# SPOTLIGHT
## on Highveld Steel and Vanadium Corporation Limited

by J. HALL*

### Introduction and Background

For many years people were aware of the vast deposits of titaniferous magnetite containing vanadium in the Bushveld Complex. From 1957 onwards some exploitation of this ore was carried out by Minerals Engineering of S.A. (later the Vantra Division of Highveld Steel and Vanadium Corporation Limited), who produced vanadium pentoxide via a roast–leach process. The tailings from this process contained 55 per cent iron, and the management of Anglo American Corporation Limited, contemplating taking over control of Minerals Engineering Company of S.A. in 1959, considered the possibility of using the ore as a source of iron as well as of vanadium. The company was renamed Transvaal Vanadium Company after Anglo American Corporation's take-over in 1960, and in August 1966 Highveld acquired the plant and machinery of this works, which now operates as the Vantra Division of Highveld Steel and Vanadium Corporation Limited.

In May 1960, the Highveld Development Company was formed by Anglo American Corporation with the following objectives:

(i) to undertake a major geological exploration to determine the extent of the available ore reserves and to acquire the mineral rights;

(ii) to undertake a metallurgical investigation into the economics of the recovery of steel and vanadium from the ore by means of a large-scale pilot plant based on electric smelting (the high titania content of the ore ruled out the possibility of conventional blast-furnace smelting);

(iii) to carry out a worldwide study of existing vanadium ore reserves and operations, including the costs of existing production, and to attempt to assess the world supply and demand in 1966.

After a combination of sponsored research work overseas and pilot-plant work at Witbank, a report was issued in 1962 that gave the principles of a recommended process. Davy United of England were asked to carry out an independent engineering study of this process and to pronounce on its practicability and economic viability. A positive reaction was given, and, after a considerable amount of further study, a decision was taken by Anglo American Corporation Limited to go ahead with the project. Davy United was commissioned to design the plant and was appointed as engineer, agent, and supervisor on site in 1965. Highveld Steel and Vanadium Corporation Limited was formed as a company in 1965, and production commenced in February 1968.

Various possibilities had been considered, but from the results of the pilot-plant work it was decided that the process would be as follows:

(a) pre-reduction of the ore in rotary kilns,

(b) smelting of the pre-reduced ore in submerged-arc smelting furnaces,

(c) removal of vanadium from the liquid iron by oxygen blowing in a shaking ladle, to produce solid 25 per cent $V_2O_5$ slag and 'blown metal',

(d) conversion of 'blown metal' to steel in a basic oxygen furnace (B.O.F.).

Ultimately, it was also decided to install a continuous casting plant for the casting of blooms and billets, and a semi-automated combination mill for the rolling of universal columns, parallel flanged beams, and a wide variety of medium sections and billets.

In the meantime, adequate ore reserves had been established and contracts for the supply of vanadium slag were made with users in Europe and the U.S.A.

The site of the steelworks is 11 km west of Witbank, the major factors in this choice being as follows.

(1) It is located on the railway line to Maputo, which is used for the export of products, and there are rail connections to the Johannesburg area and South African ports.

(2) No. 5 seam Witbank coal, the ideal coal for the smelting process, is obtained from Greenside Colliery, only 11 km distant. No. 2 seam coal used for firing the kilns is abundant in the Witbank district.

(3) With some railway extensions, the ore from Mapochs Mine at Roossenekal could be railed direct to site.

(4) The heavy power requirement was readily available from the eastern Transvaal system of the Electricity Supply Commission.

(5) A reliable water supply was available from the Witbank municipal dam.

(6) As a developing industrial town, Witbank had the necessary infrastructure to accommodate the large labour force that would be required.

Since the original development, various expansions have taken place to increase the production of iron and steel, and in August 1977 rolling was started in a plate mill that had been installed to absorb the extra steel and to widen the range of products at Highveld.

One of the major factors in ensuring satisfactory

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smelter performance is to control the quality of the Soderberg electrode paste. Consequently, Ferroveld (Proprietary) Limited, in which Highveld has a 50 per cent share, was formed in 1975 to produce electrode paste for Highveld and its partner in the undertaking, Ferrometals Limited – a company in the Samancor group.

In 1976, Highveld took over Anglo American Corporation's 65 per cent interest in Transalloys, a producer of manganese and silicon ferro-alloys. Transalloys sells ferro-alloys on the local and export markets and also supplies Highveld's requirements.

In 1978 Highveld merged with Rand Carbide Limited, and this works produces ferrosilicon, calcium carbide, Soderberg electrode paste, metallurgical char, and other products associated with the steel and ferro-alloy industries.

### The Process at Highveld Iron and Steelworks

The use of the Highveld ironmaking process, instead of the conventional blast furnace, is due to the composition of the magnetite ore, which has the following chemical analysis (in per cent):

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| Fe | 53 to 56 | CaO | less than 0,10 |
| $TiO_2$ | 12 to 15 | MgO | 0,4 to 1,0 |
| $V_2O_5$ | 1,4 to 1,9 | $SiO_2$ | 1,0 to 1,8 |
| $Cr_2O_3$ | 0,15 to 0,3 | $Al_2O_3$ | 2,5 to 3,5 |

If titaniferous ores are used in the conventional blast-furnace process, titanium carbonitrides are formed in the hearth, their high melting point making the operation impossible. Consequently, the magnetite ore is smelted in submerged electric-arc furnaces after pre-reduction in Lurgi rotary kilns. The pilot-plant work showed that, if a pre-reduction kiln preceded the smelter, coal instead of coke could be used in the burden as a reducing agent, and the power requirements of the smelting process could be lowered significantly. Both these factors pointed to a lower-cost ironmaking process. It was also shown that, if iron ore, coal, and fluxes were delivered to a pulverized coal-fired kiln and heated to 1100°C, a degree of oxygen removal from the iron ore of 30 to 40 per cent could be achieved and the coal completely charred. A charge of this nature proved to be a suitable burden for the subsequent smelting process. The pilot-plant work also showed that a concurrent firing operation of the kiln would allow the volatile matter produced during the charring of the coal to be burnt within the kiln, providing useful heat. It was also apparent that this method would simplify the design of the kiln and allow more positive control of the kiln atmosphere in the high-temperature zone than would be possible in a countercurrent firing operation. Use of the hot pre-reduced charge in a submerged-arc smelting furnace results in a molten pig iron containing 3,40 to 3,90 per cent carbon and around 1,20 to 1,25 per cent vanadium. The vanadium-bearing hot metal is then agitated and oxygen-blown in shaking ladles. This process removes virtually all the vanadium and produces a high-grade vanadium pentoxide slag. The process steps that follow are steelmaking, continuous casting, and rolling.

The activities associated with Highveld's iron- and steel-making production and rolling are described below.

### Mapochs Mine

Magnetite ore is supplied to both the iron and Vantra plants from the Mapochs Mine near Roossenekal, 160 km north-east of Witbank. Proven ore reserves of more than 120 million tons are available to the Corporation.

The ore-body lies in two seams: the top seam, under a layer of surface soil and rubble ½ to 1 m thick, is about ⅓ m thick and is separated by more than a metre of waste from the main seam, consisting of two layers totalling about 2 m in thickness. Strip-mining methods are used, and the ore is crushed, washed, and screened at the mine before being railed to Highveld.

The fines from the crushing and screening operation, which are unsuitable for smelting, are treated in a magnetic-separation plant before being railed to the Vantra plant.

Water for the mine is provided from a dam of 5,4 million cubic metres capacity, built some 10 km away on the Mapochs river.

### Iron Plant

The basic raw materials – iron ore, coal, and fluxes – are sized according to the process requirements before being delivered to site. They are blended in the correct proportions and fed to each of the eight concurrently fired kilns. Each kiln is fired with pulverized coal, the burner being located at the charge end of the kiln. Air fans, installed at intervals along the length of the kiln, inject air through pipes to burn the volatile matter in the coal. The waste gases emitted from the kilns are cooled by water sprays in a conditioning tower, and until recently were cleaned in either multicones or in electrostatic precipitators. Because of the superior performance of the electrostatic precipitators, this type of equipment is now being installed on all the kilns.

The hot pre-reduced charge leaving the kilns is hoisted in refractory-lined containers to the charging floor, which is above the closed-top electric-smelting furnaces. The six smelter furnaces each have three self-baking electrodes, the movements of which are controlled hydraulically, two separate tap holes, and one tap-hole gun per furnace. Wet gas scrubbers installed on each furnace clean the gas generated during the smelting operation, which is collected in a gas holder and used as a fuel for heating purposes in the works.

The details of the iron plant are as follows:

*Eight pre-reduction kilns:*

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| Length | 61 m |
| Diameter (inside shell) | 4 m |
| Rotating speed (variable) | 0,04 to 1,25 r/min. |

*Six electric smelting furnaces:*

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| Nominal furnace rating | 320 t/d |
| Transformer rating | 33 MVA (Furnaces 1 and 2) |
| | 45 MVA (Furnaces 3, 4, 5, and 6) |
| Furnace diameter | 14 m |
| Normal power input per furnace | 24 MW |
| Tap-to-tap time | 3½ to 4 h |
| Tap mass | 60 t. |

## Steel Plant

The pig iron is delivered from the iron plant to the steel plant in rail-mounted hot-metal transfer cars for charging into a series of shaking ladles, the charge being measured by crane weighing. After scrap or cold pig iron has been added, the ladles are transported by crane to one of three shaking emplacements, which are equipped with water-cooled hoods to collect the waste gases and fumes generated during the vanadium extraction process. Dry-plate electrostatic precipitators are installed to clean the fume emission. Owing to the inadequacy of this type of equipment to cope with high additions of anthracite, it has been found necessary to install high-energy wet scrubbers to clean the fume properly.

After the vanadium has been extracted, the metal is taken by transfer car and crane and charged to one of three basic oxygen furnaces. A scrap charge is added, and oxygen is blown onto the bath through a water-cooled copper lance equipped with a four-hole nozzle.

Hoods of a water-tube construction immediately above each furnace collect the waste gases for delivery to a dry-plate electrostatic precipitator, where they are cleaned.

The steel ladle is transferred by car and crane to the continuous-casting plant via the desulphurization station. The continuous-casting plant consists of five machines: one for billets, three larger machines for blooms, and one for slabs. The machines are of low-height design and are equipped with curved copper moulds. Equipment for cutting or shearing to length and for block cooling follows the machines.

The vanadium slag is transported to a treatment plant, where it is crushed and magnetically separated before being sent overseas for conversion to vanadium pentoxide and ferrovanadium.

The details of the steel plant are as follows:

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| *Three shaking-ladle emplacements:* | |
| Capacity | 60 to 70 t |
| Height | 5,5 m |
| Diameter (inside shell) | 4,3 m |
| *Three basic oxygen furnaces:* | |
| Capacity | 60 to 70 t |
| Height | 7,1 m |
| Diameter | 4,8 m |
| *Five continuous-casting machines:* | |
| Machine 1 (four strand) | |
| Bloom size | 180 mm by 230 mm |
| Machine radius | 10,5 m |
| Machines 2 and 3 (two strands) | |
| Bloom sizes | 570 mm by 310 mm<br>310 mm by 260 mm |
| Machine radius | 10,5 m |
| Billet machine (four strand) | |
| Billet sizes | 100mm to 140 mm |
| Machine radius | 5 m |
| Slab machine (single strand) | |
| Slab sizes | 180 mm by 1 300 mm to 1 600 mm<br>250 mm by 1 700 mm to 2 000 mm |
| Machine radius | 10,5 m |

## Structural Mill

This is a semi-automated combination mill for rolling universal columns, parallel flanged beams, standard joists, channels, angles, flats, rounds, and billets. In addition, the mill is equipped to produce rails up to a mass of 48 kg/m in lengths of up to 36,5 m, as well as specialized sections such as sleeper bar and grader blades.

The Highveld range of universal beams and columns was the first to be produced in South Africa.

The continuously cast blooms from the steel plant are heated in one of two 60 t/h walking-beam furnaces, which are fired with a mixture of smelter furnace gas and producer gas – obtained from six coal-fired gas producers sited near the mill.

To roll standard joists or rails, the blooms are first rough-shaped in a breakdown stand, passed to and further shaped in a roughing stand, and then transferred to the combination finishing stand for final rolling.

For universal beams, the blooms are rough-shaped and transferred to the universal stand, comprising a universal main stand and universal edger. The main stand forms the beam's flanges and web simultaneously, while the edger forms the flange tips. The universal shape then passes to the combination finishing stand equipped with universal rolls. All sections are sawn to length, using hot saws, cooled on two walking-beam cooling banks, and finally passed through a roller–straightener.

After straightening, the sections are inspected and placed on automatic pilers prior to stacking by crane or mobile side loader.

When rails are rolled, the finished product is despatched, after straightening, to a separate bay, where the ends are squared and drilled before final inspection.

The following are details of the structural mill:

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| *Mill stands:* | |
| Breakdown | 1 016 mm by 2 438 mm |
| Roughing | 813 mm by 2 286 mm |
| Universal main | 1 270 mm |
| Universal edger | 838 mm |
| Combination finisher | 2 286 mm by 813 mm |
| Verticals | 813 mm |
| *Range of sections:* | |
| Rails | 30 kg/m to 40 kg/m |
| Billets and blooms | 63,5 mm to 190,5 mm |
| Equal angles | 120 mm by 120 mm to 200 mm by 200 mm |
| Unequal angles | 150 mm by 75 mm to 152 mm by 102 mm |
| Channels | 127 mm by 64 mm to 381 mm by 102 mm |
| Flats | 150 mm to 550 mm wide<br>16 mm to 65 mm thick |
| Rounds | 80 mm to 160 mm |
| Universal beams | 203 mm to 133 mm to 533 mm to 210 mm |
| Universal columns | 152 mm by 152 mm to 305 mm by 305 mm |
| Universal bearing piles | 203 mm by 203 mm to 305 mm by 305 mm |

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| Sleeper bars | 20,93 kg/m and 29,26 kg/m |
| Joists | 152 mm by 89 mm to 203 mm by 152 mm |

### Plate Mill

The continuously cast slabs are cut on flame-cutting beds to the sizes required for rolling, and are heated in a gas-fired pusher-type reheat furnace to the rolling temperature of 1260°C. On discharge from the furnace, the slabs are subjected to high-pressure descaling sprays, after which they are formed in a four-high mill stand to plates of the required dimensions and hot levelled on a four-high hot leveller. When the plates have been cooled, checked, and inspected, they are cut to final size by one of two methods: those greater than 16 mm are flame cut, and the thinner plates are cut by shears. Finally, the plates can be cold levelled if necessary.

Details of the plate mill are as follows:

*Mill stand:*

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| Roll face length | 2 840 mm |
| Back-up roll diameter | 1 350 mm |
| Work roll diameter | 762 mm |
| Maximum lift with new rolls | 250 mm |

*Plates:*

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| Rolled in thicknesses from | 5,0 mm to 60 mm |
| Maximum width | 2 540 mm |
| Maximum length | 29 m (or maximum of 8 800 kg finished mass) |

### Highveld's Achievements

With eight pre-reduction kilns and six submerged-arc smelting furnaces to provide the liquid iron supply, the steel plant produced over three-quarters of a million tons of steel for the first time in the financial year ending June 1979.

Approved expansion schemes involve the construction of two more pre-reduction kilns and a fourth shaking-ladle emplacement. With these extra facilities, the plant capacity will be increased to 900 000 tons of steel by July 1981. The configuration of 10 kilns and six submerged-arc furnaces complete the first iron plant, and further development of ironmaking will involve separate off-loading, ground storage, and bunkering facilities.

The vanadium slag from the shaking-ladle operation and the vanadium pentoxide from the Vantra division constitute approximately 40 per cent of the Western World's vanadium production.

Although the first consideration has been to supply the needs of the South African market, it has been necessary to export steel sections and billets since steel production was started in 1968. A significant proportion of the ferro-alloys produced by Transalloys and Rand Carbide is also exported.

In 1966, Mr H. F. Oppenheimer said, 'Highveld represents a major single act of faith by private enterprise in the future of South Africa'. This faith has been justified by the development of the activities at Highveld Steel and Vanadium Corporation Limited into an economically viable operation, a state award for export achievement in 1978, and the earning of over 600 million rands in foreign exchange from the start of the operations at the steelworks up to April 1980.

# Canadian Institute of Mining and Metallurgy

The Finance and Executive Committees of the Canadian Institute of Mining and Metallurgy have agreed that members of SAIMM should be invited to register at all future CIM meetings at the same rate as CIM members. In other words, CIM's higher non-member registration fees will no longer be applied to members of SAIMM, and it is hoped that this offer will be accepted as a token of neighbourly hospitality from one professional society to another.

This is a reciprocal agreement, and members of the Canadian Institute will be accorded the same privilege for all similar SAIMM meetings.