Low Shaft Furnace Smelting of Pig Iron in India

A. B. Chatterjea
B. R. Nijhawan

AS IRON and steel enter in all other industries in some form or other, the industrialisation of a country depends on the production of iron and steel. Production of pig iron, which is ultimately converted into steel, depends on the availability of raw materials like iron-ore, and coking coal of suitable grades. The conventional method depends on the reduction of lumpy iron-ore or sintered iron-ore with abrasion resistant coke in presence of limestone in a blast furnace. The increase in the height of the furnace to increase the capacity and thermal efficiency necessitates the use of good strong coke which can only be obtained by carbonisation of coking coal. As the modern blast furnace consumes 1,500–2,000 lb of coke per ton of pig iron, considerable attention is paid to minimise the coke-rate and thereby reduce the cost of iron production. For this purpose the temperature of the blast furnace gas should be as low as possible to reduce the sensible heat carried away by the gas and the ratio of $CO : CO_2$ in the top gas should be as near as possible to the equilibrium value. Both these factors have contributed towards the increase in the height of the furnace. Requisite raw materials for blast smelting are becoming scarce, as in some countries coking coals are not available and the ores are soft and obtained as fines.

One disadvantage of iron ore supplies anywhere is the ever increasing quantities of fine ore produced in normal iron ore mining operations. The specifications laid down for optimum lump sizes of blast furnace ores required perfect classification of the burden yielding in the process large quantities of medium and small lump sizes. It is readily possible, of course, to pelletise, briquette or sinter the ore fines but the problem remains for the utilisation of medium sized ores too coarse for sintering but not coarse enough for direct charging into a standard iron blast furnace. The low shaft furnace process of smelting aims to overcome these difficulties. India has plentiful supplies of good grade iron-ore and its distribution is fairly even. Some of the iron ores are friable and cannot be charged directly in the blast furnace. Coking coal, however, is not evenly distributed all over India and is concentrated over a limited geographic area. Many occurrences of iron-ore are remote from coking coals. The coking coals have high ash and high phosphorus contents leading to high alumina slags and excessive pick-up of phosphorus in the pig iron.

With the production capacity of 6 million tons of steel ingots per year in the near future and with possible expansion to 30 million tons in the next 20 years, the reserves of coking coal will not last for a long time. It is considered that with an inexhaustible source of iron ore reserves, there will be a deficit in coking coal in the not too distant future. The future of the iron industry, therefore, calls for not only economy in the use of coking coal but also the development of alternative smelting methods to safeguard the future of this vital industry. Enormous deposits of lignite exist in Neyveli, South Arcot, the quality of which is comparable to lignites of East Germany. The utilisation of inferior grades of fuel like non-coking coal and carbonised lignite and the increased amount of good grade fine or soft iron-ores or poor ores focusses the attention to the alternative methods of producing pig iron. For a variety of reasons the low shaft furnace appears to be one of the most practical alternatives to the blast furnace in areas of the world where smelting of iron has to be accomplished in the absence of suitable raw materials, either ore or coal. It has been proved in East Germany, West Germany, Yugoslavia and by trials conducted at the International Low Shaft Furnace, Liege, Belgium, that the absence of coking coal no longer stands in the way of development of iron and steel industry. Though low shaft furnace is not intended to replace the conventional iron blast furnace which is the *sine qua non* of cheap iron production, it offers a practical solution to the production of iron without the necessity of using coking coals. Furthermore, the raw materials are distributed all over India and for minimising their transportation and that of finished products, it may be economical to develop smaller iron producing units which may not warrant installation of an expensive blast furnace plant with ancilliary equipment. The possibilities of other methods of producing iron, therefore, need careful examination.

The possibilities of pig iron production in India by methods other than blast furnace have been reported.[1,2,3] An attempt has been made in this

Dr. A. B. Chatterjea, Assistant Director, Low Shaft Furnace Project and Dr. B. R. Nijhawan, Director, National Metallurgical Laboratory, Jamshedpur.

1 H. Schrader and D. Jagat Ram—Possibilities of Iron and Steel Making in India without Coking coal. (Trans. Ind. Inst. Metals, 4, 1950, 81–112).

2 W. E. Krebs and D. Jagat Ram—Pig Iron Smelting Without Metallurgical Coke (Trans. Ind. Inst Metals, 5, 1951, 51–76).

3 M. N. Dastur and R. D. Lalkaka—Future of Low Shaft Furnaces in India (Trans. Ind. Inst. Metals, 9, 1955–56, 59–82).

paper to compare different techniques of iron production in low shaft furnace and to assess their commercial possibilities in the background of availability and geographical distribution of necessary raw materials in India and to indicate probable locations.

Distribution of raw materials in India

The location of iron-ore, non-coking coal or lignite and limestone deposits collected from the published data have been shown in the map of India on page 46. In India reserves of good grade iron-ore (55% Fe) amount to 10,000 million tons. It occurs in Bihar, Orissa, Madhya Pradesh, Madras, Bombay and Mysore Smaller deposits exist in the Almora district of Uttar Pradesh, Punjab and the coal fields of West Bengal. Mining of three tons of iron-ore produces about one ton of fine-ore which cannot be directly charged in the blast furnace and requires sintering. The iron-ore is generally of high grade, often containing more than 50% iron. The Salem magnetite iron-ore contains on average 36% Fe and 44% SiO_2. It has to be beneficiated to enrich iron-contents. The investigations conducted at the National Metallurgical Laboratory have shown that the iron ore can be suitably beneficiated to contain 64% Fe, with iron recovery of 89%. A good sinter can be obtained with a basicity ratio of 0·85 by the adjustment of SiO_2, Al_2O_3, CaO and MgO. Reducibility of beneficiated magnetite is comparable with hematite ores of India. It will, however, be obtained in powdery form and will require agglomeration. The Indian limestone, although poor in quality, can be employed for fluxing, as is done in conventional blast furnaces.

Enormous deposits of lignite occur in Neyveli, South Arcot and Palana in Rajasthan. The analysis of Neyveli lignite along with that of Lauchhammer, East Germany for comparison are given in Table I, on dry basis.

TABLE I.

Analysis on dry-basis of Lauchhammer & Neyveli Lignites.

Location	Ash%	V. M.%	F. C.%	Calorific Value KCal/kg.
Neyveli	4·7-5·0	51·60	43·36	5700
Lauchhammer	5·5-6·0	53·60	40·42	5710

In a discussion with one of the authors (A. B. Chatterjea) at Bergakademie, Freiburg, East Germany Prof. Rammler indicated that there was no essential difference in analysis and properties between the Neyveli and the Lauchhammer lignites. The Neyveli lignite after crushing to 0·1mm. and briquetting with 10% moisture showed a compressive strength of 250 kg/cm² (and a shear strength of 30-40 kg/cm²) compared to 180-200 kg/cm² of Lauchhammer lignite briquette containing 11-12% moisture. Although the compressive strength increases by 60% on coking, it is still too low for use in normal blast furnaces. The Lauchhammer lignite coke-briquette contains 1-2% sulphur. The sulphur content of Neyveli lignite on dry basis is 0·75%. As 40% of it is expected to pass on to the gas, a maximum of 1% will remain in the coke-briquette, which will be acceptable. If no sulphur disappears it will be 1·8%. It was also indicated by Prof. Rammler that Indian lignite presented no difficulty on grinding operation and 2·4 tons of lignite briquettes with 10–12% moisture was likely to furnish 1 ton of lignite-coke briquettes.

It has been reported that carbonisation of Neyveli lignite in a fluidised carboniser at 900°F yields 1,300 lbs of char, with a heating nature of 12,170 B.T.U./lb 25 gallons of tar and light oil and 8,000 cft. of gas, having a calorific value of 180 B.T.U./cft.

The geological survey has disclosed that very good grade lignite exists in Kutch, the quality of which is superior to its two counterparts in Bikaner in Rajasthan and South Arcot, Madras, as it has a higher calorific value. The chemical analysis of Palana lignite (Bikaner) of Rajasthan is given in Table II. The available thermal energy from the dried Palana lignite is roughly two-thirds of an equal amount of coal.

TABLE II.

Chemical Analysis of Palana Lignite

Constituents	Air dried	Dry Basis	Calorific Value
Moisture	26·7	Nil	6674 KCal/Kg or
Ash	4 4	6·0	12,013 B.T.U./lb
Volatiles	45·2	61·7	(Dry basis)
F. C.	23·7	22·3	

It has been observed that Palana lignite has lower moisture in the as mined state.

Low shaft furnace processes

Keeping in view the occurrences of the primary raw materials viz., iron-ore and fuel, it is apparent that the smelting process can be based on either non-coking coal or coke obtained by the high temperature carbonisation of lignite. A brief description of the existing low shaft furnace processes[4] working on these fuels will, therefore, be of interest.

The DHN Process: The main object of the process developed by the Demag-Humboldt Niederschachtofen is the smelting of fine iron-ore with non-coking coal in a single stage of operation. The raw briquettes contain iron-ore, limestone and non-coking coal in correct proportion, which can be adjusted to the composition of pig iron and the desired analysis of slag. For smelting trials in the DHN 12–15 tons per day low shaft furnace pilot

[4] A. B. Chatterjea—Low Shaft Furnaces as an Alternative to the Blast Furnace—Their Place in an Integrated Iron and Steel Plant (Iron and Coal Trades Review, Nov. 23, 1956, 1225–1261 and Nov. 30, 1956, 1324–1335).

plant, iron-ore containing 55% Fe and non-coking coal containing 35% V.M. and 6% ash were employed.

These raw materials are finely crushed, thoroughly mixed and briquetted under pressure in roller briquetting machines under pressure with the addition of 6–7% tar as binder. It is imperative that the briquettes should not burst on sudden heating from the atmospheric temperature to 350–400°C at the top of the furnace and it should retain its shape till it reaches the tuyere region to reduce the unnecessary loss as dust. The coking index of coal and the reducibility of iron-ore have a great influence on the smelting process[5]. In this process the carbonisation of the briquettes occurs at the upper part of the furnace shaft and the period of carbonisation affects the strength of the briquettes. The low-temperature carbonisation yields a very reactive coke and the intimate contact of the raw materials in a briquette favours rapid reduction. The use of briquettes not only assures uniform distribution of the charge without any segregation but also guarantees gas transmission which is essential for bringing the charge to the reaction temperature. Very little reduction of the iron-oxide occurs in the upper part of the furnace but rapid reduction begins at a height of 2½ ft. from the tuyere level and 80% of reduction occurs during the passage of the briquette to the tuyere level. The composition of pig iron was 4·3% C, 0·9–1·4% Si, 0·9–1·1% Mn, 0·12–0·14% P, 0·025–0·50% S, and the slag analysed Fe 1·1%, CaO 44·7%, MgO 6·8%, SiO_2 34·0%, Al_2O_3 11% having a basicity index of 1·3. In these tests blast was preheated to 480°C and blast consumption amounted to 5,050 Nm^3 (176,750 cft.) per ton of iron. The temperature of the top gas was 300–400°C. The amount of top gas was 7,300 Nm^3 (255,500 cft.) per ton of pig iron. The analysis of top gas CO_2 3·4%, H_2 7·6%, CO 30·6%, N_2 54·9% with a calorific value of 1426 kcal/Nm^3 (158 BTU/cft.). The average consumption of coal was 2,190 kg/ton of iron which is equivalent to 1,450 kg of coke. This value although high in comparison with the coke consumption in a modern blast furnace is not disadvantageous when it is considered that it includes the fuel requirements for sintering of fine ores and coking of coal in the coke-ovens which are additionally required for the blast furnace smelting. It can be further reduced by preheating the blast to 600–700°C and minimising the heat-losses through radiation and conduction in a commercial furnace.

As high top temperature has to be maintained to prevent condensation of tar, which is generated during the carbonisation of coal in the briquette, enrichment of the blast with oxygen and thereby setting up steep temperature gradient, is not possible.

Based on the experience secured in a 12–15 tons pilot low shaft furnace plant working on single-stage process of making desirable grades of pig iron from self-fluxing ore-coal-limestone briquettes, the DHN have installed a 100 tons/day commercial low shaft furnace plant at Troisdorf. It will use minette ores from Lorraine with particle size below 5 mm, German and Swedish ore fines and Ruhr high volatile coal of the same size[6]. It is interesting to note that although the pilot plant investigations were conducted in a furnace having almost a circular section, the Troisdorf furnace has a rectangular cross-section, measuring $4{\cdot}2 \times 2{\cdot}1$ m at the tuyere level. It has ten tuyeres, four on each long side and one on each small side. In a recuperator fired by the furnace gas, the blast will be preheated to 800°C and blown at about 20,000 Nm^3 (700,000 cft.) per hour. As this is the first commercial version working on the DHN single-stage smelting operation with high volatile coals and fine grained iron ores, the process and its economics are watched with great interest. If it be technically feasible and economically sound, it is expected that when the small output does not warrant the erection of a blast furnace, this type of furnace may receive consideration in view of its low capital cost as it does not require incorporation of a sintering or a coke-oven plant.

Low shaft furnace operation at Calbe, East Germany: The low shaft plant in East Germany has special significance as it is the only commercial plant in the world producing 250,000 tons foundry pig iron annually in ten furnaces each producing 80–100 tons a day. In the absence of any deposit of coking coal for producing blast furnace coke and iron-ore suitable for smelting in the conventional blast furnace, it was realised[7] that development of the iron and steel industry depends on the simultaneous utilisation of the available low-grade highly acidic iron ore containing 21–27% Fe, 22–40% SiO_2 and brown coal (or lignite) vast deposits of which exist in East Germany (DDR). The small amount of coal which is available does not result in metallurgical coke on carbonisation. The ten commercial furnaces at Calbe have rectangular section of about 11m^2 in area at the tuyere level and effective height of 4·8 m. The lignite (analysis of which is given in Table I) is carbonised at high temperature and the lignite-coke briquettes are approximately $2\frac{1}{2} \times 2\frac{1}{2} \times 1''$ thick. It has 2·5% moisture, 11·64% ash, 1–2·2% S, 80–83% F.C. having a calorific value of 6,825–7,055 kcal/kg. The furnaces operate on a bedded charge of small lumps of iron ore and limestone and lignite coke briquettes. The blast is preheated to 780°–800°C. Excluding coke, 4,533 kg of burden is required to produce 1,000 kg of pig iron with a burden yield of 22·6%. The consumption of lignite coke (B.H.T.) amounts to 2,015—2,050 kg per ton pig iron and the amount of slag produced per ton of pig iron is 2,160–2,250 kg analysing 40·8% SiO_2, 8·9% Al_2O_3, 48·0% CaO and 2·3% MgO, having a basicity index of 1·01. The

5 H. Reinfeld—Low Shaft Furnace Process (Iron and Coal Trades Review., Nov. 9, 1956, 1139–1148).

6 F. Weston Starret—Low Shaft Blast Furnace Holds New Promise (Journal of Metals, Nov. 1957, 1432–1434).

volume of the gas amounts to 11,050 Nm^3 (390,000 cft.) per ton of pig iron with average analysis of 30–35% CO, 5-6% CO_2, 0·4% CH_4, 1-2% H_2, balance nitrogen having a calorific value of 1,035–1,100 kcal/Nm^3 (110–120 BTU/cft.) with CO : CO_2 ratio of about 6. In view of the weight ratio of over 2 of slag per ton of pig iron and a volume ratio of 1 : 8 resulting from a burden yield of 20-21% higher heat loss from conduction and radiation and greater dissipation of heat through water cooling a large number of tuyeres of rectangular furnace, the consumption of coke is not high in comparison with blast furnace smelting. It has been shown that with a rich ore resulting in the increase in the iron-contents of the burden from 19·6 to 33·2% and decrease in the quantity of slag from 3,060 to 1,300 kg., the consumption of coke decreased from 2·9 to 1·63 tons/ton of pig iron. By the use of ore-lime-coke briquettes an economy in the fuel consumption of 14·7% and increase in the production of 21% was attained. Increase of oxygen in the blast[7] from 21 to 24·2% resulted in the increase of output by 15·2%. These examples are cited to indicate the various technological aspects of the smelting operation. A Calbe furnace with high grade Indian iron ore will produce about 200 tons of pig iron per day.

As the results obtained in the operation of the International Low Shaft Furnace at Liege, Belgium form the subject of another paper presented by Dr. H. Malcor, it would be of interest to summarise important conclusions only :

(*i*) Low shaft furnace can produce low silicon pig iron suitable for conversion into steel by the basic Bessemer process from fine size low grade ores and fuels unsuitable for utilisation in the blast furnace. As regards particle size of raw materials the low shaft furnace can accommodate 0 to 3/4 in. including 50% of 0 to 3/8 in.

(*ii*) Semi-coke can be used as fuel and addition of 25% anthracite or coal did not involve any operational difficulties.

(*iii*) The enrichment of the blast with oxygen was not indispensable and the low temperature of the top gas could be maintained by the burden consisting of particles of fine size.

It has been reported[8] that fine ores containing less than 30% Fe has been smelted in a low shaft furnace on pilot scale with inferior grade of coal containing 20–30% volatile matter, in Lausanne in Switzerland. The interesting factor is that the reduction gases were drawn downwards into the bottom of the recuperator, which enabled attainment of high temperature and avoided hanging. The gas can also be circulated into the reduction zone.

It is understood that Kalinga Industries Ltd. are installing a blast furnace with a low height of shaft designed by Dr. C. Otto and Co., West Germany and supplied by Messrs Fried Krupp A-G, Essen, West Germany. The furnace height is 13·80 m with an effective height of 10·20 m, effective volume of 49·36 m^3, hearth diameter of 2·5 m, and bosh diameter of 3·0 m. It has six tuyeres each having a diameter of 90 mm. The blast is supplied by a turbo-blower having an intake volume of 17,000 m^3/hr. and delivery pressure is 2 kg/cm^2. The furnace with a rated capacity of 100 tons of pig iron/day operates on high grade iron ore (64% Fe) having a particle size of 10–40 mm, limestone (45% CaO) of 10–50 mm. in size and coke (76% F.C., 22% Ash) of 12–37 mm in size. As raw materials of a selected grade of close size specifications are employed for smelting, it cannot strictly come under the category of a low shaft furnace.

Advantages and disadvantages of the low shaft furnace process

In order to assess the possibilities of low shaft furnace installation at appropriate places, it becomes imperative to ascertain its advantages and disadvantages.

As the name indicates, the height of the low shaft furnace seldom exceeds 16 ft. This reduction in height in comparison with the blast furnace, widens the choice of raw materials. As the burden is not subjected to heavy load inside the furnace, it may consist of friable and fine grained ores and fuels of inferior grade like coke-breeze, coal, lignite, the cost of which is comparatively lower than that of the raw materials for the blast furnace and are abundantly avaiable. Because of the use of raw materials of inferior grade and the equilibrium conditions obtained in the low shaft furnace, the top gas is larger in volume and has a higher amount of CO in it, thereby increasing the thermal value of the gas. This is distinctly advantageous when the cost of the gas calorie is higher than that of the fuel calorie. The higher coke-rate in the low shaft furnace is compensated by the lower price of inferior fuels and the higher gas credits.

On account of the smaller dimensions of low shaft furnaces, the requisite blast pressure is much lower than the pressure required in blast furnace operation. Therefore high capacity turbo-blowers and large hot-blast stoves are not necessary.

It has been mentioned that the single stage DHN process operates on ore-coal-limestone briquettes and prior carbonisation of coal is not required. This technique eliminates the coking plant, an indispensable equipment for blast furnace operation, and thereby reduces the capital investment considerably.

On account of its smaller volume, the starting and stopping of the low shaft furnace are simpler and the shut down period during relining takes less time. For the same reason, operational characteristics can be studied by varying the composition of the burden, increasing the pressure of the blast, oxygen enrichment of the blast, etc.

7 K. Sauberlich—Development of Low Shaft Furnace Process in German Democratic Republic (Neue Hutte I, 1950, pp. 193–201).

8 Some Important Developments during 1953 in Iron and Steel Technology (Report of the Steel Committee of the Economic Commission for Europe, H. M. Stationery Office).

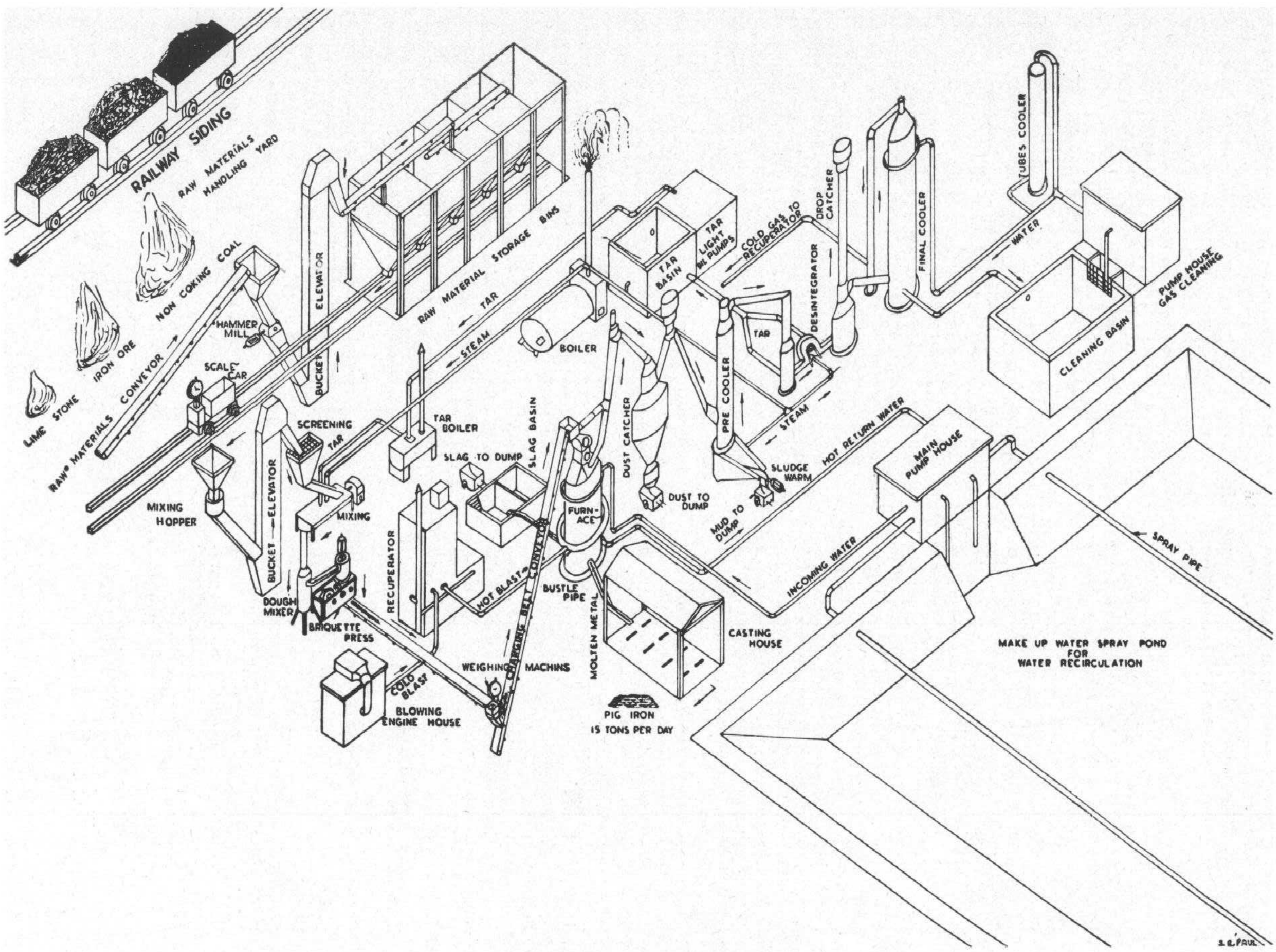
The metallurgical reactions in the low shaft furnace are similar to reactions in the blast furnace, but a higher amount of CO is present in the top gas for a greater amount of direct reduction and decreased height of the shaft. The control of smelting operation is exercised in the same way as in the blast furnace by varying the pressure, volume and temperature of the blast and fuel rate. But the absence of an unreacted zone in the low shaft furnace is distinctly advantageous in not increasing silicon with increase in the temperature of operation. Further, small effective volume of the low shaft furnace increases production rate based on the volume of the furnace to 2·5 times to that of the blast furnace.

Successful operation of the low shaft furnace demands prior preparation of the raw materials to meet the furnace requirements. Due to the decreased throughput time (which is about one eighth of a blast furnace) intimate mixing of fine grained raw materials by briquetting is very advantageous for the low shaft furnace operation.

With medium grade raw materials the capacity of a low shaft furnace is not expected to be over 200–300 tons/day. A battery of low shaft furnaces producing 1,000 tons of pig iron/day will require more man-power than a blast furnace of identical capacity and involve higher labour costs.

Description of 15 tons per day Low Shaft Furnace Pilot Plant of the National Metallurgical Laboratory and its operation: The main object of extensive investigations to be conducted in the 15 tons per day Low Shaft Furnace Pilot Plant is to assess the possibilities of making commercial grades of pig iron with raw materials like soft iron-ores, iron-ore fines, beneficiated magnetite iron-ore, with various high ash non-coking coals or carbonised lignite, plentiful supplies of which are available in India but are unsuitable for exploitation in the conventional blast furnace. The production of standard exportable grade of ferro-manganese is also envisaged. The technique, as developed by the DHN, is to smelt fine iron ore with non-coking coal and limestone in a single stage of operation. The coke ovens battery, which is an inseparable and costly installation for iron smelting by the conventional blast furnace is thereby eliminated. The raw briquettes contain an intimate mixture of fine ground iron-ore, limestone and non-coking coal in correct proportion, which can be adjusted to the desired composition of pig iron and slag. The necessary raw materials will be brought to the site by a railway siding which has been specially laid. The raw materials will then be crushed by a jaw crusher and two hammer mills, elevated by a bucket elevator and stored in five storage bunkers each having a capacity of 50 tons iron ore. The already crushed raw materials are withdrawn from the bottom of the storage bins into a hopper on trolley with a machine, in desired proportions and unloaded on a collecting hopper. These are elevated by another bucket elevator and screened by a vibrating screen. The finer particles (0–5 mm) are fed to a cylinder-type mixing worm. Molten pitch, supplied by two tar-boilers, and sulphite lye are added. The thoroughly mixed raw materials then drop into a vertical dough mixer heated by adjustable steam nozzles to about 90–100°C. The movement of the shaft with arms inside the mixer assures thorough mixing of the raw materials and uniform heat distribution. The discharging arms at the bottom transfer the mix to a belt conveyor and the rate of feed to the roller briquetting press can be regulated. There are two parallel mixing and briquetting facilities. The capacity of each briquetting press is 3·5 tons/hour of 110 g. pillow shaped briquettes measuring $55 \times 45 \times 40$ mm which are made under requisite pressure. The briquettes drop on to a cooling wire conveyor belt and can either be stored or fed intermittently into the furnace by another conveyor belt set at a slope of 23° after weighing. With the composition of raw materials available in India about 5-6 tons of briquettes are required for a ton of pig iron. The depth of the charge in the furnace is indicated by two stock-line recorders and the charging cycle can be regulated accordingly. The 15 tons per day low shaft furnace is of circular cross-section having a hearth diameter of 1,300 mm, bosh diameter 1,600 mm and diameter at the top is 1,300 mm. The heights of the hearth and bosh are 900 and 800 mm respectively. The effective height of the furnace from the tuyere level to the stock line is 3·6 m, the total capacity being 7·3 m³. The top of the furnace is closed with a hopper and two revolving drums each having a small segment open and has a distributor. The furnace bottom, hearth and bosh are lined with carbon blocks. It is lined with high alumina (40–42% Al_2O_3) around the tuyeres and the shaft is lined with fire-clay bricks (36–39% Al_2O_3). The blast is supplied by single stage turbo-blower having an intake volume of 5,000 m³/hr. with an outgoing pressure of 1·3 atm. The blast is preheated to 600°C by a metal tube recuperator, in which either fuel oil or furnace gas can be burnt by a burner. The blast is injected into the furnace through four water cooled tuyeres each of 90 mm dia. which provides a blast velocity of 95–100 m/sec. at a pressure of 3,000 mm water column. The furnace shell is cooled by spraying water. The furnace will be tapped at regular intervals and the slag will be granulated. The molten pig iron will be cast in sand-bed.

The furnace gas comes out by two uptakes which combine before their entry into the dust-catcher. The furnace gas amounting to 6,000–7,000 Nm³/ton of pig iron has to be maintained at 350°C by insulating the uptakes and the dust catcher to prevent condensation of tar. It then passes on to the primary cooler and comes in contact with a spray of warm water when dust and tar are collected in the form of a mud in the pit at its bottom. This is taken out by a sloping worm at intervals and can be used as a binder for the briquettes. The gas coming out of the primary cooler is at about 80°C and contains about 2 g.



15 tons per day Low Shaft Furnace Pilot Plant
(Schematic and not to scale)
Showing flow-sheet of operation.

of dust/Nm^3. Before entry into the Thiessen Disintegrator light oils are separated from the cooling water by water syphon. The gas by now is cooled to 25°C and passes successively through the disintegrator, the drop-catcher and the final cooler where it is scrubbed with cool water. The dust content of clean purified gas is about 0·02 g/Nm^3 and it is supplied to the recuperator by a gas-booster. About one third of the gas produced will be necessary for heating the blast. The excess gas can be burnt after the dust catcher or after its treatment in the disintegrator. Water for gas cleaning will be stored in a cooling basin and pumped into the system after cooling in a tubes-cooler. Basins have been provided for the collection of light oils and tar, which are to be pumped out. A part of the tar will be employed for briquetting. The arrangement of the furnace and the gas cleaning is shown in Figs. 9 and 10. The operation of the plant can be ascertained from the mimic diagrams and other automatic devices and can be automatically controlled.

The quantity of water for furnace cooling is 140 m^3/hr. and gas cleaning is 60 m^3/hr. : the total requirement works out to be over one million gallons a day. In order to economise the consumption of water a water recirculation system with arrangements of sedimentation of incoming raw-water and cooling of the return water has been incorporated. The amount of water necessary for slag granulation will be about 150 m^3/day which will not be recirculated and the balance will be cooled in two stages for recirculation. Taking into account the losses due to evaporation etc., it is expected that the addition of make up water will not exceed 240 m^3/day or about one lakh gallons per day.

The effective power requirement for the electrical equipment and plant lighting of 440 kW will be met from a 500 kVA transformer. It will step down the voltage from 6,600 volts to 450 volts.

It is considered that the data collected on the extensive tests on this pilot plant will be of great value for the future expansion of the iron and steel industry in India.

Future plans

The Low Shaft Furnace Project has to be extended during the years to come to include investigations on the production of ferro-manganese by the use of non-coking coals. To effect this a "tonnage oxygen plant" will have to be installed at the Low Shaft Furnace Pilot Plant. It will be necessary to extend the scope of the Low Shaft Furnace Plant to ensure maximum utilisation of the by-products derived from the Low Shaft Furnace, such as, the gases of high calorific value which will be liberated during smelting. The composition of the gas expected to be evolved is as follows :

CO_2	...	...	3-4%
CmHn	...	...	0·1-0·2%
CH_4	...	...	3-4%
CO	...	...	28-32%
N_2	...	...	52-56%

with a calorific value of about 150 BTU/cft.

It may be worthwhile to investigate the possibilities of recirculating this gas through the tuyeres into the furnaces to explore its possible role as a reductant. It would also be worthwhile to explore the possibility of using this gas for the production of sponge iron by processes such as HyL process developed by Messrs Kellogg and Co. In this connection, the example of the Soviet Union is furnished where the following integrated iron and steel plant exists at Tula for research and development work.

The Tula experimental plant of the U.S.S.R. has two blast furnaces of 850 and 330 tons per day capacity in which oxygenated air blast is used for the production of pig iron and ferro-alloys. One open hearth furnace of 10 tons capacity and one L-D oxygen converter of 10 tons capacity are also in operation. Oxygen is injected into the L-D converter through a water cooled copper lance at a pressure of 12–16 atmospheres. The L-D steel made is of low carbon type. The production of high carbon steel heat in the L-D converter is also being tried. The steel slag is used for fertiliser purposes.

There are two high pressure tonnage oxygen plants producing 10,000 cu.m. per hour and an older low pressure plant producing 14,000 cu.m. per hour of 98·5% purity oxygen. Argon and Krypton are also being recovered. The example of the Soviet Union in establishing an experimental plant just for research and development in iron and steel technology is worth emulating.

It is also considered advisable to install in conjuntion with the Low Shaft Furnace of National Metallurgical Laboratory, a 1-2 tons oxygen converter for the utilisation of the pig iron produced for investigation into steel-making by the L-D process, OLP process and other variations of the steel-making processes to suit Indian pig iron compositions and raw materials.

It is also proposed to utilise the gases liberated from the Low Shaft Furnace as a reductant in the upgrading of low grade ferruginous manganese ores. Upgrading of low grade ferruginous ores by reduction roast at a temperature of 500–550°C by the use of suitable gases has been successfully tried in the National Metallurgical Laboratory on the scale of 2 tons per day of raw ore being upgraded. Effective upgrading of low grade ferruginous manganese ore has been accomplished. It would be necessary to utilise low shaft furnace gases for effecting such reduction for low grade ferruginous manganese ores. Procurement of the pilot plant under the T.C.M. scheme for the upgrading of low grade manganese ores, at the rate of 1 ton per hour, is also being negotiated ; it is proposed to be installed at the Low Shaft Furnace Plant site.

Besides studying the effect of oxygen enrichment of the blast, controlled humidity of the blast and other theoretical aspects of the blast furnace process, these are some of our objectives for the Low Shaft Furnace Project and extending its scope to include maximum utilisation of by-products as also employing the Low Shaft Furnace Pilot Plant as a full metallurgical tool for metallurgical research and development.

When the three new State steel plants are in full operation, it is proposed to convert the project into an Iron and Steel Division along the pattern of Soviet Central Institute for research into ferrous metallurgy to handle variegated research and development problems of not only the steel plants but also those of the private sector.

The Low Shaft Furnace holds great promise not only for the objective for which it has been established but also to serve as a tool for effecting considerable investigational work, the exact items of which will emerge as the furnace goes into its full paces and as new themes and plans emerge in the light of experience gained.

Possibilities of low shaft furnace process in India

The location of ore and fuel deposits in India has been indicated in a map of India on page 46.

Keeping the geographical disposition of the raw materials and their analyses in view, the ore-coal-limestone briquetting process developed by the DHN, West Germany appears to be suitable for the utilisation of Singhbhum ore fines, using Orissa coals. The low-grade iron-ores of Bengal-Bihar may also be worked by this process using non-coking coals from Ranigaunj coal fields. Iron ore of Siddhi in Mirzapur district and Singrauli from Rewa belt can be exploited. Non-coking coal from Balharshah in Chanda district and iron ore of Chanda district in the State of Bombay may be smelted by the ore-limestone-coal briquette process.

The utilisation of iron ores in the South, or smelting with lignite coke briquettes produced from Neyveli, in low shaft furnaces similiar to those of Calbe, East Germany, appears to be possible. It appears from discussions that Neyveli lignite may be converted into coke-briquettes by a high temperature carbonisation technique similar to that employed at Lauchhammer. Similarly iron ores occurring in Jaipur and Udaipur can be smelted with Palana lignite in Rajasthan, where good quality limestone is also available.

For a country like India where large amounts of high grade iron ore are available but the coking coal is scarce coupled with the difficulties of transportation of raw materials and finished products over long distances, the smelting of iron ores in low shaft furnaces by a process appropriate to the local conditions of raw materials appears to have certain advantages and potentialities.

Summary and conclusions

The operation of the conventional blast furnace requires raw materials of excellent quality, the reserves of which are gradually diminishing. In certain areas of the world iron-ore and metallurgical coal do not occur simultaneously. The ever increasing demands for steel with a shortage of suitable grades of raw materials has led to the alternative methods of making pig iron. The necessity of utilising ore fines or soft ores and non-coking coals and lignite stimulated investigations on the low shaft furnace. The process is attractive as the operation is similar to the blast furnace and affords utilisation of furnace gas of somewhat higher thermal value. It has been found that desirable grades of pig iron can be obtained and the economics of commercial exploitation is not unfavourable particularly for countries lacking in good grade ore or coking coal but possessing inferior grades of ore and fuel. India has plentiful reserves of good grade iron ore but occurrences of coking coal are not only poor but also concentrated over a small geographic region. Large reserves of lignite are also available. The distribution of essential raw materials in India has been described. The adoption of the low shaft furnace process should be based on the use of non-coking coals and lignite as fuels. The existing low shaft furnace processes working on these fuels have been examined. The advantages and disadvantages of the low shaft furnace operation have been discussed and in has been concluded that despite the higher fuel consumption, the process may not be uneconomical. The probable locations of the low shaft furnaces in India, operating either on non-coking coal or carbonised lignite, are indicated in the background of the distribution of raw materials. The low shaft furnace is not intended to replace the blast furnace but it can fill the gap in countries possessing inferior grades of raw materials. It has been concluded that in view of large occurrences of non-coking coals, and lignite and the necessity of dispersal of iron and steel industries all over India, the low shaft furnace process has certain potentialities and deserves careful consideration. Whether this virgin venture will be pregnant with possibilities can perhaps be answered from the operational data of the 15 tons per day Low Shaft Furnace Pilot Plant installed at the National Metallurgical Laboratory.

(N.B. Further illustrations of the Low Shaft Furnace Pilot Plant appear on pp. 46–54.)