Experience with Mars pumping of underground water

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SYNOPSIS

As the result of a planned increase in production, Vaal Reefs Exploration & Mining Company Limited increased the hoisting capacity of their existing equipment to its fullest extent and installed Mars pumps and a washing plant. The layout of the installation is described, and details are given of the modifications made to overcome its weaknesses. Plans to change the present four-stage system to a seven-stage system are outlined.

SAMEVATTING

As gevolg van 'n beplande toename in produksie het Vaal Reefs Exploration & Mining Company Limited die hysvermoë van sy bestaande uitrusting tot die maksimum verhoog en Marspompe en 'n wasaanleg geïnstalleer. Die uitleg van die installasie word beskryf en besonderhede word verstrek van die wysigings wat aangebring is om sy swakplekke te oorkom. Daar word in hooftrekke 'n uiteensetting gegee van die planne om die huidige vierstapstelsel na 'n sewestapstelsel te verander.

Introduction

No. 1 Shaft at Vaal Reefs North consists of a twin-shaft system, a main vertical shaft extending from surface to 40 level (1219 m), and a sub-vertical shaft continuing from 40 level to 72 level (2194 m), which is the ore-loading station. From here the rock is loaded into skips and hoisted to surface.

The shaft was initially designed for a production of 115 000 t per month, and rock-hoisting facilities were as follows:

Main vertical shaft	2240 kW a.c. winder
Skip capacity	8,1 t at 25 skips per hour
Sub-vertical shaft	1340 kW a.c. winder
Skip capacity	6,3 t at 32 skips per hour.

Because of a planned increase in production, the hoisting capacities had to be increased, and the following improvements were carried out.

The hoisting capacity of the main shaft was increased by uprating of the skip capacity from 8,1 to 11,4 t at 25 skips per hour. This was made possible by modifications to the hoist cooling system and by the installation of light-weight Sala skips.

There was no possibility of uprating the existing hoist in the sub-shaft, and it was thus decided to install a new 1860 kW d.c. winder with a skip capacity of 9 t at 30 skips per hour.

After completion of above project, the hoisting equipment was loaded to its full extent, and it was realized that any additional increase in production would have to be handled by means other than conventional hoists. Mars pumps and a washing plant were thus installed with the following benefits in mind.

(1) The tonnage raised would be increased by the pumping of slurry to surface in addition to hoisting.
(2) Stoppages caused by sticky reef ore would be reduced by the hoisting of a washed and screened product.
(3) Leakage of fines into the air stream would be reduced considerably.

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Once the pumps were installed, another advantage was found. In addition to the pumping of the slurry produced at the washing plant, the mud from the underground settlers could be raised. In fact, all the mud from the whole Vaal Reefs Complex is now handled by the Mars pumps.

Layout of Mars Pumps and Washing Plant

The Mars pump is a twin-cylinder, double-acting type and originally had a cylinder bore of 225 mm and a stroke of 450 mm. The maximum pressure specified by the makers is 7850 kPa, and the displacement is 136,3 m^3/h at a specific gravity of 1,28. In principle, this pump differs from conventional reciprocating pumps in that it isolates the abrasive slurry from the cylinders by interposing a mass of oil between them. Fig. 1 indicates how this is done.

The pumping system consists of four stages, which are situated at 72 level (2194 m), 59 level (1798 m), 40 level (1219 m), and 20 level (601 m). The washing and screening plant (Fig. 2) is situated in the lower part of the vent shaft.

Briefly, the operation is as follows. Run-of-mine ore is fed direct from the main ore pass system by conveyor belt to a vibrating grizzly, where primary washing is carried out. The overflow from the grizzly (plus 54 mm) passes through a 32 by 42 jaw crusher to a storage bin, from which it is conveyed to the skips. The underflow is fed onto a double-deck vibrating screen, where it is again washed. The overflow from this screen (minus 54 mm plus 3 mm) also flows into the storage bin. The underflow is fed into a transfer tank, from where it is pumped through a cyclone into the ball mill. The overflow from this cyclone is fed through a secondary cyclone and is then finally transferred to the storage silo. From here the slurry gravitates to the first stage of Mars pumps at 72 level and is then pumped to surface.

The Mars pump system has now been in operation for more than five years, and 590 000 t (dry) have been raised to surface at an average value of 30 g/t.

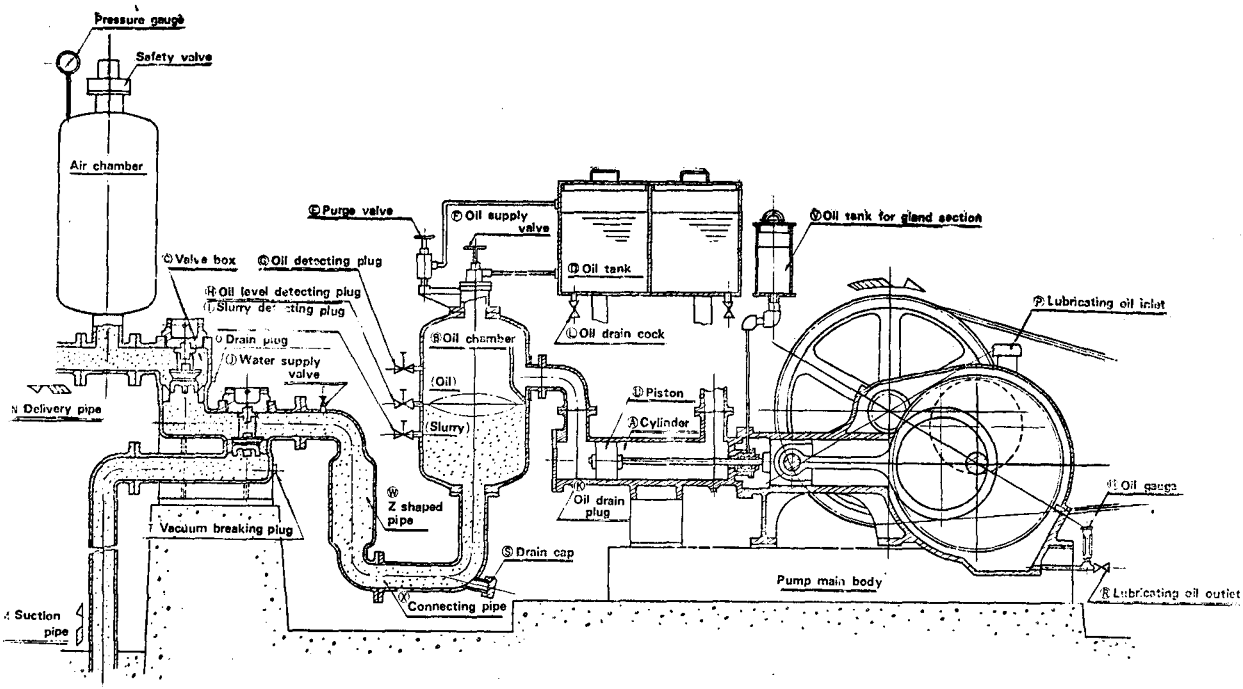

Fig. 1—The Mars pump, showing how the abrasive slurry is isolated from the cylinders by a mass of oil

Deviations from Original Design

Since the installation was based on a new concept, it was not expected to be perfect, and considerable thought and work were devoted to improving the system. Some of the major modifications are described below.

Specific Gravity Loss

In the initial design, it was realized that pump displacements between the stages would differ owing to a difference in pump efficiencies. It was considered unpractical to provide large volumes of storage between stages to overcome these fluctuations. A second alternative seemed more practical, namely, to slightly increase the discharge rate of the pumps at each successive stage. This was done by varying the pump speeds and also reducing the cylinder bores of the first- and second-stage pumps by 25 mm. Make-up water fed automatically into the transfer tank by means of a ball valve then made up for the difference in pump displacements.

Although this system was fairly trouble-free, it had the disadvantage that the product was diluted at each successive stage. The result was that the specific gravity of the slurry received in the surface plant was considerably less than that of the slurry produced in the underground washing plant. An experiment was carried out to establish the effect of different pump efficiencies by running some of the pumps at a constant displacement rate. It was found that the difference was negligible, and it was thus decided to run all the pumps at the same speed and same cylinder bore. The make-up feature was retained, and overflows were fitted to each transfer tank, thus taking care of minor fluctuations in pump displacement.

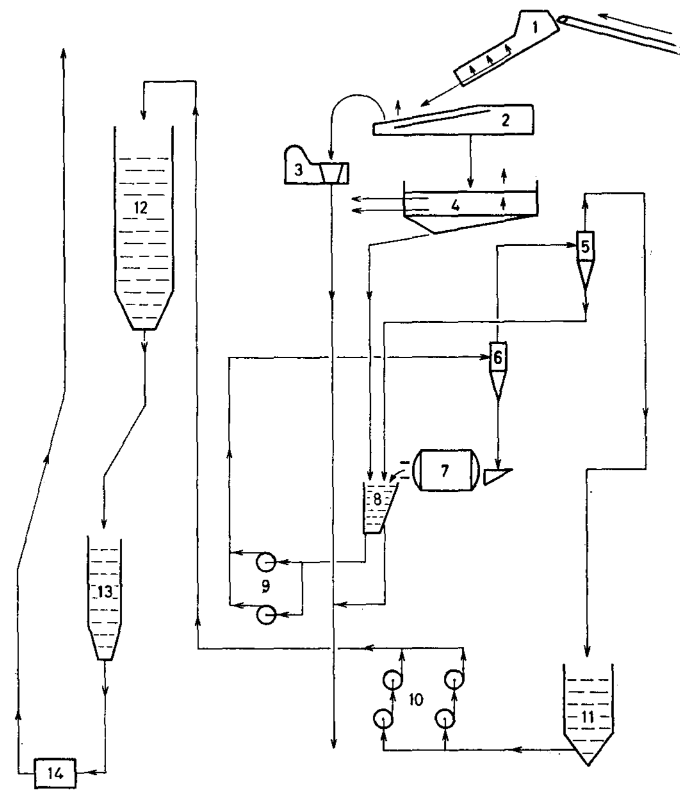

Fig. 2—The washing and screening plant 1. Main feed conveyor. 2. Vibrating bar grizzle. 3. Jaw crusher. 4. Double-deck vibrating screen. 5. Secondary cyclone. 6. Primary cyclone. 7. Ball mill. 8. Ball-mill tank and screen. 9. Ball-mill pumps. 10. Storage pumps. 11. Storage tank. 12. Storage silo. 13. Break-pressure tank. 14. Mars pumps.

Change to MK 2 Valve

Probably one of the most significant achievements has been the development of a new type of valve. For the purpose of identification, the original valve as designed by the makers is referred to as the MK 1, and that developed on the mine as the MK 2. Both valves are shown in Fig. 3.

Because of the extremely high operating costs and the short life of the valve components supplied by the manufacturers of the Mars pump, it was decided that the local manufacture of components should be investigated and that, where possible, equipment should be reconditioned.

Local manufacture proved to be cost saving: it reduced the valve costs by approximately 30 per cent. A further considerable saving was achieved by the reconditioning of components. However, in spite of these savings, it was soon realized that a new type of valve that would eliminate the weaknesses in the original design would have to be developed.

The MK 1 valve consists of a body (A), seat (B), nut (C), insert (D), and retaining plate (E). When the valve is closed under pressure, the insert compresses and spreads outwards, thus deflecting the retaining plate. This results in metal-to-metal contact between the body and the seat, which accelerates wear between faces, causing rough edges and rapidly weakening the insert. In an attempt to reduce this wear, thicker inserts were fitted. These were not successful because they increased the deflection of the retaining plates, causing them to fracture. Strengthening of the retainer plate exerted excess pressure on the nut, causing the thread to strip.

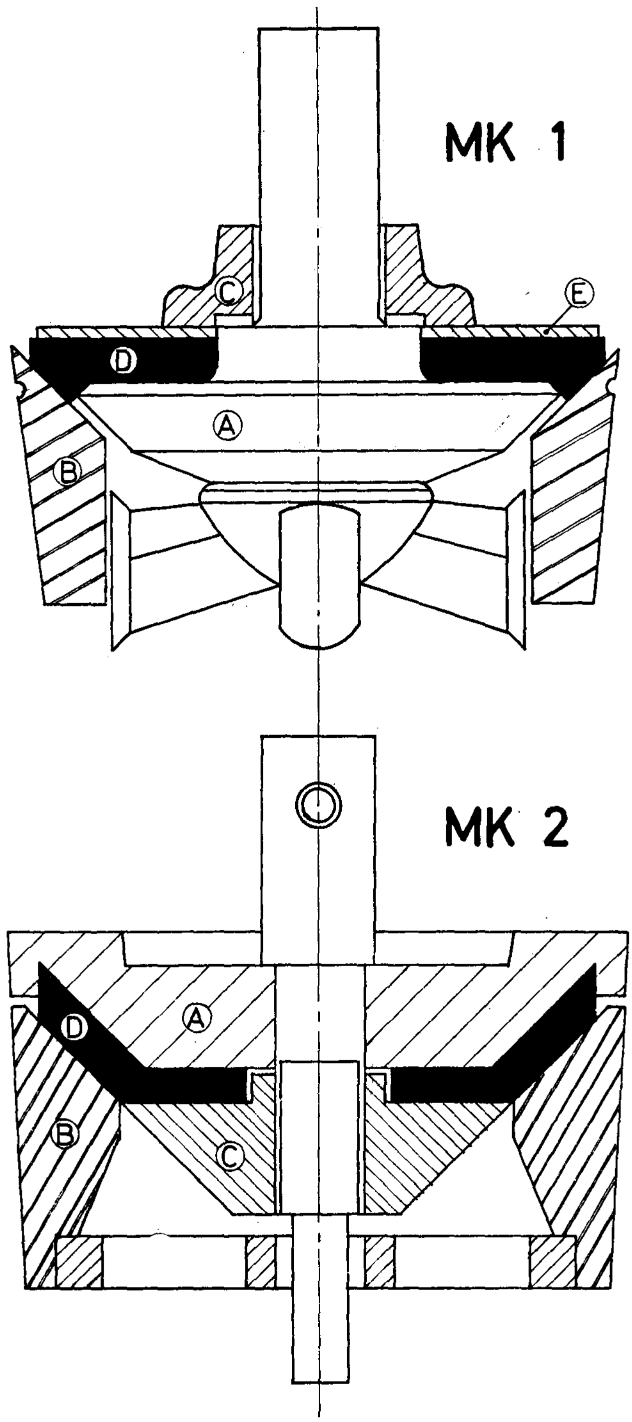

Fig. 3—The original valve, the MK I, and the valve developed at Vaal Reefs, the MK 2

The design of the MK 2 valve makes allowance for a greater sealing area between insert D and seat B. The body (A) supports the insert, and the nut (C) merely secures it in position. There is thus no pressure on the nut when the valve closes under pressure, and the metal-to-metal contact is eliminated. The cost of the MK 2 valve is approximately 40 per cent less than that of the original valves.

Newly Designed Drain Valve

The function of the drain valve is to facilitate the drainage of the pump column in case of a power failure or any other emergency, thus preventing settlement and consequent blockage in the column. The conventional valves originally installed were not successful. Most of these valves are designed for controlled opening, and thus move gradually from a closed to an open position. The passage of highly abrasive medium moving at extremely high velocities through these valves, while being opened, rapidly eroded the valve body and plug, ball, or gate. The result was that sometimes a valve would not last longer than one drain.

Different types of valves were tried, but the best results achieved were 9 drains per valve, the costs of the valves varying between R100 and R260. A new type of valve designed on the mine, the Burchard valve, includes the following features. The opening is instantaneous, which reduces abrasion while opening. The valve operates as follows (Fig. 4). Handle G is depressed, which unlatches locking slide H. The slurry exerts a pressure of approximately 7600 kPa on the inner surface of piston A, which propels the piston across, flinging it into cylinder F and against shock-absorbing rubber disc B. Cylinder F protects the outside of the

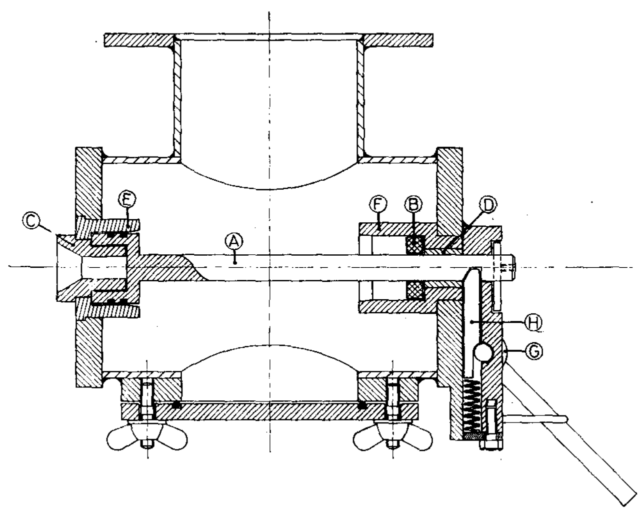

Fig. 4—The operation of the Burchard drain valve

piston from erosion while the slurry discharges to the atmosphere through a pipe of 150 mm diameter. The Burchard valve has been found to last as many as 35 drains, the only replaceable item being O-rings after 2 drains. The cost of the valve is R625.

Changing of Cylinder Bores

After a running life of less than two years, major breakdowns became frequent on some of the pumps. Most of the breakdowns were as follows:

Main gears and pinions stripped
Oil chambers burst
Pump gear casings cracked
Valve boxes damaged.

It was then thought that, although the pumps were rated by the manufacturers to cope with local conditions, they could not quite meet these requirements. In fact, it was felt that the pumps were underdesigned. In order to reduce forces on pump components such as gears and cylinders, all the cylinder diameters were reduced by 25 mm. Although the pump speeds were increased, the displacement rate decreased from 136,3 m^3/h to 114 m^3/h, resulting in a loss of production.

Alteration to Z Bends

From the commissioning of the system, blocked Z bends (Fig. 1) were a major contributor to down-time. The blockages mostly occurred when slurry was being pumped at a specific gravity of more than 1,15. An investigation revealed that the original layout lent itself to such blockages. Because the valve box was at an elevated position, settlement in the pipe between the valve box and the oil chamber was promoted. A consequent alteration in the pump layout (Fig. 5) eliminated blockages altogether.

Elimination of Sieve Bends

Originally, the flow in the washing plant was such that the vibrator underflow passed over sieve bends that separated the minus 2,3 mm product and diverted it to the ball mill. These units required considerable maintenance and were very expensive to operate. A large chute has since been installed below the double-deck screen. The required quantity of minus 3 mm material is now fed directly into the ball-mill circuit. An adjustable deflector plate installed in the chute regulates the amount fed to the ball mill, thus passing excess material into the storage bin. The elimination of sieve bends has simplified the system and also provides more space in the washing plant.

Secondary Cyclone in Ball–mill Circuit

A secondary cyclone was installed mainly as a 'back up' for the primary cyclone, from which, when overloaded, coarse material often overflowed.

Alteration to Pumps in Washing Plant

The ball-mill circulating pumps and silo transfer pumps were repositioned to facilitate maintenance and improve operating conditions. The ball-mill pumps were also slowed down to reduce surging. The gland water service pumps were replaced by gravity feed .

Alterations to Sprays

Another significant improvement was effected by the alterations to the spray equipment in the plant. Ever since the commissioning of the system, it had been a major problem to produce slurry at the rated specific gravity of 1,28. Until approximately sixteen months ago, this seemed an impossible task owing to the following difficulties experienced in the underground washing and screening plant: to wash off as much fines as possible

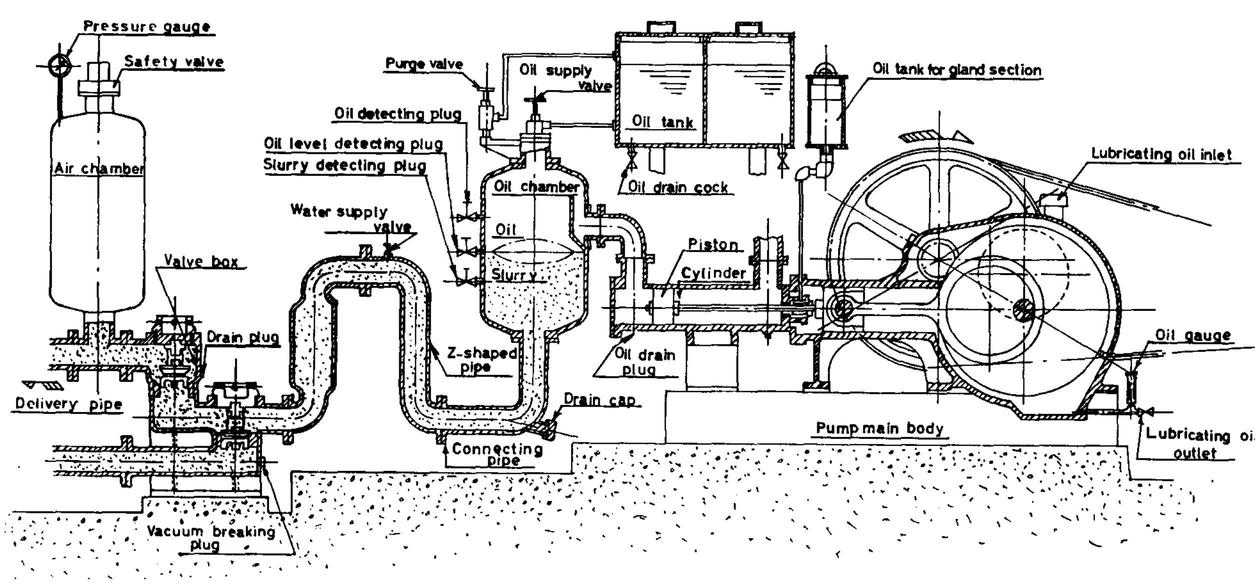

Fig. 5—New layout to eliminate blockages

required a considerable amount of water, which resulted in a very dilute product for transfer to the Mars pumps; also, since the feed of ore is very inconsistent, a lot of water has to be passed through the system during minor stoppages in order to eliminate settlement in the pipes.

The spray system has been redesigned to use an air–water spray, and thus produces a washed product with a minimum amount of water. This method has improved the specific gravity considerably; in fact, an average of 1,3 per 16 hours pumped has been achieved. The possibility of diverting flushing water into a separate air-agitated silo are being investigated at present. This would probably improve conditions even further.

Future Plans

As previously mentioned, the breakdown of major components results in large expenditures and down-time. Although cylinder diameters have been reduced, the problems have not been eliminated completely. A study has revealed that most of these breakdowns occurred to the three pumps that operate at the highest static heads, namely 59 level (580 m), 40 level (610 m), and 20 level (610 m). The lowest pump at 72 level, which pumps at a static head of only 396 m, had far fewer breakdowns than had the others.

The following is a comparison of costs and delay times for major items replaced on the pumps:

20 level	R60 300	372 h
40 level	R48 600	385 h
59 level	R45 500	265 h
72 level	R14 000	87 h.

The above figures prove without doubt that the system would operate more economically if operating pressures were reduced. If the present four-stage system were changed to a seven-stage system, maintenance costs and down-time would be reduced, thus increasing production.

The following seven-stage system is to be introduced:

1st stage	72 level	396 m	static head	(already existing)
2nd stage	59 level	275 m	static head	(already existing)
3rd stage	50 level	304 m	static head	(new installation)
4th stage	40 level	304 m	static head	(already existing)
5th stage	30 level	304 m	static head	(new installation)
6th stage	20 level	304 m	static head	(already existing)
7th stage	1000 level	304 m	static head	(new installation).

Three new installations are thus required to complete the alterations. Excavation work is at present in progress on 50 level, and this station is expected to be completed soon.

Conclusion

Although it is no secret that the Mars pumping system has its disadvantages and that it is not economically comparable with conventional hoisting, it has proved itself to be a worth-while installation on Vaal Reefs. To a certain extent it has fulfilled its original requirements, and there is no doubt that the change to seven stages will make it more effective. It is envisaged that, once this change is complete, the existing output of approximately 12 000 t per month can be increased to at least 15 000 t per month. Also, since major expenditure will decrease, it is hoped that operating costs will be considerably reduced.

Plastics in the service of man

The first South African conference on the above topic is to be held in Johannesburg from 29th August to 2nd September, 1977. It is being organized by the Plastics Institute of Southern Africa in collaboration with the Plastics Federation of South Africa, the Institute of Packaging of South Africa, the South African Bureau of Standards, and the South African Council for Scientific and Industrial Research.

The following topics are to be discussed:

Plastics in Furniture
Plastics in Mining
Plastics in the Automotive Industry
Plastics in the Electrical Industry
Plastics in Packaging
Economic Factors of Plastics (Education and Training, Design Specifications, Recycling, and Round-table Discussion).

For further details, contact Mr E. A. Olivier, Sentrachem Ltd, P.O. Box 61204, Marshalltown, 2107 South Africa.

Company Affiliates

The following members have been admitted to the Institute as Company Affiliates.

AE & CI Limited.
Afrox/Dowson and Dobson Limited.
Amalgamated Collieries of S.A. Limited.
Apex Mines Limited.
Associated Manganese Mines of S.A. Limited.
Billiton Exploration S.A. (Pty) Limited.
Blackwood Hodge (S.A.) Limited.
Blyvooruitzicht G.M. Co. Ltd.
Boart International Limited
Bracken Mines Limited.
Buffelsfontein G.M. Co. Limited.
Cape Asbestos South Africa (Pty) Ltd.
Compair S.A. (Pty) Limited.
Consolidated Murchison (Tvl) Goldfields & Development Co. Limited.
Deelkraal Gold Mining Co. Ltd.
Doornfontein G.M. Co. Limited.
Durban Roodepoort Deep Limited.
East Driefontein G.M. Co. Limited.
East Rand Prop. Mines Limited.
Engineering Management Services (Pty) Ltd.
Envirotech (Pty) Ltd.
Free State Saaiplaas G.M. Co. Limited.
Fraser & Chalmers S.A. (Pty) Limited.
Gardner-Denver Co. Africa (Pty) Ltd.
Goldfields of S.A. Limited.
The Grootvlei (Pty) Mines Limited.
Harmony Gold Mining Co. Limited.
Hartebeesfontein G.M. Co. Limited.
Highveld Steel and Vanadium Corporation Limited.
Hubert Davies Heavy Equipment (Pty) Ltd
Impala Platinum Limited.
Ingersoll Rand Co. S.A. (Pty) Ltd.
Johannesburg Consolidated Investment Corp. Ltd.
Kinross Mines Limited.
Kloof Gold Mining Co. Limited.
Lennings Holdings Limited.
Leslie G.M. Limited.
Libanon G.M. Co. Limited.
Lonrho S.A. Limited.
Loraine Gold Mines Limited.
Marievale Consolidated Mines Limited
Matte Smelters (Pty) Limited.
Natal Cambrian Collieries Limited.
Northern Lime Co. Limited.
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Otjihase Mining Co. (Pty) Limited.
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St. Helena Gold Mines Limited.
Shaft Sinkers (Pty) Limited.
S.A. Land Exploration Co. Limited.
Stilfontein G.M. Co. Limited.
The Griqualand Exploration and Finance Co. Limited.
The Messina (Transvaal) Development Co. Limited.
The Randfontein Estates Gold Mining Co.Witwatersrand Ltd.
The Robbins Co. (Africa) (Pty) Ltd.
The Steel Engineering Co. Ltd.
Trans-Natal Coal Corporation Limited.
Tvl Cons. Land & Exploration Co.
Tsumeb Corporation Limited.
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Vaal Reefs Exploration & Mining Co. Limited.
Venterspost G.M. Co. Limited.
Vergenoeg Mining Co. (Pty) Limited.
Vlakfontein G.M. Co. Limited.
Welkom Gold Mining Co. Limited.
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Western Areas Gold Mining Co. Ltd.
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Treatment of waste water

An international research symposium on 'New Processes of Waste Water Treatment and Recovery' is to be held in London from 6th to 8th September, 1977. The symposium is being organized jointly by the Water and Environment Group of the Society of Chemical Industry and the Environment Group of the Chemical Society.

Typical areas of interest would include the following:

Biological and physicochemical treatment of sewage, and of industrial and other waste waters
Methods for recovery and re-use of valuable materials, including food values, metals, chemicals, and water
The achievement of high-quality discharges
Analytical monitoring and automatic control of treatment and recovery processes
Contributions towards the technical solution of new or difficult problems in waste-water treatment
Research relevant to environmental quality standards.

Further details are available from The Conference Secretary, Society of Chemical Industry, No. 14 Belgrave Square, London SW1X8PS.