COLLOQUIUM

PRACTICAL APPLICATIONS OF INSTRUMENTATION IN THE MINING AND METALLURGICAL INDUSTRIES

Rapporteur: J. Laschinger

A colloquium and general meeting of the Institute held jointly with the Instrument and Control Society of Southern Africa at Kelvin House, Johannesburg on 18th October, 1972, had as its theme "Practical Applications of Instrumentation in the Mining and Metallurgical Industries".

Dr J. P. Hugo (President) was in the chair and about 200 members and visitors were present.

The President in welcoming delegates noted that the meeting was unique in South Africa in that it was the first occasion on which societies able to speak for the mining and metallurgical industry and for the technology of instrumentation had embarked on joint discussions. Instrumentation, with its corollaries of control and automation, represents up-to-date thinking in most industries, but its application requires special study in each industry to which it is applied. Past applications in mining and metallurgy had not always been economic and effective, and, to achieve the great benefits that had followed instrumentation in other industries, it is necessary that users, designers and manufacturers of instruments should collaborate because a full understanding of each others' problems is necessary to success. He then called on Dr R. E. Robinson to act as colloquium Chairman for the day. The session chairmen were Dr Rapson and Mr Lever.

The five papers introduced were:

"The Use of Specific Ion Electrodes for the Control of Cyanide Concentrations in the Solutions of a Gold Plant", by A. H. Mokken, Consulting Metallurgist, Union Corporation (Pty.) Ltd.

"Metallurgical Considerations in the Automating of Gold Recovery Plants", by H. Cross, Consulting Metallurgist, Goldfields of South Africa, Limited.

"The Need for Suitable Instruments in the Optimization of Plant Performance", by Dr M. I. Brittan, Anglo-American Research Laboratories.

"A Review of On-line Particle-size Analysis", by Dr A. L. Hinde and Dr P. J. Lloyd, Chamber of Mines Research Laboratories.

"Recent Advances in the Instrumentation and Automation of Uranium Processing Plants", by G. Sommer, G. T. W. Ormrod, and R. P. Chaix, National Institute for Metallurgy.

The Panel Chairman for the first three papers pointed out that the first consideration in designing instrumentation was to identify which functions it would be profitable to control. The three authors had used different approaches. Mr Mokken had selected a function whose importance was known, and had investigated the potential value of control and had gone on to describe tests aimed at the development of a system that would achieve the control required. Dr Brittan's approach had been to apply the powerful technique of multiple regression analysis to pinpoint specific parameters, and then to search for instruments to control these parameters. Clearly the ideal system would be a consolidated one in which all significant parameters were controlled. Mr Cross had shown how automation, centralized remote indication and control, interlocking and logical sequencing could be applied and combined with automatic control of unit processes, and how these functions can be built into the design of a plant. That integral design of instrumentation and control with that of the plant was necessary to obtain the great benefits of labour-saving and increased efficiency was clearly shown.

In the discussion of Mokken's paper it was noted that monitoring and control of free cyanide concentration had shown that very considerable economies could be made without residue values. The application of the cyanide specific-ion electrode in practice had been fraught with difficulties due to drift. The importance of tracing variations in the transducer signal and in the recorder-controller system separately was emphasised. The effects of pH and of velocity through the flow-cell were noted, and it was mentioned that in one case disturbances were encountered due to electrical noise, electrode drift, abrasion, liming of electrodes and temperature effects.

It was accepted that plant measurements of free cyanide were often unreliable. In summary, a specific-ion electrode for free cyanide has not yet been developed to a stage at which it is fully trustworthy as a control instrument, but the potential value of a control of free cyanide concentration has been shown to be sufficient to warrant further development.

The paper by Cross described features of the designs of the mills at the Kloof and East Driefontein Mines, in which successful use is made of instrumentation and automation, and in particular of centralized control and logical sequencing of starting-up and shutting-down procedures. The control of unit operations by closed loop systems was also described. It was clearly demonstrated that the scope for instrumentation is great, but that, to obtain its full benefit, the instrumentation should be an integral part of the philosophy of design and operation. The completeness of the paper left little room for discussion.

The paper by Brittan described the use of suitable mathematical modelling techniques applied by means of the computer to the analysis of plant data to identify key variables in the milling of gold and uranium, and so to the optimizing of benefits. When such variables have been identified, means of controlling them can be sought. When instrumentation, or indeed any change in a process, is being considered, it is necessary to

justify the capital cost of the change by comparing it with the benefits that can be estimated. Multilinear regression analysis is a powerful tool with which to make such an analysis, and to determine the most profitable points at which to apply control. An instance was cited in which the installation of a gravity-concentration section had warranted the expenditure of R350 000. Another contributor said that almost any form of concentration is profitable, and that it is not uncommon for flotation to yield about 80 per cent recovery in concentrates that can be much more easily and profitably treated than can the whole ore.

In the case described in Brittan's paper, higher specific gravity of pulp during cyanidation was associated with higher residues, but this is not always necessarily so, and the effect of leach dilution can be influenced by other conditions. The case was cited of the old Sub-Nigel Mine, where, because the ore contained much pyrrhotite, a high specific gravity had to be maintained. Low oxygen concentrations led to reprecipitation, long agitation was to be avoided, pH was critical, high cyanide was very deleterious, and specific gravity was the rate-controlling factor.

Replying to a question, the author said that analyses of the kind he had described had been developed to resolve particular cases quickly. They were based on plant records which, though they could be unreliable, could still yield useful evidence. The degree of reliability could often be identified. Because plant tests were needed to verify analyses and because input data might lack refinement, sensitivity analyses were thought not to be warranted.

A contributor mentioned several analytical estimates that had not been discussed by Dr Brittan but that would be of great value in optimizing the performance of a gold plant. The most important one, he considered, would be the on-line estimation of gold content, because the degree of grinding to be used in a cyanidation plant is indicated by the gold content of the ore, very fine grinding being justified only for ores with a high assay value. There would probably be practical difficulties in altering grinding conditions continuously as the gold content of the ore varied, but these could be overcome by having a mill with separate high-grade and low-grade streams, and using the analyser for gold value to divert the ore to the appropriate stream.

Because it may be some time before an on-stream gold analyser becomes available, it was suggested that there may be a benefit in dividing the mill feed into fractions of differing composition by one or more of the available methods of concentration; each of the fractions should then receive the form of treatment that is most appropriate for its particular composition. For example, concentrates produced by gravity treatment, by flotation with a frother only, by flotation with a xanthate, and those produced by flotation with an excess of xanthate or with some other collector are of different mineralogical composition and contain their gold in different forms; they should therefore receive different forms of treatment for optimum overall results.

The contributor also drew attention to the fact that gold-rich concentrates would also be enriched in uranium, and it could well be that there could be some recovery of uranium from ores that are too poor in uranium to justify acid-leaching. He summarized his remarks by recommending a search for an on-stream method of gold assaying and a simultaneous further exploration of the possible benefits of applying concentration more widely than is being done at present.

Dr Robinson asked whether plant data were not sometimes found to be unreliable. For instance, samples for washed residue were sometimes collected a considerable time before they were washed and would thus give false values. He also asked whether, in the course of his analyses, Dr Brittan had been able to draw up materials balances for gold.

Replying to discussion, Dr Brittan made the following points.

In virtually all cases in which the effect of leach pulp specific gravity had been examined, a decrease in residue value accompanied an increase in pulp dilution. The lower viscosity associated with lower specific gravity led to better agitation and more rapid diffusion of oxygen and other reagents. Factors such as longer agitation times and higher temperatures would tend to counteract the detrimental effects of higher specific gravity. Agitation times in Anglo American mines are not particularly long, and it might be that plants at which long agitation times were used would be less influenced by the effects of high pulp density. It is likely that too high a dilution could be detrimental, and each case would need to be considered separately.

It is true that the reliability of plant data is often unsatisfactory, but experience has shown that useful information can still be obtained by analysis of such data. A valuable feature of the technique is that it provides an indication of the degree of inaccuracy of the data, and this in turn stimulates efforts to improve the quality of records.

Every ore and every circuit has different characteristics and though some common factors are usually apparent, each plant must be treated on its own merits.

To clarify the situation regarding the approach that had been adopted, it should be stressed that the modelling technique used was not of the long-term, mechanistic variety. One could conceive of devising physicochemical models of each unit operation, and then stringing them together to provide an overall mechanistic model, but this could very well take ten to fifteen years. By that time, some of the original problems might no longer exist. The techniques used are, in fact, designed to provide a quick turn around of useful information that can rapidly be applied to obtain additional gold recovery. The philosophy is to provide a rapid diagnostic service which will identify key areas and variables in the process.

The quantitative prediction of the effects of these key variables which the model provides forms the basis of the economic optimization of the process, and also assists decisions as to what further investment in capital equipment might be required.

The models are developed by analysis of available plant records. This not only puts the vast accumulation of operating data to good use,

but also has the advantage of not interfering with normal plant operation.

With the technique and a computer, one can examine the entire process and is not constrained to examine isolated unit operations or variables. Changes can be made in such a way as to maximize the overall profit rather than to improve an isolated feature whose impact on the total gold recovery cannot be readily assessed. This does not mean that a centralized overall automatic control of the process is envisaged. It would appear at present that the plants can be very adequately controlled by closed loop analogue systems.

The key to success lies in the interpretation of the results generated by the computer. There is no substitute for a thorough knowledge of the process being analysed when interpreting the results.

Dr Brittan agreed that it is possible that some variables that are not measured may be of great significance, but that, until they can be measured, their quantitative significance cannot be assessed. With modern computers, large numbers of variables can be handled. Any parameter that can be measured should be included, and if a variable is felt to be important but is not monitored, efforts should be made to develop the instrumentation necessary to do so.

Dr Robinson had raised a valid point about deficiencies in sampling practice, where there is certainly room for improvement.

Either washed or unwashed residue gold values are considered as the dependent variable, depending on whether cyanidation efficiency alone is being examined or whether vacuum filtration parameters are included.

Though enough information is normally available to construct a gold material balance, this has not been done because priorities must be given to tasks that maximize improvements in revenue.

Multilinear regression methods are used, and the models are linear in the coefficients but not necessarily in the variables. The programme provides measures of uncertainty of the predictions and of the model coefficients.

Opening the discussion on the last two papers, the Chairman of the Panel said that the instrument engineer is too often looked upon as a person able to supply a 'black box' that can look at a process and, if the process varies from the desired condition, restore the balance. For a control system to work, it is first necessary that a suitable 'black box' should be available. Dr Hinde's and Mr Sommer's papers concerned various forms of measuring apparatus that are available, and dealt with two fundamental questions. Firstly, does the industry need the control measure sought? Secondly, can the needs of the user, such as range, sensitivity, reproducibility, and reliability be specified?

One contributor thought that Dr Hinde's criticism of sedimentation and elutriation methods was unduly severe, because 'Stokes' sizes' or 'equivalent diameters' which are indicated by these methods can be used as effectively as screen sizes as a means of controlling a grinding circuit; in some instances, the equivalent diameter can, in fact, be a more useful parameter of size. With this consideration in mind, a simple system of elutriation as a method of sizing was being tested at NIM. This system can be applied in almost exactly the same way as Dr Hinde's screen-sizing method.

A contributor from NIM said that much of Dr Hinde's dismissal of elutriation was based on inherent sources of variance as well as on his objection that the method yields a result different from that of a true sizing analysis. He considered that errors due to variations in temperature and viscosity could be controlled or compensated for.

A third effect that might be expected to introduce errors — the fact that a velocity gradient must exist across the section of any practical column — appears from the experiments made at NIM to be self-compensating. It seems probable that some statistical ordering of the mean velocity of rise or fall of individual particles must take place due to the mixing effect of eddies in the flow.

Experiments were made on a very simple elutriator, consisting of a vertical tube 108 mm in diameter and 305 mm high in the cylindrical portion, into which water was introduced through a conical bottom with a 30° included angle; the overflow was carried off through a central tube in a bung closing the top. Hydraulically the apparatus is obviously crude, because very marked velocity gradients must exist.

Experiments were made using a mineralogically homogeneous quartz ground to different particle-size distributions. It was found that results were closely reproducible, that they were independent of the size of the sample over a wide range, and that the separations took place at a sieve size very close to the 'equivalent sphere' calculated from Stokes' Law. It was also found that closely consistent results were obtained using a vessel of ten times the same cross-sectional area but the same height.

As in a sieve analysis, there was no abrupt end-point, and the rate at which material was carried over to 'undersize' approached a limiting value asymptotically. After 10 minutes, elutriation of the fraction within $2^{0,25}$ of the screen size of the separation (i.e. 19 per cent larger or smaller) was 94 per cent complete, and the total amount of undersize more than 99 per cent of its final value. The distributions at 10 minutes, taken as the end-point, were compared with screen analyses, and showed remarkably close correlations.

Apparatus of the type described can clearly be used in the same way as the sieving apparatus described by Dr Hinde, using the principle of Archimedes to estimate sample and product masses. As the signal derived, even in the presence of a heavy-mineral fraction, is a useful criterion of grinding performance, he urged its use for control purposes.

Another contributor suggested the possibility of deriving a particle-size spectrum by the use of variable swept-frequency ultrasonic scanning.

An American visitor outlined the practical application of his firm's 'PSM System 100' instrument, described in Dr Hinde's paper. The instrument is a fully on-line acoustic analyser and, as it makes in effect several hundred measurements per second, it is well able to respond to the short time variations of a cyclone classifier, and close control is there-

fore possible. Some twenty instruments had been installed, and improvements of from 4 to 10 per cent in grinding capacity had resulted due to the elimination of surges. It was interesting to note that the instrument had been developed 'in-plant'.

In his reply, Dr Hinde agreed that excellent correlation could often be obtained between sieving and elutriation techniques under controlled laboratory conditions with specimens of well-defined shapes and densities. However, Dr Hinde emphasized that such conditions and sample homogeneity do not necessarily apply to the rigorous conditions of a mining environment. He pointed out that the optical grating technique (based on the relationship between size and settling velocity) was also used to produce good results in the laboratory. However, when the instrument was taken to a mine, results were poor due partly to the presence of a high iron content in the ore, which had not been anticipated in the laboratory calibration tests.

In opening the discussion on Mr Sommer's paper, the Panel Chairman recalled that, in the past, there had often seemed to be a sort of antagonism between the suppliers and the users of instruments. This had arisen because neither side had a sufficiently full knowledge of the problems confronting the other: but experience had shown that collaboration and knowledge in depth of both process and characteristics of instruments is necessary to obtain useful results. This point is happily more often appreciated today and Mr Sommer's paper reported interesting examples of fruitful collaboration. A contributor observed that no doubt the collaboration that NIM had been able to obtain from its clients had contributed to its successes.

A delegate remarked that, just as conductance can be expressed in terms of acid concentration in grammes per litre, this could be related in turn to rands and cents. Practical application of controls had led to very appreciable economies in the use of acid and of manganese dioxide in uranium leaching. Further incidental savings in operation had also been found, for instance, in a substantial reduction of silica in pregnant solution. In solvent extraction, pH control had materially reduced solvent losses and crud formation and improved stripping efficiency. In general, plant control had enabled operators to make decided improvements in the control of effluents.

The chairman observed that, as there is no indigenous instrument-making industry in South Africa, the major potential users of instruments must convince themselves that successful instrumentation is profitable and so be willing to collaborate with suppliers in solving the problems that inevitably arise in new applications. Technical teamwork in identifying exactly where problems lie is necessary in most, if not all, new applications, and the availability of an intermediary such as NIM could have a profound effect on the development of successful techniques to the benefit of both the mining and the instrument industries.

In closing the colloquium, the President of the Instrument and Control Society of Southern Africa welcomed the growing understanding by the metallurgical industry of the need for collaboration between user and supplier that had been stressed, and of the need for users to specify their requirements precisely. The air of distrust between user and supplier is diminishing as it is becoming understood that appropriate instrumentation has a vast potential, as has been so clearly shown in the Iron and Steel and Chemical industries — though, even there, it has been appreciated that there are many pitfalls. He listed seven points that he believed to be essential for the successful use of instruments. These are:

(1) Both suppliers and users must recognize the problem to be solved.
(2) Suppliers must acquire an in-depth knowledge of the process to be controlled.
(3) Suppliers must be able to guarantee the performance of the instrument under practical conditions, and take into account all factors that may affect its performance.
(4) The user of the plant must know the design philosophy of the control system.
(5) Care must be taken to avoid unnecessary instruments.
(6) Competent maintenance staff and facilities must be available.
(7) There must be effective liaison between designers, maintenance staff and operators.

Recently, a fresh recognition has come about of the central significance of reliability once a control system had been designed into a plant. Indeed, a special study of 'reliability engineering' is being established, which includes the mathematical assessment of reliability. Such studies apply not only to the instruments but to the whole process of which they form part.

DISCUSSION

The use of specific ion electrodes for the control of cyanide concentrations in the solutions of a gold plant

by **A. H. MOKKEN**

K. G. ASHURST

Measurement of free cyanide concentrations by the cyanide ion-selective electrode depends on a reaction that consumes cyanide. The result is that the cyanide concentration close to the electrode membrane is much lower than the concentration in the bulk of the solution. This concentration change is of no consequence in solutions containing no cyanide complex ions since the same changes occur during calibration and sample measurement if the same conditions of agitation are maintained. However, the presence of ions of metals such as zinc, copper, cadmium and mercury in the sample solution causes the cyanide concentration measured by the electrode to be higher than the free cyanide concentration in the bulk of the solution. This free cyanide concentration cannot be measured directly; it can, however, be calculated from the stability constants of the various cyanide complexes and the total ion concentrations. The discrepancy between the observed and calculated values increases with increasing metal concentration.

Cyanide solutions used in gold plants can contain significant concentrations of zinc and copper. Other metals are unlikely to be present at sufficiently high concentrations to cause interference. Analyses of solutions from a gold precipitation circuit showed zinc, $4{,}4 \times 10^{-4}$ M (29 ppm); copper, $2{,}5 \times 10^{-4}$ M (16 ppm); and cyanide, 5×10^{-3} M (245 ppm as NaCN). The cyanide concentration of this solution indicated by the electrode was 42 per cent higher than the calculated value. The variation of the discrepancy with increasing zinc concentration at selected concentrations of copper and cyanide is shown in Table I.

The high values of the free cyanide concentration measured by the electrode can be explained by considering the effect of the low free cyanide concentration near the membrane on the ionic equilibria. Thus, in the case of zinc, the complex cyanides will by $ZnCN^+$, $Zn(CN)_2$, $Zn(CN)_3^-$ and $Zn(CN)_4^{2-}$. The fraction of the total zinc in each species will depend on the free cyanide ion concentration; as this concentration increases, the fraction of the total zinc present in complexes containing a greater number of cyanide ions will also increase. The effect of the lower free cyanide ion concentration near the membrane will be a redistribution of the complex cyanides that will result in preferential formation of those complexes that contain fewer cyanide ions. Thus reactions such as

$$Zn(CN)_4^{2-} \rightarrow Zn(CN)_3^- + CN^-$$

will occur to some extent. The cyanide released will then react at the membrane and will be additional to the original free cyanide concentration detected by the electrode.

Hence, if zinc and copper are present in significant concentrations in cyanide solutions, the electrode will indicate a higher free cyanide concentration than the true one and cannot be used as a measure of the absolute value of the free cyanide concentration under such conditions. However, if the metal concentrations do not show large variations, the electrode will give a reliable estimate of changes in the free cyanide concentration. Therefore the electrode could, if used with circumspection, be applied in the control of cyanide solutions.

TABLE I
THE EFFECT OF ZINC AND COPPER ON THE ELECTRODE MEASUREMENT OF CYANIDE
EXCESS FREE CYANIDE MEASURED BY THE ELECTRODE (%)

Total zinc concentration ($\times 10^{-4}$)	Cu, $7{,}5 \times 10^{-4}$ CN^-, $7{,}5 \times 10^{-3}$	Cu, $2{,}5 \times 10^{-4}$ CN^-, $5{,}0 \times 10^{-3}$	Cu, 5×10^{-4} CN^-, 5×10^{-3}
2,5	15	20	34
5,0	37	45	61
7,5	82	90	94

Acknowledgement is made to the Director General of the National Institute for Metallurgy for permission to publish this contribution.

A. R. F. MACDONALD*

When our company converted to bulk cyanide, the consumption increased to a point where the cheaper product was costing more than the expensive packaged reagent. This was mainly due to unreliable cyanide feeding apparatus.

At this time a working prototype of the Corner House Laboratories cyanide titrator was supplied to the mine on approval or for development. Subsequently, a rotary valve cyanide feeder with variable speed drive was also installed.

PRINCIPLE AND APPLICATION

A continuous sample stream of relatively clear process cyanide solution from the pre-dissolution pulp is blended with a standard silver nitrate solution stream in the volume ratio which would produce equivalence point conditions if the plant solution concentration were on target. The typical graphs of e.m.f. produced during titration illustrate the large change in potential around the equivalence point. If the end-point e.m.f. is centralised on a controlling recorder, the large voltage fluctuation recorded by suitable elec-

*Harmony Gold Mining Co. Ltd.

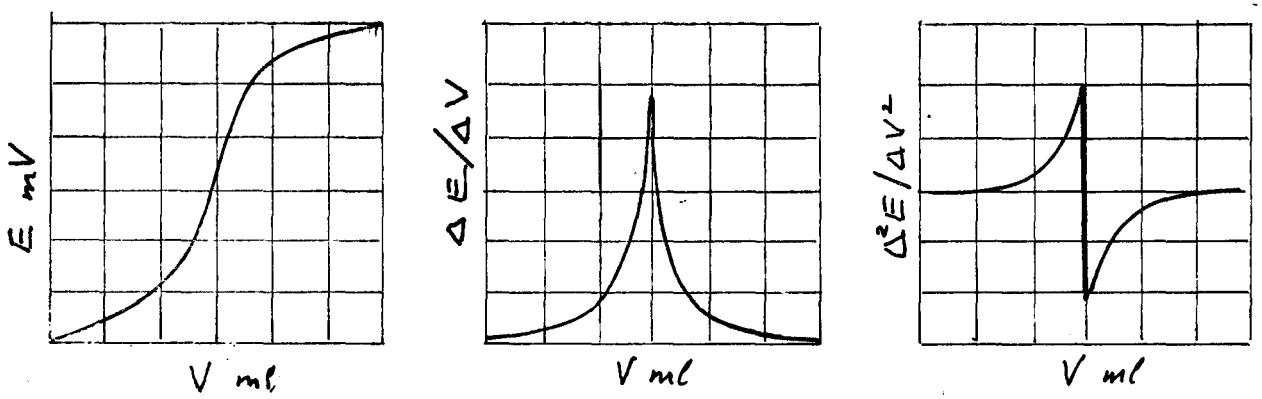

Fig. 1—Typical precipitation titration curves

trodes in the continuous titration product, for a small concentration deviation in the cyanide solution, can be utilised for precise control of reagent feed.

The current commercial C. H. Laboratory silver electrode was developed at Harmony after it was discovered that the wire electrodes presented insufficient area for reproducible e.m.f. recording. A half inch internal diameter sterling silver tube electrode prototype made in June 1969 was found suitable and is still in service. KNO_3 is used in the calomel electrode instead of KCl.

The syringe type proportioning pumps originally supplied were scrapped in favour of a mine-manufactured peristaltic pump using two S.A. AutoAnalyser tubes. In its present form the titrator controls cyanide concentration precisely, and has resulted in a reduction of "NaCN" concentration target from 0,032 per cent to 0,021 per cent. Currently, the only Brown agitators registering CN^- concentrations off-target have been influenced by systems outside the control and feed area.

Laboratory tests

Using laboratory pH meters and a reference electrode fabricated from two rolled out pure silver discs (used in bullion assay) welded to each other tee-wise, with the stroke of the tee wrapped round the tip of a Calomel electrode, titrations of plant process solutions of varying CN^- concentrations were conducted.

E.m.f. was graphed against titrant volume. It was found that all start points were roughly similar and that the curves in the equivalence zones were parallel. End points for all the solutions tested were at 260 mV, and

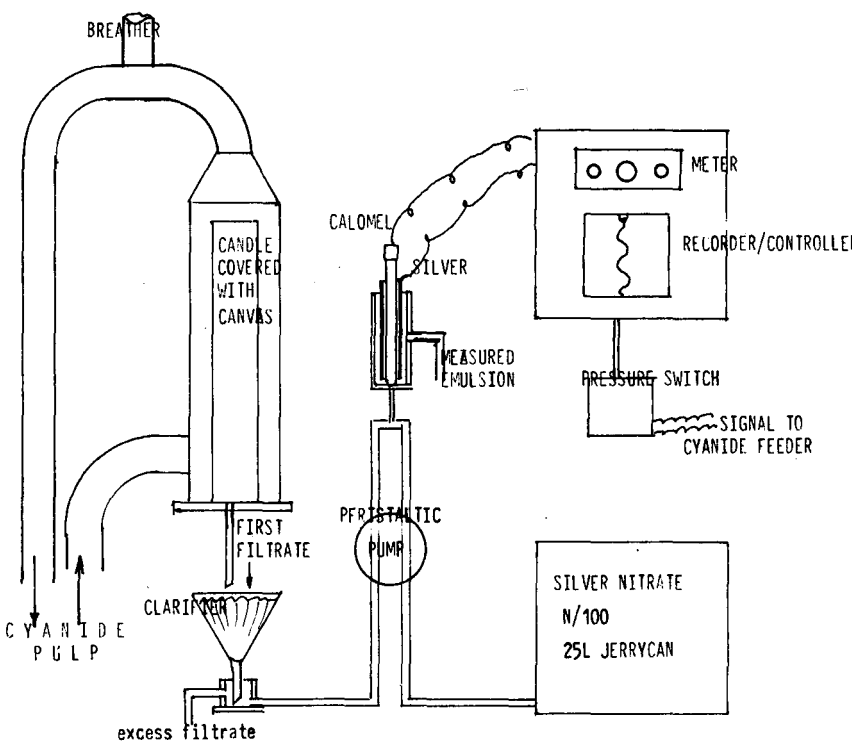

Fig. 2—Schematic diagram of titrator application at Harmony G.M.Co.

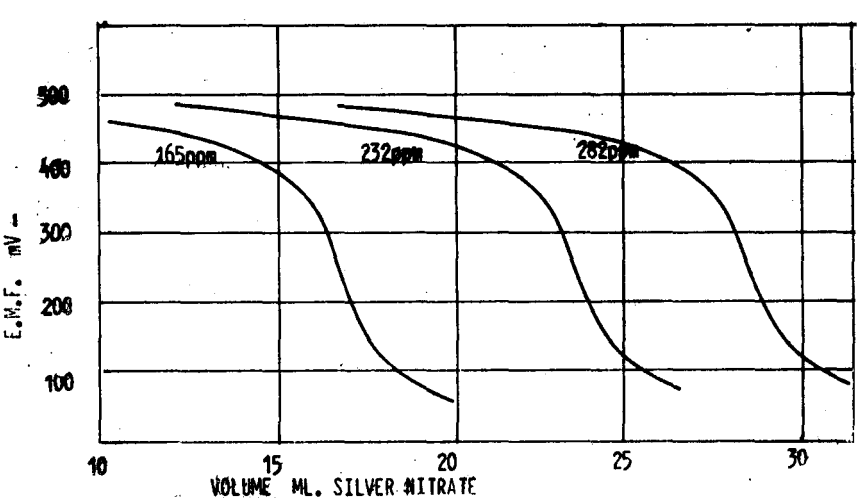

Fig. 3—Plant solution titration curves

this number could be used on graphed titrations to find end points accurately to one part per million using N/100 $AgNO_3$. The system could have some value in plant control analysis as even a colour-blind operator can read a pH meter scale.

A graph of maximum $\Delta E/\Delta V$ for the range of CN^- concentrations tested can be used to determine coarse titration pumping volume ratios. Fine adjustment is made by adjusting titrant solution concentration. The current settings on the Harmony titrator are:

(a) CN^- tube Purple/Orange 14 ml/min
(b) $AgNO_3$ tube Red/Red 3 ml/min
(c) $AgNO_3$ solution N/100 including 10 ml/litre Conc. NH_4OH to mask the effect of the 2 500 p.p.m. Chloride in the plant solution.

Future work with titrator

We feel that our titrator needs no further modification except, perhaps, the provision of a pure silver electrode. The variable speed rotary valve cyanide feeder will be modified to accept the titrator's proportional pneumatic signals instead of the current ON/OFF operation. Straight line cyanide control is expected, and further cyanide savings will be attempted.

To those at the colloquium who have been expressing the wish that a cyanide measuring instrument were available, I would like to announce that there is one.

Notices

SEVENTH WORLD CONGRESS ON OCCUPATIONAL SAFETY AND HEALTH

The congress will be held in Dublin, Ireland, from 20th-25th May, 1974.

Particulars may be obtained from:
World Congress Secretary,
Ansley House,
Dublin 4,
Ireland.

INTERNATIONAL CONGRESS ON MERCURY

The Instituto Technológico Metalúrgico "Emilio Jimeno", of the University of Barcelona, announces a "First International Congress on Mercury" for September, 1973. Sessions as well as Symposia and Panel discussions will be held on history, geology and mining, extractive metallurgy, physical metallurgy and metallography, uses (pharmacy, metallurgical and agriculture), toxicity and miscellaneous.

Sessions are planned to stress world resources, future of mercury and its wise use.

Authors are invited to send in a 250 word abstract in English before May 1, 1973, to: Primer Congreso Internacional del Mercurio, Instituto Technológico Metalúrgico "Emilio Jimeno", Facultad de Ciencias, Universidad de Barcelona, Barcelona, 14, Spain. Inquiries may be made at the same address.

PROCESS ENGINEERING OF PYROMETALLURGY

The Institution of Mining and Metallurgy and The Institution of Chemical Engineers will hold a joint one-day symposium on 'Process Engineering of Pyrometallurgy' at Imperial College, London, on 10th April, 1974.

Papers are invited, within the field of high-temperature operations, on aspects of fluid flow, heat and mass transfer rates, and on process dynamics, with particular emphasis on plant experience. Techniques of process and plant analysis which have special, or novel, relevance to high-temperature systems would be especially welcome.

The conference will be conducted in English. Papers presented will be issued to all registrants prior to the meeting.

Authors wishing to offer papers, of not more than 4 000 words, are asked to submit a title and abstract (200-300 words) to the Editor, The Institution of Mining and Metallurgy, 44 Portland Place, London W1N 4BR, before 1 April, 1973. Manuscripts of papers selected for presentation will be required in November, 1973.

SOUTH AFRICAN MINING AND ENGINEERING JOURNAL COMMEMORATIVE VOLUME 24TH MARCH, 1969

"South African Institute of Mining and Metallurgy 1894-1969".

A limited number of copies of the above volumes are available to members at a nominal charge.

Application should be made to the Secretary, S.A.I.M.M., P.O. Box 61019, Marshalltown.