FUTURE OF SPONGE IRON IN INDIA AND PLANT DESIGN DATA

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Abstract

The author tries to foresee the future of Sponge Iron Making in India and forecasts that the metallurgical supremacy of Coke Ovens and Blast Furnaces for making iron will be challenged by Sponge Iron Making. During the last 20 years since the Basic Oxygen Furnace broke through the Steel Technology, the size of the vessels has increased from 5 Tons to 400 Tons and it is now the most economical steel-making process. Nevertheless this will have a new competitor. Large Sponge Iron Plants, supplying cheaper melting stock to Ultra-High-Powered Electric Arc Furnaces for making steel and shaping by multistrand continuous casting machines will be the order of the day. Pre-reduced pellets will be produced at the iron mines to utilise the fines. Mini-Steel Plants based on Sponge-iron with 20 per cent steel scrap will be dispersed throughout the country, where bulk power will be available from a National Grid fed by giant Thermal Power Stations located in regions where coal is not available. Design Data for a 50 T/day Sponge Iron Plant is given which would form main guidelines for designers of big size plants.

A NEW star is rising on the Metallurgical horizon which is going to revolutionize the Iron and Steel Industry, especially in our country. It would practically solve our problem of inadequate coking coal reserves. The potential promise of Sponge Iron Technology would challenge the conventional method of making iron by the Coke Ovens and Blast furnaces within the next 25 years, with better economics that would cut down the cost of steel making by a sizeable margin, especially in small plants.

It was presumed a few years ago that the Sintering and Pelletising Processes would turn the Blast Furnace into a Hot Blast Cupola. The position is now changing fast and when the process of Sponge Iron Making would have been still further experimented and commercially established within the next 3 years by the N.M.L., who have carried out extensive trials on a laboratory scale on a 3½ T/day Rotary Kiln, Coke Ovens and Blast Furnaces could be installed only for giant Steel Plants. The new Technology envisages the making of Sponge Iron in large Rotary Kilns and Coolers and use it as a major melting stock to make steel in Ultra-High-Powered Electric Arc Furnaces and shape it by continuous casting.

The most important advantage of this method is that ordinary non-coking coal could be used for Sponge Iron Making and the same coal would be required for giant Thermal Power Stations to supply the enormous quantities of power to Electric Furnaces. No coking coal would then be necessary for any metallurgical operation on a smaller scale. There are over 40 Billion tons of good iron ore reserves in our country, as compared to the meagre coking coal that we have, which is fast depleting although our steel production is still very small.

About 25 years ago the Basic Oxygen Furnace made a break-through in Steel Technology and made the century old Siemens Martin Open Hearth Furnaces obsolete. The size of the vessels which had 5 ton capacity in the beginning only 20 years ago, has already reached the enormous limit of 400 tons and B.O.F. has become the fastest and most economical steel making process so far. It may be foreseen that the B.O.F. would have at least a century more of commercial usefulness. During this period the Sponge Iron Process of reducing iron ore to metallic iron by solid reductant coal may short-circuit the present long and costly route and ever-increasing size of Electric Arc Furnaces would be the order of the day. The Arc Furnace has already reached the size of 400 Tons capacity like the B.O.F. Two of these 32 ft. diameter giant UHP Arc Furnaces of 400 Tons capacity are being installed by the North Western Steel and Wire Co., at Sterling, Illinois, U.S.A. This development presumes that the expansion of Thermal and Atomic Energy Power Station would keep pace with the ever-increasing demand for power by Electric Furnace installations although the present power shortage crisis would continue for many years.

Our vast natural resources of good quality iron ore and poor quality non-coking coal, both abundantly available, could then be profitably exploited. This promises a new era when India could once again produce the cheapest steel in the world within the next 25 year if all our endeavours are focussed on the Sponge Iron Process with zeal, assiduity and determination to bring about and hasten the new Breakthrough in Iron and Steel Technology as early as possible. Many of our future steel plants would then have large Sponge Iron Plants, UHP Electric Arc Furnace with Continuous Casting Strands, backed by giant which normally haul empty hopper-wagons from the coal fields to the iron mines for supplying ore to the present steel plants could profitably carry coal without appreciably increasing the traffic, except for the extra time required for loading coal, to allow Sponge Iron to be made on the spot. In order to take care of the ore fines, pre-reduced pellets also will have to be produced side by side with Sponge Iron. Electric Arc Furnaces may be dispersed and installed at different places, where bulk power would be available from a National Grid.

Quite a large number of processes for maning Sponge Iron by solid and gaseous reductants have been established by the Metallurgical research and development efforts in the West. However, the conditions obtaining in our country being different, India will have to experiment and establish her own method of making sponge iron, suited to our raw materials and fuels, which would be commercially feasible. This is only a question of time and it is estimated that successful results would be obtained within three years from now. It is therefore necessary that everyone concerned should realise the national importance and urgency of this developmental effort. The N.M.L. has organised this Seminar on Sponge Iron Technology to focuss national attention on this vital problem.

The N.M.L. has devoted a lot of their Research and Development activities with promising results. After successfully performing extensive experiments to produce Sponge Iron in their 3.5 T/day Laboratory Kiln they are now engaged in the installation of a Pilot Plant of 50T/day capacity at Adityapur at a cost of Rs. 50 lakhs. The author has been closely associated with N.M.L. to assist them in the Engineering and Designs of their experimental plant. It is a challenge to the engineering ingenuity to design a Rotary Kiln, Cooler and all the ancillary facilities, with many difficult metallurgical specifications and design criteria to be fulfilled for successfully establishing and stabilizing a commercially profitable process to produce good quality Sponge Iron that would be operationally acceptable to Electric Arc Furnaces, which could use up to 80 per cent maximum of this material as melting stock, when steel scrap would just not be available. The B.O.F. process could also use up to 20 per cent of their total charge in the form of cold sponge iron. This would release some steel scrap to Electric furnaces which would be complementary to the 80 per cent sponge iron charge. At present 60 per cent sponge iron has been used with 40 per cent scrap in Electric Furnaces without any real difficulty and it would not be long before they would be obliged to increase the feed stock to 80 per cent sponge.

Last year the Government had granted licences to 19 new Mini-Steel Plants, with steel

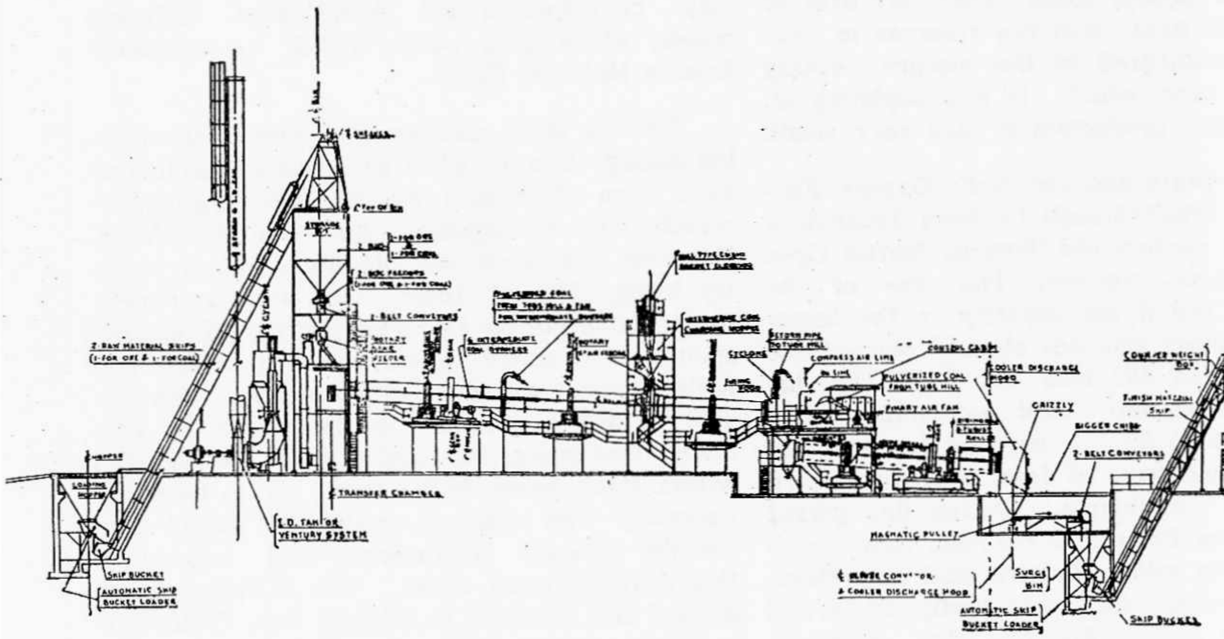

Fig. 1 General Layout of 50 t/day Sponge Iron Plant

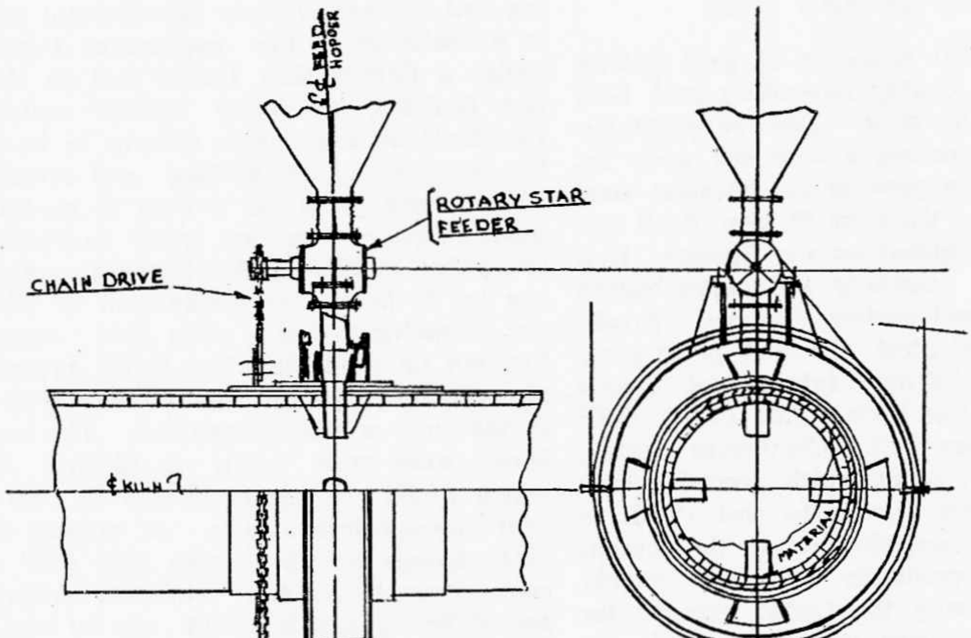

Fig. 2 Coal Throwing arrangement

scrap based Electric Arc Furnaces to produce 950,000 tons of steel per year. Unfortunately, enough steel scrap would not be available and the scrap prices are already spiralling upwards. It is practically certain that the present day price of Rs. 550 to 600/Ton for good scrap would jack up to about Rs. 800/T. in a year when the new Mini-Steel Plants would be all ready for commissioning. It is not generally appreciated that the availability of steel scrap is a function of the total steel in use in the country, imports being difficult and exhorbitantly costly. We do not have enough steel in use as in the advanced countries of the West, the normal life cycle being about 30 to 40 years for steel to return as scrap in our country. This does not include good structures such as Buildings and Bridges. The Howrah Bridge is hardly 32 years old and it may take more than a thousand years before it would go back to the steel furnaces as scrap. The major integrated Steel Plants produce 25 per cent of their total production as scrap in the normal **operation** but this is re-circulated for melting in the process, leaving hardly about 5 per cent of other users. The major source which supplies some steel scrap is the large 60,000 Km network of our railways but the demand for scrap would always outstrip the supply for many years to come. Thus Sponge Iron Making would assume utmost importance and urgency in the next few years. The sooner it is produced economically on a large scale, the better it would be for our Iron and Steel Industry Sponge Iron is the supreme need of the hour, and India hearkens her metallurgical engineers to solve this national problem with utmost speed.

The intensive metallurgical research in many parts of the world which has been directed towards developing an economic process for reducing iron ore to metallic iron without using a costly Blast Furnace for smelting with metallurgical coke has clearly proved that only a continuous reducing process in a Rotary Kiln with a cheap solid reductant, could optimise the many variable parameters required to be controlled for making good quality sponge iron especially because of the non-availability of a good and cheap reducing agent such as natural gas in our country. The Rotary Kiln easily lends itself to the use of pulverised coal, whose ash fusion point is sufficiently higher than 1050°C required for the reduction of iron ore to metallic iron, such coal of non-metallurgical quality being plentifully available at a fairly low price. This process may then be appropriately called the *Maha-Bharati Process of* producing sponge iron at low price.

For the proper design of such a Rotary Kiln and Cooler with all its ancillaries, the following metallurgical and engineering design data is required to be followed for a 50 Ton per day experimental sponge iron plant, which would form the main guide lines for the designers of industrial size plants in the near future:

1. The effective volume of the Kiln inside the refractory lining should be about 2 cu.f. per ton of sponge iron capacity per day.
2. The ratio of length of the kiln to its effective diameter, after allowance for the refractory lining, should not be less than 15. This would suggest a Kiln size of 2.25 m. dia. by 40 m. long to produce about 50 T. of sponge iron per day.
3. The coal for firing as pulverised fuel and also as a solid reductant should preferably have minimum sulphur, that is available in the country, though this is not absolutely essential.
4. The fusion point of ash in the coal should be about 200°C. higher than 1950 to 1100 C temperature required for the reduction process to avoid clinker formation.
5. Inspite of having a temperature control in the Kiln, the possibility remains of clinker formation off and on if and when the temperature of the Kiln may go higher than the fusion point of coal ash. A grizzly should therefore be provided at the outlet of the Kiln to arrest any clinkers and not allow them to go into the cooler, which may jam the outlet of the cooler.
6. The combustion gases should flow counter current to the feed charge of iron ore, coal and limestone or dolomite for more effective reduction.
7. About half the coal should be fed into the Kiln along with iron ore as a solid reductant. This should be about 37.5 T/day from a separate overhead bin of 20 cu.m. capacity ot the feeding end of the Kiln.
8. The temperature of the gases should not be more than 1100°C. which is most effective for reduction of iron ore in a reducing atmosphere.
9. Assuming that the temperature of 1050 to

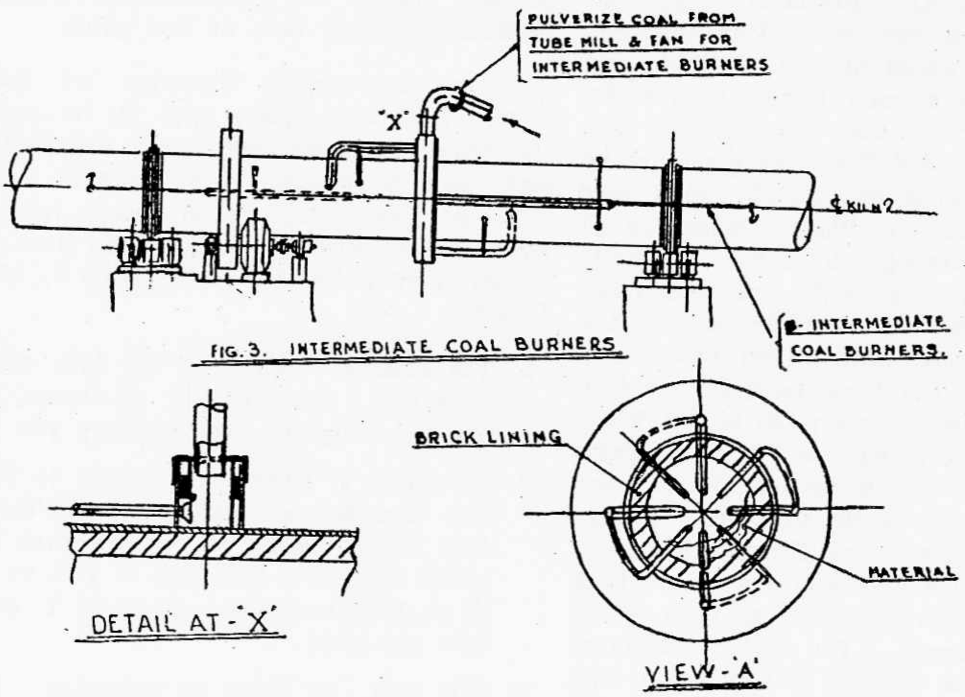

Fig. 3 Intermediate Coal Burners.

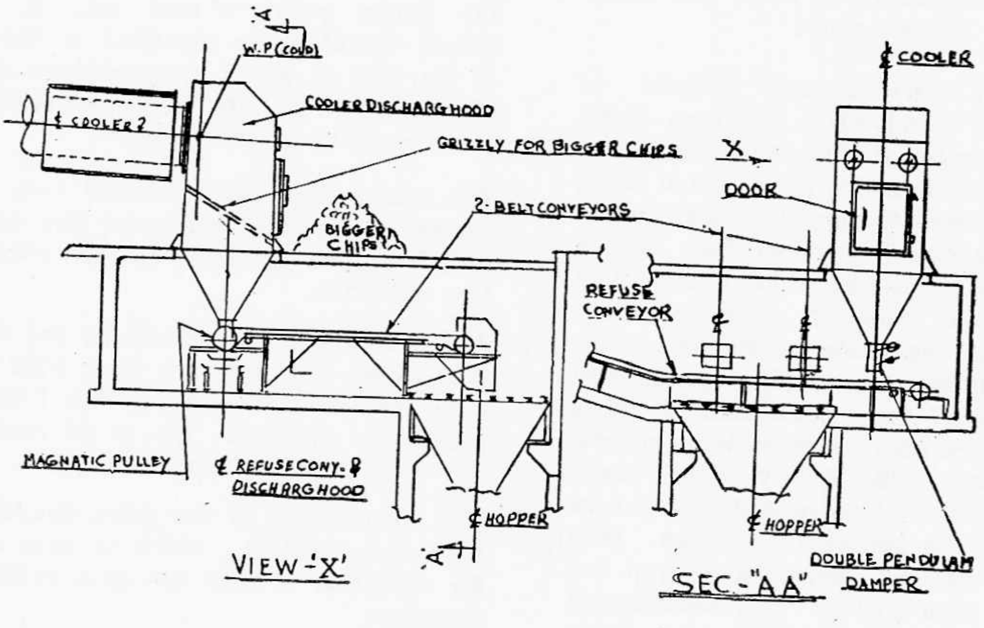

Fig 4 Cooler Discharge Arrangement

1100°C is reached at a distance of about 5 metres from the firing end, it should remain constant up on a further distance of about 25 metres inside the Kiln and then fall down to about 750 to 800°C. at the exit end.

10. There should be a reducing atmosphere in the entire length of the Kiln.

11. There should be a reducing atmosphere in the cooler also and the ingress of air at the exit end of the cooler should be minimised to avoid re-oxidation of sponge iron, with air locks through which the processed product would emerge.

12. The temperature of the sponge iron at the cooler outlet should not be more than about 80°C.

13. The sponge iron should be magnetically separated from the gangue and unburnt coal after the processed product comes out of the cooler.

14. The feed rates of iron ore into the Kiln should be variable from 1 Ton to 4 Tons per hour for experimental purpose. This should be from a separate overhead bin of 10 cu.m. capacity at the feeding end of the Kiln.

15. The feed rate of coal as a reductant into the Kiln should be ½ ton to 2 tons/hour.

16. The speed of the kiln should be infinitely variable from 1 to 2 RPM preferably by a D.C. motor drive with thyrister control.

17. The speed of the cooler should be infinitely variable from 1 to 2 RPM. by a D.C. motor drive to match the operation of the Kiln and also to ensure adequate cooling of the sponge iron before leaving the cooler.

18. The cooler should be externally cooled with water without allowing air to enter it as far as possible.

19. To maintain a reducing atmosphere inside the Kiln, half the amount of coal (about 20 T/day) should be thrown in lumps inside the rotating kiln at a distance of about 10 metres from the firing end, at an infinitely variable rate of about ½ ton to 1 ton/hour by a rotary disc feeder or a star feeder.

20. In order to maintain a constant temperature of about 1050 to 1100°C in the 25 metre length of the Kiln, ten auxiliary burners should be installed on the rotating Kiln equi-distantly placed but consecutively 90° apart radially, the fire pulverised coal of oil. with requisite amount of air which may be supplied by blowers, mounted on the rotating kiln, supplied by electric power from slip rings on the outside of the kiln. Perhaps air alone may suffice with no extra fuel required.

21. The slope of the Kiln and Cooler should be between 3 to 4 per cent.

22. Clear space should be left in front of the Kiln, at the feeding end for subsequent installation of a travelling grate, to reduce the fuel requirement by utilising the exhaust gases of the kiln at about 800°C temperature.

23. The design of the Kiln at the feeding end should be such as to allow the exhaust gases to be utilised for preheating the feed charge on a travelling grate in future.

24. In the first phase experiments, the exhaust gases from the Kiln feeding end, should be led to a chimney after passing through a Dust Catcher.

25. The draft of the Kiln should be controlled by an infinitely variable speed Induced Draft Fan or a venturi system of draft control by a forced draft fan.

26. The thermal requirement for making Sponge Iron per ton is estimated to be 15 to 20 million BTUs. Pulverised coal should be used as the main fuel at the firing end. Raw coal should be + 3 mm. — 18 mm. Pulverised coal should be 200 mesh. The capacity of the coal pulverisor should be 2 T/hour. The coal burner should be at the centre of the firing hood.

27. Alternative fuel oil firing should be provided at the firing end at a variable rate through two burners of total capacity from 125 to 500 litres per hour. The oil burners should be one on either side of the pulverised coal burner in the centre of the firing hood. Even though coal is a cheaper fuel, the capital and maintenance costs of coal firing are higher than oil firing.

28. A chimney of about 75' height should be provided at the feeding end with a Dust Catcher preceding it and the I.D. Fan or a Venturi system of draft control by a forced draft fan.

29. Two underground hoppers one of 10 cu.m.

for ore and the other of 20 cu.m. for coal should be provided at the feeding end of the Kiln with two skip hoists to lift 75 tons of iron ore and 37.5 tons of coal into two separate overhead bins, disc feeders at the bottom of the overhead bins. The capacity of the Disc feeder for ore should be variable from 2 ton to 4 tons/hour whereas that of the coal 1 to 2 tons/hour The skip hoist for ore and coal should have 6 tons/hour and 3/tons/hour capacities respectively.

30. A salt conveyor to handle hot processed products (temperature about 80°C) of 4 tons/hour capacity, with facility to spray water is necessary.
31. Two cross conveyors of 3 T/hr. capacity above the slat conveyor with Magnetic Drums to separate the sponge iron from Rejects (gangue with unburnt coal) into two separate hoppers.
32. Two Skip hoists to elevate the sponge iron and rejects into the two Overhead Bins of 20 cu.m. and 10 cu.m. capacities respectively, the skip hoists capacity being 3 tons/hour and 2 T/hour for sponge iron and rejects respectively.
33. Six thermo-couples should be fixed at approximately 5, 10, 15, 25, 30 metres from the firing end of the Kiln, with minor adjustments with regard to locations to avoid fouling the rider rings and the driving gear.
34. Four man-holes of about 400 mm. dia. should be provided at suitable places along the length of the Kiln.
35. A small shed will have to be erected over the firing end as also other electrical equipment as a protection against rain. This may be a tubular structure with asbestos cement or G.C. Sheets, to economise the capital cost. Eventually, the whole installation will have to be properly covered.
36. A central control cabin will be required at the firing end of the Kiln, with a mimic panel to control the disc feeders for ore and coal, disc feeder to coal pulverising speed of Kiln, speed of cooler, to indicate the temperatures at different points of the Kiln, draft at the chimney, etc. designed in consultation with the N.M.L. staff.
37. A motor control centre should be provided to interlock the different motors driving the various equipment. For example if the Kiln driving motor trips on some fault, all the previous motors such as those driving the disc feeders, coal pulveriser feeder, oil firing pump should stop.
38. Secondary coal throwing device should be provided which has to be specially designed with a hopper and a disc or star feeder underneath located about 10 m. away from the the firing end. The rate of coal feed be variable from 1 ton to 2 tons/hour.
39. Yield of sponge ore is expected to be 75 per cent by weight.
40. The Discharge End Hood should be retractable, provided with four wheels on two rails with a door on the front lower half, to remove any clinkers over the grizzly.
41. The Rotary Cooler may have a shell. 1.6 m. dia. 20 m. long. with cast iron liners up to 3 metres from the hot end. A refractory lined chute should transfer the hot sponge from the Kiln to the Cooler.
42. Limestone or dolomite may be mixed with coal in the required proportion in the ground hopper before skip hoisting into the overhead bin. About 15 kg. of limestone or dolomite may be required per ton of ore.

The Engineering and Design of the 50 T/day Sponge iron Plant will have to be in accordance with the above-mentioned criteria, keeping in mind that this would be an experimental plant. A few diagram indicating the important features such as cool throwing device and burners on a rotating Kiln, apart, from a sketch showing the general arrangement of the Sponge Iron Plant are given for guidance of the designer. N.M.L. will be carrying out extensive trials on this plant to record relevant data with a view to establish a commercially profitable method of making sponge iron. so that prospective entrepreneurs would embark upon Industrial size projects of about 100,000 T/year capacity per Kiln unit, which could be run with mutual profit to themselves and all the consumers who are already clamouring for this comparatively cheaper melting stock to their Electric Arc Furnace Mini-Steel Plants, especially due to the critical shortage of steel scrap, with no other suitable and practical alternative as a base raw material to make steel, in competition with the major integrated steel plants. India's Metallurgical Engineers would meet this challenge successfully in cooperation with the National Metallurgical Laboratory who have pioneered the Sponge Iron Technology in our country.