A brief description of a new metallurgical plant at St. Helena Gold Mines

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SYNOPSIS

The new metallurgical plant has a simple, compact layout, being designed for a small team of operators. The reasons for building the new plant are given, and its various sections are briefly described. These include the conveyor plant, milling plant (for run-of-mine milling), thickener plant, agitator plant, filtration, clarification, smelthouse, and central core joining the mill and filtration sections.

SAMEVATTING

Die nuwe metallurgiese aanleg het 'n eenvoudige, kompakte plan aangesien dit vir 'n klein span werkers ontwerp is. Die redes vir die bou van die nuwe aanleg word uiteengesit en die verskillende afdelings word kortliks beskryf. Die afdelings sluit in die vervoerbandinstallasie, die maalinstallasie (vir die maal van onbehandelde erts), die verdikkerinstallasie, die roerinstallasie, die filtreer- en verhelderingsinstallasie, die smeltery en 'n sentrale kern wat die maal- en filtreerafdelings verbind.

Introduction

Before proceeding with the description, it is necessary to explain that other authors plan to present a more comprehensive paper on this new plant to the 11th Commonwealth Mining and Metallurgical Congress, which is to be held in Hong Kong during 1978. Consequently, the present description is brief and should in no way be seen as duplication of the forthcoming paper.

For a number of reasons, it was considered a matter of urgency to replace the existing reduction plant at St. Helena. The new plant is now complete and is used to process the output from St. Helena. In due course it will be employed to handle ore from both St. Helena and Unisel Gold Mines.

In common with all the plants built since 1958 for the mines in the Union Corporation Group, the principle of run-of-mine milling has been adopted, and consequently there is no crusher plant nor any other mill-feed preparation system. It is interesting to note that, since the inception of run-of-mine milling, at Winkelhaak in 1958, a total of 39 mills operating on this principle have been erected by Union Corporation engineers.

The new plant has a compact layout, and was designed to be operated and maintained by a small team. Whereas the plant is well instrumented, simplicity is the keynote of the design.

Reasons for Construction of New Plant

In the late 1960s and early 1970s, the reduction plant was called on to handle increased tonnages, and various extensions were made to boost the plant capacity. Although these extensions served their purpose well enough, it became evident that the upper limit of expansion had been reached and that any further expansion would be difficult to achieve, would be extremely costly, and might well fail to achieve the desired output. In addition, the machinery was old and required an ever-increasing labour force to maintain it in running order. However, one of the most disturbing features was the condition of the structural concrete work within the plant. It was becoming increasingly apparent that failure of the fabric was likely, if not imminent, in some vital areas.

Advice was sought from outside, and the consultants indicated that the worst fears were not unfounded. Moreover, they cautioned that any repairs that could be made would be only of a temporary nature, and many areas would consequently have to be subjected to an intensive and expensive programme of continual maintenance for the remainder of the plant's life.

At about the same time, the Union Corporation, together with partners, was investigating a possible new mine some 10 km from St. Helena, and the feasibility of extending the plant at St. Helena to cope with the output of both mines was being considered. A number of schemes were studied, and it was finally decided that the ultimate cost of an extensive renovation of the plant, together with extensions to handle the output from the new mine, would be close to the cost of a new reduction plant. In view of the many unknowns that would undoubtedly have been revealed if a renovation programme had been adopted, it was decided that the wisest course would be to build a new plant and scrap the old.

Factors that influenced this decision included the possiblity that gold from the clean-up and sale of machinery would ameliorate the capital expenditure on the project. In this connection it is pertinent to point out that a plant of modern design does not capture as much gold as did the older plants.

Accordingly, the decision was made, and site work commenced at the end of 1974. Operation was started as units of the plant became available, and by February 1977 the new plant was handling the entire underground output from St. Helena.

Problems Encountered

A considerable amount of damage to the original plant had resulted from the heaving clay subsoil, which caused the concrete to crack, thus exposing the reinforcing bars to attack by the highly saline waters in the plant. The method chosen to combat the effect of heaving subsoil on the new plant was as follows. The entire site was excavated to a depth of several metres, and the

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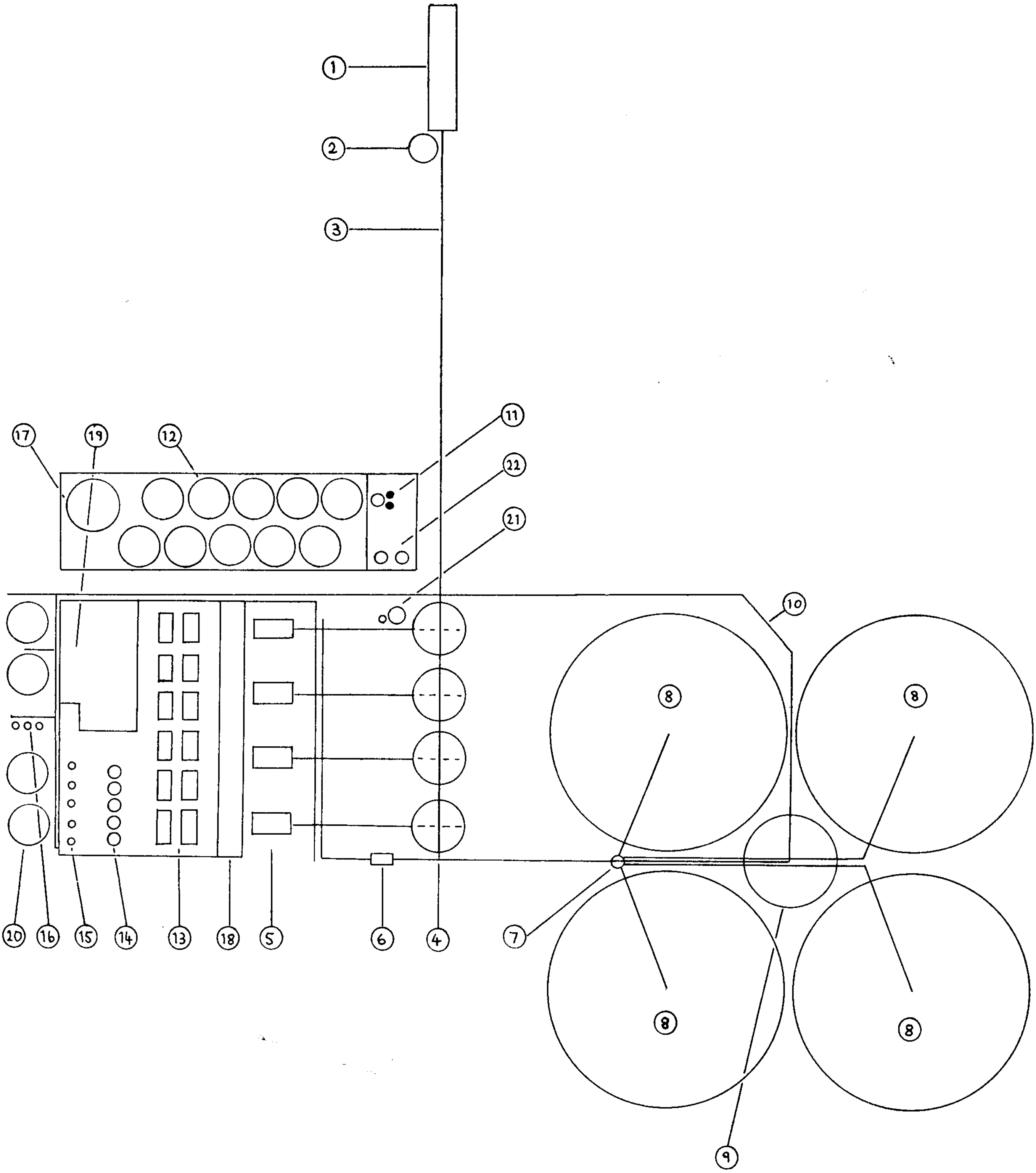

Fig. I—A diagrammatic layout of the new metallurgical plant at St. Helena

1 Ore-transfer bin
2 Spillage classifier, etc.
3 Conveyor
4 Ore-storage silos
5 Milling plant
6 Chip trommel
7 Distributor
8 Thickener tanks
9 Water tank
10 Elevated walkway
11 Slimes transfer
12 Agitators
13 Filter plant
14 Clarifiers
15 Stellar filters
16 Crowe towers
17 Spillage tank
18 Central core
19 Pump bay
20 Solution tanks
21 Lime silo
22 Cyanide storage

excavated clay was replaced by a carefully compacted mass of washed and graded waste rock, the plant being founded directly on the compacted rock mass. Flooding in the excavation is prevented by the use of pumps and drains, but the underlying clay is maintained in a saturated state. Consequently, little ground movement can occur as a result of changing moisture content.

To prevent migration of gold into the foundations, a sheet of heavy-gauge polythene was interposed between the rockfill and the top backfill of clay.

To avoid corrosion of the reinforcing bars, a rigid specification was imposed on the civil engineering. All the reinforcing has a minimum 50 mm cover of dense concrete, and all the structural steelwork was sandblasted and painted under the supervision of specialist consultants.

With the exception of the transfer bin draw-off chutes and the thickener pumps, all the major works are above ground level and safe from the danger of flooding. It was recognized that, owing to the nature of the foundations, these two areas could experience considerable hydraulic upthrust, which might well be dangerous in the event of these items being empty. As a safeguard, pumps are provided to drain the immediate vicinity of the thickener-pump tunnels and the transfer bin.

The capacity of the plant, as shown in Fig. 1, is a nominal 250 000 t per month (30 days). The plant has been designed for continuous milling.

Conveyor Plant

The ore from both mines is delivered by rail into an ore-transfer bin. The withdrawal of ore is accomplished by 18 drum feeders, which operate simultaneously and discharge onto a conveyor belt. The belt is 1370 mm wide with a total length of 700 m. The conveyor is discharged by a motorized tripper into any of the ore-storage silos. The power for driving the tripper is provided by a hydraulic generator that is driven from the conveyor.

Measurements of ore receipts are accomplished by a Nuclear massmeter, which serves the dual purpose of measuring and controlling the load. Control is achieved as follows:

(a) if the load exceeds a preset value, an alarm is registered and 6 of the drum feeders stop,
(b) if excessive load conditions persist, a further 6 feeders are stopped, and
(c) if excessive load conditions still persist, the remaining feeders are stopped.

When overload conditions clear, the drum feeders can be restarted, usually in increments of six at a time.

Spillage and hosings from this section are handled by a spillage pump, which delivers to a Rotoscoop classifier. The underflow sand is returned to the conveyor belt, and the overflow is pumped to the mill. This section also handles slime that is pumped to the reduction plant from distant shafts. It should be noted that the Rotoscoop classifier has been installed on account of its mechanical simplicity, and not for any metallurgical advantage. All the overflow from this classifier can be pumped for reclassification in the milling circuits.

A noteworthy feature of this section is that conveyance is accomplished in a single stage from transfer bin to silos. Whereas this tends to reduce the compactness of the plant, it has the advantage of eliminating all but the initial and final transfer points and consequently minimizes spillage. The simple rail layout is also a consequence of the single conveyor.

There are no facilities for the removal of trash.

Milling Plant

Each ore-storage silo has a live capacity of some 6000 t and is associated with a single mill; it is not possible to feed ore from, say, No. 1 silo to No. 2 mill. Draw-off from each silo is accomplished from 10 chutes by drum feeders equipped with d.c. thyristor-controlled motors.

The rate of feed is measured by a Nuclear massmeter. Feed control[1] is achieved by a Digicon mill-feed controller, which maintains the power draft of the mill at the maximum under prevailing conditions of mill feed. The mill can also be fed at a preset feed rate by maintaining a constant feed on the conveyor belt. This is achieved via the agency of the massmeter and motor-speed control on the drum feeder. Of the two methods of control, the first is obviously preferable.

Each mill has an internal drum diameter of 4900 mm and an internal length of 9150 mm. The construction is of mild-steel plate bolted to cast-steel mill heads terminating in heavy trunnion journals, which are carried on oil-lubricated metal bearings at each end of the mill.

All the mills are fed from the silos by the conveyor, which discharges into a hopper that is sealed against the rotating mill-inlet trunnion. The internal bore of the lined trunnion is large enough to handle massive pieces of ore or trash. Discharge from the mill is via either a screen plate and lifter arrangement through the discharge-end trunnion, or via screened ports set into the mill shell near the discharge end. In common with most mills in South Africa, the plant does not employ overflow trunnion discharge.

The mills are driven from 3000 kW motors at a speed of 17,4 r/min, which represents some 90 per cent of the theoretical critical speed of a lined mill. As is apparent from Fig. 1, each mill and silo system represents a milling module, and future expansion of the plant is envisaged as being achieved by the addition of similar modules. Each of these modules has a nominal monthly capacity of some 60 000 t. The capacity obviously depends on the feed rate, and the control of this feed rate merits some discussion.

With a given feed material, it is known that a mill can be charged at an increasing rate, which increases the power required to turn the mill at constant speed. This state of affairs continues until the volume of the charge represents 50 per cent of the total volumetric capacity of the mill. Further increases in feed rate result in a decrease in power draft and a consequent decrease in grinding ability. Thus, a mill fed with pure run-of-mine ore will have an optimum feed rate that is almost constant. It is also apparent that, unlike an autogenous mill, in which the feed composition is prepared in a crusher plant, this feed rate is fixed (unless the operator is content to run the mill below 50 per cent charge, with the attendant reduction in mill efficiency).

In run-of-mine milling, this feed rate that produces the maximum power draft is deemed to be the minimum mill feed rate. Feed rates above this minimum rate can result only from an increase in the overall density of the mill charge. Such increases in density are conveniently obtained by the addition of steel balls to the feed. The addition of steel balls can be used to increase the feed rate until the maximum limit, determined by the mill driving system, is attained. As with other grinding methods, increased feed rates result in a coarser final product. The Digicon mill-feed controller maintains the feed rate at the optimum, i.e. maximum power draft.

Each mill discharges into a separate hopper, from where the pulp is pumped to a cyclone arrangement, comprising three D26 B cyclones in parallel. The elevation of the milled pulp to the cyclones is effected by a D-frame Hydroseal pump (one per milling module), the pump being driven by a d.c. thyristor-controlled motor.

The pump delivery contains a mass flow meter, the density gauge of which provides the signal for the control of pump speed. It is intended that the density of the feed to the cyclones should be fixed at a predetermined value and the pump speed controlled to maintain this density. A constant level in the pump feed sump is maintained by the addition of water and is regulated by a level controller. Cyclone underflow is returned to the mills by a pipe discharging coaxially with the mill. Cyclone overflow represents the finished product and is discharged through an open top into sampler boxes, from where it flows to the final pulp launder.

The entire area between the mills and the silos is graded in a series of peaks and troughs to provide a low point between each mill and silo — there are no spillage launders. Spillage pumps are situated at these lowest points. In the event of a pump being unable to handle the spillage, a puddle of increasing diameter forms around the pump chamber until it reaches sufficient depth to overflow into the adjacent spillage areas. The diameter of this shallow puddle is in fact fairly small and does not inconvenience the operator. All the mill and silo spillage is handled on this spillage apron, which also handles the lime and chip-screen spillage.

Thickener Plant

The final pulp launder is constructed from heavy-grade concrete/asbestos pipe. The material was chosen because it contains no steel reinforcing. The jointing of the pipes is by rings of the same material sealed by rubber O-rings.

Because no sorting of trash or wood is practised, it is necessary to interpose a screen between the mill and the thickener plant. A trommel has been chosen for this purpose and is mounted over the spillage apron.

All the thickener feed is handled in a central distributor, which has provision to handle hosings etc. from the thickener area. There are four thickeners in the present installation, each 60 m in diameter. Thickener drive is from a pier-mounted unit at the centre of each tank. The rakes are moved by steel cables (or chains) attached to rotating booms[2].

Thickener underflow is pumped directly to a slimes-transfer system by pumps situated below the apex of each tank. The pumps are B-frame Centriseal fitted with water-lubricated stuffing boxes. The supernatant water overflows into a centrally situated tank of 30 m diameter. This tank is equipped with thickener-type rakes and an underflow pump to remove any settled solids.

An analysis of the thickener requirements shows that the settling area provided by three tanks is adequate for the designed milling capacity. However, three tanks would not permit any to be released for maintenance work. Moreover, uncontrolled water enters the process in the form of slimes from underground etc., and, when the milling rate is not equal to the rate of withdrawal, there is a necessity for a water-surge dam. A fourth thickener has therefore been provided to serve the dual purpose of a standby and a water-surge dam. In the event of only three thickeners being available because one is undergoing maintenance, the water surge may have to be dumped. It should be noted that any of the four thickener tanks can be employed as the standby/surge dam.

Agitator Plant

This plant comprises 10 agitator tanks, each having a useful capacity of 2000 m^3. Each stands 22 m high and has a diameter of 11 m.

Pulp from the thickener plant is pumped into a sampling box, from where it flows to a slimes-transfer sump. Here the reagents, sodium cyanide and lime slurry, are added. The resultant slurry is diluted to the chosen density and pumped by means of a D-frame Hydroseal pump to the head agitator. The agitators are set in two rows and are arranged on a 120° configuration so that no two tanks are at the same elevation. The nominal contact time is 45 hours.

The level in the final agitator controls the speed of the slimes-thickener underflow pumps. The level in the slimes-transfer sump in turn controls the speed of the transfer pump. Thus the rate of pumping from the thickener is controlled by the demand from the rotary filter plant.

An interesting feature is the provision of overflows on both the initial (head) and final agitator (tail). Both overflow pipes return the excess pulp to the slimes-transfer pump, which has the effect of excluding new pulp from the thickeners until the excess condition is clear.

The cyanide addition is to be monitored by Kegold electrode, and pH monitoring is also under consideration to control the addition of lime slurry.

Filtration

Filtration is achieved on 10 rotary vacuum filters, each 7300 mm in diameter and 6100 mm long. The drum drive is from d.c. thyristor speed-controlled motors transmitted through double reduction gear boxes. Special attention has been paid to the design of the filtrate header-valve chest, which is of cast iron, and to the rake blades, which are of channel section. Discharge is effected into stainless-steel chutes, which feed the residue pulp onto a belt conveyor.

Wash water is contained in a system at a constant predetermined pressure, and is discharged via orifices into the filter launders, which straddle the filters.

Constant pressure is maintained in the system, and it is therefore not necessary to reset the flow-rate when an individual filter is stopped or re-started. In fact, if all the filters are stopped, the flow of wash water ceases and flow is resumed when a filter is re-started.

Vacuum is created by a system of rotary liquid-ring vacuum pumps working in conjunction with Rootes type blowers with applied water injection. The injection water is treated in a treatment plant to prevent build-up of deposits on the rotor lobes of the blowers. All the blowers discharge into a common manifold from which the vacuum pumps draw air. Thus, any combination of blower and pump can be obtained. Because air is drawn from the filters by means of separate pipes on the top of the filtrate header-valve chests, the filtrate flows unimpeded by air to the filtrate receiver.

Of special interest is the facility for the handling of filter and agitator spillage — indeed, of all the spillage containing cyanide ions in solution. All such spillage is pumped to an elevated tank, which is equipped with rakes in the manner of a thickener. The tank has a conical floor, and a pump (B-frame Hydroseal) is situated below the cone apex. This pump delivers to the agitator transfer sump; if the spillage system is empty and agitator dilution is required, water can be added to the spillage tank. The thickener-type rakes operate continuously to clear settled solids, which would otherwise have to be hosed with a possible detrimental effect on the process. The primary purpose of this system is to obtain close control on the dilution of the agitator system. The rate of pumping from the tank is controlled by the pulp-density meter for the agitator feed.

Clarification

Prior to the precipitation of gold, it is necessary to utilize secondary filtration (or clarification) of the filtrate issuing from the rotary filters. This is achieved in large upflow pressure sand filters, which are fully automatic in operation.

Initially, this stage of the process was beset with many problems. However, they have now largely been overcome, and acceptable throughputs and effluent clarity are obtained. Effluents containing less than 1 p.p.m. (by mass) of suspended solids are now regarded as the norm.

Precipitation

Before precipitation, the solution is elevated to a bank of 3 de-aeration tanks. An unusual feature of these tanks (Fig. 2) is that they contain no gridwork or other packing. The surface of the solution is exposed as it cascades onto splash plates at the axis of the tank to 'shelves' at the inner surface of the tank wall. The 'shelves' also impart mechanical strength to the vessels, which are subject to the full pressure of the atmosphere. The manner of their construction makes it unlikely that lime scaling will be a problem.

Precipitation is effected in Stellar filters.

The Smelthouse

The smelthouse is situated on the ground floor below the precipitator units. Unusual features include the following:

(1) a belt filter, instead of the time-honoured filter press, to filter the gold slime,

(2) a tunnel furnace for the calcining operation.

To provide enhanced security, the entire smelthouse is of brick construction, its roof being formed by the first floor of the cyanide plant. The precipitators are situated on this floor, and are arranged to discharge direct through the floor into the acid-treatment vat.

Because of the construction of the smelthouse, it becomes more imperative than before to guard against detonation of the acid vat. Particular attention has been paid to the ventilation of this vat, with special reference to the immediate removal of the hydrogen generated in the process.

The ventilation of the smelting furnace has also received special attention, particularly the filtering of the smelter fume. A bag-filter is provided for this purpose. It has been found necessary to increase the capacity of this filter in order to handle the burden of smelter fume.

General

All the solution storage tanks have conical floors with draw-off below the apex. A ramp provides access for vehicles to the filter floor. Personnel lifts are provided in the central office core (described later) and to the ore-storage silos.

All the operating bays in the main building are covered by cranes on a 'wall-to-wall' basis. The mill-liner yard is an extension of the mill floor and is also served by the mill crane.

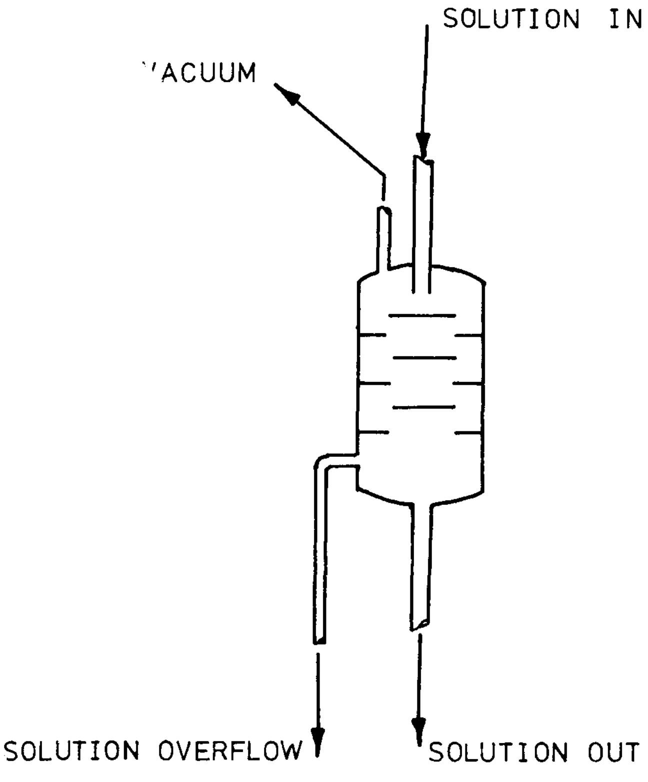

Fig. 2—A de-aeration tank

The Central Core

The mill and filter sections of the main building are separated by a central core of four floors:

Ground Floor: Stores for mill and filter-plant spares
High tension switchgear

First Floor: Cable duct

Second Floor: Change houses, grading laboratory, low-tension switchgear (which is accessible to the operators)

Third Floor: Administrative offices and central control room.

The central control room provides, on consoles, read out from all the areas of the plant. From this room, all the mills are started, stopped, and controlled, as are the filters, clarifiers, and precipitation units. Practically all the functions are monitored in this complex. The consoles provide mimic displays of the plant, together with alarms at two levels, viz information and defect. All the meters read out on these consoles. The customary system of red and green lights on the mimic panels is not employed. Instead, a red light is displayed only when a unit is not functioning correctly. This has been done to prevent confusion of the operator by a profusion of multi-coloured signals.

Staff

The design of the plant is such that a minimum operating staff will be required. At the present time, when many essential facilities including the automatic samplers are not fully operational, a routine shift is handled by 11 men, viz one shiftboss in charge of ten operators. It is expected that this complement will be reduced to about ten, i.e. one shiftboss in charge of nine operators. The maintenance crew (reliner and filter maintenance gang) consists of 33 men — one shiftboss in charge of 33 labourers.

The operating crews each include a man of high education and ability to operate the control room and to provide essential liaison. The plant is equipped with a fully automatic telephone exchange incorporating a public address system.

Acknowledgement

Acknowledgement is made to the Chief Consulting Engineer of the Union Corporation Group of Companies for permission to give this description of the plant.

References

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2. Dillon, V. S. Special features of the Kinross Mines Limited reduction plant. 9th Commonwealth Mining & Metallurgical Congress, London, 1969.

Process instrumentation

The National Institute for Metallurgy and the South African Institute of Measurement and Control are jointly arranging a symposium that will review the whole field of plant instrumentation in the processing of minerals and metals. It will be of interest to extractive metallurgists and mineral processors, as well as to instrumentation and control technologists. The last symposium in South Africa on instrumentation was held in 1972, and concentrated on gold and uranium.

The programme of papers will be divided into six sections and will deal with measurement and control equipment and its application in the following topics.

Ore-dressing: Crushing, grinding, milling, physical methods of concentration, flotation

Hydrometallurgy: Leaching, ion exchange, solvent extraction, precipitation, cementation, filtration, thickening

Pyrometallurgy: Kilns and roasters, furnaces including prereduction, smelting, melting, and refining

Electrometallurgy: Electrowinning, electrorefining

Raw materials and reagents: Agglomeration, feed and transport, production of reagents.

Special techniques

The symposium will be held on the 20th and 21st of September, 1978, in the auditorium of NIM in Randburg.

The proceedings of the symposium will not be published. The SAIMC reserves the right to publish any papers in its journal, and the authors of papers not accepted for publication may publish their papers elsewhere after the symposium.

All communications should be addressed to Mrs J. du Toit, National Institute for Metallurgy, Private Bag X3015, Randburg, 2125.

Fill mining

Mining with Backfill is the theme of the 12th Canadian Rock Mechanics Symposium to be held at Laurentian University, Sudbury, Ontario, on 24th and 25th May, 1978. It will be preceded by one-day tours of the underground operations of Falconbridge Nickel Mines Limited and INCO Metals Company.

The first day of the symposium will be devoted to a review of the state of the art, and papers will be presented from Canada, the U.S.A., Australia, Sweden, and the U.S.S.R. The second day is devoted to research aspects and innovations in fill-mining technology.

For further information write to Professor A. Farah, Laurentian University, Ramsey Lake Road, Sudbury, Ontario, P3E 2C6, Canada.