

thus easily be lost. This can be avoided if the high carbon iron briquettes are further processed at the site of the sponge iron plant. Whether pigs should be shipped or conversion to steel and continuous casting be carried out next to the direct reduction plant, depends on local conditions. An attractive economic set-up could be a sponge iron plant coupled with steelmaking facilities and continuous casting near the source of raw materials whereby billets and/or slabs would be shipped to a rolling mill situated near the consumers' market.

Generally speaking, the suggested concept is a combination of steps well-known in the metallurgical industry. It follows the principle of the blast furnace process, where prereduction below fusion temperature in the shaft is followed by final reduction above fusion temperature in the hearth. It is, of course, an advantage of the blast furnace that these two steps are carried out in one unit, but the new concept has the advantage that refining to steel can be combined with the final reduction, which is carried out in a hearth furnace.

I am very pleased that Mr. Coetzee's paper has made it possible to make some comments on the subject of direct reduction. I shall be satisfied if I succeed by my remarks in paving the way for fruitful further discussions, which need not necessarily take place here and now. I think direct reduction, or to be more precise, sponge iron production for the direct production of steel by oxygen refining, is a topic which does not only fall in the domain of the Iron and Steel Industry of South Africa. I can see no reason why, by common and determined efforts, we should not succeed in making direct reduction plus oxygen steelmaking an economic proposition. Some of the vast resources of the country's raw material could then be used to greater advantage. Further, I should mention that exploratory discussions with parties outside South Africa revealed that such a development could also lead to the most desirable export of capital goods.

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A review of the tenth international symposium of the application of computer methods in the mineral industry

G. H. Morton

The tenth international symposium on the application of computer methods in the mineral industry (APCOM) was held in Johannesburg in April; the first time it had taken place outside North America. In the technical sessions fifty-seven papers were presented, providing a review of current work and including some important original contributions. These papers and a full account of the discussion at the symposium will soon be published in a single volume.

The Technical Programme

The first session of the symposium included an opening address given by Mr J. W. Shilling, President of the Chamber of Mines of South Africa, and a keynote address

AUTHOR'S REPLY

Mr. J. P. Coetzee

As I recollect, the various case studies on the application of direct reduction carried out at Iscor never gave a clear cut favourable answer and if I further take into account the fact that, despite numerous projects, only a few sponge iron plants are actually producing on a commercial scale, then I think that the new approach to the method of sponge iron production and its utilisation as suggested by Dr. Gebhard deserves our full attention.

Should it be possible by implementing his ideas not only to achieve a decrease in sponge iron production cost, but also to establish a cheaper method of converting sponge iron to steel, then a new approach to quite a number of problems would be possible. I have in mind problems in connection with existing Iron and Steel plants as well as with the establishment of new plants.

Not infrequently, integrated Iron and Steel plants are faced with an imbalance between the capacities of the various production units. Additional Fe-supply from a sponge iron plant at reasonable capital cost can play an important role here. The production and conversion cost of sponge iron will have to be considered for each set of specific circumstances.

Another interesting aspect, which was mentioned by Dr. Gebhard, is the possibility of deviating from the orthodox pattern of the fully integrated Iron and Steel plant, i.e. to locate sponge iron plus steel-making facilities on the one hand and rolling facilities on the other hand, on different sites. I am a strong supporter of this policy. In future the work will have to be brought to the main sources of labour. Ethnological grouping of people will play a prominent part in decisions to locate industries in certain areas. Bearing in mind the great impact transport cost has in South Africa on the production cost, one should try to optimise the relative location of the various units in regard to transport cost on raw materials, semis and finished products. I imagine that greater flexibility in this respect could flow from an approach as suggested. This could lead to a most desirable decentralisation of industry.

by Mr K. F. Lane of the Rio Tinto Corporation Limited.

Mr Shilling spoke about the history of the South African mining industry and about some of the work of the Chamber of Mines. He stressed the importance of the symposium in familiarising those in mining with computer applications, and expressed his hope that it would stimulate and inspire scientists and engineers in the effort to develop safer and more economic methods of mining.

Mr Lane, talking about economic and financial modelling, gave a fascinating account of the experience of RTZ over the last twelve years. In a very honest appraisal of the substantial progress that had been made, he confessed some disappointment not only in the cost and

the failure to anticipate the scale of the effort required but also in the duplication of systems and the impact the work had had on management. He suggested two keynotes for the symposium. On marketing: since the value of a product is established by the market, which in this case is management, produce systems relevant to their problems. On professionalism: since sufficient experience has now accumulated, be realistic in making claims and honest in the assessment of the time and resources necessary to achieve them.

The first technical session dealt with exploration. A paper on corporate strategy set the scene with a discussion of the risk and profit criteria affecting the choice of exploration environment. Another contribution concerned the use of the Engel simulator in the search for uranium.

The session on ore reserve estimation included an account of the development and application of a model of Bougainville Copper's Panguana ore body, and a lucid exposition of Matheron's geostatistical method for ore reserve estimation. The highlight of the session was the outstanding paper on statistical valuation of diamondiferous deposits by Professor H. S. Sichel. In the derivation of a discrete density distribution to describe the occurrence of diamonds, an entirely new Poisson mixture distribution was developed. This distribution has far-reaching statistical significance. Combining the density distribution, the size distribution and the selling price structure a meaningful appraisal of diamondiferous ground is possible. Confidence limits can now be calculated which allow inferences from sampling to recovery.

Taking up the theme, there followed parallel sessions on exploration analysis and industry-wide projection.

A paper about estimation and depletion planning for beach diamond deposits was presented, which demonstrated the successful application of Professor Sichel's work in the South West African coastal diamond mines. Other papers were presented on the computer evaluation of geochemical data; the research of the State Geological Survey of Kansas in oil-exploration decision making and estimation of outcome probabilities for wildcat wells; the design of a data bank for drill hole information; and the choice of spacing for soil sample traverses.

Three papers, of special interest in South Africa, were delivered at the simultaneous session. Two of them came from Canada. One concerned the optimisation of public gains from the exploitation of mineral resources. The other described possible modes of Government participation in marginal mining operations and proposed a method, based on non-zero sum game theory, for relating the form of Government contributions to the lowest feasible annual production. The third paper in this session dealt with a computerised model of the South African electricity system — a model which forms the basis for forecasts of coal and uranium requirements for electric power.

The symposium continued with diverse and interesting contributions in the fields of project design and analysis. In one paper, the use of computer simulation to aid the design of crushing plant flowsheets was discussed. Another described the profitability sensitivity analysis

of a mining venture which, by case study, suggested that income tax rates and methods of depreciation only slightly effect the rate of return. Some unusual work was illustrated in a paper about the computer system that has been developed to investigate the impact of transportation networks upon the potential supply of base and precious metals from Sonora in Mexico. This investigation had shown that the existing network is well sited and had facilitated the estimation of the potential supply of copper, lead, zinc, silver and gold. A fourth paper detailed the derivation and application of an economic model of a gold mine. The potential effects of likely technical innovations on the opening of new mines in South Africa were examined. The analysis also revealed that the return from small mines, over an initial period of 20 years, was significantly greater than that from larger mines.

The following sessions on mine and open pit planning demonstrated the progress being made. Both the design of computerised open pit planning models and their application were considered. An outline of the computer methods used by the French Commissariat à l'Énergie Atomique, applicable to any type of ore deposit, was given. Two of the papers dealt with the block by block approach to open pit planning. One represented an attempt to unify economic, design and scheduling factors; the other aimed to generate an optimum design. The application of a system to aid pit planning in stratiform ore bodies was also discussed.

In 1969 most of the Ruhr coal mines amalgamated; a fascinating contribution detailed the application of computer methods to capacity calculations, investment allocation and long-range production scheduling in the new enterprise. Production planning in coal mines provided the background again for a most impressive paper about the work of the Chamber of Mines to produce a coherent system of programmes to be of aid in the full spectrum of activities in the planning of new and operating mines. This is an effort to combine to best advantage the insight of the human planner with the speed of the computer in repetitive calculation. Data base and production simulation programmes were described. And they show careful attention to the three factors that Mr Lane, in his keynote address, felt so important to successful application: simplicity of data collection; easily modifiable form of computation; and flexible, selective output reports.

Under project design, studies were presented on: design of processing plant for a large mining venture; use of dynamic programming in mill scheduling; and economics of surface mining of multiple seams.

A parallel session on geological modelling produced valuable comment on modern techniques. One paper, briefly summarising Matheron's theory of regional variables, proceeded to demonstrate the power of the Kriging estimator. Another tackled the special problems that arise in the evaluation of lateritic-type ore bodies. Unrolling, to reconstruct the original depositional geometry of folded strata, provided the theme for a paper from the Zambian Copperbelt. A simulation programme to guide the layout of surface or underground workings was used in the development of an

exploration model for tabular orebodies and was described in a different paper. The method of harmonic analysis proved an interesting approach in a statistical study of copper and gold occurrences in the Arribiti area of the Canadian Shield.

Production planning and control were the main subjects discussed in the third day of the symposium, which began with two more papers from Zambia. One concerned long-term production scheduling; the other a linear programming approach to medium-term operational planning for a group of copper mines. From Sweden came the account of a neat and effective application, again of linear programming, to investment analysis. The opportunity existed for investment in different kinds of mining and process plant. The questions were: how does total profit vary with alternative investment possibilities and what effects would the investments have on the whole system. The model made it possible to analyse investment proposals in a totally new way and gave clear insight into the problem. The different and, perhaps, more controversial technique of simulation featured in a paper from the Chamber of Mines on underground stoping and transportation. The two simulation programmes have been designed to reproduce accurately the behaviour of a mining process; they make it easy to compare different systems under identical conditions.

Linear programming again figured in models of copper leach and solvent extraction plant and underground copper mines. From Nevada came the description of a recently developed programme to produce a 40-day production forecast for underground stoping. The quite different caving method of mining was discussed in another paper which proposed a dynamic method of ore reserve assessment.

The special ventilation automation problems of interconnected open pit and underground workings in Finland (where the atmospheric temperature varies between $+30^{\circ}\text{C}$ and -30°C) were described.

The history of the work done and results achieved by the Chamber of Mines in strata control was the subject of a most impressive paper. Another significant paper on this topic described computer aid in the solution of problems in rock mechanics. A new approach was postulated, with the potential to perform linear three-dimensional continuum analysis at practical cost.

Four papers came under the general heading of operations planning and control—underground liquid flow, equipment maintenance, evaluation of production strategies and simulation of open pit operations. The parallel session included a discussion of computer design of flash smelting installations and three papers on ventilation. The methods employed in the planning, checking and controlling of ventilation in German coal mines were detailed in one. The two other papers centred upon the development of heat flow models and the coal mine ventilation systems in use in the United States of America.

The final day of the symposium opened with discussion on process control, illustrating the progress that is being made in the design and control of crushing and flotation plant. The relevance of techniques such as

simulation and multiple spline regression was considered. And the control of flotation at the Canadian Ecstall concentrator, perhaps the most spectacularly successful example of computer application in the whole symposium (a capital-cost payback period of 0,17 years), was described.

The last technical session dealt with market analysis. An economic model of the mineral sands industry, the dynamic control of a mining enterprise and the relevance of computer methods to the economics of the mineral industry were subjects under examination.

A panel discussion followed. In debate about the opportunities and problems highlighted in the course of the symposium, distinguished delegates and authors gave their views on the practical value of existing computer applications and suggested worthwhile directions for further effort.

With closing remarks by Mr P. W. J. van Rensburg, the symposium chairman, the final day came to an end. Not only did the tenth international symposium on the application of computer methods in the mineral industry provide a stimulating review of recent achievements but, with discussion of obstacles to effective application, it also emphasised the scale of the problems still to be overcome.

The Social Programme

As well as being a formal opportunity for the exchange of ideas, the symposium was a social occasion and for overseas visitors a chance to see South Africa. With this in mind, a varied social programme was planned. The apparent ease with which both technical and social programmes were conducted was a tribute to the work of the organising committee.

The symposium lasted from 10 April to 14 April. The visitors were accommodated at three large hotels in Johannesburg. Technical sessions were held at the Wanderers Club; and a coach service was arranged to and from the hotels. Overseas delegates began arriving on Saturday 8 April and nearly all of them were met at the airport by members of the organising committee.

The first social event occurred even before registration. A coach trip to a display of African tribal dancing was arranged. In the intimate arena of East Rand Proprietary Mines, the colour and rhythm of the dancers made a stirring sight.

That evening, an informal coffee party at one of the hotels gave an opportunity to register early and meet colleagues. A very large proportion of delegates attended this pleasant function. Afterwards a dinner was held for authors and session chairmen, at which the committee introduced themselves and made detailed arrangements for presentation of papers.

The symposium began on Monday 10 April with registration, an opening session and technical discussion of exploration, ore reserve assessment and industry-wide projection. For wives of delegates, a ladies programme was organised. After the opening, the ladies left for a tour of Johannesburg's northern suburbs, lunch at the Chamber of Mines Sports Club and a trip to the Post Office Tower. They rejoined their husbands

for a reception given by His Worship the Mayor of Johannesburg at Wemmer Pan, where, on a beautiful evening, members of the symposium were able to watch the unusual musical fountains. After a buffet meal by the lake, the Mayor gave a special welcome to the foreign guests.

The technical programme continued on Tuesday with contributions on project design, mine and open-pit planning, and geological modelling. The ladies spent the day in Pretoria with a visit to the Union Buildings, a very interesting tour of the South African Bureau of Standards and lunch at the headquarters of the Transvaal Provincial Administration. The most interesting pavilion of the Chamber of Mines at Milner Park show-grounds was the venue for a cocktail party and buffet supper for all delegates and their wives given by Mr J. W. Shilling, President of the Chamber of Mines, in the evening. Permanent displays and mining films made a lively background to a pleasant party.

On Wednesday, technical discussion was set aside for a choice from six day-tours. One of the most popular was the visit to the Libanon and Venterspost gold mines; a chance to go underground, see a stope and look over a reduction works. An alternative was the tour of the impressive steelworks of the South African Iron and Steel Corporation at van der Byl Park. Of special interest, too, was a visit to the National Institute for Metallurgy. A visit, by air, to Kimberley made another exciting alternative; it included a tour of the Kimberley mine of De Beers Consolidated Mines, their unique diamond exhibition and most interesting museum, as well as a flight over the 'Big Hole'. The fifth tour went to the Chamber of Mines to see some of the extensive work at the research laboratories. Finally, for those

seeking a broader view of South Africa, there was a drive around the Soweto African township to the south of Johannesburg, continuing to the Krugersdorp game park with a braai at the nearby bird sanctuary and, afterwards, a visit to Sterkfontein caves, the scene of the discovery of man's earliest ancestors. That night delegates were invited by Professor Bozzoli, Principal of the University of Witwatersrand, to a cocktail party as part of the celebrations marking the University's Golden Jubilee.

Technical sessions were resumed on Thursday with discussion on production, operations and technical planning, ventilation and rock control. For ladies it was a free day in Johannesburg. In the evening, Professor

H. Zemanek, President of the International Federation for Information Processing, was the guest speaker for the symposium dinner at the President Hotel, which was attended by most of the delegates and their wives. A world authority on computers, he gave a fascinating description of cybernetics and an account of its history.

The Friday sessions dealt with process control and market analysis and ended with a panel discussion. The ladies spent the morning touring a diamond cutting works. Some of their husbands, having defected from the technical sessions to join this tour, found they had made an expensive mistake when persuaded to buy 'samples'. The programme for the ladies concluded with a farewell lunch at the Johannesburg Country Club.

The symposium was over. However, an extra tour of Libanon Gold Mine was arranged on Saturday morning at the request of those who had opted for some other tour on Wednesday. There followed the five-day post-symposium tour for the forty delegates who had booked for it.

The tour left Johannesburg early on Sunday morning on the first stage to Phalabora via Magoebaskloof and through the beautiful scenery of the escarpment. The next morning was spent at the huge Palabora Mining Company open-pit and included a tour of the milling plant, smelter and refining works. In the afternoon the delegates left for the Kruger National Park and stopped at Olifants camp for the night. The following day was devoted to game watching. Plentiful rains and thick bush made the rare animals difficult to spot. However those new to South Africa found the herds of buck, giraffe, wildebeest and many smaller animals and birds exciting. Camped at Skukuza that night with the sounds of game all around there was a memorable 'braai'. The next morning was again spent in the park, when a few lions were seen at a distance. In the afternoon the tour continued to Witbank where the following day was spent visiting the Highveld Steel and Vanadium Corporation. It was an interesting opportunity to learn about the unique Highveld process. Returning to Johannesburg that evening, the tour ended after five hectic but happy days.

The social events had been diverse, exhausting and enjoyable. Outstanding among many pleasant memories is, perhaps, the memory of the hospitality of every individual and organisation that entertained the delegates.

Flotation of cassiterite by D. A. Viljoen

Presented at the Colloquium on Flotation

Author's reply to discussions

The comments by Mr Chaston were constructive and much appreciated.

Considering firstly the recovery of cassiterite from fine deslimed material. A size distribution analysis shows that 58 per cent of cassiterite in Union Tin flotation concentrate reports in the minus 15 micron (quartz) size range. This is achieved at a recovery of 67 per cent and concentrate grade of 42.6 per cent.

It is of interest to note that at Altenberg in East Germany 85 per cent of the tin in deslimed minus 43 micron material is recovered into a 14 to 16 per cent Sn

concentrate using para-tolyl arsonic acid as collector. Reconcentration of this material is then carried out using two shaking table stages which recover 53 per cent of the tin in a 50 per cent Sn concentrate. Flotation was resorted to after recovery rates of 35 per cent and concentrate grade of 30 per cent had been achieved in a 275 ton per day plant comprising 130 tables. Tests on tabling of deslimed minus 43 micron material have not been carried out at Union Tin.

The cost of equipment actually associated with cassiterite flotation amounts to about R60 000. The