

# Automated sorting on a South African gold mine

by P. J. BARTON\*, Pr. Eng., B.Sc. (Min. Eng.), M.S.A.I.M.M., and  
N. F. PEVERETT†, Pr. Eng., B.Sc. (Min. Eng.), F.S.A.I.M.M.

## SYNOPSIS

A brief review of the development and ultimate design of the Model 16 Photometric Sorter is given, including the differences between it and its predecessor, the Model 13, which is currently in operation at Doornfontein.

A description of the West Driefontein sorting plant is given, together with the rationale of its design. The installation programme for the sorters is described, and current operating and maintenance procedures are discussed.

Operating results are tabulated and compared with the original test results. Operating costs are also discussed.

## SAMEVATTING

Daar word 'n kort oorsig oor die ontwikkeling en uiteindelijke ontwerp van die Photometric Sorter Model 16 gegee asook die verskille tussen hierdie model en sy voorganger, Model 13, wat op die oomblik by Doornfontein gebruik word.

Die sorteeraanleg by West Driefontein word beskryf en die redes vir sy ontwerp uiteengesit. Die installeringsprogram vir die sorteerders word beskryf en die huidige bedryfs- en onderhoudprosedures bespreek.

Die bedryfsresultate word getabelleer en met die oorspronklike toetsresultate vergelyk. Verder word die bedryfskoste ook bespreek.

## Introduction

Sorting is the original process for concentrating mineral ores as they occur in the mined state. Until this century, this function was performed only manually, and today is still carried out in this manner where labour is readily available and cheap — for example in India and large parts of the African continent. Manual sorting requires that there is a visual difference between the mineral-bearing rocks and the barren rocks.

During 1966 Gold Fields of South Africa undertook a joint programme with Rio Tinto-Zinc through their subsidiary, Ore Sorters, to develop photometric sorters for specific use in the South African gold-mining industry. This programme culminated in the installation of a prototype photometric sorter — Model 13 — at Doornfontein Gold Mining Company during November 1972, where it has continued to play an important role to this day<sup>1</sup>.

As a direct consequence of this installation, serious enquiries were received from around the world for similar equipment. This encouraged the development of a commercially producible general-purpose machine, which is now known as the Model 16 Photometric Sorter.

Model 16s are now in commercial operation in Greece (magnesite)<sup>2</sup>, Australia (wolfram), the U.S.A. (reclamation of scrap), and South Africa (gold reef). It is this latter application that is discussed in this paper, specifically the sorting operation at the West Driefontein Gold Mining Company Limited.

Although the Model 16 has been described fully<sup>2, 3</sup>, perhaps it is of value to discuss the main differences between the prototype Model 13 at Doornfontein (Fig. 1) and the production Model 16s now operating at West Driefontein (Fig. 2). This is most easily shown in tabular form (Table I).

The most significant differences are the introduction of rock stabilization on the Model 16; the scanning of rocks in free flight against a 'black' background rather than on a white background conveyor; and a speeding

up of all operations, viz belt speed, number of mirror facets, and number of valves in operation. This has culminated in a machine capable of sorting up to 200 tons of material per hour in the 160 to 180 mm size range, and 25 tons per hour in the range 10 to 20 mm.

## Before Photometric Sorting

Two reefs are mined at West Driefontein — the Carbon Leader and the Ventersdorp Contact Reef (VCR). Owing to metallurgical-processing considerations, these materials are processed in separate crushing installations. In this paper consideration is given only to the Carbon Leader circuit.

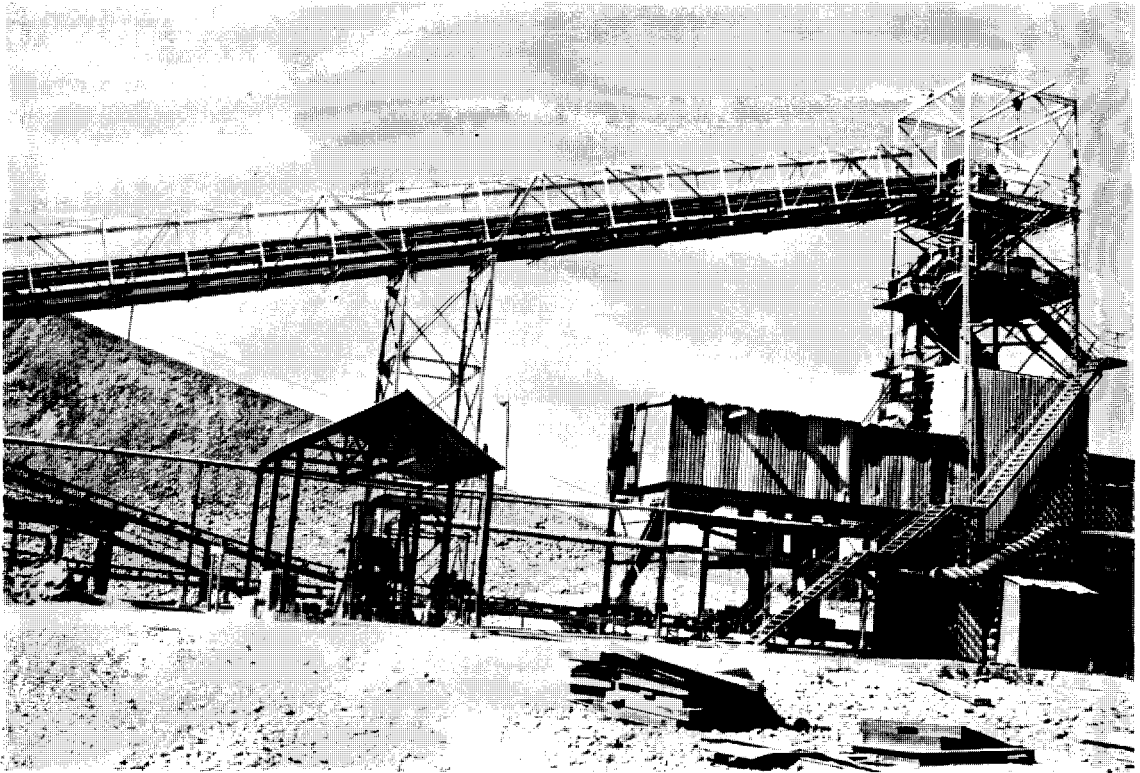
At West Driefontein the material from the Carbon Leader is softer and more friable than that from the VCR. It is a material of high gold values and medium uranium values in which the gold and uranium concentrate in the finer (minus 3 mm) fraction of the run-of-mine ore. This property was made use of in the original plant design, which was aimed at the production of a uranium upgrade ('high grade') for uranium extraction and preferential gold leaching, and a low-grade oversize for stockpiling. Testwork indicated that, by screening and reef picking, some 72 per cent of the mass containing 97 per cent of the gold would be milled. The milled

TABLE I  
COMPARISON BETWEEN THE MODEL 13 AND THE MODEL 16  
PHOTOMETRIC SORTERS

Parameter	Model 13	Model 16
Effective sorting width	810 mm	800 mm
Slide plate	Mild steel	Stellite
Stabilization	Natural	Accelerator/stabilizer assembly
Belt speed	2 m/s	4 m/s
Belt colour	White PVC	Black rubber
Scanning	On belt	In free flight
Mirror	Composite	Single unit
	8 facets	20 facets
	2000 r/min	6000 r/min
Scanning interval	5 mm	2 mm
Electronics	2nd generation	3rd generation
Separation	30 air valves	40 to 80 air valves

\*Formerly of RTZ Ore Sorters, Johannesburg.

†Gold Fields of South Africa, Johannesburg.



**Fig. 1—The Model 13 sorting plant at Doornfontein**



**Fig. 2—The Model 16 sorting plant at West Driefontein**

material would be upgraded from 24,5 g/t to 33 g/t. At the prevailing gold price of \$35 an ounce and prevailing working costs and possible mining rates, there were distinct economic advantages in restricting the capacity of the milling installation and stockpiling 28 per cent of the mined material at a value of some 2,5 g/t. The crushing plant was designed to screen at 32 mm and rescreen at 38 mm. The middling fraction was to be intensively waste-sorted to reduce the bulk, while the oversize would be reef-picked to remove all obvious high-grade material and to supply pebbles for the twenty pebble mills. The original circuit is shown in Fig. 3. The plant operated on this basis until late in 1974, when an underground fire and a fall-off in labour resulted in reduced underground production.

For a period at this time while gold prices were high, stockpiled material was returned for milling. As the Model 13 had been operating successfully for some eighteen months at Doornfontein on similar material, consideration was given to the sorting of the stockpile return. Tests on the Model 16 prototype indicated a

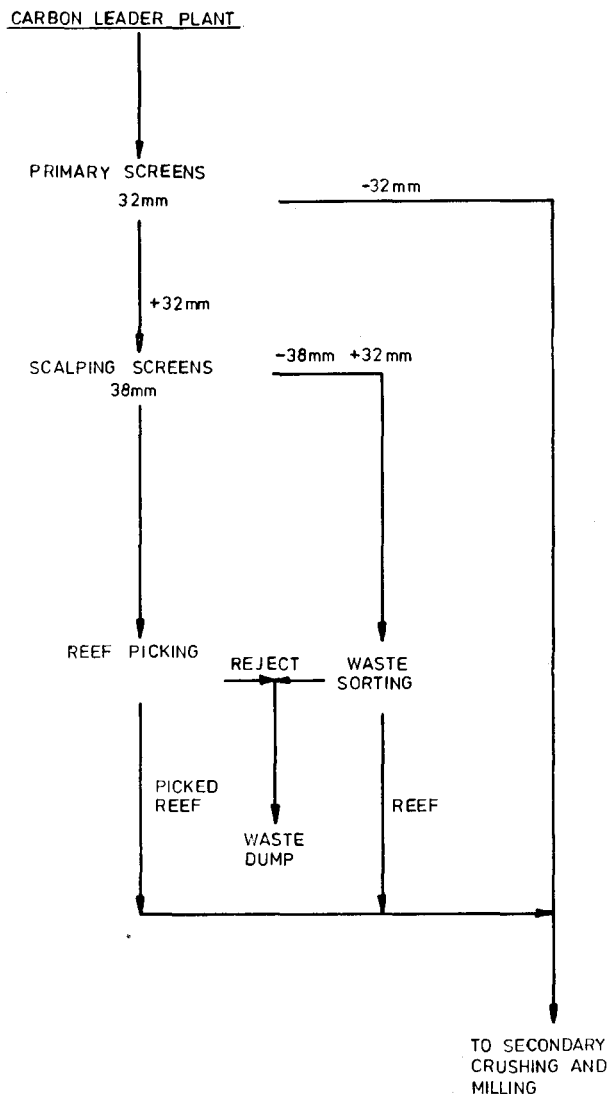


Fig. 3—Before the introduction of photometric sorting at West Driefontein, the circuit at full capacity

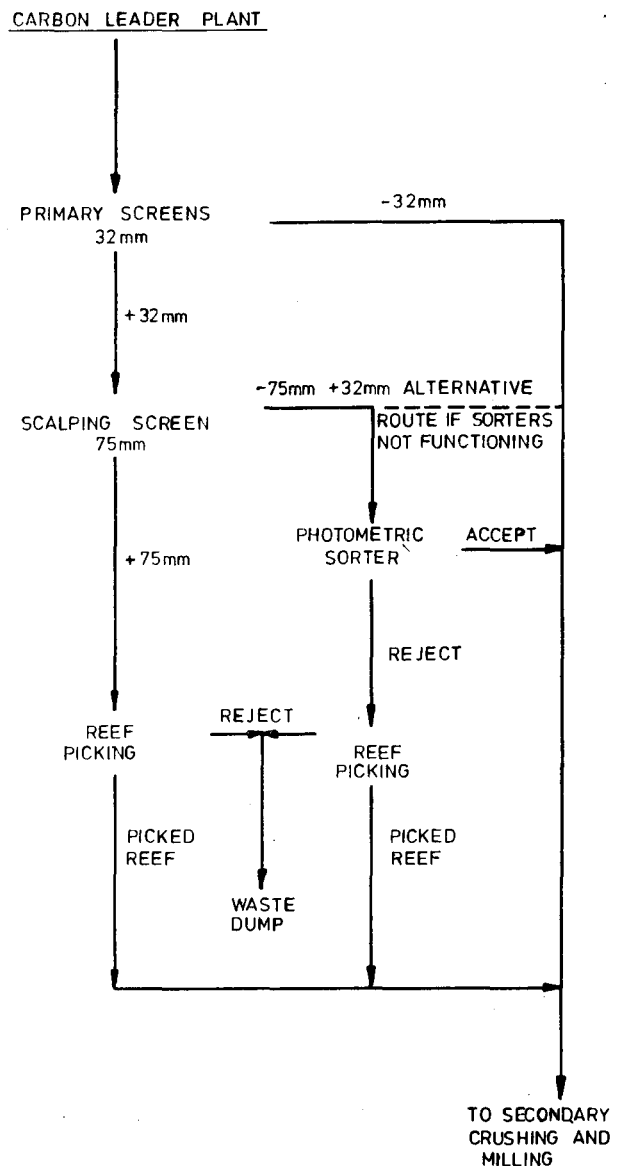


Fig. 4—The circuit at West Driefontein after the introduction of photometric sorting

high financial return from the milling of an upgrade from the stockpile.

Monitoring of the stockpile return showed that the pickers had preferentially and effectively removed the reef from the plus 75 mm fraction but had only lightly picked the minus 75 mm fraction. Anticipating a return to higher underground production before sorters could be installed for stockpile sorting, consideration was given to the installation of Model 16 sorters to sort current material in the size between 75 mm and 32 mm and for expansion to sort the fraction larger than 75 mm.

Sorting in the fraction between 75 mm and 32 mm would reduce the values to the stockpile to an acceptable final discard value. Sorting in the fraction larger than 75 mm would have little effect on the sorting efficiency and the gold milled, and would be justified only on cost- and labour-saving considerations.

#### With Model 16 Sorters

The modified flowsheet at West Driefontein is shown

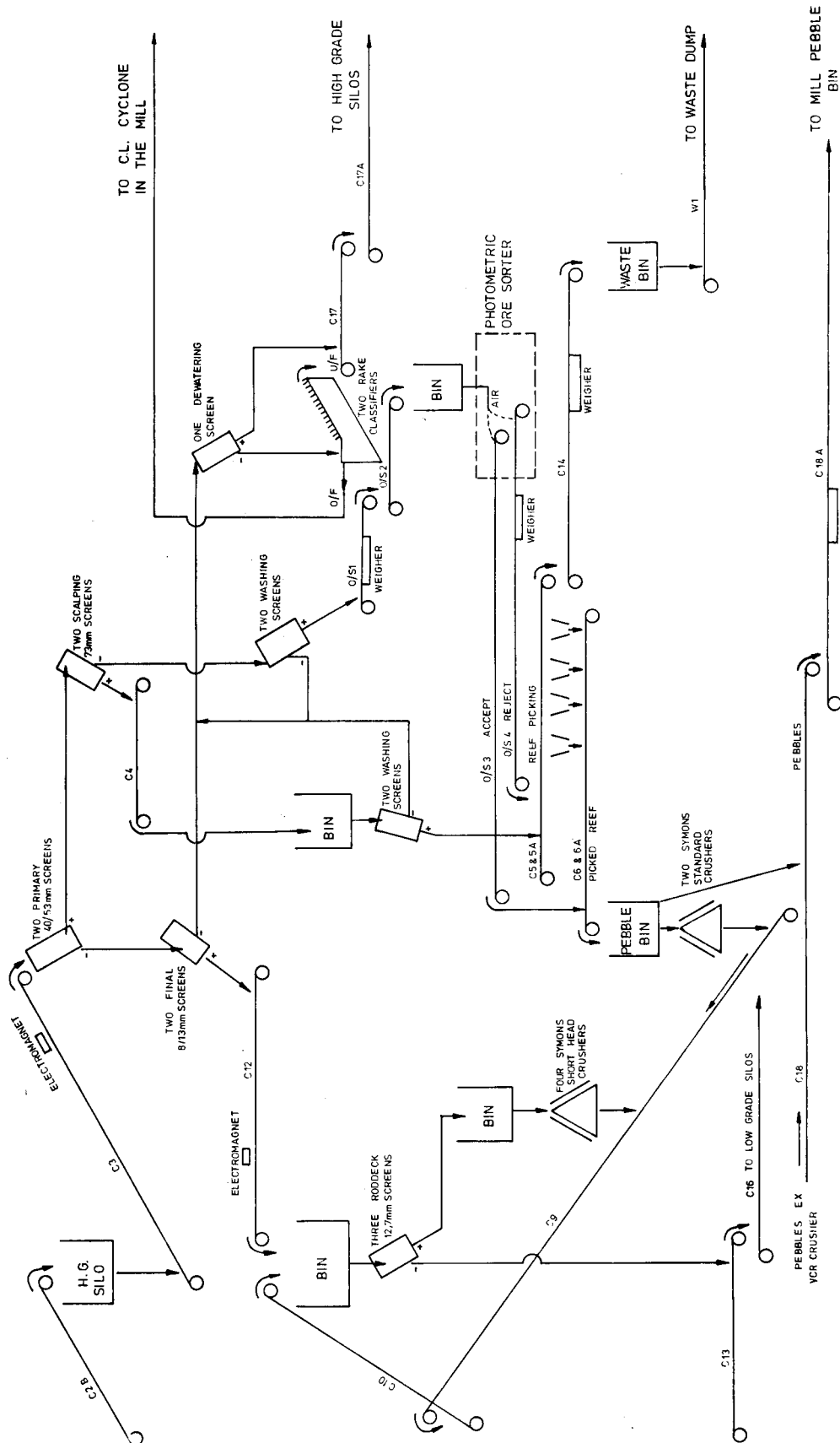
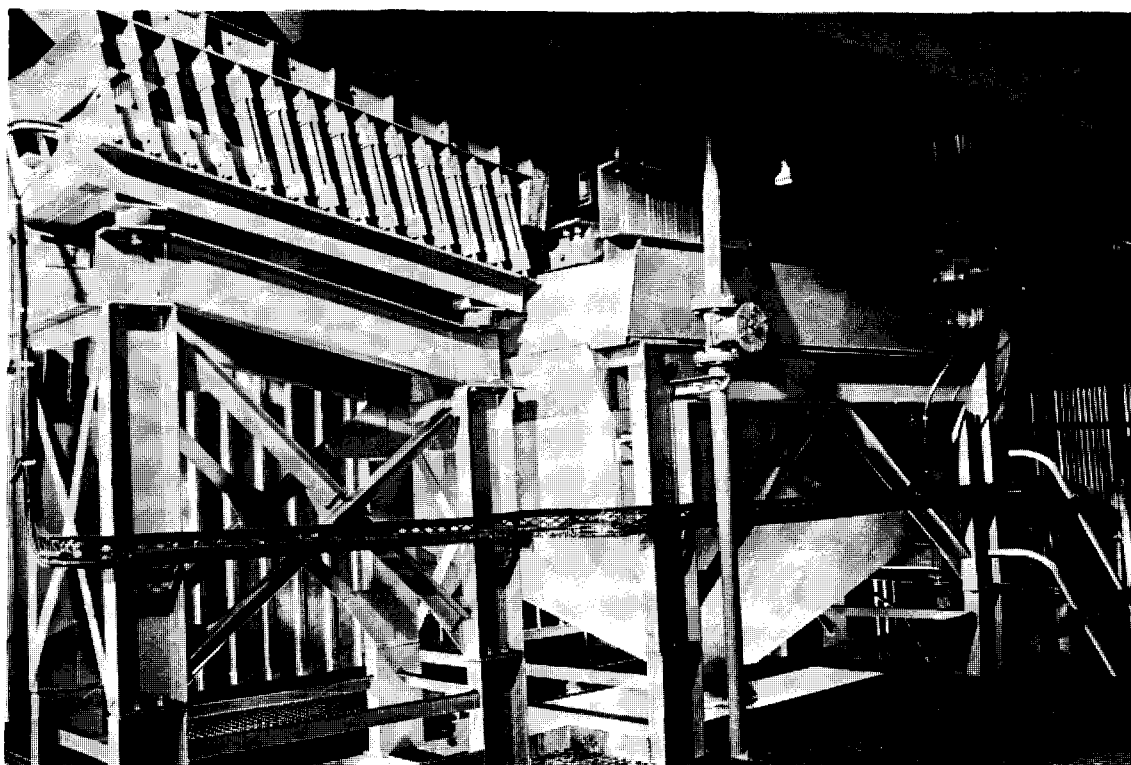
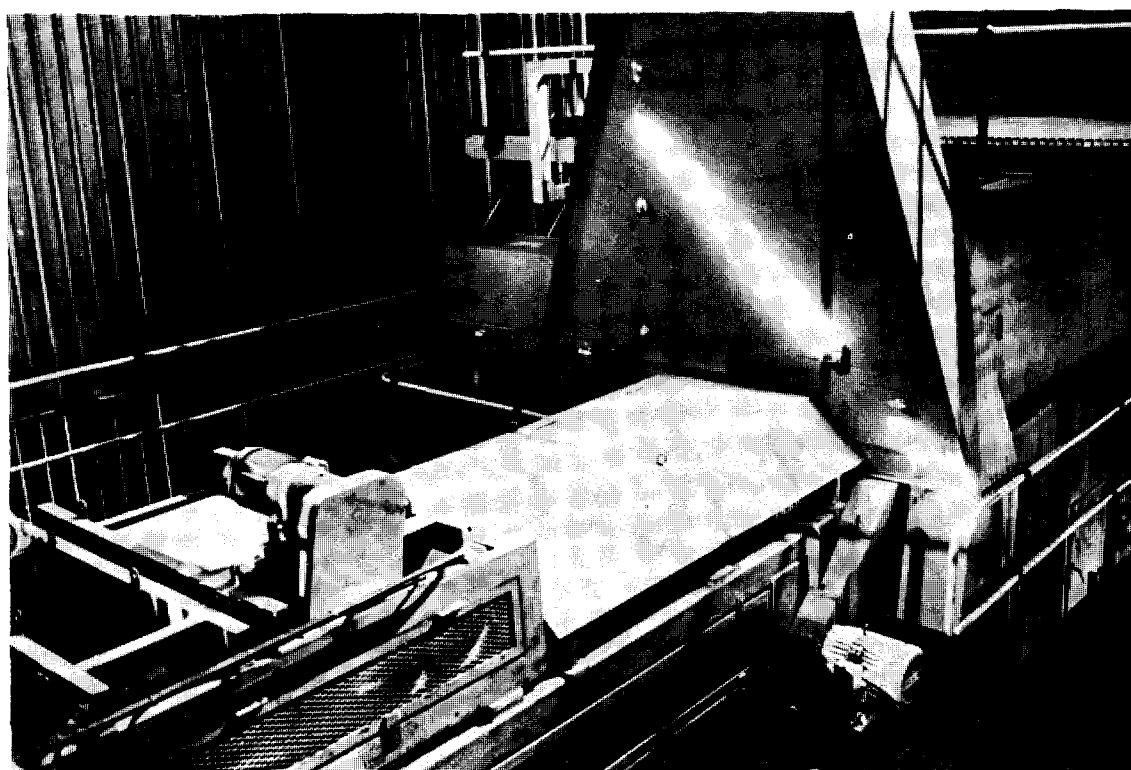


Fig. 5—Carbon Leader crusher station at West Driefontein



**Fig. 6—Feed from main storage over final washing screen, Model 16 at West Driefontein**



**Fig. 7—Model 16 photometric sorter at West Driefontein, highlighting the scanning bridge**

in Figs. 4 and 5. The crusher-plant feed is still screened at 32 mm, but it is rescreened at 75 mm instead of 38 mm. The fraction between 75 mm and 32 mm, amounting to 21 per cent of the total tonnage to the screening plant, is sorted photometrically, and the plus 75 mm material is reef-picked manually as before. It was anticipated from the start that the machines would reject a limited quantity of reef, which would have to be recovered manually by backpicking. The final reject from the fraction between 75 mm and 32 mm joins the plus 75 mm reject for disposal. A new waste dump was established to accommodate the final reject.

It was also anticipated that the reliability of the installation would equal, if not better, the 97 per cent availability achieved by the Doornfontein Model 13 since there had been considerable improvements in the mechanical and electronic functions, and there were two machines with a combined capacity of 140 t/h to sort 90 t/h. The installation allowed for the milling of the entire fraction between 75 mm and 32 mm during the very occasional periods when there might be complete failure of the sorter installation.

The installation allows for the rock between 75 mm and 32 mm to be conveyed on a new conveyor system from the rescreening screen discharge to the sorter feed bin in the new photometric sorter building. In the unlikely event of sorter failure, the plant can revert to the original flowsheet by the use of retractable shuttle conveyors.

The photometric sorting plant comprises an 80 t feed bin, feed-preparation systems (Fig. 6), sorters (Fig. 7) and associated control gear (Fig. 8) and air compressors, accept and reject return conveyors, and an undersize-dewatering system. The accept and reject rock streams

are conveyed to the reef-picking plant. The accept material joins the picked reef, and the reject joins the to-be-picked material for backpicking and final discard.

The main storage bin feeds two sorters operating in the fraction of material ranging from 75 mm to 32 mm. The design adopted is the conventional 'box' construction with timber walls. A natural dead cone is achieved above each of the two discharge points, thus giving the required protection against wear.

A Jöst feeder (Fig. 6) situated below each discharge point feeds material to the respective feed-preparation systems. These systems each comprise a Dabmar vibrating washing screen (Fig. 9) with 25 mm mesh polyurethane decking for the elimination of washings and fines. The fines/slimes fraction from these screens is dewatered on a common secondary Dabmar screen of 6 mm polyurethane mesh. The oversize from the dewatering screen discharges onto the feed conveyor to the main mill bin. The slimes are pumped via the crusher-plant dewatering screens to classifiers. The Dabmar dewatering system was installed when it became apparent that the quantity of grits generated in the transportation of material to the sorting plant would create a pumping problem.

Surges in washing-screen oversize — the sorter feed — are controlled through a small surge bin/chute. This chute is of very simple design and competes favourably with the elegant load-cell system used at Grecian Magnesite<sup>2</sup>. The chute discharges onto tandem feeders that control the manner in which the material reaches the main conveyor of the sorter.

Ambient light is kept to a minimum in the sorting plant since it can affect the sorting efficiency. All lighting



Fig. 8—Model 16 control room at West Driefontein

is directed away from the scanning cabinet, and daylight enters only through translucent fibreglass sheeting in the walls of the building.

The feed-preparation systems, the sorter mainframe, and the scanning cabinet that houses the optics systems are mounted on separate steelwork foundations. This has been done so that no unnecessary vibration will be transmitted to the optical system. This is standard technique in the design of Model 16 installations.

The accept and reject streams from each machine are combined on common conveyor-belt systems. This layout provides a simple and inexpensive discharge system, but has made the sampling and evaluation of individual machine performance inconvenient.

Nuclear-type weighers have been installed on the main feed belt and the reject belt. Owing to the non-uniformity of the particles, the weighers have not performed as well as anticipated, although they are proving to be reliable and need little maintenance.

The control room (Fig. 8) has been positioned to give a commanding view over both sorters and the associated feed-preparation systems. It contains the control panel and electronic processor for each sorter, as well as a custom-designed control panel for operating all the subsidiary systems of the sorting plant. Although this room has been constructed of brick and double glazing, noise is still a problem. This noise can be dampened by lining the bare steel 'blasting' compartments of each machine with brick, rubber, or cork.

Large double doors and crawl beams allow for quick mechanical service and maintenance. For example, the system allows for the changing of a complete stabilizer,

so avoiding disassembling and reassembling of the stabilizer *in situ* and the resultant loss of valuable production time.

### Installation of the Sorting Plant

The initial engineering was undertaken in May 1976, when the order was placed for the photometric sorters. This was undertaken by the Consulting Mechanical and Electrical Engineers' Department of Gold Fields of South Africa Limited with assistance from Ore Sorters' engineering staff. Tenders were issued in January 1977, and all the steelwork was completed by July 1977. The sorters were then installed, and their commissioning started in October 1977. Trial running was initiated in November 1977 with different feed systems on the machines. After certain modifications, the sorting plant became fully operational in February 1978.

Although the total elapsed time was approximately 20 months before the project was completed, this must be considered in relation to the technology and experience available at that time. The West Driefontein application, the first such installation in South Africa, was operating in a run-of-mine mode and was based on the experience of only one other operating sorting plant in the world. It was with these considerations in mind that a protracted installation was effected.

Two of the early problems that led to subsequent modification were as follows.

(i) *The Feed System on Number 2 Sorter*

It had been thought that the slide plate might be made redundant so that the feeding system would feed direct to the stabilizer/accelerator assembly.

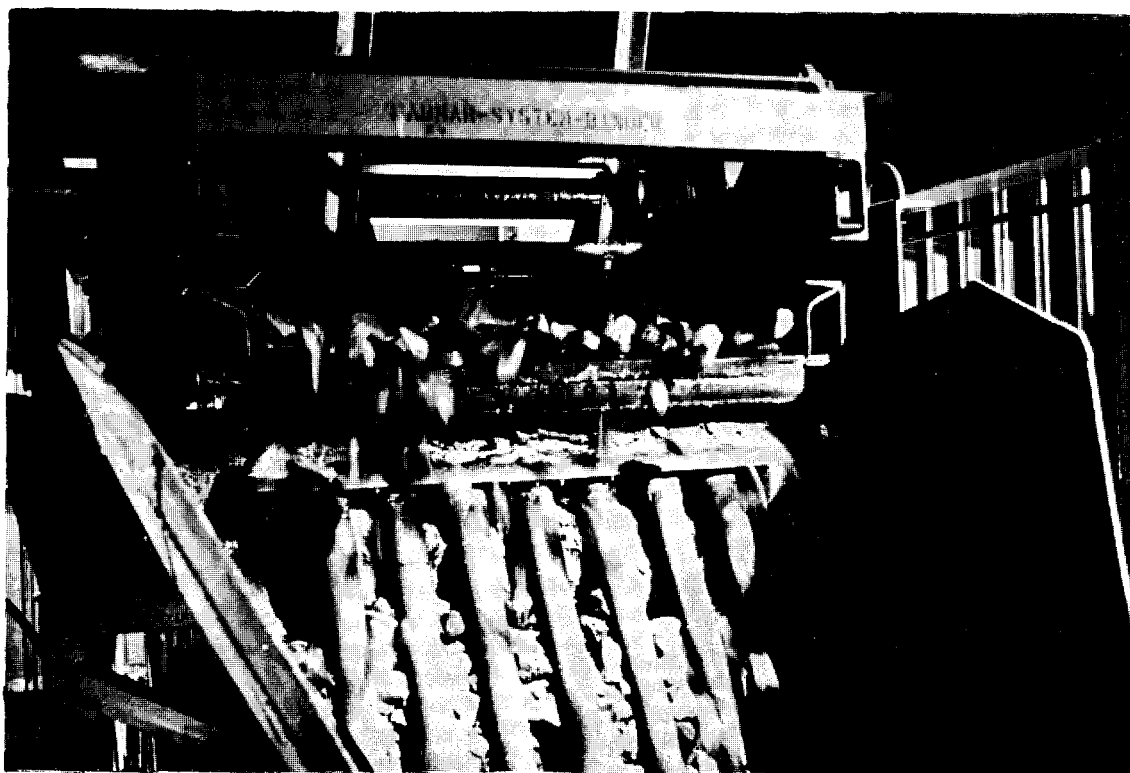


Fig. 9—Feed leaving the final washing screen, Model 16 at West Driefontein

This was found to cause significant instability and wear problems, and was modified within a very short time.

(ii) *The Fragmentation of Sorter Feed*

Despite in-line screening prior to transfer to the sorter plant, sufficient grits were generated in the transportation of the material to the sorter plant to create a problem in the pumping of the washings and fines from the feeding screens back to the main crusher plant. A 6 mm dewatering screen, for the elimination of grit, had to be introduced into the circuit.

### Operation and Maintenance

The Carbon Leader crusher plant operates for two 10-hour shifts each day. Daily maintenance is carried out between 08h00 and 12h00 on all sections of the plant, including the sorters.

The operating complement of the Model 16 sorter plant is five per shift, comprising the Shift Sampler, and

four general labourers. The Shift Sampler is responsible for all the operating, sample collection, and preparation, as well as for limited maintenance. Operating and maintenance problems beyond his terms of reference are referred to the Reduction Official in charge of the crushing plant, who in turn reports to the Supervisor of the crushing plant should mine maintenance staff be required. Ore Sorters' staff are called in only for major problems.

The five operators are responsible for the following:

- (i) clearing the feed-belt magnet of the sorter plant and removing tramp material such as wood and cloth;
- (ii) regulating the flow by visual checking of the feed hopper in the sorter plant (no automation is provided), a function that provides for the starting and stopping of the second sorter and the closing down of the plant as the feed demands;
- (iii) sampling the sorter feed, accept, reject, and total waste on an hourly basis;
- (iv) general housekeeping.

TABLE II  
ACTUAL SORTER PERFORMANCE

Fraction	1974			1978		
	Mass %	Value g/t	Gold %	Mass %	Value g/t	Gold %
Dark reef	24,1	23,15	82,0	13,75	34,39	75,37
Light reef	18,3	5,17	13,9	21,24	4,88	16,51
Dark waste	24,0	0,60	2,1	20,82	1,20	3,99
Light waste	33,6	0,41	2,0	44,19	0,59	4,13
	100,00	6,82	100,00	100,00	6,27	100,00

TABLE III  
SORTER PERFORMANCE AT 100 PER CENT EFFICIENCY

Fraction	1974			1978		
	Mass %	Value g/t	Gold %	Mass %	Value g/t	Gold %
Accept	42,4	15,40	95,9	34,99	16,47	91,88
Reject	57,6	0,49	4,1	65,01	0,79	8,12
	100,0	6,82	100,0	100,00	6,27	100,00

TABLE IV  
PREDICTED SORTER PERFORMANCE

Fraction	1974			1978		
	Mass %	Value g/t	Gold %	Mass %	Value g/t	Gold %
Accept	66,3	9,85	95,8	58,22	10,34	96,83
Reject	33,7	0,84	4,2	41,78	0,48	3,17
	100,00	6,82	100,0	100,00	6,27	100,00

TABLE V  
ACTUAL SORTER PERFORMANCE SINCE START-UP

Fraction	Feb.-Jun. 1979			Recent		
	Mass %	Value g/t	Gold %	Mass %	Value g/t	Gold %
Accept	58,97	10,04	94,44	63,47	10,02	96,27
Reject	41,03	0,85	5,56	36,53	0,67	3,73
	100,00	6,27	100,00	100,00	6,61	100,00

Further supervision of this plant amounts to less than 4 hours each day under normal operating circumstances.

An operational log-sheet is completed for each shift, and a log-book is kept in the control room in which all malfunctions, maintenance, and other anomalies in the plant are recorded.

The engineering staff keep records of the parts used and the time spent on engineering activities specifically associated with the sorting plant. The engineering time is normally two hours a day.

### Sorter Performance

The run-of-mine Carbon Leader ore in the size fraction between 75 mm and 32 mm can be readily separated into four fractions: light and dark reef, and light and dark waste. The 1974 test split and the 1978 run-of-mine material split up to the time of writing are shown in Table II.

Table III shows what a sort of 100 per cent efficiency would be on the materials listed in Table II, and Table IV shows the predicted sorts based on the 1974 test results.

The sort achieved from the start-up in February until the end of June 1979, based on weightometer readings and hourly samples of the sorter feed and of the accept and reject fractions, of which the first three months' results were separated into the four fractions before assaying, is shown in Table V, together with the most recent results.

The 1974 test results indicated that, at the then prevailing gold-extraction rate of 98,2 per cent, a gold price of R3678 per kilogram, and 1974 treatment costs, and allowing for the gold that would have been recovered by reef-pickers, an additional 101 kg of gold, yielding a monthly working profit of R318 000, would be realized. The capital pay-back period would be less than four months.

On the current sort, at the reduced throughput of the plant, some 63 kg of additional gold is being extracted. At a gold price of R5600 per kilogram and the present treatment costs, an additional working profit of R306 000 is being achieved. The capital pay-back period is still less than four months.

The profit calculations include the normal gold-extraction rate, and the cost of sorting, crushing, milling,

cyaniding and precipitation, smelting, refinery charges, and realization, with a credit for the cost that would have been incurred if the tonnage that is now being milled were dumped.

### Sorter Costs

The installation cost R1 135 000. The operating costs are as follows:

	R
Operating and maintenance labour	800 per month
Labourers including backpickers	2 820 per month
Power at 1,49c per unit	0,067 per ton of feed
Water	No charge
Spares	0,062 per ton of feed
Total cost at full capacity of 90 t/h	0,225 per ton of feed.

### Conclusion

It should be mentioned that the installation of photometric sorters at West Driefontein was contemplated at a time when long-term planning was aimed at a reduction of the mining rate in the Carbon Leader. The installation was planned to recover the maximum amount of gold from the fraction larger than 36 mm for the milling capacity that would become available at the reduced mining rate.

### Acknowledgements

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## Forging

The 9th International Forging Conference, organized by the Verein Deutscher Eisenhüttenleute (VDEh) in association with the Vereinigung Deutscher Freiformschmiedern (VDF), is to be held in Düsseldorf from 4th to 8th May, 1981. The purpose of the meeting is to show — as have the previous International Forging Conferences — the most recent advances in the field of open-die technology and to extend the international exchange of experience.

The following are the main topics envisaged for the Conference:

- A. Manufacture of forging on heavy open-die forging presses using special facilities and tools
- B. Special processes for the manufacture of forging grade ingots and their processing
- C. Experience gained with open-die forging of slightly ductile materials
- D. Measures for rationalization in forges
- E. Quality features of highly stressed heavy forgings.

Further information is available from the Verein Deutscher Eisenhüttenleute, Schmiedeausschuss, Postfach 82 09, D-4000 Düsseldorf 1, West Germany.