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The potential role of fluidized beds in the metallurgical industry*

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SYNOPSIS

The scope of this paper is confined to gas-fluidized beds in pyrometallurgical applications.

After considering the general characteristics of these fluidized beds, the author deals with their potential applications, using the following processes, which are currently under investigation, as examples: pretreatment of chromite, prereduction of manganese-ore and iron-ore fines, roasting and prereduction of ilmenite, and roasting and pyrolysis of gold-bearing pyrite.

He concludes that fluidized beds are potentially of great benefit to the metallurgical industry, although much developmental work remains to be done.

SAMEVATTING

Die veld wat hierdie referaat dek, is beperk tot gasfluïedbeddens in pirometallurgiese toepassings.

Nadat hy die algemene eienskappe van hierdie fluïedbeddens in oënskou geneem het, behandel die skrywer hul moontlike toepassings met die volgende prosesse, wat tans ondersoek word, as voorbeelde: die voorbehandeling van chromiet, die voorreduksie van fynmangaanerts en -ystererts, die roostering en voorreduksie van ilmeniet, en die roostering en pirolise van goudhoudende piriet.

Sy gevolgtrekking is dat fluïedbeddens die moontlikheid van groot voordeel vir die metallurgiese bedryf inhou, hoewel daar nog baie ontwikkelingswerk gedoen moet word.

Introduction

Proposals for the use of fluidized beds in metallurgical processes are certainly not new. The earliest known reference to what is currently called a fluidized bed appears in a United States patent[1] granted to Charles Robinson in 1878. His invention related to the roasting of ores, particularly gold-bearing ores. He described a vertical shaft furnace into which preheated air that is generated in a separate combustion chamber is introduced at the bottom. The solids are suspended by the stream of gas, which causes the bed, as the inventor picturesquely describes it, to 'boil and play like the waters of a fountain'.

In the century that has elapsed since Robinson's suggestion[1], widely diverse metallurgical processes have been tested in fluidized beds. Processes relating to pyrometallurgy include the reduction of iron ore, manganese ore, and chromite; the selective reduction of iron in ilmenite, laterite, and other more-complex ores; the roasting of copper, zinc, iron, nickel, and molybdenum sulphides; and the chlorination of rutile and carnallite. Other interesting examples include the heat treatment of alloys, ion exchange, electrodeposition, and the regeneration of activated carbon for adsorption processes.

Despite the broad range of these processes, relatively few of them have been implemented commercially. Almost the only metallurgical process commonly carried out in a fluidized bed is the roasting of sulphide ores. The majority of other metallurgical applications that have been developed are regarded as novelties.

However, the apparent lack of commercial success has not diminished interest in fluidized-bed technology, and its advantages are becoming more evident as resources of high-grade ores dwindle and the cost of electrical power increases.

The scope of the present paper is restricted to a consideration of gas-fluidized beds in pyrometallurgical applications.

General Characteristics of Gas-fluidized Beds

A fluidized bed can be considered for any process that requires the uniform treatment of fine particulate materials with a gaseous reactant. Although particles of up to 25 mm can be accommodated in a fluidized bed, a mean particle size in the range 100 μm to 6 mm is preferred. Further, the particle-size range must be limited so that the ratio of the largest to the smallest particle size is approximately 10 if segregation within the bed and dust losses are to be kept within acceptable limits. Tighter restrictions on the particle size are necessary if a mixture of solids is to be treated, especially if there are large differences in the densities of the particles.

Materials that have a tendency to agglomerate under the desired operating conditions are usually unsuitable, since the presence of large aggregates within the bed leads to defluidization. Arrangements can be made for agglomerates to be withdrawn from the bed, but this is acceptable only if they can be regarded as a product.

The processing of friable solids in a fluidized bed is also generally excluded. The vigorous motion of the particles results in severe attrition, and the fines generated in this way are elutriated from the bed. This means that extensive gas-cleaning equipment is needed and, possibly,

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some means by which the fines can be re-injected to ensure adequate conversion.

The turbulent nature of a fluidized bed ensures uniformity of temperature and particle composition. However, there is a distribution of residence times in continuous operation, so that a small proportion of feed can pass through the bed without significant conversion while other particles will have reacted to a very high degree. If particles become sticky at high conversion, clinkers may be formed. Also, the presence of highly reacted particles in the fluidized-bed product may render the material unsuitable for subsequent processing. These two factors may limit the mean conversion that can be achieved in a single stage. On the other hand, the bed depth or feed rate can be varied to control the mean residence time of the particles. Semi-batch processing can be employed where a highly uniform product is essential. This technique has been adopted in the H-Iron process[2] for the reduction of iron ore.

The majority of investigations on fluidized beds have been conducted on a small scale, i.e. on units smaller than 300 mm in diameter, and the scale-up from such units to a commercial bed with a diameter of several metres can be unreliable. Nevertheless, fluidized beds are suited to large-scale operations. The smooth, liquid-like flow of particles permits continuous automatically controlled operation with relative ease of solids handling. Further, because of the high heat- and mass-transfer rates that can be achieved, the space velocities are high, and the equipment can be considerably smaller than that required for other types of reactors, such as shaft furnaces and rotary kilns. Capital equipment of smaller size not only reduces the initial investment required, but may be an important consideration if the addition of a fluidized bed to an existing process plant is contemplated.

The turn-down ratio of a fluidized bed is bounded at its lower limit by the requirement that the superficial gas velocity must be sufficiently high for the particles to be maintained in a fluidized state, and at its upper limit by the elutriation of fines. The minimum flowrate of gas required for adequate mixing is frequently in the bubbling range. Hence, bubbles pass through the bed with little or no reaction of the gas. Multiple stages or gas recycles are then required so that reasonable conversion of the gas phase can occur.

It is generally recognized that exothermic processes are more easily accomplished in a fluidized bed than endothermic processes are. Preheating of the fluidizing gas or solids, or both, is usually practised where an energy deficit must be supplied. The heat-transfer rates between the particles and the walls of the vessel or immersed tubes are high, so that temperature control can be conveniently implemented, especially cooling. Typical arrangements of heat-transfer surfaces[3,4] are shown in Figs. 1 and 2. One drawback of immersed tubes is that erosion rates can be high when abrasive particles are being processed. In some instances, a spray of water directed onto the surface of the fluidized bed is used for cooling, for example in some zinc roasters[5].

Although these general characteristics show clearly that fluidized beds have limitations, they have many advantages that are pertinent to the requirements of the metallurgical industry.

Potential Applications in Pyrometallurgy

The potential function of fluidized beds in pyrometallurgical processes is rather to complement existing or projected furnaces than to replace them. As the need for industry to utilize fine ore and reducing agents becomes more pressing, fluidized beds can be used as pretreatment stages for drying, calcining, preheating, roasting, and prereducing the feed. Such treatments can be accomplished with coal or furnace off-gas as the source of energy. By more complete utilization of the carbon in the reducing agent, the consumption of electrical energy in the furnace can be reduced by 20 per cent or more. In addition, coal rather than coke can be used in a fluidized bed, since the volatile matter can be driven off and combusted. Thus, heat is provided for the pretreatment and devolatilized coal is supplied to the furnace. The overall energy required per ton of product is not diminished, because this is determined by the thermodynamics of the process; instead, there is a shift away from electrical energy to the use of less expensive sources. Also of particular interest in the context of evolving furnace technology is the compatibility of the fluidized bed with certain plasma processes: both treat fine ore without prior briquetting or pelletizing, and both are high-intensity reactors with relatively high specific capacities.

By way of illustration of this broad statement, some applications currently under investigation, or projected, are described.

Pretreatment of Chromite

The cost of electrical energy is an important component in the overall cost of ferrochromium production. Significant savings could be effected if part of the electrical energy required were derived direct from coal or from furnace off-gas. Two schools of thought have arisen as to what constitutes an appropriate pretreatment for the feed. One view is that the highest possible degree of prereduction should be sought, since this will minimize the consumption of electrical energy in the furnace. Proponents of the second view argue that the overall process economics are at their optimum when only preheating is employed, because the retention time for preheating is a few minutes whereas that for prereduction is a few hours. Hence, a smaller capital investment is required for preheating, which makes it more attractive than prereduction overall because of the higher return on investment.

Kawasaki Steel Corporation have filed several patents for a prereduction process using a fluidized bed[6-8]. Their approach is to produce a highly prereduced feed for the furnace. Pilot-plant work has been carried out in a bed of 1,2 m diameter on chromite from the Philippines and South Africa. Gas at a temperature of 1350 to 1400°C from a smelting furnace mixed with cooler coke-oven gas is introduced at the bottom of a single-stage fluidized bed. Fine chromite ore is either conveyed into the bed by a screw feeder or entrained with the fluidizing gas, depending upon the particle size of the ore. The results[7] given for the reduction, at 1200°C, of South African chromite with a mean particle size of 325 μm indicate that a residence time of 12 to 15 hours is required. The degree of reduction achieved is not stated; the product is described only as being highly reduced. It

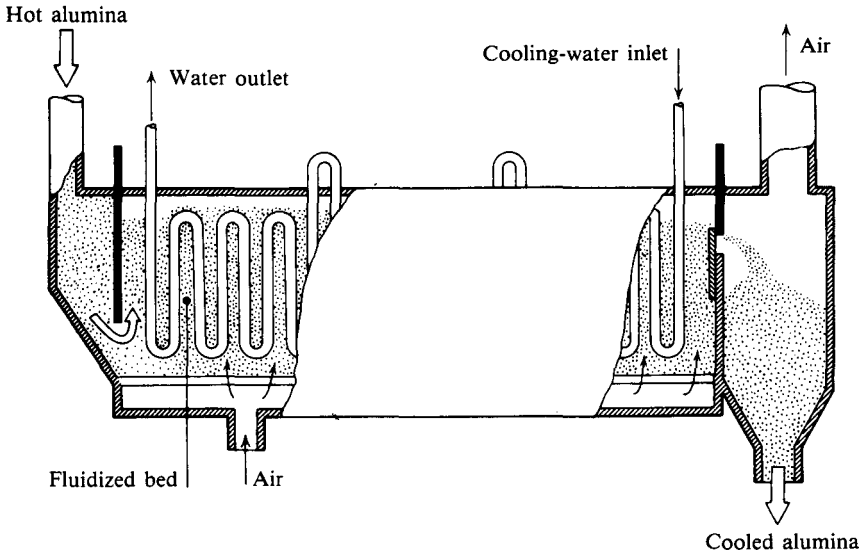

Fig. 1—Cooler for hot particles of alumina (after Kunii and Levenspiel[3])

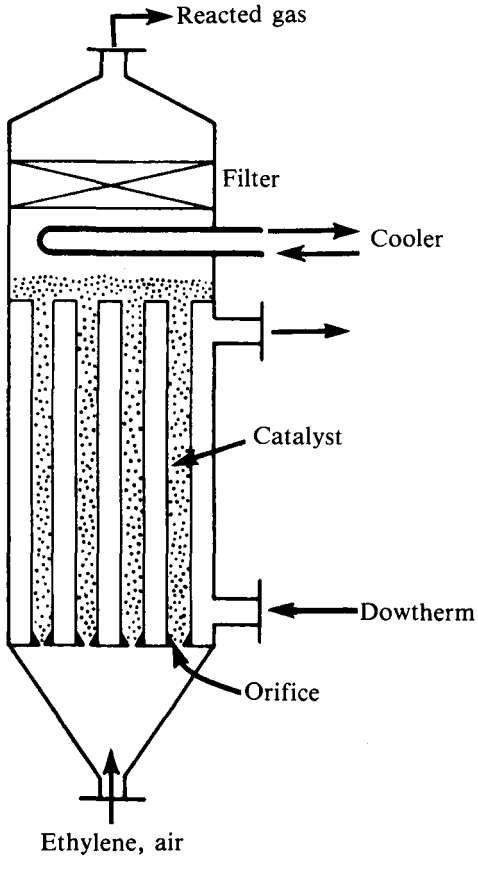

Fig. 2—Fluidized-bed reactor for the production of ethylene oxide (after Corrigan[4])

is claimed that the light hydrocarbon gases in the coke-oven gas make a major contribution to the reduction of the chromium. When furnace off-gas, which comprises mainly carbon monoxide, was used alone, only limited reduction of the iron was achieved. It is believed that thermal decomposition of the hydrocarbons deposits coke on the particles; it is known that solid carbon aids in controlling the oxygen potential in the bed.

Work done at the Council for Mineral Technology (Mintek) has concentrated on preheating with fine coal and carbon monoxide as the fuel. It has been found that Winterveld chromite ore with a particle size ranging from 0,3 to 3,5 mm (mean diameter 0,5 mm) can be preheated to 1200°C without operational difficulty. Above this temperature, the formation of clinkers disrupts stable operation. Mineralogical examination of the agglomerates showed that the gangue material present in the ore was responsible for inter-particle bonding. When the chromite fraction smaller than 300 μm was included in the feed, clinkers formed at temperatures as low as 1050°C. This is consistent with the observation that the gangue binds the clinkers, since the very fine particles are known to be relatively rich in gangue minerals.

The mean residence time of the chromite in the bed ranged from 4 to 20 minutes. A conservative estimate of the capacity of a fluidized bed for the preheating of chromite to 1200°C is 5000 kg/h per cubic metre of bed volume. This figure is in contrast to a figure of about 150 kg/h for the Kawasaki reduction process.

On the basis of the results obtained at Mintek so far, a process is proposed for the preheating of the total charge to a plasma furnace producing ferrochromium. This is shown schematically in Fig. 3. A two-stage fluidized bed is used, chromite ore, quartz, and dolomite being fed into the upper stage, where they are dried and preheated by the hot gas issuing from the lower stage, before overflowing to the lower stage. Coal is introduced into the lower bed, where it is devolatilized, and the combustion of the volatile matter provides the energy required.

Instead of, or in addition to, the partial combustion of coal, furnace off-gas can be used as fuel in this process. The charging of hot (1200°C) feed to the furnace can be expected to decrease the electrical energy required from about 3,6 MW·h to approximately 2,8 MW·h per ton of alloy produced, i.e. by some 22 per cent.

This decrease in the consumption of electrical energy is not as dramatic as that achieved by the Showa-Denko process[9] as used by CMI in Lydenburg. In that process, highly reduced (about 70 per cent) chromite ore is

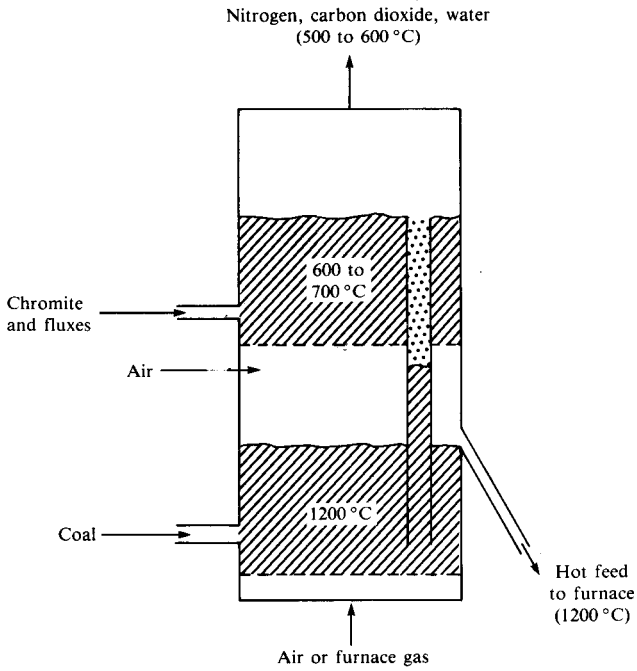

Fig. 3—Fluidized bed for preheating chromite fines

prepared by the treatment of pellets of finely milled chromite ore and coke in a rotary kiln. The electrical energy required in the furnace smelting the kiln product is about 2,1 MW·h per ton of ferrochromium produced[9].

The advantages of preheating in a fluidized bed over the Showa-Denko process are as follows:

(1) coal is used rather than coke,
(2) the ore and the reducing agent need not be milled,
(3) the capital costs are lower, and
(4) no pulverized coal is required as fuel.

This process is not without potential problems, one of which is contamination of the alloy with sulphur. Experimental investigations of the path followed by the sulphur in the coal are therefore imperative. Dolomite is an effective sorbent for sulphur released during the combustion of coal, and is used in fluidized-bed combustors for emission control[10]. Careful control of the process may be necessary so that contamination of the alloy with the sulphur carried into the furnace in the limestone can be avoided.

Finally, although attempts to reduce chromite in a fluidized bed by gasification of the coal *in situ* have met with limited success, further development may result in a process that has a competitive edge over the Showa-Denko process. However, much developmental work on this potential application is still required.

Prereduction of Manganese-ore Fines

The particle size of the ore fed to conventional submerged-arc furnaces producing ferromanganese must be larger than 6 mm if eruptions and unstable operation are to be avoided[11]. It is believed that eruptions are associated with the presence of higher oxides than MnO, larger quantities of gas being evolved during the reduction of MnO_2, Mn_2O_3, and Mn_3O_4 than of MnO. The presence of fines decreases the permeability of the burden, so that gas evolves, resulting in a build-up of pressure and hence eruptions.

Thermodynamic considerations indicate that the higher oxides are readily reduced in the solid state of MnO by carbon monoxide, whereas they cannot be reduced to the metal by this method. Prereduction of the fine ore to MnO may enable a larger proportion of such fines to be used in the furnace feed. Another potential use is in the production of manganese metal or manganese chemicals by leaching of the prereduced fines.

Prereduction of the higher oxides to MnO can be achieved in a fluidized bed using furnace off-gas as the fuel and reducing agent.

Experiments in a single-stage fluidized bed using a mixture of carbon monoxide and air as the fluidizing gas resulted in better than 95 per cent reduction to MnO at 930°C, with a retention time of 20 minutes. The advantages of such a process are the utilization of fine ore and furnace off-gas.

Prereduction of Iron-ore Fines

Most of the direct-reduced iron (DRI) produced in the world is made in shaft furnaces. The Midrex process[12] is used more widely than any of the various alternative processes, with a claimed total capacity of 22 Mt/a for plants in operation, under construction, and contracted[13]. However, a shaft furnace cannot accommodate ore fines directly.

High degrees of metallization of iron ore can be achieved by direct reduction with coal in a rotary kiln, and this process is being adopted increasingly in the iron-and-steel industry. Iscor recently commissioned a plant producing 720 kt of sponge iron per year at their Vanderbijlpark works. The fraction of the ore smaller than 6 mm is removed from the feed, and usually requires processing in a sinter plant and crushing before being charged to a furnace. However, by far the major proportion of the fines generated in a mining operation are stacked at the mine. For instance, magnetite fines from the Palabora Mine alone are accumulating[14] at the rate of 4 Mt/a.

Fluidized-bed processes have been developed for the reduction of iron ore, but the majority of these require hydrogen as the reducing agent. The Elred process[15], which uses fine coal, is an exception. However, the feed must be milled and screened to a very narrow size fraction (70 to 90 μm), because a dilute-phase circulating fluidized bed is used. The salient features of the most significant processes are summarized in Table I.

The largest commercial fluidized-bed plant for the reduction of iron ore, which is situated in Puerto Ordaz, Venezuela, has an annual production of 1 Mt of 95 per cent reduced ore in the form of briquettes for the blast furnace. This plant is based on the Nu-Iron process[16,17] developed by US Steel.

A simplified flowsheet of this process[16] is shown in Fig. 4. The ore is crushed, milled, and screened to between 40 and 800 μm before being dried in a fluidized bed. The temperature is elevated to about 920°C (some 220°C above the temperature in the reducer) in a multistage fluidized-bed preheater. The preheated ore is reduced by a countercurrent stream of preheated hydrogen in a two-stage fluidized bed. Countercurrent

processing allows a hydrogen utilization of 32 to 36 per cent to be achieved. The exhaust gas is cooled until its contained water condenses, and it is then scrubbed of particulates before being recycled. Powdered DRI with approximately the same particle-size distribution as the feed is withdrawn from the bottom stage of the reducer and briquetted. As reduction is carried out at 700°C, the product is not pyrophoric. Hence, no passivation is required and the briquettes do not re-oxidize appreciably if stacked in the open.

The cost of hydrogen would make this process economically unattractive in South Africa. Ample supplies of natural gas are available at the Puerto Ordaz plant, and the necessary hydrogen is generated by partial combustion of the natural gas, followed by the water–gas shift reaction and adsorption of the carbon dioxide.

Work is in progress at Mintek on a fluidized-bed reduction process that can accommodate material of a relatively wide particle-size distribution and that uses fine coal as the reducing agent. Sintering of the bed above 800°C limits the process temperature. A multistage process is envisaged that will ensure complete combustion of the carbon to carbon dioxide, using the sensible heat of the exhaust gas to preheat the feed. The product of such a process could be briquetted and fed to an open-arc furnace or charged hot to a plasma furnace. The utilization of ore fines is of great potential benefit in the South African context since they represent a plentiful and inexpensive feedstock: the mining costs have already been recovered, and there is no other use for them at the present.

Roasting and Prereduction of Ilmenite

At Richards Bay Minerals[25], ilmenite, rutile, and zircon in a dune deposit are separated by a variety of techniques. One of the products of this plant is high-titania slag (86 per cent TiO_2), which is made by the smelting of ilmenite. This is exported to manufacturers of pigments.

The ilmenite contains about 46 per cent TiO_2, but is not suitable for direct smelting because it is high in Cr_2O_3, which reports to the slag in the smelter and renders the slag unacceptable to pigment manufacturers. The minerals containing Cr_2O_3 are not readily separable from ilmenite by magnetic means, because their magnetic susceptibilities are too similar.

A magnetizing roast in a fluidized bed increases the magnetic susceptibility of the ilmenite alone. For this, two fluidized beds in parallel are used, each of which comprises three roasting stages and two cooling stages. The cooled product is passed over low-intensity drum magnets, from which a low-chromium fraction containing approximately 49 per cent TiO_2 is obtained. This fraction is charged to two 105 MVA electric smelting furnaces together with charred anthracite, which is prepared on site. Low-manganese iron and high-titania slag are tapped individually from these furnaces. A large proportion of the furnace off-gas is used as fuel for heating and drying operations; the remainder is flared.

The electrical energy consumed by this process could be reduced if the ilmenite were prereduced and charged hot to the smelter. Excess furnace gas and coke-oven gas, supplemented by solid reducing agent, could be used for this purpose. Alternatively, charring of the anthracite and prereduction of the ilmenite could be achieved simultaneously by charging of the anthracite and ilmenite to a fluidized bed. The stringent specifications of the high-titania slag require that the feed to the smelter should be of consistent quality. For this reason, a semi-batch fluidized-bed process could be considered to ensure a uniform product.

Roasting and Pyrolysis of Gold-bearing Pyrite

In the extraction of gold from ores containing pyrite, the pyrite is separated from the quartzite by flotation because the gold contained in the pyrite cannot be recovered by direct cyanidation. It is then usual for the flotation concentrate to be roasted in a fluidized bed, which renders the gold leachable. The sulphur dioxide liberated in the roasting step is used to produce sulphuric acid.

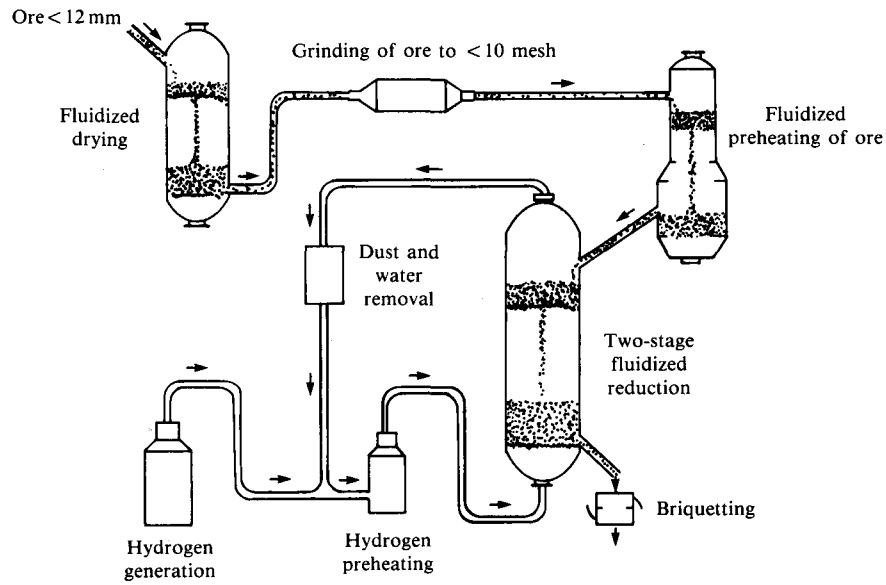

Fig. 4—Simplified flowsheet of the Nu-Iron process (after Reed *et al.*[16])

TABLE I
SUMMARY OF FLUIDIZED PROCESSES FOR THE REDUCTION OF IRON ORE

Process	Ref.	Largest scale t/d	Feed	Fe in feed %	Size of feed μm	Reductant	Gas	Temp °C	Abs. pressure kPa	Gas velocity m/s	No. of stages	Product
H-Iron	2	110	Magnetite concentrate	71	75 to 850	H_2	H_2	530	2800 to 3000	0,3 to 0,8	3	Pyrophoric Fe powder
Nu-Iron	16, 17	3000	Concentrate	–	40 to 800	H_2	H_2	640 to 700	200 to 250	0,6	3	Non-pyrophoric Fe powder
Fior (Esso)	18	300	Concentrate	64 to 70	200	H_2+CO	H_2+CO	800	100	–	3	Non-pyrophoric Fe powder
Novalfer	19	10	Concentrate	–	40 to 1000	H_2	H_2	600	100	0,2 to 1	1	–
Battelle	20	Bench	Concentrate	–	44	H_2	H_2	850	100	3	1	Fe granules
Elred	15	10	Concentrate	65	70 to 90	Coal 0,2 to 1 mm	Air	950 to 1000	600	2	1	Sponge iron
Montecatini	21	1100	Pyrite cylinder	48	150 to 4750	Oil	Air	670	100	–	3	Magnetite
Stelling	22	0,1	Hematite	62	1000	CO	CO	600	100	0,17	1	Fe_3C+FeO
Demag	23	5	Iron ore	–	8000	Coke 0 to 1 mm	CO	1200	100	–	1	Liquid Fe
Hasegawa	24	Bench	Hematite	58	74	Oil	N_2	850 to 1050	100	0,04	1	Sponge-iron pellets

*red reduced
met metallized

The pyrite concentrate is introduced to the fluidized bed as a water-based slurry. For autothermal operation of the roaster, the sulphur content of the concentrate must be at least 30 per cent. As flotation does not give perfect separation, some quartzite reports to the concentrate and some pyrite remains in the underflow. Typically, 80 per cent of the pyrite is recovered, with sulphur levels of 30 to 40 per cent in the concentrate. The gold contained in the pyrite that is not separated from the underflow is lost, since this gold is not recovered in the leaching step.

It is estimated that, of the gold lost to the tailings on South African gold plants each year (worth approximately 1000 million rands), some 30 to 50 per cent is associated with pyrite[26]. If the recovery of pyrite could be increased to about 90 per cent, an estimated additional 200 million rands in gold revenue could be generated.

In addition, the sulphur content of the concentrate would fall to about 15 to 20 per cent. With dry feed, the limiting sulphur level for autothermal roasting is about 15 per cent[26]. Because of the additional pyrite recovered, approximately twice as much of this concentrate would have to be roasted than is roasted at present, and this would require the operation of the roasters to be modified. Drying of the concentrate or firing of auxiliary fuel in the roaster could be considered as a means of balancing the supply of energy with the demand. A higher throughput could be achieved by enrichment of the fluidizing gas with oxygen or by the installation of additional fluidized-bed roasters. The latter approach might prove more economically advantageous.

Many questions relating to the recovery of a greater proportion of the pyrite (so that the gold recovery can be increased) remain unanswered, and an optimum method for the treatment of the concentrate must still be determined. If the roaster could be operated at higher throughputs, the influence of the shorter residence times on the porosity of the pyrite, which directly affects the recovery of gold in the leaching step, may be a limiting factor. The effect of lower sulphur dioxide levels and the presence of fuel-combustion products in the roaster gas on the acid plant also require investigation.

As there is usually an over-production of acid and a shortage of elemental sulphur, the pyrolysis of pyrite is an attractive alternative if the sulphur can be recovered. A fluidized bed suggests itself for the pyrolysis of the fine flotation concentrate (90 per cent smaller than 100 μm)

TABLE I (contd)

Size of product μm	Quality of product*	Use	Mode of operation
45 to 850	98% red	Moulding powder, briquettes	Semi-batch
40 to 800	95% red	Briquettes for blast furnace	Continuous
200 (45% <45)	94% red 89% met	Briquettes for blast furnace	Continuous
–	–	–	Continuous
800 to 1400	98% Fe as metal	–	Continuous
–	60 to 70% met	Charged to d.c. arc furnace	Continuous
150 to 4750	96% Fe_3O_4	Magnetite pellets	Continuous
1000	60 to 90% Fe_3C	$Fe_3C + FeO$ $Fe + 4CO$	Continuous
–	–	–	Batch
Cylinders 3 by 5 mm	91% red	–	Batch

without prior pelletization.

A cursory investigation at Mintek has resulted in a process concept in which a fluidized bed with a draught tube is used[27], as shown in Fig. 5. The draught tube is a pipe that is concentric with the containing vessel, divides the bed into two zones, and allows a gross circulation of solids to be established up the draught tube and down the annular region. Direct resistive heating of the fluidized bed is used to supply the energy required for pyrolysis without contamination of the product. The wall of the vessel serves as one electrical contact, and the draught tube serves as a hollow electrode. The bed is filled with relatively coarse particles of coke to provide conduction paths for direct resistive heating of the bed, which is maintained at 700 to 800°C; decomposition of the pyrite will occur at temperatures above 690°C[28].

The fine pyrite, which is introduced near the top of the annulus, is entrained downwards as a result of the downward flow of the coke particles. Pyrolysis occurs in the annulus, sulphur vapour being carried off with the fluidizing gas. The retention time of the pyrite in this zone can be controlled by varying the gross circulation rate of the coke so that conversion is complete by the time the bottom of the annulus is reached. At that point, the solids are swept into the draught tube. The fine particles of pyrrhotite are elutriated from the draught tube and carried off with the product gas, and the coke particles spill over into the annulus.

The solid product is separated from the gas stream in a cyclone and is leached under mildly oxidizing conditions prior to cyanidation and final recovery of the gold. The gas stream can be cooled against the incoming feed in a fluidized bed before passing through a condenser in which elemental sulphur is collected.

Although the energy for pyrolysis could be provided by the combustion of natural gas or oil, these are not viable options in South Africa. The use of coal as a fuel

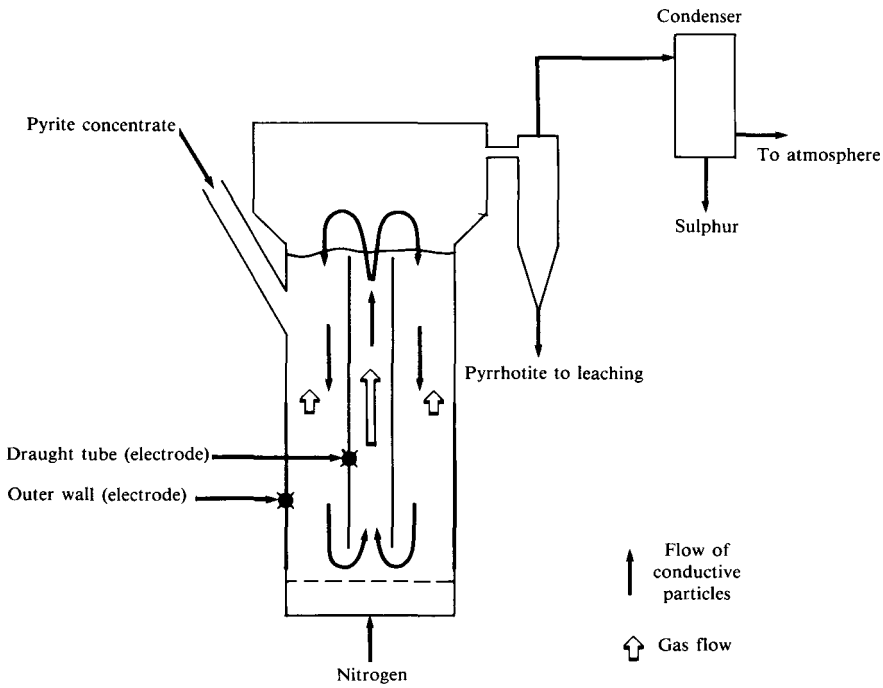

Fig. 5—Proposed process concept: pyrolysis of pyrite in a resistance-heated fluidized bed with a draught tube

in the fluidized bed is excluded because contamination of the pyrrhotite with fine flyash would result in a lower gold yield in the downstream processing.

Conclusions

A fluidized-bed reactor is not the only option for the processing of fine materials. However, because of its comparatively low cost, it promises to be the most economically attractive option in applications for which it is technically viable. The fluidized-bed reactor, especially when used in conjunction with a plasma furnace, offers a means for the utilization of fine ores, of which South Africa has an abundance. Fine coal, and possibly even high-ash coal, can be used instead of more expensive coke, and the dependence on electrical energy can be decreased. Improved utilization of furnace gas as a substitute for electrical energy further enhances the overall economics of the process. The requirements for preparation of the feed are usually minimal, since extensive milling and briquetting or pelletization are eliminated.

Fluidized beds are therefore potentially of great benefit in the metallurgical industry, but developmental work on these processes is far from complete. The increasing cost of electrical energy and the need for ore fines and low-grade ores to be utilized has given added impetus to development programmes. Fluidized beds may yet prove to be the complement to existing and proposed processes that will enable local producers to continue to compete on world markets.

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