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Tapping the ORE de plasma arc furnace pilot plant at Mptek
INFACON 6
(Incorporating INCSAC 1)

Volume 1
FERROALLOYS

Edited by
H. W. GLEN

The conference was organised by
The Council for Mineral Technology
The South African Institute of Mining and Metallurgy
and
The Ferro Alloy Producers’ Association

THE SOUTH AFRICAN INSTITUTE OF MINING AND METALLURGY
Johannesburg 1992
CONTENTS
Volume 1

<table>
<thead>
<tr>
<th>Foreword</th>
<th>xiii</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preface</td>
<td>xiv</td>
</tr>
<tr>
<td>Committees and Sponsors</td>
<td>xv</td>
</tr>
<tr>
<td>Units and Ferroalloy Nomenclature</td>
<td>xvi</td>
</tr>
</tbody>
</table>

SECTION 1
Plenary and Keynote Addresses

| The status of the ferroalloy industry with special reference to South Africa, H. J. Smith | 3   |
| Strategic planning parameters for the steel and ferroalloy industries, P.H. Smith       | 13  |
| Plasma-arc technology for ferroalloys, Part II, D.R. Mac Rae                           | 21  |
| The availability and marketing of vanadium, T. Jones                                   | 37  |
| Commercial relationships now and into the twenty-first century, A.A. Apotsos           | 43  |

SECTION 2
Ferrochromium

| The reduction of synthetic iron chromite in the presence of various metal oxides - a thermo-analytical study, C.P.J. van Vuuren, J.J. Bodenstein, M. Scarone and P. Kestens | 51  |
| The solid-state reduction of chromite, M.J. Niayesh and R.J. Dippenaar                   | 57  |
| Kinetic aspects of chromite ore reduction with coal at 1200 to 1550°C, D Neuschütz       | 65  |
| Solid-state fluxed reduction of LG-6 chromite from the Bushveld Complex, P. Weber and R.H. Eric | 71  |
| The importance of chromite pretreatment in the production of ferrochromium, M. Honkanien, H. Krogerus, J. Daavitilva and P. Oilkarinen | 79  |
| The melting behaviour of chromite ores and the formation of slag in the production of high-carbon ferrochromium, S. Xu and W. Dai | 87  |
| The reduction of chromite in Fe-Cr-C-Si alloys, O. Demir and R.H. Eric                  | 99  |
| An evaluation of process alternatives for the reclamation of ferrochromium from slag, J. Visser and W. Barrett | 107 |
| Commissioning and operating an induction furnace at Zimasco (KweKwe Division) to melt high-carbon ferrochromium, S. Jena and S.T. Ravasingadi | 113 |
| Operating and marketing results of the production of intermediate-carbon ferrochromium in a CLU converter, P.H.F. Bouwer | 119 |
| Technology for the combined production of chromium metal and ferrochromium, R.L. Wang   | 123 |

SECTION 3
Ferromanganese

| A case study of the production of high-grade manganese sinter from low-grade Mamatwan manganese ore, P.C. Pienaar and W.F.P. Smith | 131 |
| The production of special SiMn using the gas and powder injection process, R. Kamata, Y. Kizu and H. Tsujimura | 139 |
| The development of technology for the production of refined ferromanganese in China, Z. Jinhua and L. Zhizhong | 145 |
High-productivity operation of a shaft-type ferromanganese smelting furnace, S. Suzuki and M. Masukawa ................................................................. 149
The two-stage production of high-carbon ferromanganese in a blast furnace: A method for the treatment of a lean manganese ore, T. Zhang ................................................................. 155
Solid-state decarburization of high-carbon ferromanganese, P.J. Bhonde and R.D. Angai ................................................................. 161
Thermodynamic activity of manganese oxide in ferromanganese slags, and the distribution of manganese between the metal and slag phases, H. Cengizler and R.H. Eric ................................................................. 167

SECTION 4
Silicon and Silicon Alloys
Silicon-metal production on a trial basis from river pebbles originating in Australia, D.P. O'Shaughnessy, A.E. Firek and J.E. Trunzo ................................................................. 177
The effect of reductant moisture on the production of 75 per cent ferrosilicon, D. Retallick ................................................................. 181
The production of high-quality silicon metal at Simcoa, C.J. Szymkowski and J.M. Multitude-Paull ................................................................. 185
The refining of silicon and ferrosilicon, J.K.S. Tus et ................................................................. 193
On-line laser measurements of silica dust, E.B. Gudmundsson and T. Hannesson ................................................................. 201
The total quality programme at Bozel, J. Finardi and I.C. da Silva ................................................................. 205
Intermetallic compounds in metallurgical silicon, T. Margaria, J.-C. Anglezio and C. Servant ................................................................. 209

SECTION 5
Vanadium, Minor Ferroalloys, and Special Topics
The use of vanadium – A Brief review, P.S. Mitchell ................................................................. 217
Pyrometallurgical processing of vanadiferous slag using plasma/induction heating, R.L. Howard, S.R. Richards, B.J. Welch and J.J. Moore ................................................................. 225
Maximizing the return from electrode investments, C.F. Fulgenzi ................................................................. 233
The heat-recovery system at Minami-Iwate Works, K. Kosaka, H. Ota and Y. Tamura ................................................................. 237
Air-pollution control in the Amazonia region: Dust extraction in a silicon-metal plant, R. Civile and H. de Raedt ................................................................. 243
Electrical factors affecting the economic optimization of submerged-arc furnaces, A. de Waal, I.J. Barker, M.S. Rennie, J. Klopper and B.S. Groeneveld ................................................................. 247
The monitoring and repair of furnace linings at TEMCO, M. Williams ................................................................. 253
Planning for future ferroalloy production in South Africa, M.A. von Below ................................................................. 261

SECTION 6
Ferroalloys in Steelmaking
Wire injection of metallurgical powders into molten metal, G.P. Crawford ................................................................. 271
The optimization of parameters for the carbothermic production of ferroboron, O. Yücel, O. Addemir and A. Tekin ................................................................. 285
CONTENTS

Volume 2

Preface ........................................................................................................................................................................... iv
Committees and Sponsors .................................................................................................................................................. v
Units and Ferroalloy Nomenclature .................................................................................................................................. vi

SECTION 1

Plenary and Keynote Addresses
The potential of the 'chrome chain' for South Africa, P.R. Hatty ......................................................................................... 3
The continuous casting of stainless steels, J.K. Brimacombe, S. Kumar, C.O. Hlady and I.V. Samarasekera ....................... 7
Dephosphorization of stainless steels, N. Sano and H. Katayama ......................................................................................... 25
Nitrogen control in chromium steels, R.J. Fruehan .............................................................................................................. 35
The potential of chromium as an alloying element, G.T. van Rooyen ................................................................................ 43
Developments in zirconia sensors during the 1980's – Laboratory and in-plant applications in iron- and steelmaking, M. Iwase ......................................................................................................................... 49

SECTION 2

Chromium Steel and Alloys
The austenite-ferrite transformation in 11.5 per cent chromium steels, P.G.H. Pistorius, H.J. de Klerk and G.T. van Rooyen ...................................................................................................................................................... 65
High-chromium controlled-hardenability steels, J. Hewitt .................................................................................................... 71
Optimization of the AOD process at POSCO, H.S. Song, S.M. Byun, D.J. Min, S.K. Yoon and S.Y. Ahn ........................................... 89
Mechanical properties of a 316L forging material modified for resistance to sensitization, E. Protopappas, C.A. Smal and F.G. de Lange .......................................................................................................................... 97
A simple experimental technique for the determination of MnO activities at 1600°C in (MnO-MgO-SiO₂) slags saturated with (MnO-MgO) solid solutions, J.M.A. Geldenhuis, E.B. Pretorius and R.J. Dippenaar ........................................................................................................... 105
Carbothermic reduction and desulphurization of chromite with nickel oxide and sulphide, W. Dresler, B.C. Jena and A. McLean ........................................................................................................................................... 111
Design criteria for stainless-steel structural members, P. van der Merwe and G.J. van den Berg ............................................................................................................................................................................. 117
The effect of anisotropy on the fatigue and fracture of a 12 per cent chromium steel, M.B. Cortie, C.J. Fletcher and W. Veldsman .................................................................................................................................................. 121
Metallography of high-carbon ferrochromium, A. Lesko, E. Navara and T.R.C. Fernandes .................................................. 131
The toughness of the heat-affected zone of welds in 11.5 per cent chromium steels, J.J.J. Zaayman and G.T. van Rooyen ........................................................................................................................................ 137
Duplex ferrite-martensite steels containing 16 Wt per cent chromium, R.D. Knutsen and R. Hutchinson .................................... 143
Reducing the nickel content in metastable austenitic stainless steel, O.E. Schmid and R.D. Knutsen ........................................... 143
The effect of martensite content on the corrosion and mechanical properties of dual-phase 12 per cent Cr steels, A. van Bennekom, L.M. Matthews, J.N. Tarboton and F.P.A. Robinson ........................................................................................................................................... 157
Influence of stress and electrochemical effects on initiation and morphology of pits in stainless steels exposed to an aqueous solution of boiling magnesium chloride, D.J. Simbi, M. Dingwiza and B.D. Barker ............................... 165


Performance of buried 3CR12 pipes in various soil environments, R.T. White and E.A. Duligal ................................................................................................................................. 179


Analysis of preferred orientations in duplex chromium-nickel steels, H.J. Bunge, A. ul Haq and H. Weiland ...................................................................................................................... 197

From niche to commodity, 3CR12— a ten-year scenario, D.K. Maxwell, K. Dewar and I. Warrington ......................................................................................................................... 203

Modern stainless steels to combat chloride-induced localized corrosion, J. Olsson .......... 211

The influence of carbon content on the oxidation and wear resistance of Fe-20% Cr alloy at elevated temperatures, J.D. Xing and Q.D. Zhou ................................................................. 217

The susceptibility of 12 per cent chromium steels to stress-corrosion cracking, R.F. Sandenbergh and P.G.H. Pistorius ................................................................. 225

Stainless steel, with 11 per cent chromium and high yield strength, for welded constructions resistant to corrosion and abrasion, J.C. Charenton, P. Rombeaux, B. Hurtaud and J.M. Hauser ................................................................................................................................. 229

Influence of ruthenium content on the corrosion in sulphuric acid of a duplex stainless steel, J.H. Potgieter, W. Skinner and A.M. Heyns ........................................................................... 235

The effect of an oxygen atmosphere on the creep-fatigue failure of iron-chromium alloys at 600°C, E. Aghion, J. Ferreira and D. Eliezer ........................................................................... 241

Smelting reduction of chromite ore in an oxygen converter, T. Izawa, H. Katayama and N. Sano ......................................................................................................................... 245

Ferroalloy production by the smelting-reduction process with a coke packed bed, H. Itaya, S. Taguchi, K. Igawa and T. Nozaki ......................................................................................... 253

A dynamic process-control system for steel converters, P. Hahlin ................................................................................................................................. 259

The role of ferroboron and ferrotitanium in steels: production methods, quality aspects, and addition techniques, R.W. Bebbington ................................................................. 263
Foreword

There are undoubtedly many people and organizations who still have on their bookshelves a copy of the Proceedings of the first INFACON, which was held in South Africa in 1974.

That first congress represented a big step forward for collaboration among ferroalloy industries around the world, and the papers presented demonstrated the value of the cross-fertilization that can arise in conferences of this type. Four other INFACONs have been held, and the International Committee has established INFACON as a much-respected feature of technical liaison.

These two volumes contain the papers that are to be presented at the 6th INFACON, which has introduced another innovative feature by combining the topics of chromium and stainless steel with that of ferroalloys. There is much of common interest in these topics, and we are sure that the combination will prove to be most interesting and valuable.

More importantly, as regards the challenges that lie ahead for the steel industries of the world, it is vital that the producers of raw materials, intermediate products, and final consumer products should form a coherent chain of collaboration, coordination, and cross-fertilization. INFACON helps to achieve this.

I sincerely hope that these proceedings will be the forerunner of many similar conferences in the future.

R. E. ROBINSON
Chairman: INFACON 6
Organizing Committee
Preface

The papers published in this volume are grouped according to the technical sessions in which they were presented at INFACON 6. However, all the plenary and keynote papers are included in the first section. The main technical groupings are according to the major ferroalloy groups, namely ferrochromium, ferromanganese, silicon and silicon alloys, and vanadium and minor ferroalloys. The applications of ferroalloys in steelmaking was chosen as a session topic in recognition of the new chromium steels and alloys. The papers dealing with chromium steels and alloys are published in the second volume of these proceedings.

The papers accepted for publication have been refereed and edited according to the customary criteria stipulated by the SAIMM. Apart from editorial changes, the papers are in the form in which they were finally submitted to INFACON 6. These Proceedings are the first produced on the SAIMM’s new desktop publishing system. Although this system has many special features, the tight deadlines have resulted in some inconsistencies such as the use sometimes of decimal points, instead of the decimal commas that are standard South African practice. Other examples include the use of weight per cent instead of mass per cent, and calories or BTUs instead of joules.

I extend my thanks to Mr J.D. Austin (Publication Committee), Mr W.A. Gericke (Sub-Committee Chairman—Manganese), Mr B.R. Rohrmann (Sub-Committee Chairman—Silicon, Ferrosilicon, Vanadium, and Minor Ferroalloys), and Dr D. Slatter (Sub-Committee Chairman—Chromium), who served on the INFACON 6 Technical Programme Committee for ferroalloys, and to Mrs B. Watkins and Ms Y.M. Arnold (Secretariat). Mr H.F. Boshoff’s assistance is acknowledged.

I give my sincere thanks to Dr H.W. Glen for the tremendous amount of work that she put in to ensure that these Proceedings were published on time. My thanks are also due to the many referees who assisted in vetting the papers; to Mr A.J. Cowey, Mr R. Stimson, Mrs C. Buys, and Ms M.M. Joubert for their sub-editing and proof-reading work; and to the staff of the SAIMM and Mintek for their efforts in preparing this publication. Gratitude is also expressed to the authors for contributing their papers to INFACON 6 and for their co-operation in meeting the stringent deadlines. Special thanks are due to Mrs Claire Kearney, Mrs Pam Smith and Mrs Susan Luddick, of the SAIMM, who co-ordinated the whole publishing task.

N. A. BARCZA
Chairman: Technical Programme Committee
INFACON 6, 1992
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Units and Ferroalloy Nomenclature

Throughout this volume, the use of the International Metric System (SI) units has been preferred. Some of the relevant basic and derived SI units are as follows:

### Basic SI units

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Unit</th>
<th>Symbol</th>
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<tbody>
<tr>
<td>Electric current</td>
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<td>A</td>
</tr>
<tr>
<td>Electric potential</td>
<td>volt</td>
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<tr>
<td>Length</td>
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<td>m</td>
</tr>
<tr>
<td>Mass</td>
<td>kilogram</td>
<td>kg</td>
</tr>
<tr>
<td>Time</td>
<td>second</td>
<td>s</td>
</tr>
<tr>
<td>Luminous intensity</td>
<td>candela</td>
<td>cd</td>
</tr>
<tr>
<td>Temperature</td>
<td>kelvin</td>
<td>K</td>
</tr>
<tr>
<td>Amount of substance</td>
<td>mole</td>
<td>mol</td>
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</table>

### Derived SI units

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Unit</th>
<th>Symbol</th>
<th>Derivation</th>
</tr>
</thead>
</table>
| Force                           | newton     | N      | kg/m/s²
| Frequency                       | hertz      | Hz     | s⁻¹
| Pressure, stress                | pascal     | Pa     | N/m²
| Work, energy, quantity of heat  | joule (calorie) | J (cal)† | Nm
| Capacitance                     | farad      | F      | m²kg⁻¹s⁴A⁻²
| Electric potential              | volt       | V      | m²kg s⁻³A⁻¹
| Impedance                       | ohm        | Ω      | m²kg s⁻³A⁻²
| Conductance                     | siemens    | S      | m²kg s⁻³A⁻²
| Power                           | watt       | W      | m²kg s⁻¹
| Quantity of electricity         | coulomb    | C      | SA
| Weight                          | newton     | N      | m kg⁻²
| Restarting                      | ohm. metre | Ωm    |
| Resistance                      | ohm        | Ω      |
| Temperature                     | (centigrade) | °C     |
|                                | (kelvin)   | K      |
| Flow                            | (gas, liquids) | Nm³   |
| where N means normal (i.e. STP) |            |
| Feedrate                        | (solids)   | kg/h or kg/min |
| Annual production rate or capacity |         | Kt/a |
| Emissivity                      |            | E      |
| Mean particle size              |            | d₅₀   |
| Atmosphere                      |            | atm    |

† (1 cal = 4.1818J)

Since it is not practical to use only the basic and derived units of the accepted system, their decimal multiples and submultiples are formed by adding prefixes to the units. The prefixes are shown in the table below:

### Multiples, Prefixes and Symbols

<table>
<thead>
<tr>
<th>Factor by which the unit is multiplied</th>
<th>Prefix</th>
<th>Symbol</th>
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<tbody>
<tr>
<td>10⁶</td>
<td>giga</td>
<td>G</td>
</tr>
<tr>
<td>10⁵</td>
<td>mega</td>
<td>M</td>
</tr>
<tr>
<td>10³</td>
<td>kilo</td>
<td>k</td>
</tr>
<tr>
<td>10⁻³</td>
<td>milli</td>
<td>m</td>
</tr>
<tr>
<td>10⁻⁶</td>
<td>micro</td>
<td>μ</td>
</tr>
<tr>
<td>10⁻⁹</td>
<td>nano</td>
<td>n</td>
</tr>
<tr>
<td>10⁻¹²</td>
<td>pico</td>
<td>p</td>
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### Abbreviations/Nomenclature related to Ferroalloys

<table>
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<tr>
<th>Chromium alloys</th>
<th>FeCr</th>
<th>ferrochromium</th>
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<tr>
<td></td>
<td>ChCr</td>
<td>charge chromium</td>
</tr>
<tr>
<td></td>
<td>HCFeCr</td>
<td>high carbon ferrochromium</td>
</tr>
<tr>
<td></td>
<td>FeCrSi or CrSi</td>
<td>ferrochromium silicide or silico chrome</td>
</tr>
<tr>
<td>Manganese alloys</td>
<td>FeMn</td>
<td>ferromanganese</td>
</tr>
<tr>
<td></td>
<td>HCFeMn</td>
<td>high carbon ferromanganese</td>
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<td></td>
<td>FeMnSi or MnSi</td>
<td>ferromanganese silicide or silico manganese</td>
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<tr>
<td>Silicon alloys</td>
<td>FeSi, Si</td>
<td>ferrosilicon, silicon</td>
</tr>
<tr>
<td></td>
<td>CaSi</td>
<td>calcium silicide</td>
</tr>
<tr>
<td>Minor ferroalloys (examples)</td>
<td>FeV</td>
<td>ferrovanadium</td>
</tr>
<tr>
<td></td>
<td>FeTi</td>
<td>ferrotitanium</td>
</tr>
<tr>
<td></td>
<td>FeB</td>
<td>ferroboron</td>
</tr>
<tr>
<td>Carbide</td>
<td>CaCr</td>
<td>calcium carbide</td>
</tr>
</tbody>
</table>
SECTION 1
Plenary and Keynote Addresses

Session Chairmen
A. M. Edwards
R. J. Dippenaar
P. A. Brink
N. Keys
H. J. Smith