SPOTLIGHT
on pyrometallurgy

by C. W. P. FINN*

On 14th April, 1980, 76 delegates from industry, universities, and research laboratories gathered at the University of the Witwatersrand to attend the Pyrometallurgy Vacation School. Professor H. B. Bell, Chairman of the Department of Metallurgy at the University of Strathclyde, Scotland, was there to lead the School, along with 12 local lecturers, who had gathered at the Hotel Devonshire at 07h30 for an Authors' Breakfast.

The School was opened by Mr D. A. Viljoen, President of the South African Institute of Mining and Metallurgy, who reviewed the role of pyrometallurgy in Southern Africa. Professor Bell opened the formal lectures of the School by discussing the application of free-energy diagrams to pyrometallurgical processes, using the smelting of chromite to ferrochromium as one of his examples. Dr H. J. S. Kriek, Refractories Consultant at Iscor, then presented the first of two lectures on refractories, outlining the properties of the ideal refractory and pointing out that no ideal refractor exists. He discussed the properties and availability of refractories in the Republic, emphasizing that both quantity and quality are important. Professor Bell then gave the first of two lectures on the thermodynamics of solutions.

Dr Kriek's second lecture dealt with the proper application of refractories, especially in steelmaking. As a vivid example, he quoted the vast improvement in the performance of refractories in the basic oxygen furnace (BOF) achieved by the control of the acid: base slag ratio and temperature. At present, one of the Iscor BOF's at Vanderbijlpark is approaching a world record for refractory life.

The Case Study, which was prepared by the National Institute for Metallurgy (NIM), was introduced by Dr N. A. Barcza, who described the state of a hypothetical 75 MVA ferrochromium furnace with a broken electrode. The participants in the Case Study were faced with the task of returning the furnace to normal production within four days, using computer simulation. There were three programmes available: a design programme, an electrical programme, and a furnace performance programme. The 40 participants were divided into teams of eight, and a lively competition ensued. Although the School cocktail party was scheduled for 17h15, several teams were still at their terminals until 18h00.

Ferro Alloy Production

On Tuesday morning, Professor Bell continued his discussion of solution thermodynamics, after which the emphasis shifted to the ferroalloy industry, with a presentation by Mr R. A. Featherstone of Samancor on the production of ferrochromium and ferromanganese in South Africa. Dr H. Bartlett, of J.C.I., discussed the production of ferrochromium by the direct-reduction process as practised at Consolidated Metallurgical Industries, and Mr A. B. Stewart, of NIM, detailed the electrical aspects of the design and control of submerged-arc furnaces. The roles of reactance and inter-electrode interferences in furnace control were outlined.

These topics were complemented by Professor Bell, who lectured on slag-metal equilibrium in both ferrous and non-ferrous systems, using as his examples the Imperial Smelting Process for the production of zinc, and manganese and phosphorus partitioning in steelmaking. After the lectures, the Case Study teams laboured into the night with variable success.

Wednesday morning was devoted to matte-smelting processes, Professor Bell leading off with a detailed presentation on the thermodynamics of sulphide smelting, which he demonstrated with diagrams showing the effects of oxygen and sulphur pressure on the smelting reactions. Mr M. Hodges, of Palabora Mining Company, in outlining smelting and converting practice at PMC for the production of copper, emphasized the unique nature of the Palabora copper deposit, which, because of its basic ($CaCO_3$) gangue has unusual fluxing requirements. He also pointed out the role of magnetite in the control of converters.

Dr Bartlett discussed the smelting of copper–nickel concentrates containing platinum-group metals. He outlined the reasons for electric smelting (slag with a high liquidus temperature in most cases), and showed how laboratory measurements were used in the design of the new electric furnace at Bindura Smelting and Refining Company in Zimbabwe.

After lunch, Professor Bell introduced the use of oxygen-exchange diagrams in the analysis of reduction reactions. By application of this concept, a remarkable amount of information can be compressed into a simple diagram. In careful stages, Professor Bell showed how the direct reduction of iron ore can be analysed by the use of these diagrams.

The Case Study groups met in the afternoon to complete their task. The computer was due to switch off (for routine maintenance) at 17h30 and this was their last chance. The study wound up with a short talk by Dr I. J. Barker, of NIM, on the electrode controller that had been developed at NIM and used on an operating ferrochromium furnace.

Thursday was devoted to steelmaking. Dr T. B. Beeton, of Iscor Research Laboratories, started with a 'Review of Steelmaking in South Africa', outlining the

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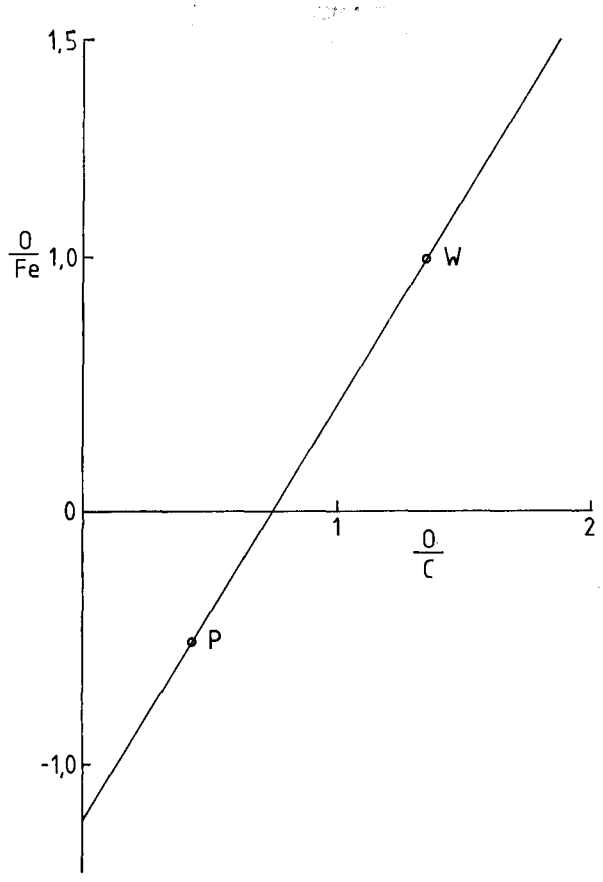

Fig.—1 Oxygen ezchange diagram
W=Chemical P=Thermal

history of the industry in the Republic. He showed how Iscor became the largest steelmaker but emphasized the important role of others. He did not comment in detail on Highveld owing to a subsequent paper, but mentioned Dunswart Steel's unique position as the only producer of direct-reduced sponge iron (DRI) in South Africa, while predicting that they will not hold that honour for long. He finished with a description of the interaction between research and production in a large company, and the long lead times between laboratory tests and plant application.

Oxygen Exchange Diagrams

Professor Bell then gave a detailed demonstration of the application of oxygen-exchange diagrams to the blast-furnace smelting of iron. He illustrated how the furnace 'operating' line was determined by two points: one set by chemical equilibrium via the reaction $FeO+CO \rightarrow Fe+CO_2$, and the other by thermal-energy considerations. Although this technique was first introduced by André Rist* in 1964 and has been taught at Strathclyde University for some years by Professor Bell, this was the first time that the latter had had his notes prepared in printed form. Professor Bell showed these diagrams (Fig. 1) can be used in the case of oxygen enrichment, fuel injection, direct as against indirect reduction, and blast pre-heat.

*A. Rist and N. Meysson, *Rev. Metall.*, vol. 61. 1964. pp. 121-145.

Mr B. Röhrmann, of Highveld Steel and Vanadium, then followed with a detailed description of the complex processes used at Highveld Steel. These include kiln prereduction, electric smelting to molten iron, shaking ladle removal of vanadium-rich slag, and BOF conversion of iron to steel. Especially noteworthy are the improvements in kiln and BOF life resulting from improvements in refractories and processing over the past four years.

Desulphurization

After lunch, Professor Bell talked about sulphur control in iron-and steelmaking. He commented particularly on the need for an integrated approach to sulphur control, and the current shift around the world toward ladle desulphurization. He emphasized the important role of oxygen control in the removal of sulphur and advocated the simultaneous addition of a deoxidizer (such as aluminium) and a desulphurizer (such as calcium oxide) in the final steelmaking stages.

Mr R. D. MacPherson, of Richards Bay Minerals, then described the smelting of ilmenite ($FeO.TiO_2$) concentrate to pig iron and rutile slag. He illustrated his talk with colour slides and emphasized the environmental protection practised at Richards Bay. Every product of the process is either sold or returned to the sand dunes from which they had been taken.

The final say of the day went to Professor Bell, who presented a lecture on the deoxidation of steel, emphasizing the thermodynamics and kinetics of various deoxidants. He showed that the removal of non-metallic inclusions from deoxidized steel is as important as the removal of dissolved oxygen in the first place.

Many of the delegates then availed themselves of the invitation to tour the laboratories of the NIM Pyrometallurgy Research Group on the University of the Witwatersrand campus. The Group is financed jointly by NIM and the Ferro Alloy Producer's Association, and its research efforts lie mainly in the field of ferro-alloy production. Research students in the group explained how they obtain fundamental pyrometallurgical data and showed the visiting delegates the various equipment available to the Group.

After a long and interesting day, the delegates were entertained to dinner at the Chamber of Mines Club. Mr J. C. Mostert, Chairman of the S.A.I.M.M. Vacation School Committee, gave a brief but thoughtful after-dinner speech thanking Professor Bell for his efforts.

On the last day, Professor Bell talked on the thermodynamics and kinetics of the vacuum treatment of liquid steel, emphasizing that the requirement was not a high vacuum but rather a high pumping capacity at moderate pressure. Dr C. W. P. Finn, of the University of the Witwatersrand spoke of the difficulties in pyrometallurgical research. He was asked by one of the delegates, 'Now that you've convinced yourself that pyromet research is impossible, what will you do for a living?'

Mr A. R. Barnes of the NIM Pyrometallurgy Research Group, then discussed the use of semi-quantitative X-ray diffraction in the control of copper smelting. He dealt with the role of the relative proportions of copper sulphides in the copper:iron ratio in reverberatory copper

matte, flux requirements, and converter scheduling. He presented data that showed marked improvement in converter performance over a limited trial period as a result of this control method.

After lunch Dr Barcza took the chair for the Case Study report. Each of the five Group Leaders presented the approach taken by their Group and the results obtained.

Case study tactics

Group A, led by Mr J. W. P. Bennie of Southern Cross Steel, aimed for maximum production by rapid electrode slipping on the broken electrode and maximum power on the two sound electrodes. Group B, led by Mr W. P. Channon of Rhodesian Alloys, took an even more aggressive approach, and slipped at more than the recommended maximum rate; by day 3 their furnace had returned to full production. Group C, led by Mr B. Lund of Palmiet Chrome, took a very conservative approach and asserted that, 'since all the other groups had re-broken their electrode', his group had in fact achieved the best result! Group D, led by Mr D. P. O'Shaughnessy of Consolidated Metallurgical Industries, was the most aggressive of them all. By a combination of rapid slipping and alteration of slag chemistry, Group D achieved the maximum production after the shortest time. Group E, led by Mr N. F. Scheepers of Southern Cross Steel, got a jump on all the other groups by starting corrective action at the beginning of day 0, rather than at the end as the other groups had done; in spite of this advantage they finished marginally behind group D owing to their otherwise moderate approach.

In summing up, Dr Barcza awarded first place to Group D, but said that he pitied their plant manager's ulcers. All the groups expressed appreciation to NIM for the preparation af a stimulating and educational case study.

Mr Mostert closed the School with a brief but detailed summary of the week's proceedings, thanking all the lecturers for their efforts. He complimented Professor Bell not only for giving 14 well-delivered lectures but also for providing an excellent set of printed notes for future reference. These notes, previously unpublished, will form the basis for a monograph on pyrometallurgy, co-edited by Dr Finn and Prof Bell.

Analytical chemistry

Euroanalysis IV will be held in the town of Espoo, approximately 9 km from the centre of Helsinki, from Sunday, August 23rd, to Friday, August 28th, 1981.

Euroanalysis IV will aim, as did the earlier conferences, at the broadest possible coverage of analytical chemistry. The programme is being planned to appeal both to practising analytical chemists at industrial and control laboratories, and to those teaching and doing research on analytical techniques at universities and research institutes.

The programme will consist of invited plenary and keynote lectures, contributed papers, and special sessions. In order to ensure the high quality of the programme, all contributed papers will be refereed by an international panel.

All those intending to participate in the Conference are welcome to submit papers to be included in the scientific programme. The Scientific Committee will consider papers according to their relevance to the Conference programme and their scientific contents. A listing of possible topics is given below, but other areas of analytical chemistry will also be considered.

1. Atomic Spectrometry
2. Automated Techniques
3. Chromatography
4. Clinical Analysis
5. Computers in Analytical Chemistry
6. Electroanalytical Chemistry
7. Emission Spectroscopy
8. Environmental Analysis
9. ESCA and Related Techniques
10. Geochemical Analysis
11. Food Analysis
12. Forensic Science
13. Kinetic Methods of Analysis
14. Materials Science
15. Mass Spectrometry
16. Microchemical Techniques
17. Molecular Spectrometry
18. Nuclear Techniques
19. Pharmaceutical Analysis
20. Photometric Analysis
21. Polymer Analysis
22. Reference Materials
23. Spectroscopic Techniques
24. Thermal Analysis
25. Trace Analysis
26. X-ray Techniques
27. Other

Enquiries should be addressed to Euroanalysis-IV, Association of Finnish Chemical Societies, Mr Veikko Velamo, Executive Director, Pohj. Hesperiankatu 3 B 10, SF-00260 Helsinki 26, Finland.