The pumping of water from mines in the Central Witwatersrand

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SYNOPSIS

This paper describes a system for the removal of underground water in the mines of the Central Witwatersrand, some of which are defunct. The water is pumped by a pump station on 24 level at E.R.P.M. to a surface lime plant and then to a surface treatment plant, where it is treated so that it meets the specification of the Department of Water Affairs relating to the deposition of water in public streams.

SAMEVATTING

Hierdie referaat beskryf 'n stelsel vir die verwydering van ondergrondse water in die myne van die Sentrale Witwatersrand waarvan sommige nie meer werk nie. Die water word deur 'n pompstasie op vlak 24 by E.R.P.M. na 'n bogrondse kalkaanleg en dan na 'n bogrondse behandelingsaanleg gepomp waar dit behandel word sodat dit aan die Departement van Waterwese se spesifikasies in verband met die wegdoening van water in openbare strome voldoen.

Introduction

In the early 1950s it was evident that, as mines closed in the Central Witwatersrand area, which stretches from Rand Leases to East Rand Proprietary Mines (E.R.P.M.), the burden of pumping would fall on the remaining mines. In 1956 it was realized that the problem would rest ultimately with the mining companies in the Rand Mines organization, and a detailed investigation into the situation was initiated. This investigation revealed that the boundary pillars between mines, major dislocations, and dykes had either been mined or developed to such an extent that there was no possibility of containing the water in any compartments below the water table. In 1963, developments in the industry indicated conclusively that no mines in the Central Witwatersrand would outlive E.R.P.M. in the event of an increase in the gold price. It was known that E.R.P.M. could not prevent water flowing into its workings once the defunct mines began flooding, and, on the assumption that pumping costs would be lower on a working mine than on a mine that had ceased operations, it was accepted that E.R.P.M. was the logical mine on which to site a pumping scheme for all the water from the Central Witwatersrand compartment. The quantity of water to be handled ultimately was estimated to be about 31,8 to 36,4 Ml/d, varying between 27,3 and 81,82 Ml/d in the dry and wet seasons.

Planning of the Pumping System

The water was known to be acidic and to contain a high proportion of solids. Before being treated, the water had the following analysis, no detergents, oil, or known bacteria being present:

pH	3,2
Solids in suspension	16 p.p.m.
Total dissolved solids	10 000 p.p.m.
Fe_2	1 400 p.p.m.
Fe_3	100 p.p.m.
Al_2O_3	100 p.p.m.
SO_4	6 400 p.p.m.
CaO	600 p.p.m.
Cl	200 p.p.m.
MgO	400 p.p.m.

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A study of the geographical and geological structures indicated that, if thirteen plugs were installed, it would be possible to contain the water to the west of E.R.P.M. to an elevation of 871,6 m below surface, providing a reservoir of about 64 000 Ml. The location and capacity of the main pump station on 24 level horizon (1059,5 m below surface) were based on these parameters.

It was estimated that, if all the pumping in the compartment ceased, five years would elapse before the reservoir filled. As a result, the commissioning date was never definite but depended on the rate of closure of the companies operating within the compartment. The cessation of operations on any mine meant additional pumping for one or more of the remaining companies, and for this reason the six affected companies (E.R.P.M., Rose Deep, Simmer & Jack, Robinson Deep, City Deep, and Crown Mines) entered into an agreement to subsidize the pumping of water on behalf of a closed mine. This agreement, together with the State Aid Pumping Scheme and an increase in the gold price, extended the lives of individual mines with the result that the final commissioning date was deferred to September 1976. This fortuitous deferment has made it possible for the original plans to be modified to take advantage of modern pumping technology, and, more important, it has provided time for a thorough investigation to be made into the treatment of underground water. This has resulted in the installation of a sophisticated treatment plant with a process unique to the industry. The design of this plant was centred on the stringent specifications of the Department of Water Affairs relating to the deposition of water in public streams, which demand that the deposited water should have a pH value between 5,5 and 9,5. In addition, the suspended solids should be removed so that the water contains less than 25 p.p.m. of suspended solids, and the water must be treated and aerated so that it contains less than 7 p.p.m. of iron in solution.

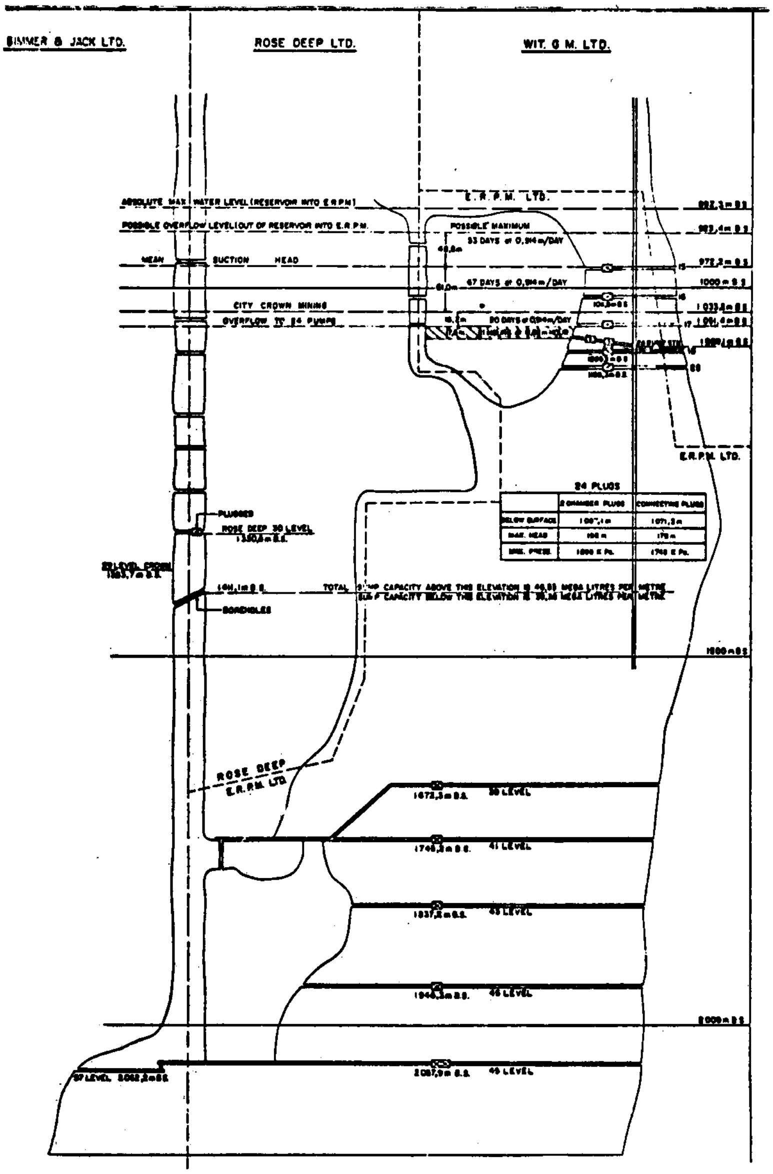

Fig. 1—Plugs installed in the Far West Section of E.R.P.M.

The Pumping System

The system required to fulfil all the requirements of the specifications consists of three separate units that operate automatically: a pump station on 24 level, a surface lime plant, and a surface treatment plant.

The Pump Station on 24 Level

The Layout

In the Far West Section of E.R.P.M., thirteen Colgrout plugs were installed at selected positions in accordance with the Government Mining Engineer's specifications so as to form a reservoir for water in the defunct mines in the Central Witwatersrand compartment to the west of this property (Fig. 1).

The elevation of the pump chamber in the South West Vertical Shaft was positioned so as to allow for 53 days of standby time calculated at an inflow of approximately 50 Ml/d.

When the pump station was designed, it comprised a pump chamber, a sub-station, and sumps. It was envisaged that the water would be tapped at the required rate from the reservoirs. This, with the additional 1,82 Ml/d from the defunct mine of Witwatersrand Gold Mining Company, would be fed to the sumps.

In 1971 it was decided to pump run-of-mine water from the reservoir, which necessitated a change in planning. The single haulage was duplicated, and a mixing chamber was included in the layout. Provision had also to be made for the pumping of the Witwatersrand Gold Mining Company water through the plugs into the reservoir (Fig. 2).

The pumping of run-of-mine water eliminated the need for settling. This scheme has the advantage of flooded suction with a mean head of 107,9 m, which results in a considerable saving in power costs. Pumping of the water direct from the sump is also beneficial in that the water in the reservoir is never exposed to the

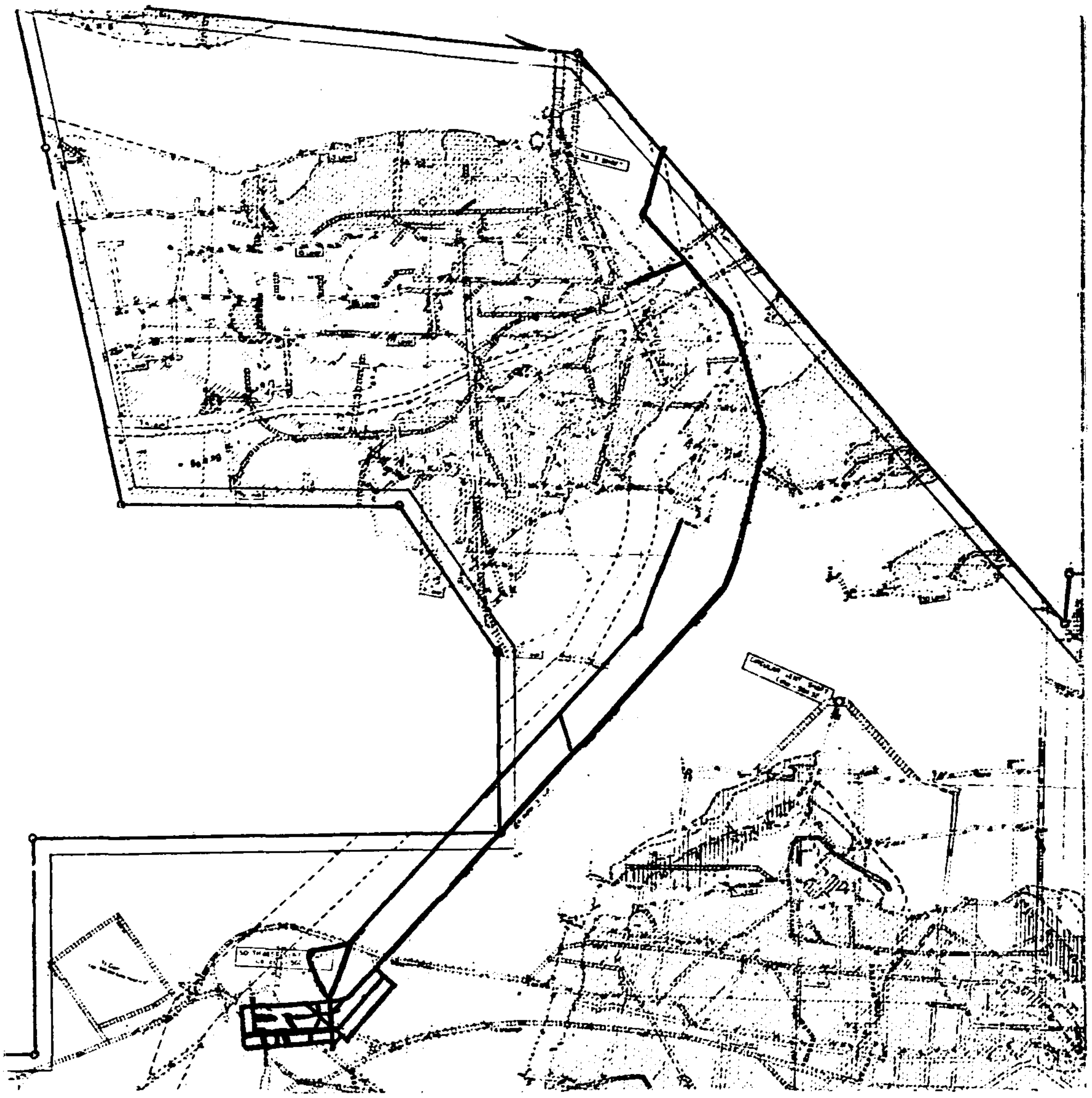

Fig. 2—Provision for the pumping of water from Witwatersrand Gold Mine into the reservoir

atmosphere. This prevents the oxidation of the iron in the water, which in turn uses less lime. This not only is less costly but also ensures that less calcium sulphate is deposited in the rising mains.

The Pumping Plant

Two concrete control plugs have been constructed on this sub-level. Each plug is 3,35 m square and 4,88 mm long. Four 300 mm stainless-steel flanged suction pipes, one stainless-steel flanged delivery pipe 200 mm in diameter, and one stainless-steel flanged control pipe 100 mm in diameter, were built into each plug during construction. On the dry side of the plug on each 300 mm column, a 300 mm diameter stainless-steel stop valve and ball valve are bolted. The ball valves are fitted with electric actuators for controlling the flow of water.

At 12 m from the plug, the four 300 mm diameter pipes converge into a lime-mixing chamber of 1,07 m diameter (Fig. 3). The lime is introduced into this vessel (which is rubber lined) through a range from the surface lime plant.

From the mixing chamber, each pump is served by its own suction column and each column is fitted with a bursting diaphragm that fails if the suction pressure becomes excessive.

The four main pumps are each capable of 0,9 Ml/h against a head of 1050 m (Fig. 4). These pumps are reputed to be the largest underground pumps for this head and are fitted with Mitchell bearings on the thrust side. The impellers are 530 mm in diameter and all the bearings are water-cooled Each pump is coupled direct to a 4000 kW motor running at 1470 r/min. The pumps normally run in pairs, each pair pumping through one 356 mm diameter column. It is interesting to note that, prior to starting up, the 356 mm rising mains must be full of water and the delivery valves must be open. This is contrary to normal practice, but it prevents the washing of the valve that would take place because of the high pressure.

Visual and audio instrumentation is installed on all the pumps to alert the staff of pending failure and to

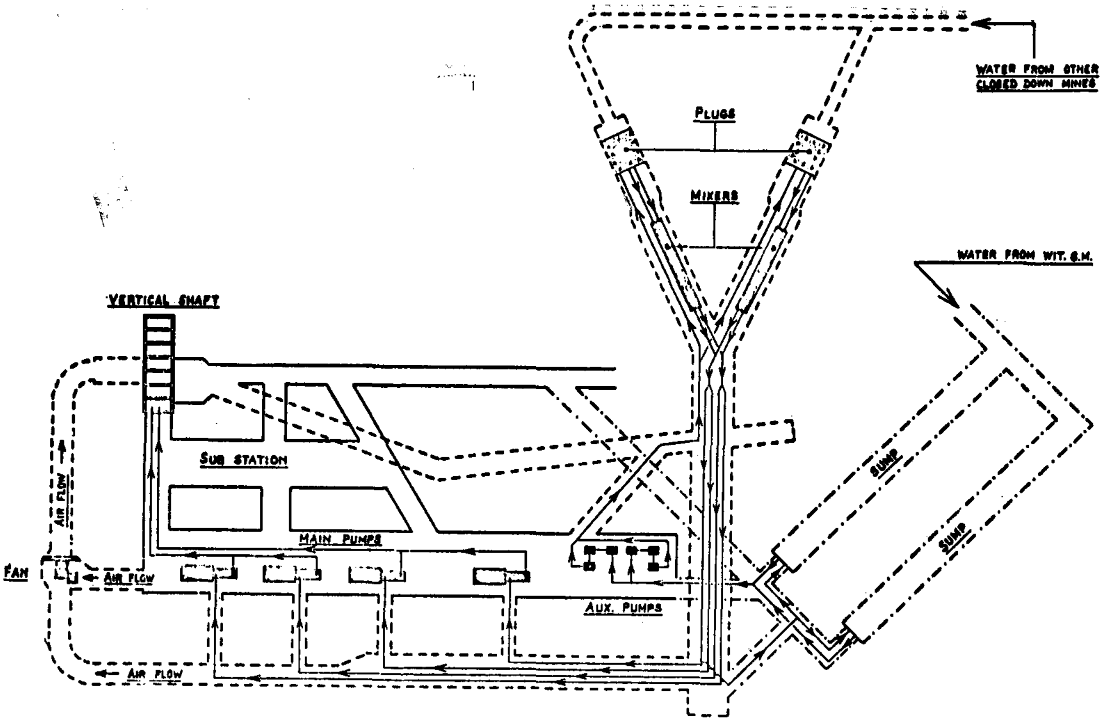

Fig. 3—The arrangement of the pump station on 24 level

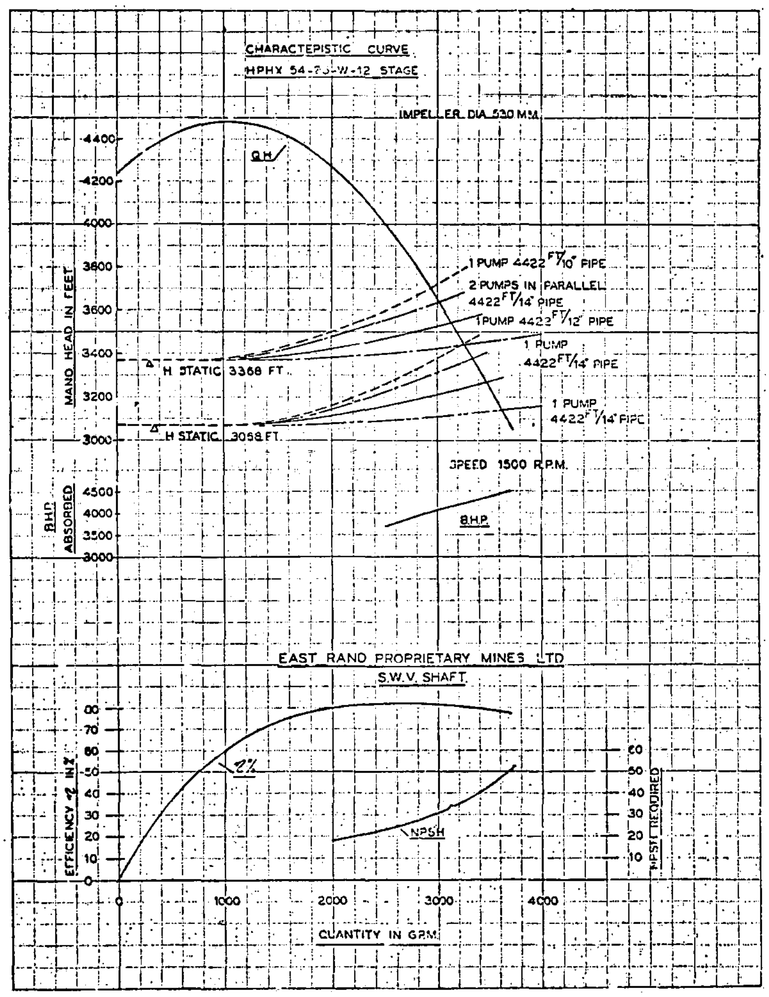

Fig. 4—The efficiency of the four main pumps

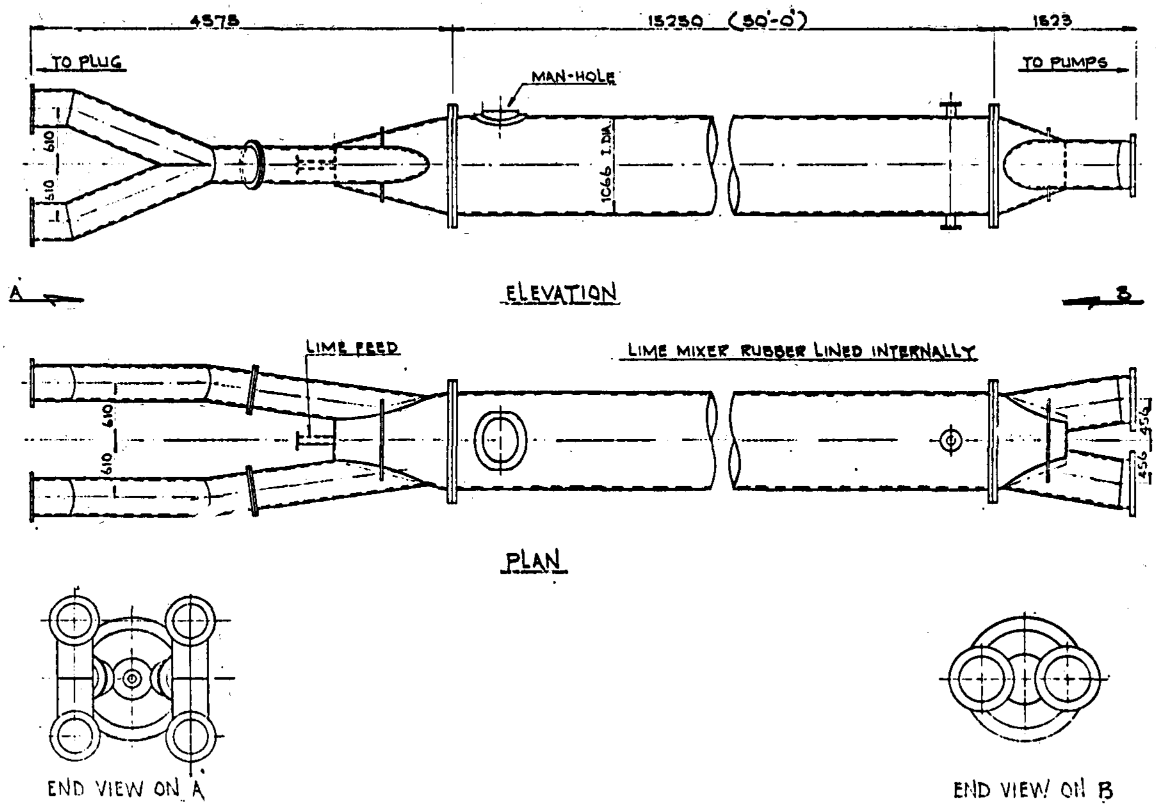

Fig. 5—The lime-mixing chamber

prevent damage. The main safety features include the following.

(a) Temperature trips are installed on the pump bearings.

(b) The rising mains are fitted with automatic drain valves to reduce the head when the pumps have stopped.

(c) As the pumps operate in pairs through a common rising main, each pump is fitted with a directional switch that closes if a running pump trips or stops. If this happens and the non-return valve fails to close, there will be a reversal of flow owing to the water pressure from the sister pump. When the directional switch closes, the delivery valve and the rising-main valve close and the drain valves open automatically, thus preventing reversal of flow on the immediate delivery side of the pump.

(d) The ammeter circuit of the pump motor is wired through a current relay that operates a 'load loss' protective device. This scheme is fitted to trip the pump if the suction valve is closed or if the suction column becomes blocked, thus starving the pump of water and turning the pump into a pressure vessel. The same applies if the delivering valve or rising-main valve is closed when the pump is running.

As water reaching the pump station from the Witwatersrand Gold Mine cannot be gravitated into the reservoir, it is collected in the horizontal settling sumps (Fig. 3) and pumped behind the plug by two sets of auxiliary pumps. Each set of auxiliary pumps comprises three pumps in series, the third pump in the series being driven at variable speed by a d.c. motor to compensate for variable head and quantity.

Mixing Chambers

Water tapped from the reservoir is crystal clear. When lime is added to the water under atmospheric conditions, the water turns inky black owing to the solids in suspension. If the solids are allowed to settle, the volume of sludge becomes large and handling becomes an additional problem. The installed system takes cognizance of these problems and provides for the introduction of lime under pressure. This reduces the amount of lime used because there is an oxygen deficiency and chemical reaction is inhibited.

The lime-mixing chambers (Fig. 5) are rubber-lined pressure vessels. Slaked lime from the surface lime plant is pumped to a steady-head tank in the shaft, from which point it gravitates to the pump station and is fed direct into the plug side of the lime-mixing vessel. The dimensions of this vessel are 15,25 m long and 1,066 m in diameter. The design is such that the action of the slaked lime on the water is calculated to be complete before the water leaves the mixing chamber.

Automation and Electrical Equipment

The pump station is equipped with four 4000 kW 1470 r/min 6600 V motor-driven pumps. Each pump motor has its own independent 6600 V 50 Hz supply. The motors are of the slip-ring type with a bank of condensers across the supply to improve the power factor.

All the auxiliary pumps and electrical valves operate

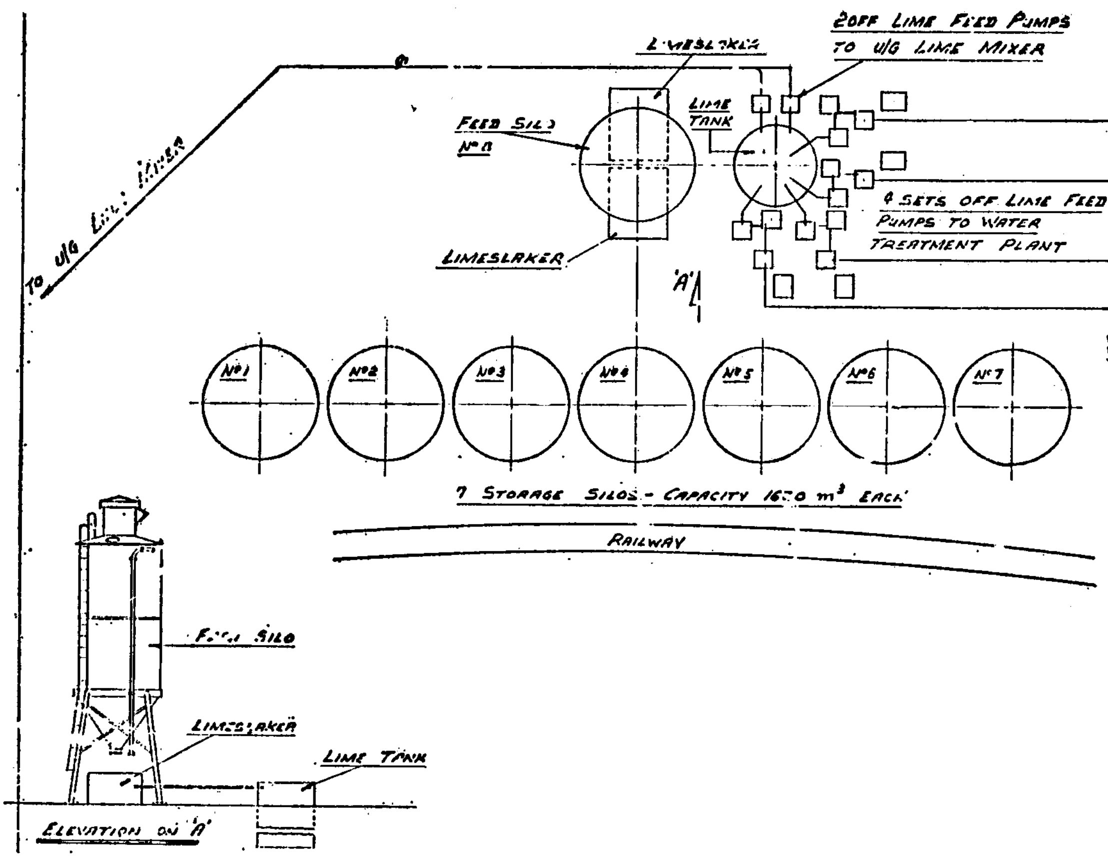

Fig. 6—The surface lime plant

from two 500 kV.A 3300 to 550 V transformers from the mine's underground 3300 V 50 Hz system.

Each pump can be started up through either one of two banks of resistances via selector high-tension switches.

The pump chamber is equipped with a mimic board on which lights indicate the position of each of the 40 electrically-operated and 10 manual valves. The valves are opened or closed from push buttons on the flow diagram of the mimic board. All electrical switching of the high-tension circuit breakers is indicated on the mimic board. The control panel of each pump is equipped with 40 indicating lights to indicate fault trip-outs, valve failures, high-tension switching, etc.

The pumps are started as follows. When the protective devices have been reset, the suction valve, delivery valve, and rising main valve have been opened, and the pump drain valve has been closed, one of the two starting resistance banks is selected and the signal is transferred to surface to start up the surface lime plant. When the surface lime plant is running, a return signal is transmitted to the pump control panel, which illuminates the pump 'ready to start' light and permits putting the pumps on load.

Ventilation

It is estimated that the installation of four 4000 kW pumps in the station will produce 630 kW of heat. Each pump motor is designed to handle 4 m^3/s of air with a temperature increase of 30 °C dry bulb through the motor.

With this amount of heat it is calculated that, if the air from the pump motor is mixed with 14 m^3/s of downcast air (at 20,0 to 26,5 °C), the temperature of the mixture will be about 25,6 to 48,0 °C, which is too high for personnel to work in safety. Thus, it is essential for the heat to be ducted directly from the motors out of the pump chamber.

The problem of heat rejection was investigated, and it was established that the fan pressures required to pipe the air direct to return airways were too high, and the rejection of this air into the pump water would be too complex and inefficient. The decision to dissipate the heat into the downcast airway was accepted. (It is calculated that the rejection of 700 kW of heat into the downcast air system, if there is perfect mixing, will increase the air temperature from between 20,0 and 26,5 °C to between 21,0 and 30,0 °C.) These conditions are acceptable, the only requirement for the implementation of this scheme being a fan with a duty of 30 m^3/s at 3,84 kPa.

Surface Lime Plant

The surface lime plant (Fig. 6) comprises seven 250 t storage silos, one similar operational silo, two lime slakers, and a lime tank.

Powdered lime is delivered to the plant by rail in special containers, from which it is transferred pneumatically to the storage silos. A 10 t transfer vessel runs on rails beneath the storage silos and transfers the powdered lime pneumatically to the operational silo, which in turn feeds the slakers through a manually controlled rotary valve.

Each lime slaker is capable of a maximum output of 40 t of slaked lime per day, the output varying according to the retention time. The slaked lime is delivered into a steel tank, where it is agitated mechanically to prevent settlement. Two pumps draw lime from this tank and feed a steady-head tank in the shaft, from where it gravitates to the lime mixers at the pump station on 24 level. Four other sets of three pumps in series deliver slaked lime from the storage tank to the next stage of the operation, which is the surface treatment plant.

Surface Treatment Plant

The purpose of the treatment plant is to produce water suitable for discharge into a public stream, i.e., water with a minimum pH value of 5,5 and less than 25 p.p.m. of suspended solids. The pH value of the water delivered to the plant and the amount of lime used in the plant are controlled automatically.

The plant comprises two concrete thickener tanks of 100 m diameter, two concrete lime-mixing tanks, and four concrete aeration tanks. The process is being conducted under licence to Bethlehem Steel Corporation and cannot therefore be described here.

The sludge from the thickeners is pumped either to the reduction plant, where it is used for repulping, or direct to the slimes dam.

Conclusion

The success of the scheme is the result of extensive research and sound planning. The estimates based on the early investigations were remarkably accurate, and the rise of water in the reservoir has averaged 0,80 m/d as forecast. Fluctuations in the rate of rise between the wet and dry seasons was not as large as anticipated, but this is the result of action taken by E.R.P.M. and the Department of Mines to reduce the storm water entering the outcrop workings.

Acknowledgement

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Competition for student members

Each year the South African Institute of Mining and Metallurgy offers a prize (or prizes should the entries warrant it) of up to R100 for the best paper or dissertation on a topic appropriate to the interests of the Institute. The competition is open to all Student Members of the Institute.

A Student Member who is in full-time study at a university may submit the dissertation or thesis he has to write in part fulfilment of his university degree, provided that it is presented in a manner and on a topic suitable for publication in the journal.

Entries for 1977 should reach the Institute by 31st December, 1977.