

precipitation with zinc in single-stage reactors on a batch basis, gold-bearing filtrates from the intensive cyanidation being combined with the eluate from elution. The precipitates will be recovered by the use of three pre-coat rotary-drum vacuum filters. Testwork has shown that de-aeration, addition of lead nitrate, and acid treatment are not required. The precipitates will be calcined and smelted in submerged-arc furnaces.

### Contracts

The major civil contract for the ore-receiving bins, mill-feed silos, and mill building was awarded in March 1984.

In April 1984, a second civil contract was awarded for the thickening plant, and for the leaching and adsorption areas. All this work is virtually complete.

A contract for structural steelwork for the mill building and conveyor gantries started in June 1984 and will be complete by the third quarter of 1985. Work is in progress on the platework in the leaching and adsorption areas, and is due for completion in August 1985. Contracts for piping, mechanical work, and electrical installations have been awarded and are due to start in June 1985. Contracts for the installation of the instrumentation will be allocated in July.

## Mintek reports

The following reports are available free of charge from the Council for Mineral Technology, Private Bag X3015, Randburg, 2125 South Africa.

### Report M161

*Improved recoveries of gold from auriferous calcines and pyrites by fine milling.*

Ultra-fine milling of gold-bearing calcines prior to leaching in cyanide is a method that will lead to higher gold recoveries than at present. The economic implications are better for calcines that emanate from refractory ores since they contain more occluded gold.

Milling to between 80 and 90 per cent finer than 11  $\mu\text{m}$  resulted in 36 per cent more gold being extracted from the calcine residues originating from non-refractory gold ores, whereas 40 per cent more gold was extracted from those originating from refractory ores.

For gold-bearing pyrite concentrates, ultra-fine milling resulted in improved gold extractions, but more work on the optimization of the leaching conditions is required. Costs are not available for the ultra-fine grinding of calcines and pyrites since this technique is not currently employed on a plant.

The recovery of gold from the solutions produced by the leaching of finely milled calcine residues and pyrite concentrates requires some consideration. Problems are likely if activated carbon is used in this treatment because of blockage of the carbon micropores by fine calcine or pyrite that is generated in the milling step.

### Report M171

*The development of a versatile computer programme for the evaluation of batch-flotation results.*

The computer programme, which is designed for use with the Apple 64K minicomputer, can evaluate batch-flotation results by the use of any one of five different flotation models and can evaluate the batch-flotation results for more than one valuable mineral species in an ore at a time.

All the relevant results for recovery and grade can be presented in tabular and graphic form to facilitate the comparison of flotation results and of flotation models. Curves for recoveries and grades determined in experiments and those predicted by a model can also be plotted.

Several options are incorporated in the programme, making it versatile and easy for an operator to use.

### Report M178

*The reduction of chromite in a transferred-arc plasma furnace.*

The reduction of low-grade chromite ores by the use of transferred-arc plasma technology instead of submerged-arc technology was investigated. The experiments on chromite were performed 'in bath' in a transferred-arc molten-anode plasma furnace and 'in flight' in a transferred-arc ancillary-anode plasma furnace. The effects of controllable furnace parameters on the reduction are reported and discussed.

Complete in-bath reduction of chromite was readily accomplished when the furnace parameters were balanced correctly since these parameters are related to both the chromium chemistry and the plasma arc. Although the dissolution of chromite into the slag was accomplished each time, the conditions were not always adequate for the complete reduction of chromite from the slag once it had been dissolved. This situation was overcome by the use of chromite and reducing agent of the correct particle sizes, or by control of the arc as a uniform source of heat.

Complete in-flight reduction of chromite was not accomplished. However, when a number of furnace parameters was controlled, 50 per cent of the total chromium and 60 per cent of all the iron oxide were reduced within the arc.

It was found that, besides the expected influence of the chemical reactions resulting from the smelting of chromium, the following parameters controlled the reduction: arc power, arc length, cathode design, flowrate and composition of the primary plasma gas, arc rotation, anode design, and feed rate.

Recommendations are made for further research in this area.

### Report M179

*Optimization of an inductively coupled plasma by the simplex method.*

A 5 kW nitrogen-cooled, argon inductively coupled plasma (ICP) was used in an investigation on the basic and modified simplex methods of optimization. The optimum conditions for plasma operation were found for the analysis for 23 commonly determined elements covering a wavelength range from 180 to 340 nm and including an approximately equal number of atomic and ionic lines.

Initially, the optimization of the operating conditions for the plasma was applied to single-element analysis on

the basis of two responses: net signal-to-background ratio (SBR) and interference due to ionization in the plasma.

During this preliminary investigation, the elegance and speed of the modified simplex technique in the determination of the optimum conditions for the plasma became apparent, as did the need for an improved nebulization system. Once the nebulization system had been improved, more material reached the plasma, and the application of the simplex technique then required higher power to be applied to the plasma to yield optimum conditions. The SBRs and detection limits improved significantly.

In experiments aimed at the achievement of maximum SBRs, interesting correlations were found between the optimum power required on the one hand, and the difficulty of excitation of the elements and the determination of the optimum flowrate of the intermediate gas on the other, which throw some light on the question of whether local thermal equilibrium exists in the argon-nitrogen plasma.

Finally, a method was devised for the optimization of the operating conditions for the plasma in multi-element analysis, based on the sequential use of the maximum SBRs and the minimum interference due to ionization in the plasma. This method was tested successfully against several routine analytical methods. It permits the rapid determination of the optimum conditions for the plasma under which the loss in the SBRs of the individual elements is less than 25 per cent, and the interferences due to ionization in the plasma (aqueous solution relative to a sodium solution) are generally less than 8 per cent. These conditions result in an analytically useful plasma that gives good detection limits as well as minimum interference effects due to ionization in the plasma.

#### **Report M182**

*A techno-economic evaluation of five routes for the comminution of gold ores in South Africa.*

The following routes for the comminution of gold ores are examined:

- (1) crushing followed by primary and secondary pebble milling,
- (2) crushing followed by primary ball milling and secondary pebble milling,
- (3) crushing followed by primary rod milling and secondary pebble milling,
- (4) semi-autogenous run-of-mine milling, and
- (5) semi-autogenous run-of-mine milling followed by secondary ball milling.

It is shown that, unless there is a strong case for waste sorting or definite benefits result from the adoption of the conventional routes, routes 1 to 3 can be ignored.

Crushing is considered to be more energy-efficient than grinding, but the advantages are offset to some extent by the power required for additional conveying, screening, pumping, and so on. The total power requirements for the five routes evaluated are similar.

The capital costs for semi-autogenous run-of-mine milling (route 4) are higher than for semi-autogenous run-

of-mine milling followed by ball milling (route 5), but the operating costs are lower.

#### **Report M183**

*The determination of molybdenum and tungsten in resin by X-ray-fluorescence spectrometry.*

This report describes a method using X-ray-fluorescence spectrometry for the determination of molybdenum and tungsten in ion-exchange resins.

The dried resin is milled with sand, binder, and an internal-standard mixture before being briquetted. Niobium and zinc are used as the internal standards for molybdenum and tungsten respectively. Intensity measurements are made with the gold anode tube. Corrections are made for the interference of the Mo  $K\alpha$  analytical line on the background intensities used for the Mo  $K\alpha$  and Nb  $K\alpha$  lines. The precision of the analysis for molybdenum ranges from a relative standard deviation of 0,02 at 5 mg/g to 0,045 at 55  $\mu\text{g/g}$ ; for tungsten, the relative standard deviation ranges from 0,04 at 5 mg/g to 0,055 at 55  $\mu\text{g/g}$ . The limits of determination in the original resin sample were found to be 40  $\mu\text{g/g}$  for molybdenum and 80  $\mu\text{g/g}$  for tungsten.

The laboratory method is given in an appendix.

#### **Report M184**

*The analysis of silicates, ores, slags, and other materials by X-ray-fluorescence spectrometry.*

The recommended procedure is applicable to a wide range of samples. Mineralogical effects are eliminated by fusion and grinding of the samples; this avoids the difficulties often encountered in the preparation of glass beads with flat surfaces. Matrix effects are reduced to an insignificant level by the addition of a heavy absorber in the form of lanthanum oxide. The calibrations are linear over wide ranges of concentrations, and the calibration standards are interchangeable.

The accuracy has been assessed as good relative to chemical analyses and to the analysis of reference materials. Relative standard deviations,  $s_r$ , range from 0,050 (at concentrations of 0,5) to 0,005 per cent (at concentrations greater than 20 per cent).

The measurements are made on a Siemens MRS 400 MP simultaneous X-ray-fluorescence spectrometer, the high sensitivity enabling limits of determination between 0,02 and 0,05 per cent in the sample to be achieved. Alternatively, a Siemens SRS 200 sequential X-ray-fluorescence spectrometer or an equivalent spectrometer can be used.

#### **Report M188**

*Determination of relative sensitivity factors for use in spark-source mass spectrometry.*

Six synthetic standards were prepared containing various combinations of 40 elements in a matrix of 90 per cent silver. These synthetic standards were analysed by spark-source mass spectrometry, and a large suite of relative sensitivity factors was compiled by the use of 22 internal standards.