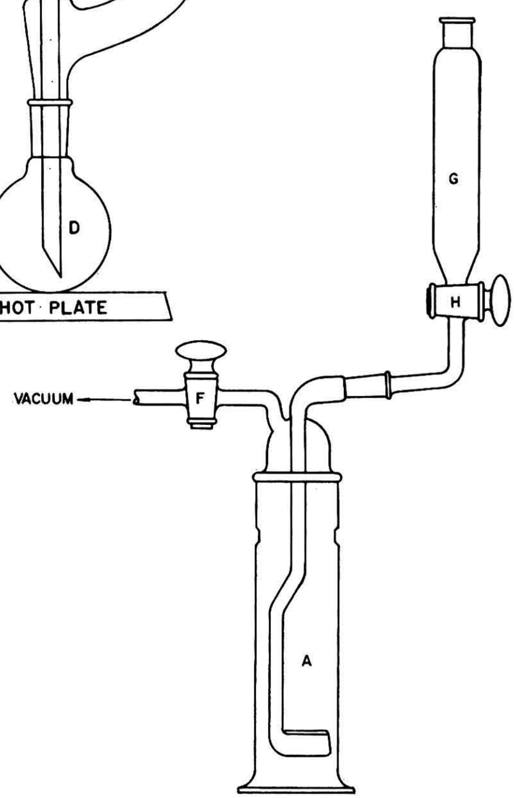

Fig. 2.
Apparatus for the Addition of Reagents to the Sulphide Solution.

SULPHIDE DETERMINATION.

Apparatus.

The apparatus required includes the absorption apparatus shown in *Figs.* 1 and 2, and the usual laboratory volumetric apparatus.

Reagents.

SODIUM THIOSULPHATE 0·05N.—Dissolve 12·5 grammes of $Na_2S_2O_3 \cdot 5H_2O$ in distilled water, add 1 ml. of chloroform and make up to 1000 ml. with freshly boiled distilled water. Avoid exposure to light and do not use borax as a preservative [8]. Standardise against potassium iodate KIO_3.

IODINE 0·05N.—Dissolve 10 g. of iodate-free potassium iodide in 20 ml. of distilled water contained in a 1000 ml. glass-stoppered standard flask. Weight out 6·3 g. of A.R. iodine on a rough balance (never on an analytical balance), transfer it to the concentrated potassium iodide solution and shake without heating until all the iodine has dissolved. Make up to 1000 ml. with distilled water. Preserve in small glass-stoppered bottles which should be completely filled and kept in a cool dark place. Standardise against the 0·05N sodium thiosulphate.

STARCH SOLUTION.—Make a thin paste of 1 g. of starch in cold water. Add 0·1 g. of thymol to 100 ml. of boiling water, add the starch paste and boil for 1 minute. Allow the solution to cool and add 3 g. of iodate-free potassium iodide.

85-per cent. Phosphoric Acid A.R.-grade.

HYDROCHLORIC ACID—STANNOUS CHLORIDE SOLUTION.—Dissolve 150 g. of A.R. $SnCl_2 2H_2O$ in 500 ml. concentrated hydrochloric acid and add 1000 ml. distilled water. Store in a glass aspirator fitted with a bubbler containing alkaline pyrogallol.

SODIUM HYDROXIDE 0·05N.—Dissolve 2 g. of A.R. NaOH in 1000 ml. of freshly boiled distilled water and store in a glass aspirator fitted with a bubbler containing alkaline pyrogallol.

NITROGEN.—Cylinder nitrogen is suitable provided "low oxygen" (10 v.p.m.) type is used.

Procedure.

The iodometric determination of sulphide is reliable, but is subject to certain errors[5] which may be minimised by attention to the following:—

1.—The prevention of the formation of a sulphide precipitate since large particles may enclose particles of unreacted sulphide and iodine.

2.—The avoidance of reagents of high ionic strength so as to prevent the formation of large particles of sulphur during the reaction.

3.—The exclusion of air to avoid atmospheric oxidation of the sulphide.

4.—The acidification of the solution prior to the addition of iodine, since iodine in alkaline solution oxidises sulphide through sulphur to sulphate.

5.—The cooling of the solution before the addition of iodine to reduce losses due to volatilisation.

All these factors have been considered in the development of the method described in this report.

The procedure is first to pour 50 ml. of 0·05N sodium hydroxide into Drechsel bottle A (*Fig.* 1). The bottle is then connected to the apparatus as shown. 30 ml. of hydrochloric acid-stannous chloride mixture are placed in the dropping-funnel B, with the tap C closed. About 0·25 g.(W) of slag is accurately weighed into the round bottom flask D and the flask placed in position. A stream of water is passed through the condenser E. Taps C and F are opened to allow the hydrochloric acid-stannous chloride mixture to flow into flask D. A stream of nitrogen is passed through the apparatus at a fairly rapid rate while the contents of flask D are boiled for at least 30 minutes. At the end of this period the Drechsel bottle is removed with the stream of nitrogen still flowing. The hot plate is then removed and the stream of nitrogen is stopped. The dropping-funnel G (*Fig.* 2) is now attached to the Drechsel bottle A, tap H is closed, tap F is opened and attached to a vacuum line until fine bubbles appear, whereupon tap F is closed and the apparatus removed from the vacuum line.

2 ml. of 85-per cent. phosphoric acid are poured into the dropping-funnel and washed into the solution in the Drechsel bottle without admitting any air. The contents of the bottle are mixed well by shaking and allowed to cool. 10 ml. of standard 0·05N iodine solution are added to the bottle in the same manner as the acid was added and the bottle is again shaken well.

The bubbler is then removed and all adhering solution is carefully washed into the Drechsel bottle.

The excess iodine is titrated with standard 0·05N sodium thiosulphate, starch indicator being added near the end point.

The sulphide content expressed as a percentage is calculated from

$$S = (10 \times NI_2) - (T \times NNa_2S_2O_3) \times \frac{16{\cdot}033}{1000} \times \frac{100}{W}$$

where NI_2 = normality of iodine solution
$NNa_2S_2O_3$ = normality of sodium thiosulphate solution
T = titre of sodium thiosulphate solution
W = weight of sample
16·033 = equivalent weight of sulphur.

The sulphide content of mixtures of Portland cement and blastfurnace slag can be determined in a similar manner, samples containing approximately 0·25 g. of slag being used.

SEPARATION OF BLASTFURNACE SLAG FROM MIXTURES CONTAINING BLASTFURNACE SLAG AND PORTLAND CEMENT.

Should samples of the pure slag and the Portland cement used in producing a mixture not be available, the following procedure is adopted to separate a slag-rich fraction from the mixture.

The mixture is screened and the fraction between 147μ and 44μ retained. This fraction is washed well with ethyl alcohol to remove all adhering particles smaller than 44μ and dried at 110°C. A hand magnet is used to remove particles of iron.

The fraction retained on the 44μ screen is then passed through a Frantz Isodynamic separator (Model L-1). The separator consists of an electromagnet having two long specially-shaped pole pieces with an air gap into which fits a vibrating non-magnetic chute divided longitudinally. The pole pieces with the chute may be accurately set in directions parallel to and at right-angles to their length. The strength of the magnetic field is controlled by selector switches and a rheostat. A feed-bin and two receptacles for the separated components are provided. The following approximate settings are employed:

Forward slope: 30 deg.

Side slope: 15 deg. against the direction of the magnetic field.

Amperage: 0·5 amp.

The rate of feed is adjusted until a stream of material about 2 mm. thick flows into the chute. The side slope and amperage are adjusted for each different mixture until there is very little admixture of Portland cement with the slag. The residual mixture of slag and cement is rejected and the enriched slag is again passed through the separator, small adjustments being made to the side slope and amperage to increase the degree of separation. These small adjustments are continued until no further improvement in the degree of separation is obtained. The slag-rich fraction is then passed through the separator a number of times.

MICROSCOPIC EXAMINATION.

Approximately 25 mg. of the slag-rich fraction are mounted on a microscope slide using Canada balsam as mounting material. A slide of the separated Portland cement is also prepared since a prior knowledge of the appearance of the slag and Portland cement under the microscope is a great aid in identifying Portland cement particles present in the separated slag-rich fraction. The amount of material on the slide should be such that the grains are adjacent but the concentration must not be so great that overlapping of the grains occurs.

The lighting for microscopic examination is important for, if the field is excessively illuminated, there is a tendency to miss grains of the transparent slag. Optimum results are obtained with a ground glass filter between the light source and the slide.

The counting of the two types of grains is performed with the aid of a ' point counter '. Greater accuracy is obtained by scanning a large area in coarse steps than a small area in fine steps. Counts are taken across the slide in two mutually perpendicular directions. A total of approximately 400 grains is counted. This represents a count of approximately 20 grains in two groups of ten rows each in mutually perpendicular directions. The proportions by weight of slag and Portland

TABLE 1.—VARIATION IN THE DETERMINATION OF ZINC SULPHIDE

Weight of ZnS used.	Weight of ZnS recovered.	Percentage of ZnS recovered.
mg.	mg.	
20·1	19·3	96·0
20·1	19·6	97·5
20·5	19·9	97·1
20·4	19·6	96·1

cement are calculated by multiplying the percentage of each component determined from the count by its respective specific gravity.

CALCULATION OF SLAG CONTENT.

The sulphide content of the separated slag-rich fraction is determined and the sulphide content of the pure slag is calculated from this value by applying a correction to account for the proportion of Portland cement in the fraction as determined by the microscopic count.

The sulphide content of the mixture of blastfurnace slag and Portland cement is determined and the slag content calculated from this result and the sulphide content of the pure slag.

RESULTS

Variability in Sulphide Determination.

In the absence of a suitable sulphide standard, zinc sulphide was used to determine the variability of the method of determining sulphide, although the zinc sulphide was not regarded as an ultimate standard. The procedure adopted was to weigh out approximately 20-mg. portions of zinc sulphide; the sulphide was then determined as described and the percentage of zinc sulphide recovered was calculated. The results are given in *Table I*.

TABLE II.—ACTUAL AND CALCULATED PERCENTAGE SLAG PRESENT IN MIXTURES WHEN SULPHIDE CONTENT OF THE PURE SLAG IS KNOWN.

	Actual percentage of slag in mixture.	Determined percentage sulphide of mixture.	Calculated percentage slag in mixture.
Slag C (sulphide content 0·94%)	10	0·111	11·8
	20	0·205	21·8
	30	0·293	31·2
	40	0·369	39·3
	50	0·506	53·8
	60	0·586	62·3
	70	0·659	70·1
	80	0·761	81·0
	90	0·862	91·7
	100	0·940	100·0
Slag N (sulphide content 1·36%)	10	0·154	11·3
	20	0·285	20·8
	30	0·422	30·9
	40	0·531	38·8
	50	0·672	49·2
	60	0·828	60·6
	70	0·952	69·7
	80	1·064	77·8
	90	1·228	89·9
	100	1·366	100·0
Slag V (sulphide content 1·34%)	10	0·153	11·4
	20	0·258	19·3
	30	0·407	30·5
	40	0·539	40·3
	50	0·668	50·0
	60	0·801	60·0
	70	0·928	69·5
	80	1·068	79·9
	90	1·219	91·2
	100	1·336	100·0

On the basis of these results the determination may be carried out with an accuracy of ± 0·28 per cent. at the 95-per cent. confidence level.

Slag Content of Mixtures when Sulphide Content of Slag is Known.

Three different types of blastfurnace slag were mixed separately with Portland cement in proportions by weight varying between 10 and 90 per cent. of the total weight of the mixture and in increments of 10 per cent. The sulphide content of each of the pure slags and mixtures was determined as described and the slag content calculated from the values obtained. The results are set out in *Table* II.

Slag Content of Mixtures When Sulphide Content of Slag is Unknown.

The results of the determination of the blastfurnace-slag content of the same series of mixtures when it was assumed that the sulphide content of the slag was not known and slag was separated from the mixtures by a magnetic separator are presented in *Table* III.

TABLE III.—ACTUAL AND CALCULATED PERCENTAGE SLAG PRESENT IN MIXTURE WHEN THE SULPHIDE CONTENT OF THE PURE SLAG IS UNKNOWN.

Slag	Actual percentage of slag in mixture	Sulphide content of separated slag Per cent.	Microscopic count of percentage slag	Calculated sulphide content of pure slag Per cent.	Sulphide content of mixture Per cent.	Calculated percentage slag in mixture
Slag C	10	0·75	77	0·97	0·11	11·3
	20	0·69	68	1·01	0·21	20·8
	30	0·87	94	0·93	0·29	31·2
	40	0·87	93	0·94	0·37	39·4
	50	0·88	94	0·94	0·51	54·3
	60	0·87	94	0·93	0·59	63·4
	70	0·92	96	0·96	0·66	68·8
	80	0·92	98	0·94	0·76	80·9
	90	0·94	99	0·95	0·86	90·5
	100	0·94	100	0·94	0·94	100
Slag N	10	0·89	66	1·35	0·15	11·1
	20	1·10	89	1·24	0·29	23·4
	30	1·12	91	1·23	0·42	34·1
	40	1·12	89	1·26	0·53	42·1
	50	1·16	90	1·29	0·67	51·9
	60	1·17	89	1·31	0·83	63·4
	70	1·21	92	1·32	0·95	72·0
	80	1·23	93	1·32	1·06	80·3
	90	1·23	94	1·31	1·23	93·9
	100	1·32	100	1·32	1·32	100
Slag V	10	0·86	67	1·28	0·15	11·7
	20	1·14	79	1·44	0·26	18·1
	30	1·19	90	1·32	0·41	31·1
	40	1·25	92	1·36	0·54	39·7
	50	1·26	96	1·31	0·67	51·1
	60	1·29	94	1·37	0·80	58·4
	70	1·33	95	1·40	0·93	66·4
	80	1·34	96	1·40	1·07	76·4
	90	1·35	96	1·41	1·22	86·5
	100	1·35	100	1·35	1·35	100

Statistical Analysis.

Linear regression lines of the type $y = bx$, for the relation between known and calculated slag contents for each of the two groups, that is when the sulphide content of the slag is known and when the sulphide content is unknown, were calculated from the data contained in *Tables* II and III and the following results were obtained.

Least-squares regression line when sulphide content of the slag is known:

$$y = 1{\cdot}0045x.$$

Least-squares regression line when sulphide content of the slag is unknown:

$$y = 1{\cdot}006x.$$

y = calculated slag content; x = known slag content.

The 95-per cent. confidence region in the case of one observation for values of x estimated from these lines becomes $0{\cdot}996\,y \pm 2{\cdot}40$ and $0{\cdot}994\,y \pm 4{\cdot}39$, where the sulphide content of the slag is known and unknown respectively.

CONCLUSION.

The results of the experimental investigations reported in this paper show that, with the method adopted, it is possible to determine the slag content of mixtures of milled blastfurnace slag and Portland cement with a reasonable degree of accuracy. Where a specimen of the slag used for the production of the mixture is available, the determination may be carried out to an accuracy of $\pm$ 2·4 per cent. of the slag content. If, however, a pure specimen of the slag present in the mixture is not available, it may be separated from the mixture in a magnetic separator and the results obtained under these conditions are accurate to within $\pm$ 4·4 per cent. of the slag content of the mixture.

Tentative investigations on interground mixtures of slag and Portland cement indicate that the method is equally applicable to such mixtures.

The determination of the slag content of mortars and concretes produced from slag cements is intended to be the subject of a future paper.

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Concrete Structures for Cement Works.

THE three books, which have been published recently and are noticed in the following, although of general application to building and civil engineering structures, contain much that is likely to be of interest and use to those concerned with the special structures required for cement works and distribution depôts.

Prestressed Concrete.

The first of two volumes of a book[1] which deals comprehensively with many aspects of prestressed concrete contains much of interest not only to engineers in the cement industry who are concerned with the design and construction of structures but also to research workers dealing with the constituents of concrete. The work has been prepared in such a way that it should be of use not only to specialists in prestressed concrete, but that it should serve as an introduction to the subject to such as the aforementioned engineers and research workers. The results of the author's research have been incorporated and practical applications of prestressed concrete based on the author's experience are included. The work carried out at many other research institutes, prestressing works and building sites in Great Britain and abroad, and matters discussed at international and national associations are the bases of many useful observations. Since prestressed concrete lends itself only too easily to complicated calculations and lengthy formulæ, the author maintains the view that it is not " mathematics " but " strength " and " elasticity " that are the properties of materials which are of primary importance.

The complete book of two volumes will be divided into five parts, the first three of which are in the first volume; in Part I, common principles and a general survey are given. Part II contains descriptions of various methods of prestressing, while Part III deals with the behaviour of materials and structures, and in particular the properties of steel, concrete, structural lightweight concrete and resinous plastics. Since some knowledge of metallurgy is of importance, this subject is also included. One chapter deals with the essential properties of concrete; some readers may find this important chapter too long, while others may consider it too short. The matter on resinous plastics in general and adhesives in particular is necessary since these materials are becoming important for connecting precast concrete elements.

Subsequent chapters deal with the behaviour of reinforced and prestressed concrete. Some readers may be surprised by the inclusion of reinforced concrete in a book on prestressed concrete, but it represents the limit at which the prestressing force is zero and, in fact, the behaviour of both prestressed and reinforced concrete at failure is in most cases identical or very similar. Fire resistance and durability of materials in general and prestressed concrete in particular are included.

The technical terms employed are those in general use and are fully defined. A system of notation has been adopted which should be easily remembered.

For an " introduction," this book will be found to be a remarkably comprehensive treatise and if the subsequent volume, which it is understood will deal more particularly with practical design, with not too much theory, is of a like nature, the two books will be an important contribution to the extensive literature of prestressed concrete.

Water Towers and Silos.

A well-known book on the design and construction of reinforced concrete water-towers, bunkers, silos, gantries, and similar elevated structures has been extensively revised and enlarged. The book[2] is a companion volume to "Reinforced Concrete Reservoirs and Tanks," by the same authors, but it is, however, self-contained and may be used without reference to this other book. Some trench and pit structures associated with industrial installations are also included for the sake of completeness, and methods of handling materials stored in bunkers and silos are treated briefly. Descriptions of special constructional methods and illustrations of works in progress are given. The additional material includes the design of plain-slab water-towers, and descriptions of some typical and unusual structures constructed recently in this country or elsewhere are given. Two new appendices are included, one of which contains notes and design charts relating to B.S. Code of Practice CP.2007 (1960), "The Design and Construction of Reinforced and Prestressed Concrete Structures for the Storage of the Water and Other Aqueous Liquids," and the other describes the calculation of bending moments on the walls of rectangular bunkers and silos.

Domes and Shell Roofs.

A new book[3] now replaces three earlier booklets, which were entitled respectively "Design of Domes," "Design of Arch Ribs for Reinforced Concrete Roofs," and "Design of Pyramid Roofs." The information given in these booklets is retained, but additional matter relating to domes and, in particular, to simple shell roofs is now included. A detailed description is given of Professor Lundgren's beam method for the analysis of long cylindrical shells; a completely-worked example of a shell roof of 80-ft. span is included. Particular emphasis is placed on practical design and the reader is assumed to have no special mathematical knowledge.

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[1] "Introduction to Prestressed Concrete: Volume 1." By P. W. Abeles. (London: Concrete Publications Ltd. 1964. Price 60s. By post 62s.; 15.0 dollars in Canada and U.S.A.)

[2] "Water Towers, Bunkers, Silos and other Elevated Structures." By W. S. Gray. Revised by G. P. Manning. (London: Concrete Publications Ltd. 1964. Price 36s. By post 38s.; 9.0 dollars in Canada and U.S.A.

[3] "Design of Non-Planar Concrete Roofs." By J. S. Terrington & F. H. Turner. (London: Concrete Publications Ltd. 1964. Price 15s. By post 16s.; 3.75 dollars in Canada U.S.A.)

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