SPOTLIGHT
on coal-based direct reduction at Iscor

by S. VISAGIE*

By 1984 Iscor's first direct-reduction plant will be operating at the Vanderbijlpark Works, and for the first time the Corporation will have an alternative method to the blast furnace for producing iron from ore. The performance of Iscor's four-kiln plant, which will be the largest coal-based plant in the world producing sponge iron, will undoubtedly be watched with great interest by steelmakers throughout the world.

The technical and economic reasons for Iscor's decision to install the 100 per cent coal-based rotary-kiln direct-reduction process are described in this article.

Alternative Process Routes for Making Steel

In the planning of an integrated steelworks on a greenfield site, there are two main choices of process for the making of steel: that using the conventional coke-fuelled blast furnace to produce molten iron, which is refined into steel by the basic oxygen furnace (BOF); and that using a direct-reduction unit to produce metallic iron (sponge iron), which is smelted and refined in an electric-arc furnace. The decision as to which process route to use is based on technology as much as on economics, and involves a consideration of the location, forms of energy available, optimum plant size, selection and availability of raw materials, and possible process variations.

In blast-furnace steelmaking, there is a further choice between conventional coke and form coke, and in direct reduction there is the choice between gaseous and solid reductant, and between static-bed, moving-bed and fluidized-bed processes.

Of the many known direct-reduction processes available, 90 per cent of the total world sponge-iron production, which in 1978 amounted to 2 per cent of the pig-iron production, is provided by gaseous reduction, the two major processes used being the Midrex (moving bed) and Hyl (static bed) systems. Together they account for some 80 per cent of the production. The rest of the world production is by solid reduction in rotary kilns of Lurgi, Krupp, or Allis Chalmers design or origin.

Iscor recently decided to install a direct-reduction plant with four rotary kilns to produce 600 kt of sponge iron per year. This sponge iron will make up the predicted shortage of scrap feed to the Vanderbijlpark arc furnaces. Thus, the direct-reduction plant will be a vital source of high-quality iron units for use as a substitute for scrap in the arc furnaces, and not as a rival to the blast furnace. Being smaller in size and capacity than a blast-furnace installation, which has a minimum economic capacity of 1,4 Mt/a, the direct-reduction plant will produce the required iron units with a lower capital investment cost.

Direct Reduction Technology

Direct reduction is a method of producing sponge iron from iron ore without its reaching the molten stage as occurs in the blast-furnace process. In blast furnaces, the temperature of the molten metal is as high as 1450 °C, whereas the maximum temperatures obtained in direct-reduction processes are less than 1000 °C, a temperature at which iron is still a solid.

The direct-reduction process involves the intimate mixing of prepared (sized) iron ore with a reductant, which is generally also used for heating the ore bed to the temperature needed to achieve adequate reduction rates. The reductant can be a gas or a solid. Natural gas is ideal for the gaseous direct-reduction process; otherwise, coke-oven gas or gas produced by the gasification of oil or coal can be used. For the solid reductant, coal, char, or coke is suitable. In all cases, the reduction of the iron ore is carried out by means of hydrogen, or carbon monoxide, or both.

Direct Reduction with a Gaseous Reductant

In the gaseous reduction processes, a vertical shaft kiln is used in which iron ore is fed into the top of the kiln and finished sponge iron is drawn off the bottom after cooling to prevent re-oxidation. The reducing gas is passed through the ore bed, and spent gas is recirculated after heating and reforming to a mixture of carbon monoxide and hydrogen in a reformer, where it is also heated to a temperature of 950 °C, which is the temperature needed to achieve adequate reduction reaction rates.

These processes all use vertical kilns either as holding vessels operated as batch charges (static bed), where the kiln is filled with ore, reduced, and discharged as in the Hyl Process, or as continuous-flow vessels, where the ore is added to the top and withdrawn from the bottom as in the Midrex, Purofer, and Armco Processes. With the use of fine ore they can be operated on a fluidized-bed system.

Gas-based processes are being used world wide, mainly in the developing countries. They have been built in unit capacities of up to 600 kt of sponge iron per year. These processes are technologically well proven but, because of their gas requirement, their use is restricted to areas where abundant supplies of natural gas or refinery tail gas are available. In South Africa, where such gas supplies are not available, gas would have to be generated from coal in a separate coal-gasification plant.

Direct Reduction with a Solid Reductant

These processes are characterized by the use of rota-

* Iscor, P.O. Box 450, Pretoria 0001.

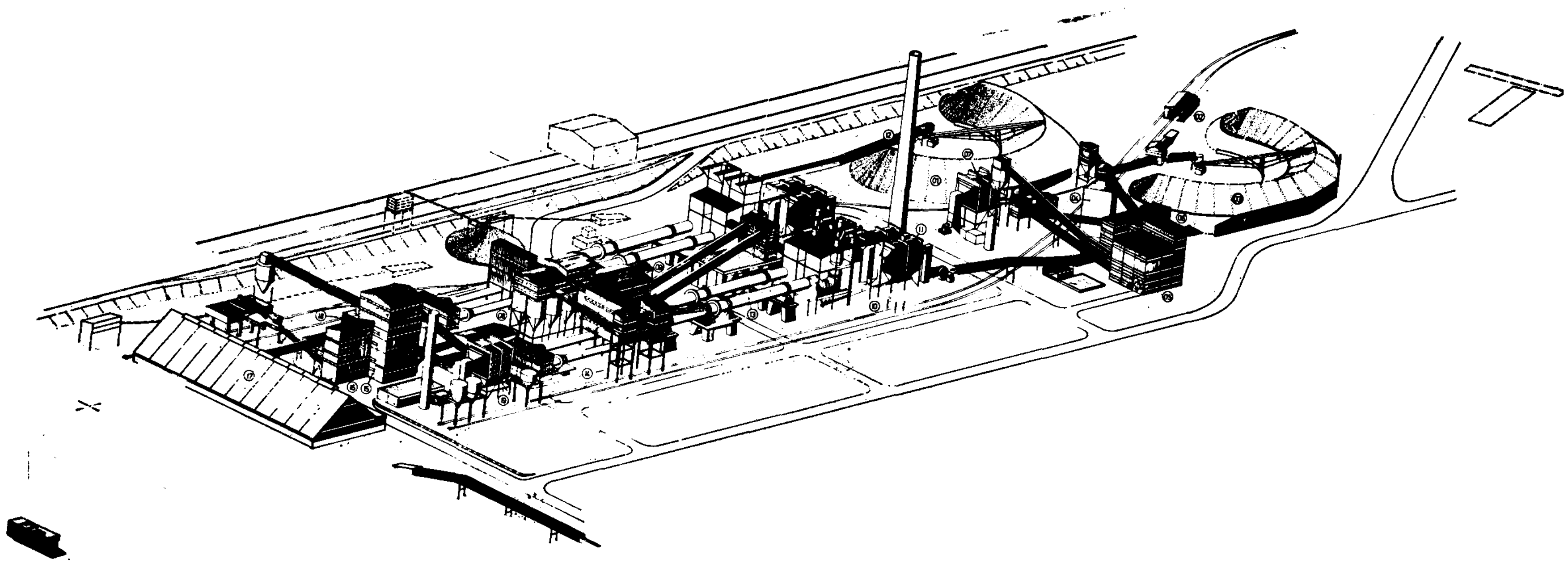

Fig. 1—SL/RN direct-reduction plant at Iscor, Vanderbijlpark (maximum annual capacity: 720 kt).

01. Ore storage pile.
02. Coal and dolomite unloading station.
03. Coal storage pile.
04. Dolomite bin.
05. Ore crushing building.
06. Coal crushing building.
07. Electrostatic precipitator for plant dedusting.
08. Raw materials day bins.
09. Central control room.
10. Waste-heat boilers.
11. Electrostatic precipitator for waste-gas dedusting.
12. Waste-gas stack.
13. Rotary reduction kiln.
14. Rotary cooler.
15. Product separation building.
16. Briquetting building.
17. Product storage building.
18. Cooling towers.
19. Electrostatic precipitators for plant dedusting.

ting kilns into which a mixture of coal and sized iron ore is fed and the mixture is combusted by blowing air into the kiln to generate the carbon monoxide reducing gas and the heat to sustain the reduction process.

The rotary kiln rests at a slope of about 3 degrees to the horizontal and is rotated at a speed of up to 1 r/min which, together with the rate of feeding the feedstock, determines the retention time in the kiln and provides control for the degree of metallization of the sponge iron. Upon leaving the kiln, the sponge iron is indirectly water cooled in a rotary cooler to prevent re-oxidation.

Rotary kilns that use coal for reduction and heating are supplied by Krupp, Lurgi (SL/RN), and DRC (Direct Reduction Corporation) on a commercial scale. The Accar process is marketed by Allis Chalmers.

Rotary-kiln processes are not as well developed as gas-based processes, but are receiving increasing attention because of the growing scarcity and ever-increasing cost of natural and tail gas. Units of up to 150 kt/a capacity are in operation. In the long term, the rotary kiln will become more important because of the large energy reserves in the form of non-coking coal and because of the favourable energy price of coal, which is similar in quality to the steam-raising coal used for the generation of electricity. However, careful selection of a suitable coal is necessary to ensure successful and economic kiln operation. The main requirements are that the ash content should be less than 16 per cent, the ash melting deformation point more than 1400 °C, the sulphur content less than 0,8 per cent, and the coal reactivity as high as possible.

TABLE I

A COMPARISON OF THE COSTS OF ROTARY-KILN AND GAS-SHAFT PLANTS

Item	Relative cost/t sponge	
	Rotary-kiln plant	Gas-shaft plant
(a) Capital investment - 20 year redemption at 11 % per year interest	36	32
(b) Iron ore	38	38
(c) Coal	15	—
(d) Gas (i) Capital redemption	—	31
(ii) Coal	—	15
(iii) Labour, electricity, maintenance spares, etc.	—	21
(e) Labour, electricity, maintenance, spares, briquetting, etc.	11	12
Total	100	149

Economics of Gaseous Versus Solid Reductants

A comparison made by Iscor, based on extensive budget and other cost details obtained from plant suppliers, is given in Table I.

South Africa's use of synthetic gas made from coal for the established processes such as Midrex and Hyl would be far from competitive because the capital costs of a gas-based direct-reduction plant, together with a matching coal-gasification plant, are about double those of a rotary-kiln installation. Iscor's study confirmed that the operating costs of rotary kilns are comparable with those of shaft kilns, and that the influence of the capital and operating costs of the coal-gasification plant on the costs of gaseous-reduced sponge iron will result in sponge iron from shaft kilns costing about 50 per cent more than sponge iron from rotary kilns.

On the basis of the abovementioned investigation, Iscor concluded that in South Africa the rotary-kiln direct-reduction route is more economic than the gaseous direct-reduction route for the production of sponge iron.

Conclusion

A contract valued at more than 90 million rands for the erection and commissioning of a four-kiln plant was awarded to Lurgi SA (Pty) Ltd in November 1981. The four kilns, each of which is 80 m long and 4,8 m in diameter, are due to be commissioned in 1984.

The Vanderbijlpark plant will produce 600 kt per year of plus 1 mm sponge iron with a metallization of 93 per cent and a sulphur content of less than 0,010 per cent. The plant will also produce about 150 t of steam an hour by means of waste-heat boilers, whereby the energy consumption of 19 GJ per ton of iron will be reduced to 14 GJ per ton of sponge iron.

Beneficiation of tin

The Southeast Asia Tin Research and Development (SEATRAD) Centre is a regional oganization, formed by the Governments of Indonesia, Malaysia, and Thailand with assistance from the United Nations, to conduct, coordinate, and promote research and training in the various fields of tin production, including geology, prospecting, mining, mineral processing, and smelting.

The SEATRAD Centre will be organizing a seminar on 'The Beneficiation of Tin and Associated Minerals', which will be held from 7th to 9th October, 1982, in Bangkok, Thailand. A field trip to Phuket will be organized in conjunction with the Seminar from 11th to 13th October, 1982.

The objective of the Seminar is to provide a forum for discussion on the beneficiation of tin and associated minerals, with a view to promoting the exchange of information and collection of data on the practices in different tin-producing countries of the region and the world. It is hoped that the Seminar will cover not only existing technologies but also new technologies, as well as to identify areas where further research needs to be done.

Enquiries about the Seminar should be sent to The SEATRAD Centre, 14 Tiger Lane, Ipoh, Malaysia. Tel.: 05-517124 and 05-517833. Cable: TINCENTRE IPOH.