J. S. Afr. Inst. Min. Metall., vol. 84, no. 3.
Mar. 1984. pp. 57–63.

The performance of an industrial wet high-intensity magnetic separator for the recovery of gold and uranium

by I. J. CORRANS*, W. A. GILBERT§, K. S. LIDDELL†, and R. C. DUNNE‡

SYNOPSIS

After bench-scale and pilot-plant tests in which it was shown that wet high-intensity magnetic separation (WHIMS) can achieve good recoveries of gold and uranium from Witwatersrand residues, a production-size machine was installed at a gold mine. The mechanical and metallurgical performance of this machine have been satisfactory, and the economics of the process are attractive.

WHIMS can be combined with other unit operations like flotation for the optimization of overall gold and uranium recoveries. This concept is shown to be relevant, not only to operations for the retreatment of tailings, but to processes for the treatment of coarser material. In the latter, there is a saving in energy consumption compared with the energy required for the fine grinding of the total feed, and a material suitable for underground backfill can be produced.

Improved, more cost-effective WHIMS machines currently under development are also described.

SAMEVATTING

Na bankskaal- en proefaanlegtoetse waarin daar getoon is dat nat magnetiese skeiding by 'n hoë intensitiet (WHIMS) goeie herwinnings van goud en uraan uit Witwatersrand-residu's kan verkry, is daar 'n produksiegrootte masjien by 'n goudmyn geïnstalleer. Die meganiese en metallurgiese werkverrigting van hierdie masjien was bevredigend en die ekonomie van die proses is aantreklik.

WHIMS kan met ander eenheidsbewerkings soos flottasie gekombineer word vir die optimalisering van die totale goud- en uraanherwinning. Hierdie idee is nie net op bewerkings vir die behandeling van uitskotte van toepassing nie, maar ook op prosesse vir die behandeling van growwer materiaal. In laasgenoemde geval is daar 'n besparing in die energieverbruik vergeleke met die energie wat nodig is vir die fynmaling van die totale toevoer en 'n materiaal wat vir ondergrondse terugvulling geskik is, kan geproduseer word.

Beter en meer koste-effektiewe WHIMS-masjiene wat tans ontwikkel word, word ook beskryf.

Introduction

A paper[1] published some years ago discussed in detail the recovery, by wet high-intensity magnetic separation (WHIMS), of gold and uranium from many Witwatersrand cyanidation residues and some ores and flotation tailings. It was shown that WHIMS can recover over 50 per cent of the gold and uranium from many residues into a concentrate that usually varies between 6 and 12 per cent by mass of the original feed. Of further interest was the finding that WHIMS can also recover additional gold and uranium from the tailings of a flotation process that uses a cyanidation residue as feed, i.e. that WHIMS and flotation can complement each other. This finding was interpreted from the mineralogical point of view. Briefly, it was reported that most of the refractory gold remaining in the residues is intimately dispersed in pyrite or locked in silicates. Flotation recovers some of the former, and WHIMS some of the latter.

That paper[1] further described how the WHIMS process was tested on a continuous pilot-plant basis at two operating gold mines. During the tests, a major mechanical problem was brought to light, namely the tendency for the matrix of iron balls (6 mm in diameter) within the separator to become progressively blocked with ferromagnetic material and fine wood fibres. A solution to this problem was obtained by the development of a washing system that permits the balls used in the matrix to be continuously removed from the machine and, after being washed in a trommel screen, to be returned to the separator. Details of this washing system are given in a patent specification[2] and a paper[3].

With the washing system installed, several successful pilot-plant operations were carried out on cyanidation tailings from a mine in the Klerksdorp area. Typically, 55 per cent of the gold and 45 per cent of the uranium was recovered into a magnetic concentrate that was 14 per cent by mass of the original feed.

On the strength of the pilot-plant results, the mining group that had supported the tests decided to purchase and install two full-size WHIMS machines, each of which was fitted with the washing system described. One machine was installed at a fluorspar operation, where it is being used on a full-time basis to reduce impurities in the fluorspar concentrates; the other was used to treat part of the cyanidation residue from a gold mine in the Klerksdorp area.

This paper describes the experience obtained over the past three years in the installation, commissioning, and operation of the machine at the gold mine, and includes some brief comparisons, where relevant, of the performance of this machine with that of the machine at the

* Director
† Mineral Processing Engineer.
‡ Group Leader: Process Engineering.
All of the Ore-dressing Division, Council for Mineral Technology (Mintek), Private Bag X3015, Randburg, 2125 Transvaal.
§ Chief Consulting Metallurgist (Projects), General Mining–Union Corporation Ltd, P.O. Box 61820, Marshalltown, 2107 Transvaal.

SA ISSN 0038–223X/$3.00 + 0.00.

fluorspar operation. In general, all the information refers to the gold-mine operation, except where otherwise stated.

Description of the WHIMS plant

The flowsheet of the WHIMS installation at the gold mine is given in Fig. 1, and a general view of the plant in Fig. 2.

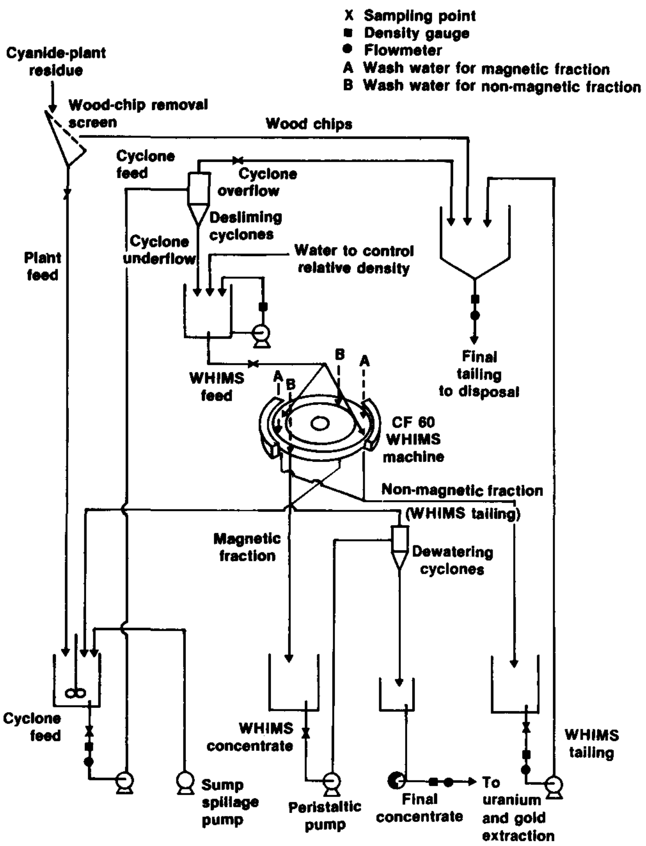

Fig. 1—Flowsheet of the WHIMS installation at a gold mine

Fig. 2—A general view of the WHIMS plant at a gold mine

A bleed sample of the residue is taken from the cyanidation plant and delivered onto a vibrating screen to remove as much of the wood-chip fibre as possible. The pulp (at a relative density of 1,4) is fed to the screen at a rate of 55 t/h. The screen is 1,8 m^2 in size and is fitted with a screen deck having 1 mm square apertures. The screen underflow passes to a 6 m^3 mixing tank, where its relative density is adjusted to 1,09 before the pulp is pumped to the desliming cyclones, which are arranged as a nest of polyurethane cyclones each 100 mm in diameter. The cyclone underflow passes to a holding tank, where water is added to adjust the relative density to 1,35. The pulp is then fed by gravity flow to the magnetic separator.

Two products are delivered by the WHIMS machine: a non-magnetic tailing and a magnetic concentrate. The concentrate is first dewatered and then pumped to an operating extraction plant for the recovery of the gold and uranium.

No desliming is carried out at the fluorspar installation, which has a much simpler plant with an improved layout.

Details of the WHIMS Machine

The WHIMS machine, an Eriez CF-60 model manufactured in South Africa, is illustrated schematically in Fig. 3. This is a double-pole type, the magnetic field being produced electrically in coils wound round an iron yoke. The carousel passes through gaps in the yoke, where the magnetic separation takes place. The outer diameter of the carousel is 3546 mm, and the matrix space is 150 mm wide and 200 mm deep. The carousel, which rotates at 1,1 r/min, has an inclined retaining grid fitted at the bottom and a flexible belt that retains the matrix of iron balls, which are 6 mm in diameter. The balls are removed for washing at one point, as described previously[1,3], and are passed through a trommel screen and washed with water sprays before being returned to the machine. The system for washing and returning the balls is illustrated in Fig. 4.

A maximum flux density of 1,0 T (tesla) could be produced in the air gap; however, the machine was normally run at 0,75 T by the use of a different tapping on the windings.

The CF-60 was designed to treat 30 t of dry solids per hour in a pulp of 40 per cent solids (i.e. 15 t/h at each pole pair). After the pulp has passed through the matrix between the poles, water is added to rinse any adhering non-magnetic material. At a point outside the field, the matrix is again washed with water to remove most of the magnetic material. (The external ball-washing system is designed to remove the remaining magnetic material.)

Mechanical Aspects of the Plant Operation

Desliming Cyclones

The desliming cylcones performed well, but were a continual source of irritation because the inlets and spigots were subject to blockage with scale that had broken loose from the inside of the pipes feeding the WHIMS plant. Standby cyclones were available, and were brought on-line when an operational cyclone became blocked.

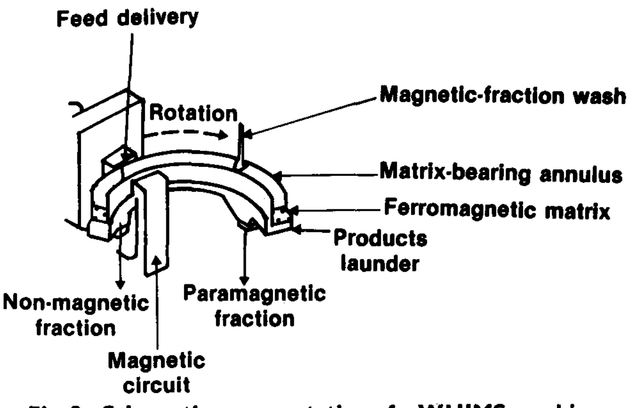

Fig. 3—Schematic representation of a WHIMS machine

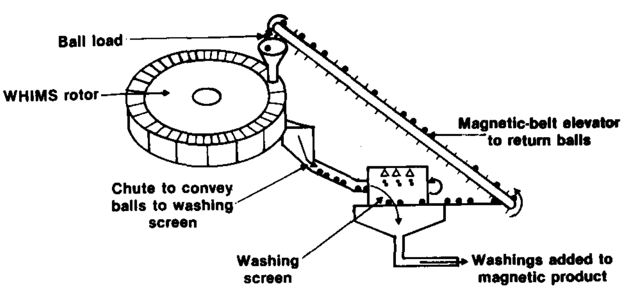

Fig. 4—The WHIMS rotor, showing the system for cleaning and returning the balls

WHIMS Machine

One of the most serious problems encountered on the machine was the fairly rapid build-up of lime scale on the grates that retain the balls in the carousel. This scale had a detrimental effect on the performance of the machine since it tended to impede the discharge of pulp from the matrix and thus reduced the effective feed rate. The extent of the scale problem can be clearly seen in Fig. 5. Before any testwork was carried out, the carousel was washed with acid to remove this scale but, over a period of a few days, the effect of scale could be easily observed. (Acid cleaning once a week is necessary to maintain adequate performance.)

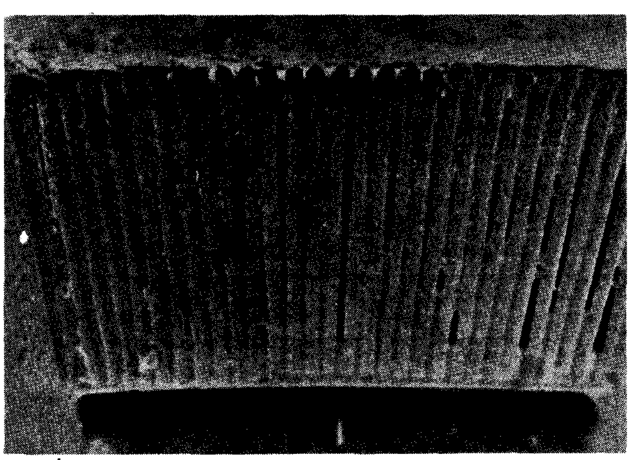

Fig. 5—Limed-up grates on a WHIMS machine

Several different types of material were tested on the belt that retains the balls in the machine. The best life was obtained from a nylon type of belt covered with soft rubber to withstand abrasion. Over 36 months, the average belt life at the gold mine was 30 days; at the fluorspar mine, it was 90 days.

Initially, serious problems were experienced with metal fatigue and cracking on the carousel caused by unbalanced forces acting on the central bearing. This could have been partly due to the fact that the two electromagnets were not interlocked electrically, and it was therefore possible for one of these to be switched on accidentally, thus causing severe strain on the central bearing. After the carousel had been redesigned to improve its rigidity, no problems were experienced.

Metallurgical Aspects of the Plant Operation

After the plant at the gold mine had been in operation for 18 months, a team from the Council for Mineral Technology (Mintek) was sent to the operation to assist the plant personnel to accurately sample the various streams and to evaluate the performance of the process.

Desliming Cyclones

Samples of cyclone feed, overflow, and underflow were taken during each shift for 17 continuous shifts. The three streams were sized, and the Tromp distribution calculated for each shift. The average d_{50} was found to be 17,3 μm with an E_p of 8,0. The cyclone underflow was calculated as 58,8 per cent by mass of the cyclone feed; this compares very well with the figure of 62,1 per cent that was obtained direct from the reliable mass-flow readings.

The average particle-size distribution of the feed to the desliming cyclones is shown in Table I, together with the size distribution for the same material during the pilot-plant tests in 1978. Clearly, the grind currently in use is much finer than that used previously, and this has increased the amount of uranium that is rejected in the slimes of the cyclone overflow.

TABLE I

AVERAGE PARTICLE-SIZE DISTRIBUTION OF CYCLONE FEED

Test	Year	% passing particle size indicated		
		< 75 μm	< 27 μm	< 12 μm
Plant tests	1981	84,4	60,1	40,1
Pilot-plant tests	1978	79,6	45,9	31,0

Complete mass balances for U_3O_8, gold, and sulphur are given in Table II. The upgrading of U_3O_8 into the cyclone overflow and the upgrading of gold and sulphur (pyrite) into the underflow are of particular interest. These effects were also evident during the previous pilot-plant runs.

On average, 23 cyclones were in operation. The relative densities of the pulp streams were 1,08 for the feed and 1,45 for the underflow.

TABLE II

MATERIAL MASS BALANCES FOR DESLIMING CYCLONES

Material	Mass flow of solids t/h	Mass %	Assay			Distribution, %		
			U_3O_8 p.p.m.	Au g/t	S %	U_3O_8	Au	S
Feed	53,4	100	172	0,308	0,308	100	100	100
Overflow	20,4	37,9	210	0,144	0,826	43,8	18,4	29,6
Underflow	33,0	62,1	164	0,363	1,2	56,2	81,6	70,4
Calculated feed			181	0,283	1,06			

WHIMS Machine

During the test period of 17 continuous shifts, samples of the WHIMS feed (desliming-cyclone underflow), WHIMS concentrates, and WHIMS tailings were taken accurately during each shift. Each sample was assayed for gold, uranium, and sulphur, and was sized. In addition, representative composite samples of the streams were prepared.

Mass balances were drawn up based on information on the feed, physical measurement of the concentrate flow, measurement of the tailings with a calibrated instrument, and, where necessary, the two-product formula. In general, the balance obtained was good, with good agreement between the measured and the calculated head values.

The mass balance for the WHIMS machine is given in Table III, and the overall mass balance for the whole plant in Table IV.

The recoveries of gold and uranium were good and up to expectation. However, the concentrate grades were lower than had been expected.

As an adjunct to the tests conducted on the operating WHIMS plant, a series of WHIMS batch tests was carried out at Mintek on samples of deslimed feed taken at the mine. In these tests, the plant conditions were simulated as closely as possible, iron balls from the operating machine being used in the batch machine and mine water for pulping and washing. The magnetic loading in the matrix was also similar. The solids content of the feed pulp for the batch machine was 40 per cent, and the magnetic flux density in the air gap was set to 0,85 T.

The results of the batch tests are given in Table V, with corresponding results for the large continuous machine in parentheses.

It can be seen that the distributions (recoveries) and the tailings grades for the batch tests and the large machine are similar, but that the concentrate grades obtained on the large machine are lower than those obtained by batch separation. The tailings assays and mass percentages for the concentrate indicate substantial dilution of the magnetic concentrate by the tailings during operation of the continuous machine. It is believed

TABLE III

MATERIAL MASS BALANCE FOR THE WHIMS MACHINE

Material	Mass flow of solids t/h	Mass %	Assay			Distribution, %		
			U_3O_8 p.p.m.	Au g/t	S %	U_3O_8	Au	S
Feed	33	100	164	0.36	1,2			
Concentrate (magnetic fraction)	5,01	15,2	633	1,32	2,07	56,4	51,4	25,1
Tailings (non-magnetic fraction)	28,0	84,8	84	0,21	1,08	43,6	48,6	74,9
Calculated head			164	0,37	1,22			

TABLE IV

OVERALL MATERIAL MASS BALANCE FOR THE WHOLE PLANT

Material	Mass flow of solids t/h	Mass %	Assay			Distribution, %		
			U_3O_8 p.p.m	Au g/t	S %	U_3O_8	Au	S
Cyclone feed	53,4	100	172	0,308	1,14			
Cyclone overflow	20,4	37,9	210	0,144	0,826	42,9	18,8	29,3
Concentrate (magnetic fraction)	5,01	9,5	638	1,32	2,07	32,2	43,2	17,8
Tailings (non-magnetic fraction)	28,0	52,6	84	0,21	1,08	24,9	38,0	52,9
Calculated head			181	0,29	1,07			

TABLE V

MATERIAL MASS BALANCE FOR WHIMS BATCH TEST

(The feed was a composite sample for 6 shifts; the values in parentheses are the results obtained on the large operating WHIMS machine for the same feed material.)

Material	Mass %	Assay U_3O_8 p.p.m.	Assay Au g/t	Distribution, % U_3O_8	Distribution, % Au
Feed	100	170	0,38		
Concentrate (magnetic fraction)	9,9	1187	2,25	58,8	59,8
	(15,7)	(633)	(1,36)	(56,3)	(51,8)
Tailings (non-magnetic fraction)	90,1	90	0,17	41,2	40,2
	(84,3)	(87)	(0,22)	(43,7)	(48,2)
Calculated head		199	0,37		

that two factors were chiefly responsible for this dilution effect: the build-up of scale on the ball-retaining grid during machine operation, and contamination of the WHIMS feed with calcine from an adjacent acid plant, both of which restrict the flow of pulp through the matrix with consequent flooding and entrainment of gangue in the concentrates. The calcine, which contains some magnetite, is recovered as a magnetic material that is not efficiently removed from the balls owing to its residual magnetism; if the calcine is excessive, it can block the matrix. In such a case, the WHIMS feed should first be scalped of ferromagnetic material by a low-intensity wet-drum separator. When scalping was carried out, the magnetic fraction, which represented 0,14 per cent of the original mass, was found to have a calcine content of 28,2 per cent, the rest of the material being mill steel with entrained quartz.

As proof that gangue is entrained in the concentrates, samples of the magnetic material from the large continuous machine were retreated on the batch separator. The grades of the concentrates produced were similar to those obtained in the original batch tests, while the gangue rejected as non-magnetic material was correspondingly low in uranium and gold. These results reinforce the conclusion that the concentrates were diluted by tailings.

The effect of the build-up of lime scale was clearly shown by the change in the U_3O_8 grades of the concentrates over a 6-day period. On day 1, the average U_3O_8 grade was 896 p.p.m.; on day 6, it was 532 p.p.m. On both days, the tailings grade was approximately 80 p.p.m.

A sample of lime scale was subjected to qualitative spectrographic analysis, which showed that the content of crystalline calcium carbonate was 99 per cent. An investigation is currently in progress on the manner in which the lime scale forms and the factors influencing its formation and growth.

Operating Costs

Details of the operating costs over a 12-month period during 1981/82 are given in Table VI.

A comparison of these costs with the operating costs of WHIMS at the fluorspar mine (as shown in Table VII) is of interest. No desliming is done at the fluorspar mine and to equate the cost with the gold mine cost, the figure of 41,8 cents per ton should be reduced by a factor of 0,6 (the desliming ratio in Fig. 6), bringing it to 26 cents per ton of desliming cyclone feed; 30 cents per ton would be a more realistic figure for a large, efficient WHIMS installation.

An example of the economics of a WHIMS installation according to Fig. 6 is given in Table VIII.

The feasibility of WHIMS in alternative flowsheets at other locations can be readily obtained in a similar fashion by use of the results given here for the operating costs of desliming and WHIMS.

TABLE VI

OPERATING COSTS AT A GOLD MINE, 1981–1982

Item	Rand	% of total	Cost* c/t
Power†	37 579	16,9	11,5‡
Balls	23 310	10,6	7,2
Water	22 782	10,3	7,0
Wages	50 020	22,6	15,4
Matrix belting	3 571	1,6	1,1
Maintenance	9 862	4,4	3,0
Screens and pumps	60 378	27,4	18,6
Consumables	13 736	6,2	4,2
Total (desliming + WHIMS)	221 238	100,0	68,0
Total (WHIMS only)			44,0

* Per ton of plant feed to the desliming cyclones, as per Fig. 6.
† Cost of electricity 1,64 cents per kilowatt-hour
‡ Cost of power for WHIMS machine itself 2,4 cents per ton

TABLE VII

OPERATING COSTS AT A FLUORSPAR MINE, 1982

Item	% of Rand	% of total	Cost c/t*
Power†	30 510	41,4	17,3
Balls (2735 kg)	16 878	22,9	9,6
Water	9 379	12,8	5,3
Wages	7 200	9,8	4,1
Matrix belting	4 734	6,4	2,7
Maintenance	4 983	6,7	2,8
Total (WHIMS only)	73 684	100	41,8

* Per ton of feed to WHIMS machine, no desliming done
† Cost of electricity 3,34 cents per kilowatt-hour

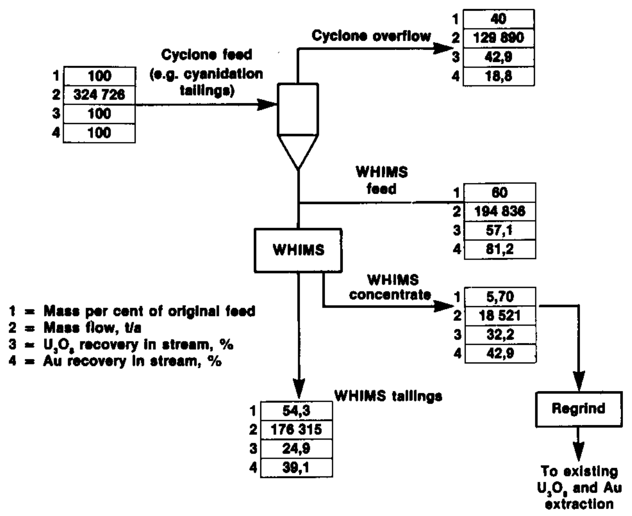

Fig. 6—Mass flow and recoveries on a gold mine

TABLE VIII

AN EXAMPLE OF THE POTENTAIL PROFITABILITY OF WHIMS AS SHOWN IN FIGURE 6

(All costs are per ton of plant feed, i.e. cyclone feed, based on an operation of 400 kt per month)

Item	Au		U_3O_8
Head grade, g/t	0,5		175
Recovery by WHIMS, %	43,2		32,2
Recovery by existing leach, %	90		90
Recovery by WHIMS, g/t	0,19		51
Gross revenue, R/t	2,85		4,10 (6,95 total)
Operating cost* of WHIMS and desliming, R/t		0,54	
Operating cost of regrinding, R/t		0,11	$(2,00\times0,057)$†
Leaching cost, R/t	0,30		0,50
Total operating cost, R/t		1,45	
Net operating profit, R/t		5,50	
Estimated amortization, R/t		0,60	
Profit, excluding tax, including amortization, R/t		4,90	

* WHIMS 30 cents per ton; desliming 24 cents per ton

† Concentrate 5,7 % by mass of feed

Discussion

The two operating WHIMS machines gave good recoveries of gold and U_3O_8, indicating that WHIMS installations can be highly profitable. The direct operating costs were as low as 30 cents per ton of feed to produce a magnetic concentrate containing up to 55 per cent of the gold and 45 per cent of the uranium.

Further work is needed to provide more detailed information on the technical aspects and cost of the downstream treatment of concentrates for the recovery of gold and uranium. Various processes warrant investigation and optimization. Mintek is currently engaged in this field, and is examining, *inter alia*, fine grinding, leaching for uranium and gold, and the precipitation of values by resin or carbon or both.

It must be clearly understood that, when optimizing the recovery of gold from residues, one is dealing essentially with residual refractory gold. Unit operations do not necessarily then become mutually exclusive, but rather, for mineralogical reasons, complement each other. Very simply stated, Witwatersrand residues contain some free gold, some gold in sulphides (mainly pyrite), and fine gold locked within various silicate minerals. Straight leaching with cyanide recovers free gold, flotation recovers pyrite, and WHIMS recovers much of the silicate-locked gold and some of the free gold. The mineralogical reasons for the magnetic recovery of gold have been given previously[1,4], the main reason being the presence of iron impurities and coatings. It is not economically feasible for gold locked in pyrite or silicate minerals to be liberated by grinding of the total feed, but, after the production of a reduced mass of concentrate, roasting (for pyrite) and fine grinding (for silicates or pyrites) can liberate these materials.

Essentially, the same arguments hold true for the recovery of uranium, although the mineralogical interpretation is far more complex.

When one is operating a plant for the retreatment of residues, it is of prime importance to ensure the maximum economic recovery of gold and U_3O_8. While the pulp is in transit, an additional unit operation is far more feasible than further retreatment at a future date. It seems unlikely that residues, already treated twice and running at under 0,2 g/t, will ever be reclaimed from slimes dams for yet further treatment.

The necessity for the production of backfill for deep-level mining is becoming ever more important. At grinds coarser than the grinds conventionally used for cyanidation of the whole feed, it is easier for backfill to be produced and placed within worked-out stopes. However, at coarse grinds, the recovery of gold by cyanidation decreases. Much of the technology applicable to the treatment of refractory residues is, however, applicable to the optimization of gold and uranium recovery from pulps that have been subjected to a coarser primary grind, i.e. the unit operations complement each other. In particular, it has already been demonstrated that the use of WHIMS with coarser primary grinds is feasible[1].

At a grind of 50 per cent passing 75 μm, excellent recoveries of gold and uranium can be achieved by a combination of gravity concentration, WHIMS, and leaching. A uranium concentrate can also be produced from a feedstock not normally suitable for the extraction of uranium. By the use of a much coarser primary grind, energy savings of up to 10 kW·h per ton of feed are possible in milling, and the costs due to liner wear are reduced.

The present-generation WHIMS machines tested in this investigation have a maximum throughput of approximately 35 t/h under ideal conditions at a minimum cost per unit in 1983 of R350 000, i.e. R10 000 per ton of feed capacity. Because the intrinsic design incorporates a heavy iron yoke, it is unlikely that larger machines can be built. This has two distinct drawbacks: the cost-effectiveness cannot be improved substantially, and any large-capacity operation could require well over fifty individual machines. Problems associated with feed distribution, the pumping of tailings and concentrates, maintenance, etc., become enormous.

The problem of large-capacity machines has already, at least partially, been solved. Large, third-generation WHIMS machines have been built in which the iron-yoke system is eliminated by the utilization of a solenoid concept. For Witwatersrand residues, these machines have an estimated capacity of 150 t/h. However, the problem of matrix blockage on these machines is still an unknown factor, and the cost-effectiveness is no better than R10 000 per ton of feed and may be worse.

Mintek is currently working on the development of a large-capacity WHIMS machine with a throughput of up to 250 t/h. The cost-effectiveness of this machine could be between R2000 and R3000 per ton of feed. The machine is being designed with a matrix-washing system to overcome blockages. The lower unit machine cost will make it possible for the flowsheet to be simplified by elimination of the desliming cyclones. (These were installed only because recovery in the slimes fraction is low, and capacity in high-cost machines is somewhat wasted.) This, in turn, will mean that the overall capital costs and operating costs will be lower than those for current WHIMS installations.

Acknowledgements

The authors thank the management and staff at both mines for the assistance received during the testwork and in the gathering of cost information. The paper is published by permission of the Council for Mineral Technology (Mintek) and General Mining–Union Corporation Limited (Gencor).

References

1. Corrans, I. J., and Levin, J. Wet high-intensity magnetic separation for the concentration of Witwatersrand gold–uranium ores and residues. *J. S. Afr. Inst. Min. Metall.*, vol. 79, no. 8. Mar. 1979. pp. 210–228.
2. Corrans, I. J. Improvements in or relating to magnetic separators. *S. Afr. Pat.* no. 78/1467. 14th Mar., 1978.
3. Corrans, I. J. A development in the application of wet high-intensity magnetic separation. *INTERNATIONAL SYMPOSIUM ON FINE PARTICLES PROCESSING, LAS VEGAS, NEVADA, FEBRUARY, 1980. Somasundaran, P. (ed).* vol. 2. New York, AIME, 1980.
4. Levin, J. Wet high-intensity magnetic separation. Laboratory tests conducted in 1978 and 1979. Randburg, Council for Mineral Technology, *Report* 2076. Nov. 1980. 51 pp.

IMM awards

Given below are details of the trust funds to which application are invited for grants payable in 1984. Application forms, which must be returned to the Secretary before 15th March, 1984, are available on request. Applicants should note that, in general, preference will be given to members of the Institution.

Bosworth Smith Trust Fund

Approximately £2000 will be available in 1984 for grants from the Bosworth Smith Trust Fund for the assistance of post-graduate research in metal mining, non-ferrous extraction metallurgy, or mineral dressing. Applications will be considered for grants towards working expenses, the cost of visits to mines and plants in connection with such research, and the purchase of apparatus.

Stanley Elmore Fellowships

Applications are invited for Stanley Elmore Fellowships, which are awarded by the Institution and are tenable at United Kingdom universities, for research into all branches of extractive metallurgy and mineral processing. Fellowships to the value of £1500 to £6000 per annum will be available from October 1984.

G. Vernon Hobson Bequest

Applications are invited for awards from the income of the G. Vernon Hobson Bequest, established for 'the advancement of the teaching and practice of geology as applied to mining'. It is expected that approximately £1000 will be available in 1984. One or more awards may be made for travel, research, or other objects in accordance with the terms of the Bequest.

Edgar Pam Fellowship

The Edgar Pam Fellowship will be awarded in October 1984 for post-graduate study in subjects within the Institution's fields of interest, which range from exploration geology to extractive metallurgy. Those eligible for the award are young graduates, domiciled in Australia, Canada, New Zealand, South Africa, and the United Kingdom, who wish to undertake advanced study or research in the United Kingdom. The value of the Fellowship, which is tenable for one year, will be of the order of £1300.

Application forms for Institution awards may be obtained from The Secretary, The Institution of Mining and Metallurgy, 44 Portland Place, London W1N 4BR. Telephone 01-580 3802; telex 261410.