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Improvements in stabilizing control at Black Mountain

by T.R. TWIDLE*, P.C. ENGELBRECHT†, and J.W.S. KOEL‡

SYNOPSIS

The process flows of the three flotation circuits at the concentrator of the Black Mountain Mineral Development Company (Pty) Ltd are described. Because of the complexity of the circuits and the associated reagent régime, the plant is equipped with a comprehensive range of control equipment.

The different process-control strategies are discussed, and the modifications that have been necessary to the stabilizing control loops in the copper, lead, and zinc flotation circuits are shown in detail. It is concluded that the control strategies have continued to bring about benefits and improvements to the process.

SAMEVATTING

Die vloei diagram van die drie flotasie stroombane by die Black Mountain Mineral Development Company (Pty) Ltd aanleg word beskryf. As gevolg van die kompleksiteit van die vloei en die samehangende reagense stelsel, is die aanleg voorsien van 'n omvangryke reeks van beheer uitrusting.

Die verskillende prosesbeheer strategie word bespreek en die veranderings wat in die stabiliserende beheerlusse van die koper, lood en sink stroombane genoodsaak was, word in detaïl getoon. Daar word tot die gevolgtrekking gekom dat die beheer strategie voortdurende verbeteringe en voordele vir die proses inhou.

Introduction

Black Mountain Mineral Development Company (Pty) Ltd, which is located in the north-western Cape Province of South Africa, is currently treating 1,125 Mt of complex sulphide ore from the Broken Hill deposit per annum. The economic minerals present are chalcopyrite, galena, and sphalerite, together with associated silver. The gangue minerals consist mainly of magnetite, pyrite, pyrrhotite, amphibolite, and, to a lesser extent, garnets, free silica, and feldspar.

After crushing and grinding, copper, lead and zinc concentrates are produced by sequential flotation, with silver reporting primarily to the lead concentrate and to a lesser extent to the copper concentrate. Because of the complexity of the flotation circuits and the reagent régime, the plant is equipped with comprehensive on-line analysing and control systems.

Ore Processing

The concentrator is designed to treat 1,125 Mt per year of copper–lead–zinc ore containing 0,6 per cent copper, 9,0 per cent lead, 2,4 per cent zinc, and 131 g/t silver. The annual output is 22,7 kt of copper concentrate, 133,7 kt of lead concentrate, and 35,1 kt of zinc concentrate.

After initial crushing underground at 150 mm, the ore is hoisted to surface and conveyed to five storage silos. Two further stages of crushing reduce the ore to a top size of 16 mm, after which it is stored again prior to milling.

The grinding circuit comprises a rod mill in open circuit and a ball mill in closed circuit with hydrocyclone classifiers. The circuit is designed to grind 141 t/h to a final size of 75 per cent less than 74 μm.

The addition of reagents starts in the milling circuit. Minerec 2030 (isopropyl ethyl thionocarbamate) for the collection of copper and zinc sulphate for the depression of sphalerite are added to the rod mill.

After grinding and prior to copper flotation, the pulp is subjected to aeration for either 15 or 30 minutes as conditions dictate. This ensures that the redox potential of the pulp is at the correct level for successful copper flotation.

Copper Flotation

The pH value of the pulp is adjusted to between 7,2 and 7,8 by the addition of sulphurous acid. Collectors Xanthate Z-4 (sodium ethyl xanthate) and Minerec 2030, together with FBM2 frother (a mixture of alcohols and polyglycols), are added during two stages of conditioning. Copper rougher flotation with a further addition of sulphurous acid produces a concentrate that is sent direct to cleaning. Sodium ethyl xanthate is added to the rougher scavenger flotation, and the concentrate is recycled to the first conditioner.

Cleaning is done in either two or three stages, the final concentrate being pumped to the copper concentrate thickener. The addition of sulphurous acid to the first cleaning stage reduces the pH value to 6,5, and the first cleaner concentrate is heated to 60°C with 'live' steam before cleaning. Lime is fed intermittently to the second cleaner to loosen the froth and depress pyrite. Sodium ethyl xanthate is used intermittently in the first cleaning

* Plant Superintendent.
† Assistant Plant Superintendent.
‡ Senior Plant Metallurgist.
All the above of Black Mountain Mineral Development Co. (Pty) Ltd, Private Bag X01, Aggeneys, 8893 Cape Province.

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stage in conjunction with a cleaner–scavenger bank to ensure a good recovery from the cleaner circuit.

The cleaner–scavenger tailings are recycled to the first conditioner, and the rougher–scavenger tailings are directed to lead flotation.

Copper recovery is more than 72 per cent, with a silver recovery of 13 per cent, into a concentrate containing 26,0 per cent copper, 4,5 per cent lead, 3,5 per cent zinc, and 850 g/t silver.

Lead Flotation

The first lead cleaner tailings, together with the rougher–scavenger tailings from the copper flotation, are thickened prior to being fed to four conditioners in series. Lime is added to the first conditioner to raise the pH to 8,5, and sphalerite is depressed with zinc sulphate and calcium cyanide. Sodium ethyl xanthate and Cyanamid R242 (salts of aryl dithiophosphoric acid) are added in the third conditioner as collectors, and MIBC (methyl isobutyl carbinol) is added as frother in the last conditioner.

The rougher concentrate is cleaned three times, and the final concentrate, grading 70 per cent lead and 750 g/t silver, is pumped to the lead concentrate thickener. Collectors are stage-added in the second roughers and rougher–scavengers, and the rougher–scavenger concentrate is recycled to the first conditioner.

The recoveries of lead and silver are 91 per cent and 72 per cent respectively, giving an overall silver recovery of 85 per cent from copper and lead flotation.

Zinc Flotation

Lead rougher–scavenger tailing is sent direct to zinc flotation. After the addition of lime to a pH value of 9,5, sphalerite is reactivated with copper sulphate and is collected either with Minerec 2030 or Xanthate Z-4; MIBC is added to the first rougher. Copper sulphate and Xanthate Z-4 are added as required on an intermittent basis to the second rougher and rougher–scavenger cells respectively.

The rougher concentrate is cleaned in three stages at a pH value of between 10,0 and 11,0, and is then sent to the zinc concentrate thickener. A cleaner–scavenger stage returns concentrate to the first cleaner and the rougher–scavenger concentrate and cleaner–scavenger tailings are recycled to the head of the circuit. The zinc rougher–scavenger tailing is cycloned when required for backfill feedstock, and is then impounded on a tailings dam.

A zinc recovery of 76 per cent is achieved into a concentrate containing 50,5 per cent zinc.

Concentrates

After thickening, the individual concentrates are filtered and stored, and are then transported by road, rail, and sea to local and overseas smelters.

Process Control Equipment

The process control equipment at Black Mountain has three principal components: field instrumentation, the Courier 300 on-stream analyser, and the Proscon system.

Field Instrumentation

The field instrumentation consists of mass flowmeters, pulp-density meters, pH probes, automatic air valves, and float sensors (to measure the level in the flotation cells) together with transmitters and reagent feeders.

The plant was originally equipped solely with cup-and-disc reagent feeders incorporating an adjustable splitter, but these are being gradually replaced by either peristaltic or pulsating variable-speed pumps. This is because the cup-and-disc feeders were shown to exhibit a hysteresis effect when the feed rate was varied over the entire span from zero to maximum and then back to zero, and different rates of addition were measured at the same splitter setting on each cycle. In addition, the variable-speed pumps are totally enclosed, thus eliminating the spillage that used to occur from the cup-and-disc feeders, which was fairly significant. A further benefit is that, because the variable-speed feeders are not constantly splashed with chemicals, their maintenance and upkeep costs are substantially lower than those of the cup-and-disc feeders.

On-stream Analyser

The Courier 300 system serves as the foundation of all the flotation control strategies and provides on-stream analysis of fourteen process streams. Copper, lead, zinc, iron, and percentage solids are measured on all the streams, and silver is analysed on four streams. The processing of the X-ray counts and the movement of the measuring head are controlled by a PDP 11/34 32K computer. A multiple linear-regression model is used in the calculation of the assay values.

The analytical principle employed is that of X-ray fluorescence. Because of the complex matrix effects and variable metal ratios in the ore, continuous updating of the instrument's calibration parameters is essential. To this end a complete set of calibration samples is taken on three days a week for wet-chemical analysis.

After the initial problems of pumping and presenting the sample slurries to the analyser had been resolved, it was found that the single most important factor influencing the availability of results was the pulp density of the slurry samples. Since the results of X-ray fluorescence are affected by pulp density, only a narrow range of pulp density is permissible on each stream. Outside these limits, no result is recorded and an alarm is raised, indicating the nature of the problem to the operating staff.

The accuracy of the Courier 300 analyses has been found to be good, and the principal objective has been to maintain an adequate availability of slurry to the analyser. Availabilities of more than 90 per cent have been achieved regularly, and the present aim is to raise this to 97 per cent on all streams. The average availabilities over one year and the quality of the Courier analyses based on calibration data for a three-month period are depicted in Table I. It will be seen that the problematical slurries as regards availability are the three tailings samples and the copper rougher concentrate. The coarser size distribution in the tailings streams has tended to cause blockages; to counteract this, water is added to the primary sample, but this can cause pulp-density alarms.

The highly variable flow and composition of the copper rougher concentrate has similarly led to an unsteady pulp density of the sample slurry. A smoothing effect is given by the copper tailings thickener to the lead and zinc rougher flotation, thus preventing a similar problem in

TABLE I
SUMMARY OF COURIER AVAILABILITY AND ACCURACY

Sample stream	Availability %	Copper, % A	Copper, % B	Lead, % A	Lead, % B	Zinc, % A	Zinc, % B
Flotation feed	93	8,0	8,7	10,0	10,2	7,0	7,6
Copper rougher concentrate	88	8,0	7,9	12,0	10,6	12,0	10,4
Copper rougher–scavenger concentrate	93	20,0	13,3	15,0	14,9	20,0	11,1
Copper final tailings	88	15,0	15,0	15,0	9,8	10,0	8,8
Copper cleaner–scavenger tailing	92	15,0	15,9	12,0	9,2	20,0	22,1
Copper final concentrate	92	6,0	5,6	10,0	8,6	12,0	14,9
Lead rougher concentrate	94	12,0	11,7	6,0	7,3	8,0	8,9
Lead first cleaner tailing	95	25,0	32,0	10,0	11,2	15,0	14,9
Lead final concentrate	95	25,0	19,0	3,0	3,4	15,0	6,6
Lead rougher–scavenger tailing	84	25,0	29,1	10,0	11,5	12,0	13,7
Zinc rougher concentrate	90	20,0	18,6	20,0	28,4	8,0	7,9
Zinc cleaner–scavenger tailing	94	30,0	44,3	20,0	18,8	12,0	15,9
Zinc rougher–scavenger tailing	85	30,0	33,7	20,0	13,8	20,0	25,4
Zinc final concentrate	94	20,0	11,3	15,0	17,5	3,0	1,5

A = Target relative error B = Actual relative error

those circuits.

As a result of the gradual improvement in the Courier analyses, the shift-control samples, which were initially done in the laboratory on a two-hourly basis throughout the day, have been completely eliminated. This has meant a reduction of fifteen thousand determinations per month by atomic-absorption spectroscopy in the laboratory since the start of operations.

Proscon System

The Proscon (process control) system comprises two computers: the Proscon 103, which uses a PDP 11/34 32K processor and works in real time, and the Proscon 105, which has a separate stand-alone PDP 11/34 128K processor that employs a time-sharing system. The Proscon 103 is interfaced with the Courier system and with the field instrumentation through a Foxoboro Spec 200 array; it drives the process operator's console and reporting typewriters, and executes control functions.

Such variables as ore feed, water addition, reagent feed rates, air addition to the flotation cells, and pulp levels in the flotation cells are monitored and controlled. The control functions use direct P.I.D., ratio, and cascade control.

The Proscon 105 is used principally for higher-level control strategies, for the storage and processing of metallurgical data, and as a tool for metallurgical investigations. The system's peripherals include two RK06 disc drives, two RX 11 floppy-disc drives, two high-speed printers, two hard-copy terminals, five video terminals, and an X–Y plotter.

Process Control Strategies

Three levels of process control in the flotation circuits can be executed with the Proscon system. In order of increasing complexity, they are as described below.

Direct Digital Control (DDC)

Direct digital control is implemented by the Proscon 103 system to operate control devices (e.g. air valves and reagent feeders) by pulses. Setpoints can be changed manually, or automatically by a higher-level control in the Proscon 103.

Stabilizing Control

Stabilizing control drives setpoints of both the DDC and analogue variables in order to maintain concentrate grades and reagent additions at setpoint. Both feedforward and feedback algorithms are used. Stabilizing-control setpoints are chosen either on the subjective judgement of operating staff or by the higher-level optimizing control. By seeking to stabilize the process at steady state, the aim is to achieve a target or desired combination of concentrate grade and metal recovery.

Optimizing Control

Optimizing control calculates the combination of concentrate grade and metal recovery that will achieve the highest economic return per unit of ore treated under current conditions. Continually updated multivariable regression models of grade and recovery are used to determine the requisite stabilizing-control loop setpoints that will result in the economic optimum, and the setpoints are then changed by the optimizing routine. Optimizing control has been implemented in the lead flotation circuit for a period of twenty months, and has brought about a substantial improvement in the metallurgy of this circuit.

Stabilizing Control of Copper Flotation

Since the start of operations, copper flotation has been the most difficult circuit on which to impose stabilizing control. The reasons are twofold.

(1) Owing to the low copper head grade relative to those of other minerals, a concentrate of low mass has been produced by very selective separation. Copper flotation is therefore much more sensitive and responsive to changes in the addition rates of air and reagents, and of pulp level, than lead and zinc flotation.
(2) Being the first flotation circuit after milling, the copper circuit is subjected to the full effects of such destabilizing factors as changes in the rate of treatment, and variations in metal ratios, pyrrhotite content, and alkalinity of the ore. Sudden variations in these parameters are to a large extent smoothed out

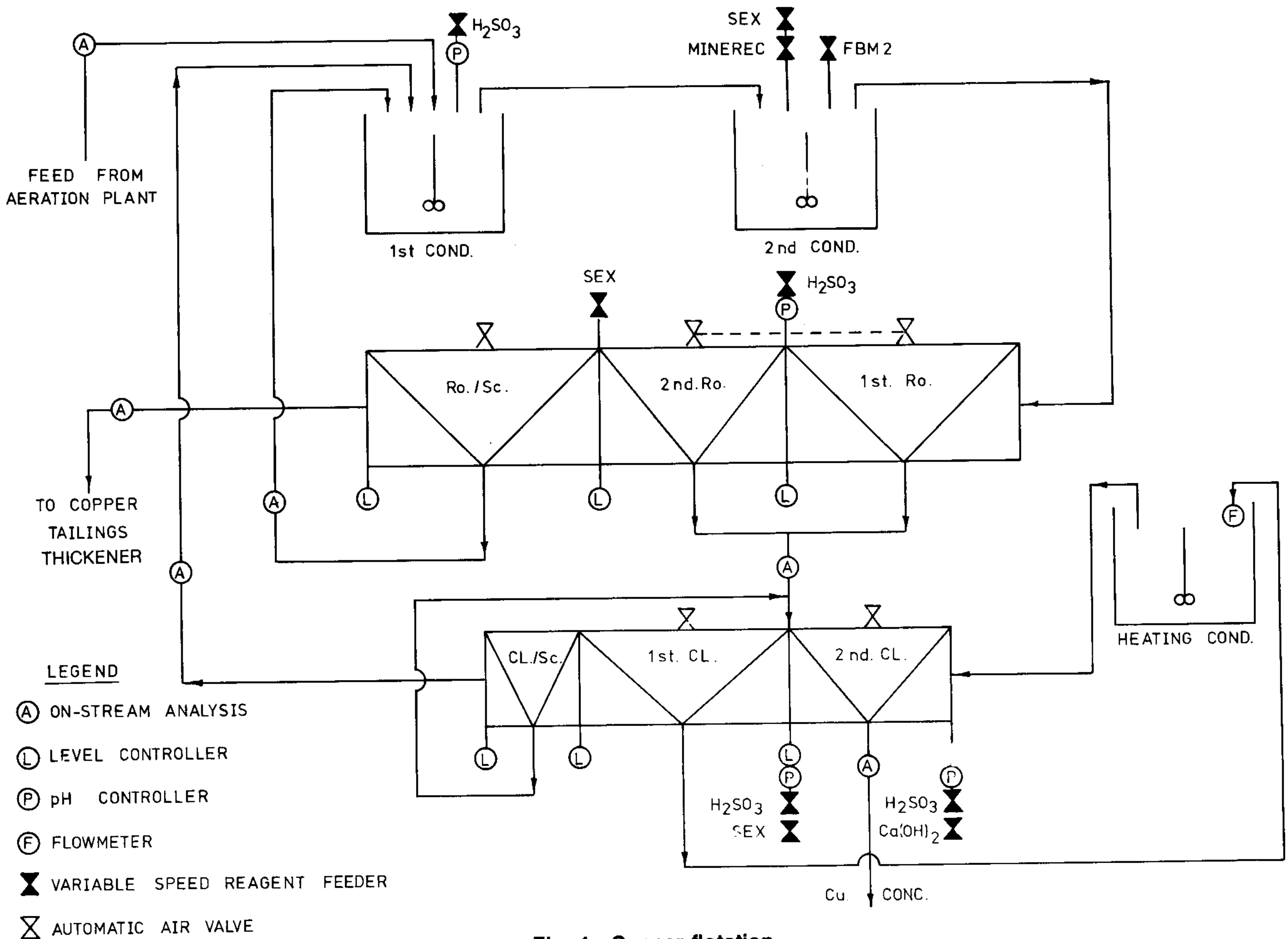

Fig. 1—Copper flotation

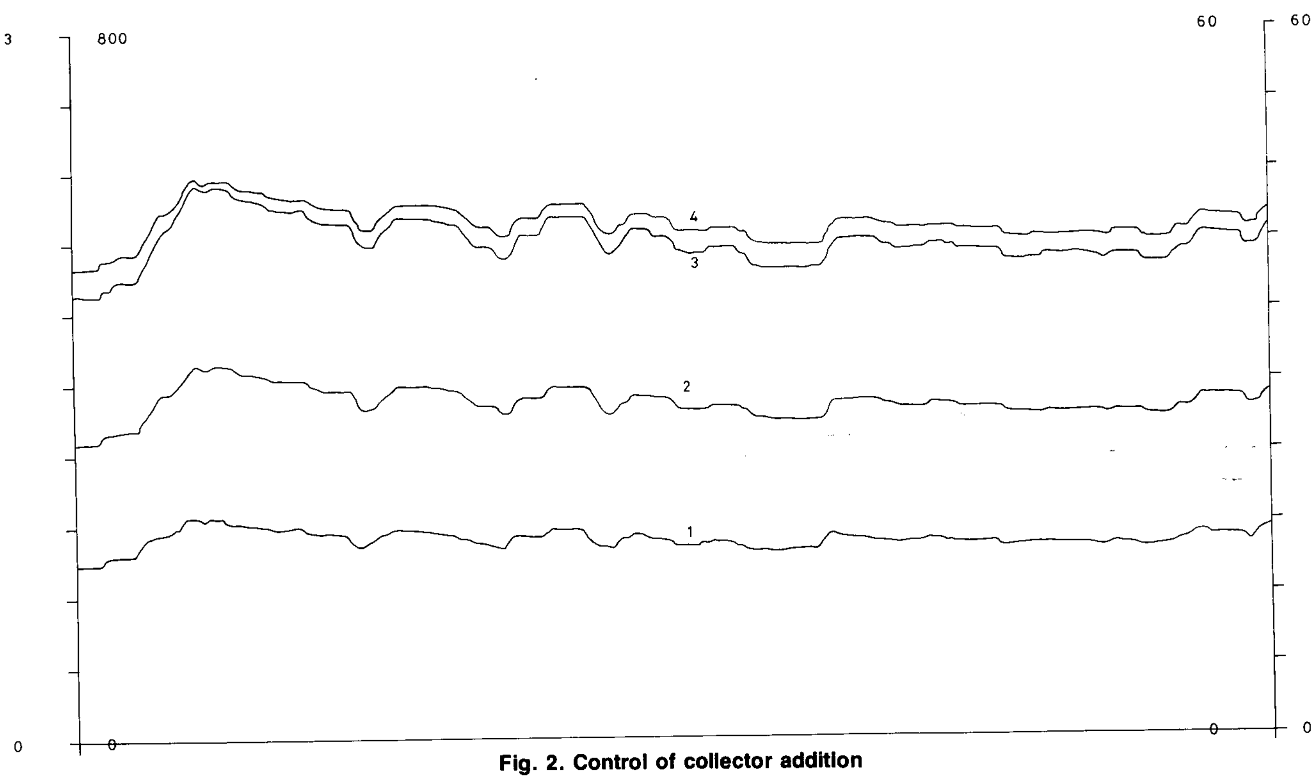

Fig. 2. Control of collector addition

1 Flotation feed, % Cu
2 SEX to Cu conditioner, cm^3/min
3 Minerec to Cu conditioner, cm^3/min
4 Minerec to rod mill, cm^3/min

TABLE II

STABILIZING CONTROL LOOPS IN THE COPPER CIRCUIT

Controlled variable	Controlling variable	Control action
Addition of Minerec 2030 to rod mill	% Cu in feed	Feedforward
Addition of Minerec 2030 to Cu conditioner	% Cu in feed	Feedforward
Addition of Xanthate Z-4 to Cu conditioner	% Cu in feed	Feedforward
Ratio of % Zn:% pyritic Fe in Cu rougher concentrate	Addition of sulphurous acid to Cu conditioner	Feedback
pH in Cu second rougher cells	Addition of sulphurous acid to Cu second rougher feedbox	Feedback
% Cu in Cu rougher concentrate	Air addition to Cu rougher cells	Feedback
% Cu in Cu rougher–scavenger concentrate	Air addition to Cu rougher–scavenger cells	Feedback
% Cu in Cu final concentrate	Air addition to Cu second cleaner cells	Feedback
pH in Cu first cleaner cells	Addition of sulphurous acid to Cu first cleaner feedbox	Feedback
pH in Cu second cleaner cells	Addition of sulphurous acid to Cu second cleaner feedbox	Feedback

in the copper tailings thickener prior to the flotation of lead and zinc.

Progressive developments in the copper-flotation circuit and reagent régimes since the start of operations have paved the way for more effective stabilizing control[1]. The present circuit configuration, together with the reagent-addition and control points, is depicted in Fig. 1. The present status of stabilizing control in the copper circuit is shown in Table II, and recent improvements are enumerated below.

The addition of sulphurous acid to the copper conditioner initially used the pH measurement in the conditioner tank as the controlled variable. However, this control action did not provide stable pH, probably because of inadequate mixing as a result of the large volume of acid added; the nature of the froth in the rougher flotation was consequently highly erratic and variable. Control actions using the percentage zinc and percentage lead in the copper rougher concentrate for acid addition were similarly unsuccessful.

Only when a control algorithm based on the ratio of zinc to pyritic iron in the copper rougher concentrate was used as the controlled variable were good control and stability achieved. In the calculation of the pyritic iron content, allowance is made for the iron content of the chalcopyrite and sphalerite, and it is assumed that no magnetite reports to the copper rougher concentrate. Feedforward control of the collectors to copper flotation is depicted in Fig. 2.

TABLE III

STABILIZING CONTROL LOOPS IN THE LEAD CIRCUIT

Controlled variable	Controlling variable	Control action
Addition of Xanthate Z-4 to Pb conditioner	% Pb in delayed feed	Feedforward
Addition of R242 to Pb conditioner	% Pb in delayed feed	Feedforward
Ratio of % Zn:% Fe in Pb rougher concentrate	Addition of calcium cyanide and zinc sulphate	Feedback
% Pb in Pb rougher concentrate	Air addition to Pb rougher cells	Feedback
% Pb in Pb rougher concentrate	Pulp level in Pb rougher cells	Feedback incorporating a dead band
% Pb in Pb first cleaner tailings	Air addition to Pb first cleaner cells	Feedback
% Pb in Pb final concentrate	Air addition to Pb third cleaner cells	Feedback
Air addition to Pb second cleaner cells	Air addition to Pb third cleaner cells	Feedforward

Stabilizing Control of Lead Flotation

Stabilizing control in the lead flotation circuit is currently working in conjunction with optimizing control. (This latter higher level of control is the subject of a separate paper[2].) If optimizing control is to be functional, the stabilizing loops must be working at all times. The stabilizing control loops at present in use are shown in Table III, and the circuit flow is depicted in Fig. 3.

The addition of zinc sulphate and cyanide to the lead conditioner is used to inhibit the flotation of sphalerite into the lead rougher concentrate.

When the zinc analysis of the rougher concentrate was used as a control variable, it was found that very unstable conditions sometimes developed, with large quantities of sphalerite being floated into the rougher and final concentrates. The addition of extra cyanide and zinc sulphate only made conditions deteriorate even further. As the result of bench-scale investigations, it was concluded that the ratio of zinc to iron in the lead rougher concentrate would be a better process variable on which to base the addition of cyanide and zinc sulphate than the zinc content alone. The inclusion of the iron content (predominantly in the form of pyrite and pyrrhotite) screens out the effects of fluctuating air addition to the roughers on the zinc content of the rougher concentrate, the net result being that the zinc-to-iron ratio identified changes in the activity of zinc in the lead rougher circuit more precisely than did the zinc content alone. A fur-

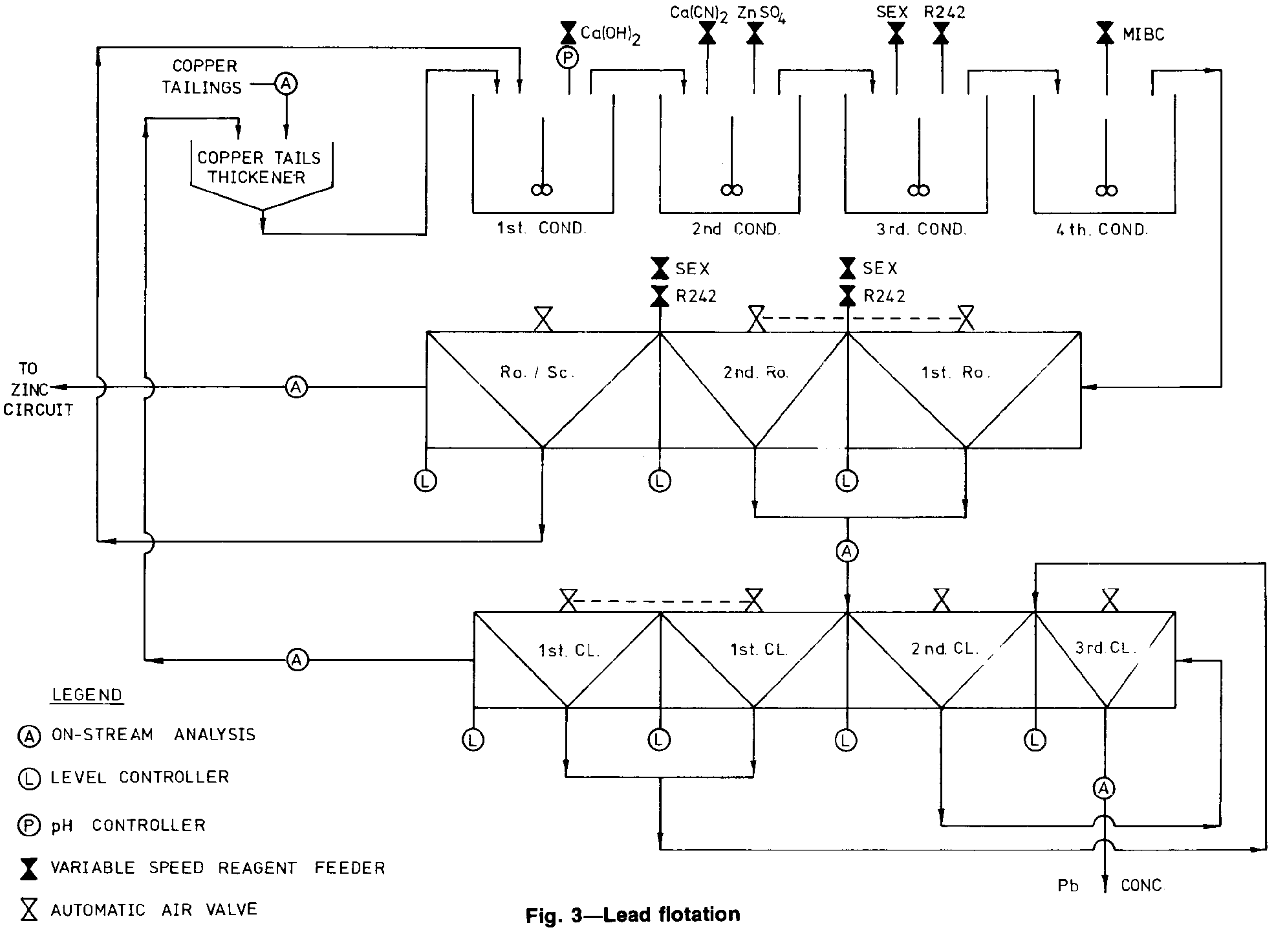

Fig. 3—Lead flotation

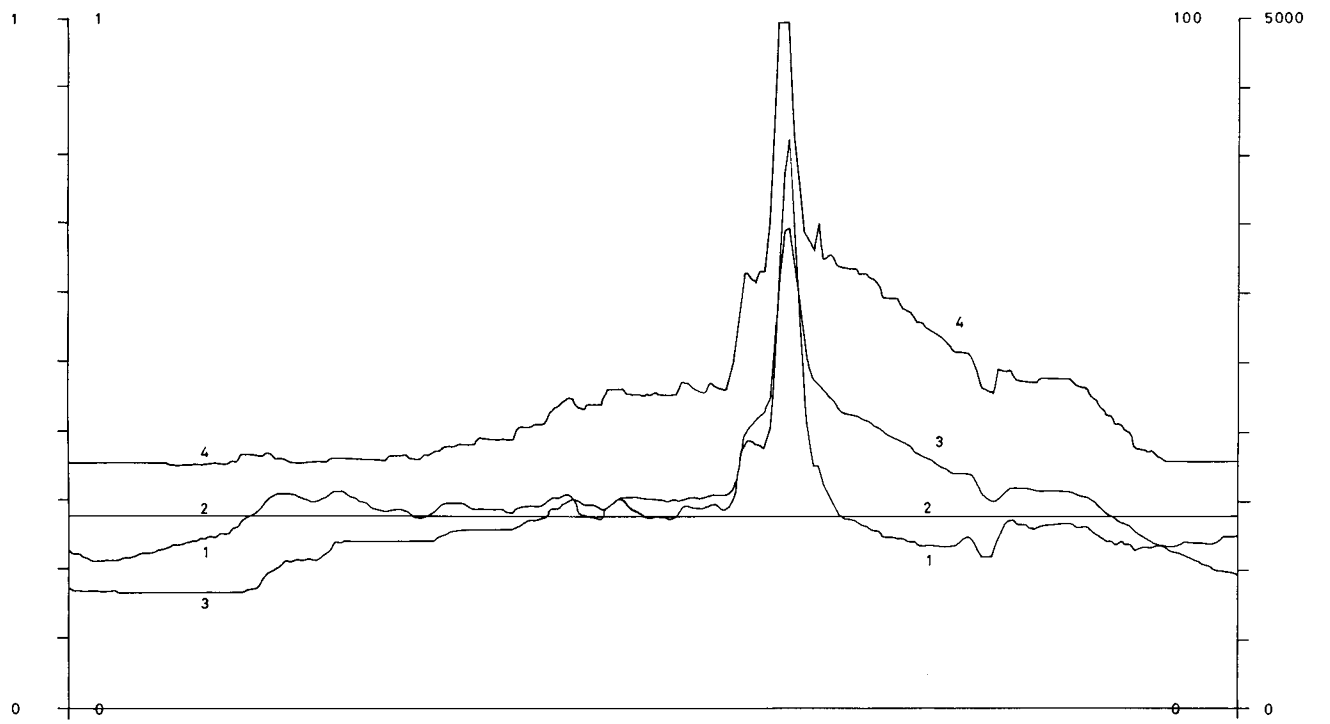

Fig. 4—Depression of sphalerite in lead flotation

1 Zn:Fe ratio of Pb rougher concentrate
2 Zn:Fe ratio setpoint
3 % cyanide to Pb conditioner
4 Zinc sulphate to Pb conditioner, l/min

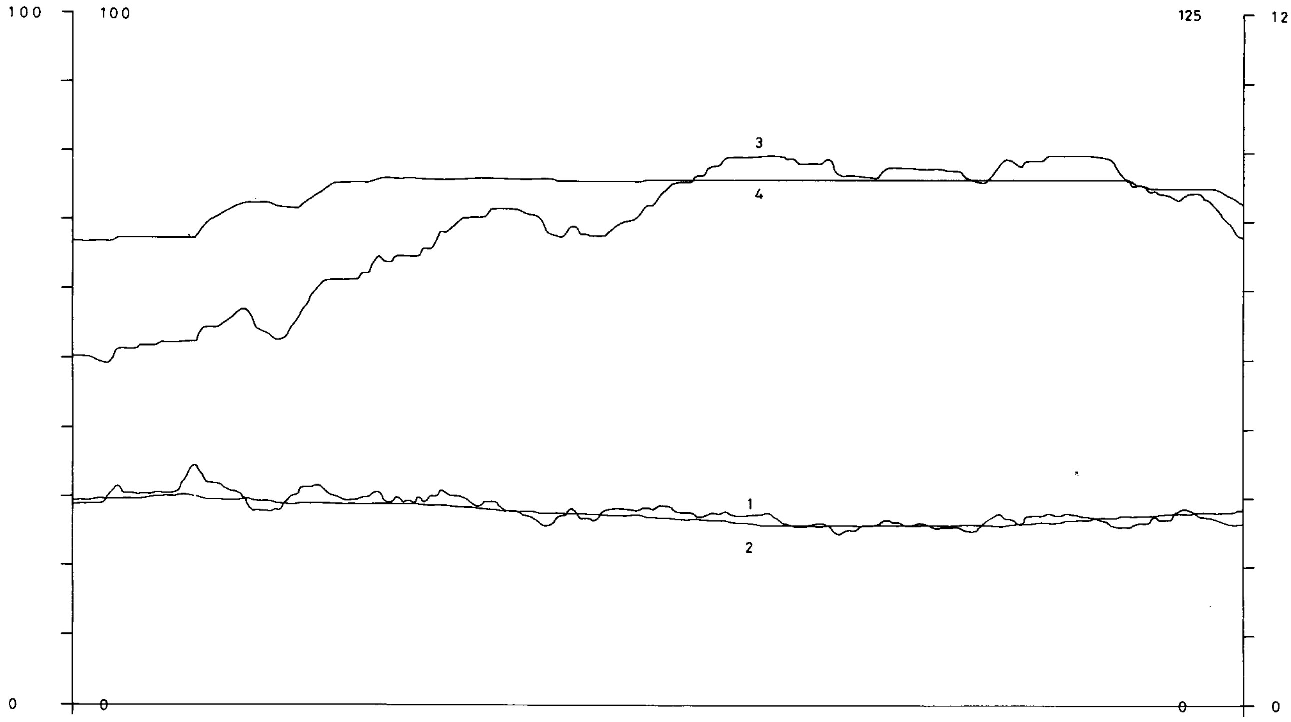

Fig. 5—Control of lead rougher flotation

1 Pb rougher concentrate, % Pb
2 Pb rougher concentrate, % Pb setpoint
3 Pb rougher air valve
4 Pb rougher level setpoint

ther modification was the addition of zinc sulphate and calcium cyanide at a constant ratio of 3:1. Testwork had shown that this was the optimum mix ratio, and a considerable improvement in the usage of zinc sulphate was also brought about. Fig. 4, which shows a plot of the response to a sudden change in the nature of the ore, demonstrates how effective this control action is. Results showed that the quantity of misplaced zinc in the lead final concentrate was either unchanged or better at a lower consumption of cyanide.

Optimizing control has brought about a refinement in the stabilizing control of lead rougher flotation. If the setpoint for percentage lead in the lead rougher concentrate cannot be attained by the addition of air, the setpoint for the pulp level in the rougher cell is changed in cascade control. This occurs when the analysis of the rougher concentrate moves out of specified dead-band limits on either side of the setpoint.

The control action has been very successful in supplementing the original feedback loop, and Fig. 5 demonstrates the pertinent control functions.

A further refinement has been implemented in the lead cleaning circuit, where the final concentrate grade was initially controlled via two independent feedback loops based on the air-addition rates to the lead second and third cleaners. Matching of the response of the two separate loops proved difficult, and in some instances the situation arose where the rate of mass transfer from the third cleaner cells was higher than that from the second cleaner cells, resulting in poor upgrading ratios in the cleaning circuit. A new strategy, based on the maintenance of a fixed ratio between air additions to the second and the third cleaners, has improved upgrading ratios, and the destabilizing effect of manual corrective adjustments to the cleaner air setpoints has been reduced.

Stabilizing Control of Zinc Flotation

The stabilizing control loops in use for regulating the zinc flotation are shown in Table IV, and the circuit is shown diagrammatically in Fig. 6.

Three modifications were introduced to the stabilizing control of zinc flotation.

The first was to provide measurement and control of the percentage zinc in the cleaner–scavenger tailing stream. As had been experienced in the lead circuit, manual control in the cleaning circuit was found to give rise to unstable conditions and high circulating loads. This, in turn, had a detrimental effect on the rougher–scavenger tailing, causing recovery losses. The Courier stream, which had been allocated to the measurement of the copper rougher tailing, was therefore changed to the zinc cleaner–scavenger tailing. A typical plot of feedback control using air as the controlling variable for percentage zinc in the zinc cleaner–scavenger tailing is shown in Fig. 7. As expected, the reduction in circulating load has had a beneficial effect on the overall recovery.

The strategy of a fixed ratio between the air-addition rates to the second and the third cleaner, as discussed under stabilizing control of lead flotation, has been implemented with similar success in the zinc circuit.

A further refinement to the original control strategy for the grade of the zinc concentrate has been the inclusion of a dead-band feedback control loop based on the adjustment of the pH setpoint for the zinc second cleaner. This in turn cascades to the lower-level analogue pH-control loop, which increases or decreases the addition of lime to the zinc second cleaner cell. The lime has a depressing effect on the pyrite, pyrrhotite, and galena in the zinc cleaners. The strategy has been found to complement the cleaner air control and has obviated the need to make drastic changes in pH setpoints in the zinc clean-

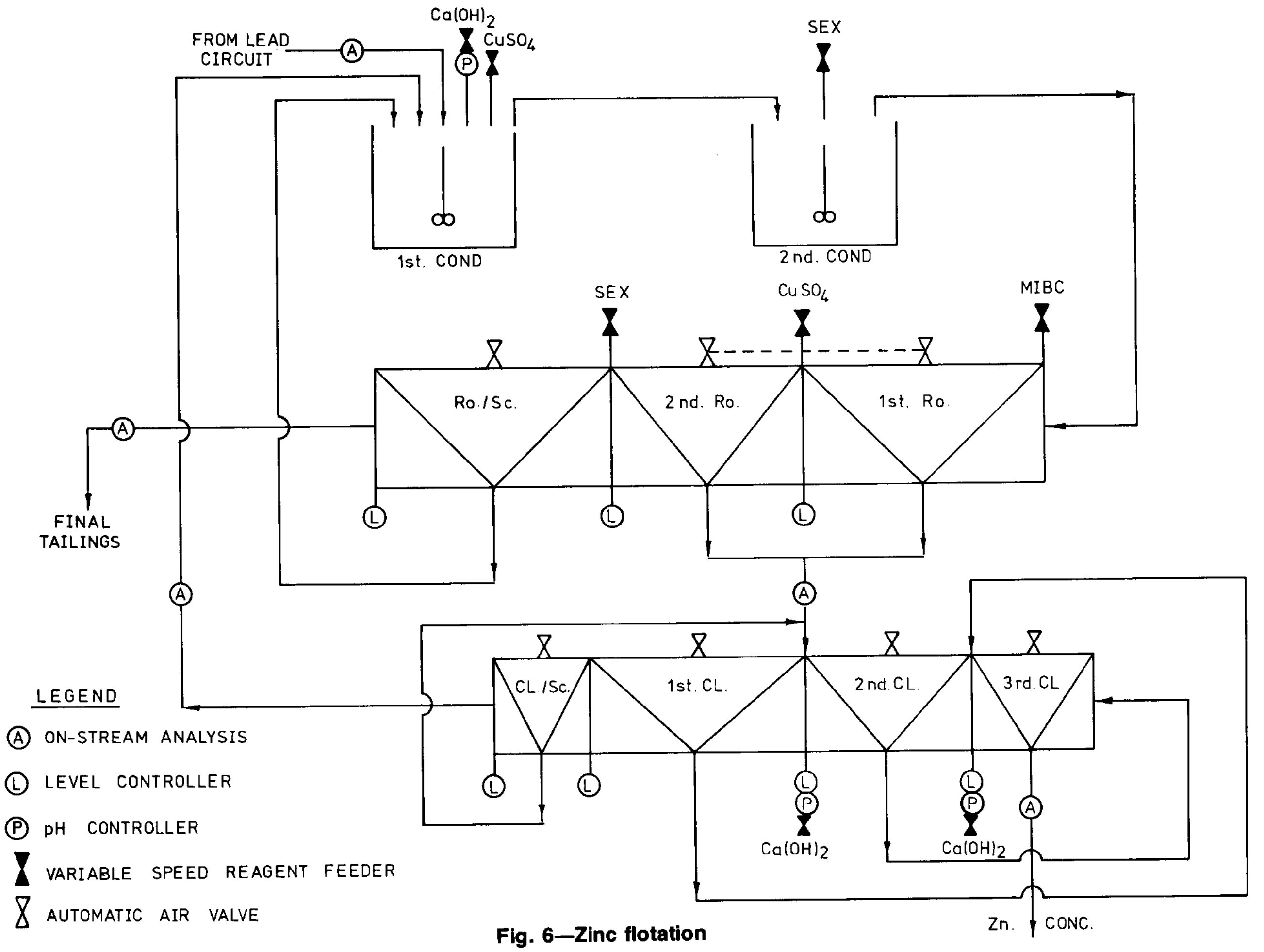

Fig. 6—Zinc flotation

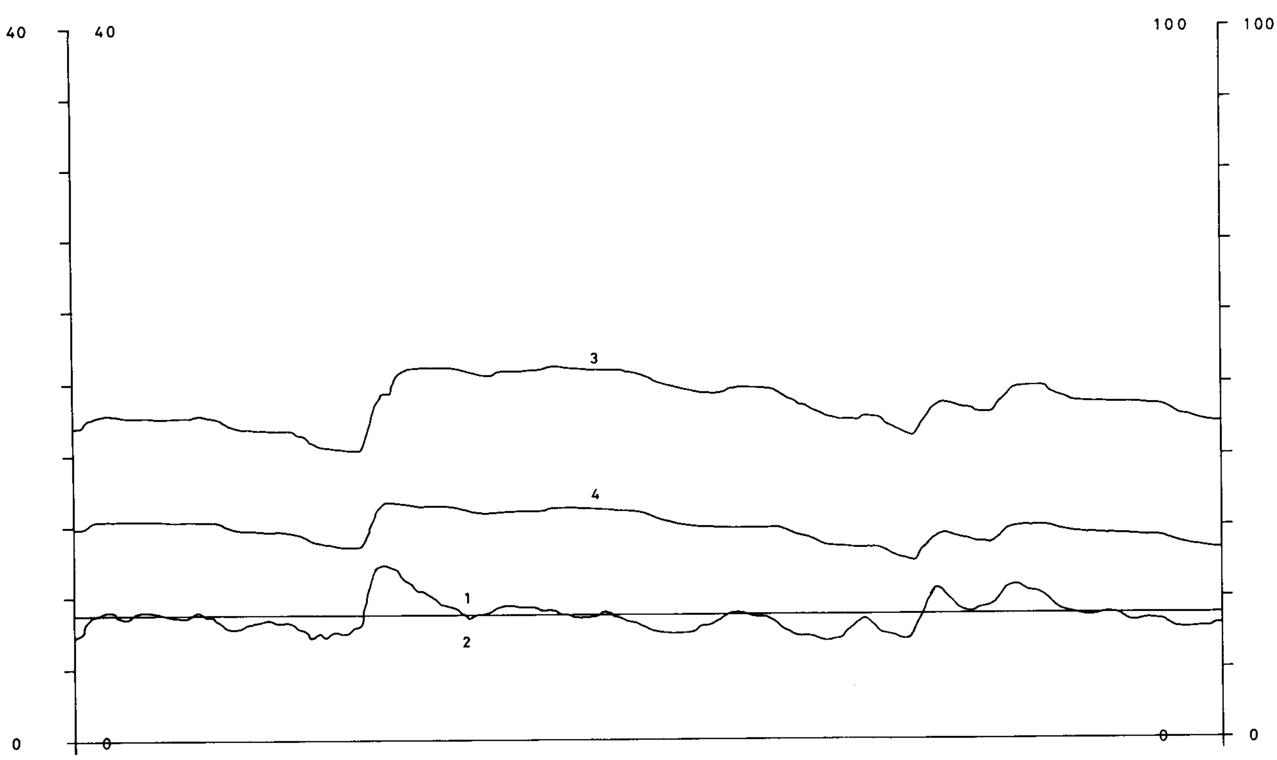

Fig. 7—Control of zinc cleaner-scavenger tailing

1 Zn cleaner-scavenger tailing, % Zn
2 Zn cleaner-scavenger tailing, % Zn setpoint
3 Zn first cleaner air addition
4 Zn cleaner-scavenger air addition

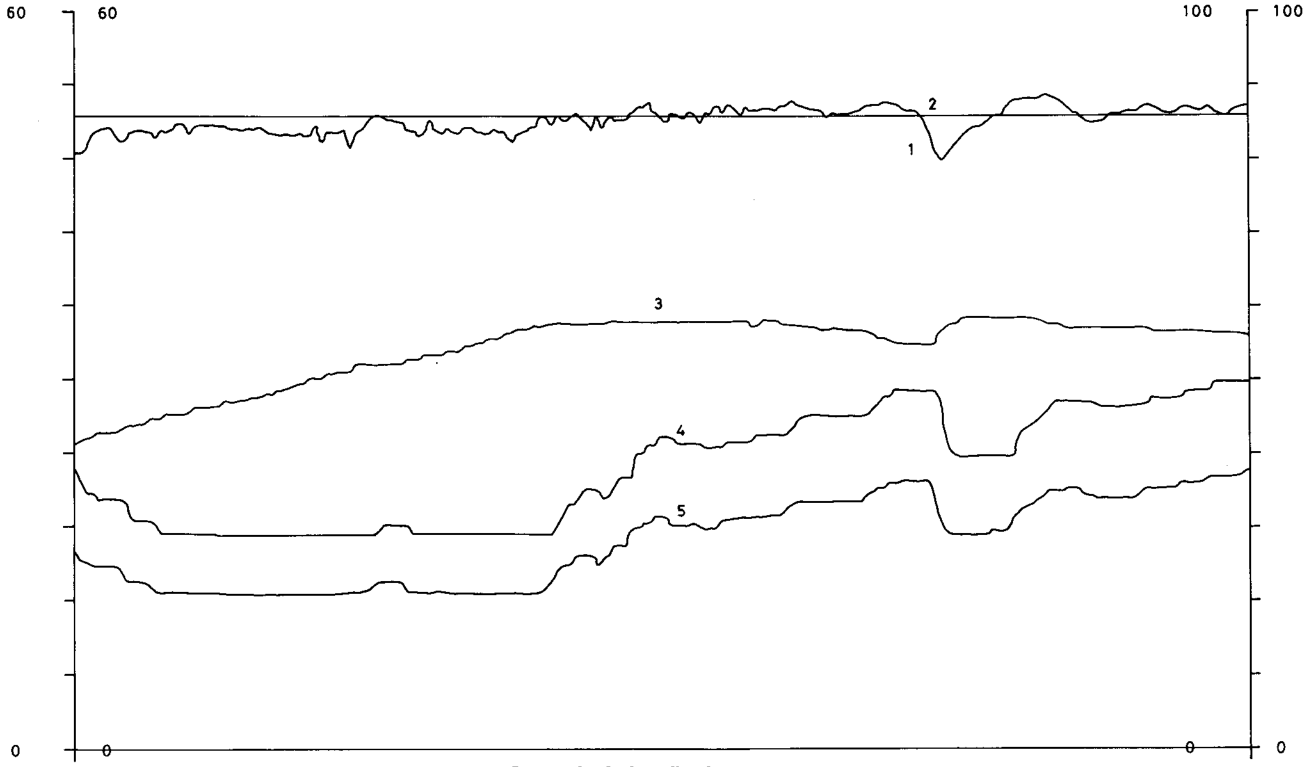

Fig. 8—Control of zinc final concentrate

1 Zn concentrate, % Zn
2 Zn concentrate, % Zn setpoint
3 Zn second cleaner pH
4 Zn second cleaner air addition
5 Zn third cleaner air addition

TABLE IV
STABILIZING CONTROL LOOPS IN THE ZINC CIRCUIT

Controlled variable	Controlling variable	Control action
Addition of Xanthate Z-4 to Zn conditioner	% Zn in lead rougher-scavenger tailing	Feedforward
Addition of Minerec 2030 to Zn conditioner	% Zn in lead rougher-scavenger tailing	Feedforward
Addition of copper sulphate to Zn conditioner	% Zn in lead rougher-scavenger tailing	Feedforward
% Zn in Zn rougher concentrate	Air addition to Zn rougher cells	Feedback
% Zn in Zn cleaner-scavenger tailing	Air addition to Zn cleaner-scavenger cells	Feedback
% Zn in Zn cleaner-scavenger tailing	Air addition to Zn first cleaner cells	Feedback
% Zn in Zn final concentrate	Air addition to Zn third cleaner cells	Feedback
% Zn in Zn final concentrate	pH setpoint in Zn second cleaner cells	Feedback incorporating a dead band
Air addition to Zn second cleaner cells	Air addition to Zn third cleaner cells	Feedforward

ing circuit, thus improving circuit stability.

A typical response of air-addition rates to the second and third cleaners, and of pH setpoints in the second cleaner, to fluctuations in the final zinc concentrate grade is illustrated in Fig. 8.

Conclusions

The benefits brought about by stabilizing control to the recovery and the consumption of reagents, as mentioned in a previous publication[3], have continued to be apparent. However, over the past three years other important benefits have been derived from stabilizing control.

Operating personnel have been released from exclusive attention to the flotation circuits and have been able to spend more time supervising other areas of the plant, namely crushing, milling, filtration, thickening, concentrate handling, and reagent preparation. This, in turn, has decreased the number of people required for the supervision of the process.

In the laboratory, there has been an enormous reduction in the work load and a consequential reduction in staff requirements that is directly attributable to continuing improvements in the accuracy and availability of the Courier on-line analyser. There have been isolated occasions when the system has failed for a number of days, usually owing to a breakdown of the X-ray head of the Courier, and during this time the overall metallurgical performance of the flotation circuits has been extremely poor. Without the measuring and control systems that are in use, the metallurgical efficiencies at the Black Mountain concentrator would have been much lower than those attained.

Additionally, the system has continued to provide a fascinating learning, instructional, and research tool and, as such, has been a motivating force for the entire staff of the concentrator.

Acknowledgement

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Robotics

The 1st South African Symposium on Robotics and Computer Integrated Manufacture (SAROCIM '86) is to be held in Randburg from 25th to 28th March, 1986. The Symposium is being sponsored by The South African Council for Automation and Computation, together with several co-sponsors, and is being organized by The Division of Continuing Engineering Education of the University of the Witwatersrand.

The objectives are as follows:

- To inform potential users of robotics and CIM technology of the principles, capabilities, and limitations of these technologies
- To develop an awareness within the manufacturing sector of the necessity to exploit this high-technology approach
- To provide case studies of successful applications in South Africa and overseas
- To enable forward planning by describing current R&D in robotics and computer integrated manufacture.

The programme includes several workshops and three technical visits.

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SATS wins premier award*

The National Award of the Associated Scientific and Technical Societies of South Africa is the premier South African award for outstanding achievement in the fields of science and engineering. In 1985 this recognition was accorded to the South African Transport Services for the mechanical- and electrical-engineering aspects of the 25 kV alternating-current coal-export railway line between Ermelo and Richards Bay. The Award, in the form of a plaque, was presented at the Annual General Meeting of the Associated Societies in November 1985.

The 450 km coal line passes through some of the most difficult terrain in the country from an engineering point of view. Originally designed for diesel–electric haulage, the line was electrified at 25 kV alternating current in 1978 because of the rapid growth in coal traffic and increased fuel prices. When electrified, the line had a capacity of 20 Mt per annum.

At that stage it was projected that increased export demand would reach 44 Mt by 1986, and the immediate problem facing the South African Transport Services was to increase the capacity of the existing single line while at the same time allowing operation to be stopped for 5 hours a day to permit rebuilding of the tracks to the higher standards required for the eventual loading. World-leading developments were initiated by the mechanical and electrical engineers of the South African Transport Services, and these have resulted in the regular transport of close to 40 Mt of coal per year—double that for which the line was designed. This target was achieved by the introduction of trains of a gross tonnage of 14 kt, which requires the hauling capacity of 8 powerful electric locomotives class 7E and which, owing to limitations in the coupler strength of trucks, are marshalled with 3 locomotives at the head and 5 locomotives in the middle of a 176-truck train.

The regular commercial operation of electric trains of this size with midtrain helper locomotives is an engineering feat without parallel anywhere in the world. With 24 MW of output power, these are also the most powerful electric freight trains in regular service in the world. An unusual feature is that the train, which is 2,27 km long, may be on three different gradients at one time, requiring one locomotive to deliver full power while the other may be in full braking. This required the development of a new driving technique, by which two crews of two men each drive the train with radio communication between the crew in the front 3 locomotives and that in the middle 5 locomotives.

Although this operation of 176-truck trains with 3 locomotives at the front and 5 locomotives in train was introduced as an interim measure and was originally intended to operate for less than one year, it has now, because of its practical success and financial considerations, been in operation for 3 years and will continue for a further 2 years. This result was achieved by South African Transport Services only through the closest cooperation between its mechanical and electrical engineers, and through a remarkable display of individual and team initiative and innovative engineering ability.

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