EXECUTIVE SUMMARY

1. Sponge Iron is iron ore reduced directly in solid state using coal gas, natrual gas or coal as reductants and is also known as Directly Reduced Iron (DRI). The need for development and commercialisation of sponge iron manufacturing process arose in late 50's when Electric Arc Furnaces (EAFs) engaged in manufacturing steel started facing problems of availability of scrap of desired quality, the traditional source of their iron metallics. The DRI processes soon became popular and since the inception of first DRI plant in 1957 in Mexico, there has been a continuous growth of this industry in last three decades. This is evident from the steep rise in world DRI production during the past three decades. India, entered the sponge iron industry only in 1980, when the coal based DRI plant of Sponge Iron India Limited (SIIL) was commissioned at Kothagudem, in Andhra Pradesh.

2. The reasons for the tremendous growth of the sponge iron industry world over could be attributed to the advantages of using sponge iron in electric arc furnaces, partly substituting scrap, the conventional charge to the furnaces. Further, the use of sponge iron in other steel manufacturing processes has also been well proven. The advantages of sponge iron use in EAFs are summarised below:-

- Uniform known composition
- Low levels of residuals/tramp elements
- Capability to maintain phosphorous level in steel within 0.002%
- Maintenance of sulphur in steel by its removal in sponge manufacture.
- Low content of dissolved gases
- Uniform size and higher bulk density as compared to scrap
- Capability of forming protective cover of foamy slag in the bath
- Lower refining requirements of steel produced
- Potential of sensible heat recovery from waste gases
- Possibility of producing variety of steels

3. The industry is gaining further importance due to proven utility of sponge iron in other steel manufacturing processes like L.D. Converters, Open Hearth Furnaces (OHFs), Blast Furnaces (BFs) &

Basic Oxygen Furnaces (BOFs), Induction Furnaces (IFs) and Cupolas. There are a few disadvantages of the use of sponge iron in the arc furnaces such as lower liquid metal yield, lower metallisation, lower carbon content in sponge iron produced in coal based plants, gangue content of the sponge iron resulting in additional requirement of electrical energy in its melting and higher meltdown time. However, an ever widening gap between the demand and availability of scrap clearly indicates a bright future for the sponge iron industry.

4. The demand for finished steel, has been estimated to be 31 million tonne by the end of this century, while the production projected to be 28.2 million tonne. The production from integrated plants would be 17.6 million tonne. The wide gap between the demand and availability of steel from the integrated steel plants is assumed to be filled up by the Mini Steel Industry (MSI). This means that the mini steel industry has to grow substantially. The main constraints for the growth of mini steel industry are the shortages of power and scrap. As regards power situation in the country, it is fast improving due to massive investments in super thermal power stations. The situation of scrap availability, however, will be worsening due to reduced generation of scrap on account of upgradation and improvements in steel melting technologies. Under these circumstances, sponge iron which can partly substitute scrap, would be playing an important role in the growth of mini steel industry and therefore in achieving country's steel production targets.

5. The substitution of scrap by sponge iron has some limitations depending on the furnace operating conditions. Only 20% to 30% of sponge iron can be used in the furnace charge when feeding is done in batches. The proportion of sponge iron in the charge can however be increased to 40-50% by providing continuous feeding arrangements. A further increase in sponge proportion is possible by use of high power furnaces with higher capacity transformers. The Department of Steel has estimated the demand for sponge iron by the steel industry to be 8 million tonne and 11 million tonne during the periods 1994-95 and 1999-2000 respectively.

6. Various technologies developed for the manufacture of sponge iron may be classified as:

A. Gas Based Technologies

- ¤ Fluidised Bed Technologies
    - Technologies using hydrogen as reductant

SPONGE IRON

- Technologies using carbon monoxide as reductant

- Technologies using mixture of both hydrogen and carbon monoxide as reductant

¤ Static bed technologies using mixed gas as reductant

¤ Moving bed technologies using mixed gas as reductant

The gas based technologies were capable of using either natural gas associated with oil or reducing gas derived from coal.

B. Solid Reducant or Coal Based Technologies

Out of the several technologies developed only a few were proved to be commercially successful; the plants based on the others like Purofer, Armco, Wiberg Sodefors, NSC, Plasma red and Usco were either closed down or dismantled for various reasons. The success of some of the technologies was limited to a few plants of small capacities only. The most successful technologies were the gas based static bed HYL- I technology of Hojalata Y Lamina of S.A. (HYLSA), gas based moving bed technologies of Midrex Corporation of USA and HYL-III process of HYLSA. These contribute over 80% of world sponge iron production today. Out of the coal based technologies SL/RN technology of Lurgi GmbH, West Germany has been the most successful one. Little success has been achieved by other coal based technologies namely CODIR technology of Krupp Industriatechnik now Mannesmann Demag, W.G., DRC technology of Davy Mckee, USA; ACCAR technology of Allis Chalmers now Boliden Allis, USA and the TDR, the only indigenously developed technology of Tata Steel. Recently Jindal Strips have claimed to have developed indigenous coal based technology and that they are installing many sponge iron units based on the new technology. Besides this, Sponge Iron India Limited has absorbed the imported technology and are offering the same to the entrepreneurs.

7. The direct reduction processes available for commercialisation are

A. HYL III Process : The process involves reforming of natural gas, reduction of iron ore by reducing reformed gases and cooling of the product. The gas reforming comprises preheating and desulphurisation of natural gas using zinc oxide, its mixing with steam and passing it over nickel catalyst. Sensible heat of reformer gas is recovered and used elsewhere in the process. For the reduction, the reducing reformed gas is mixed with lean reformed gas from the reactor after removal of its CO_2 content, preheated and used in shaft kiln reactor for reducing iron oxides. The product sponge iron is cooled by counter current cooling gas in cooling section from where the cooled product is removed continuously.

B. Midrex Process : In Midrex technology reforming is effected by low pressure stoichometric operation which involves formation of reducing gas by passing the mixture of natural gas and recycled top gas from the reactor through the catalyst bed. The reformed reducing gas contains 90% to 92% hydrogen and is used directly in the reduction reactor to reduce iron ore in its upper section. Hot product is continuously discharged from here to lower cooling section where it is cooled by independent cooling circuit. Midrex technology provides for production of specialised product called 'Hot Briquetted Iron'. While producing this, the hot DRI is directly discharged into hot briquetting machine and cooling circuit is eliminated. Hot HBI from briquetting is separated to individual briquettes and cooled.

C. Coal Based Direct Reduction : Coal based direct reduction technologies involve reduction of iron oxides in a rotary kiln by using non-coking coal as reductant. Limestone or dolomite is used as desulphurising agent. The normal operating practice is to feed the kiln with desired proportion of iron oxide, non-coking coal and limestone or dolomite. Some processes use optimum quantity of recycle char in the feed for minimising coal consumption. The charge is preheated in the preheat zone and the reduction of iron ore is effected by reducing gases derived from coal gasification. The heat for the process is provided by burning coal volatiles and excess carbon monoxide emerging from the charge. This is done by introducing controlled quantity of air in the kiln free board along the preheat and reduction zones of the kiln. Part of coal is introduced from the kiln discharge end to supply energy at discharge end, maintaining reducing atmosphere at discharge end to prevent reoxidation of DRI and for controlling degree of metallisation and carbon content of DRI. The separation of the product is more or less similar in all the coal based processes and involves screening and magnetic separation for removal of non magentic ash, char and used desulphuriser. SL/RN, CODIR, DRC, ACCAR, TDR and Jindal's are the available coal based DR processes and the two main operations where different technologies use different techniques are feeding/blowing coal and introduction of air for the process.

Raw Material : Direct reduction processes are very sensitive to chemical and physical characteristics of raw materials used in the process. Iron ore or pellets, reductant natural gas or non-coking coal and limestone/dolomite are the main raw materials. For the successful operations the process licensors of DR technology have specified the characteristics of the raw materials to be used in the process. The quality requirements of the raw materials in general are:

Iron Ore : Lumps or pellets with high iron content, low gangue content, good mechanical strength, readily reducible and of non decrepitating variety.

Natural Gas and Non-coking Coal : These are the reductants in the process. The characteristic desired for non-coking coal are that the non-coking coals should have high fixed carbon content and high volatiles content. Ash, sulphur and moisture in coal should be low. The ash fusion point of coal is required to be high. The coal should be highly reactive and should have low coking and swelling indices.

Limestone and Dolomite : These should have lime or lime and magnesia content of 45% or above. The grain size of raw materials is also important factor in direct reduction process.

The availability of these raw materials for the fast growing sponge iron industry should not pose any problems considering the large reserves of iron ore, coal, limestone and dolomite in the country. However, depending on the number of gas based units coming up which in turn will depend on Government's natural gas allotment policy, pelletisation capacity of the country may have to be increased. Similarly, planned production of superior grade non-coking coal will not be adequate to meet the requirements and timely steps to increase production of the desired quality coal are necessary.

Capital Equipment Required for DR Processes: The basic equipment required for the gas based plants is:

- Natural gas reformer
- Reduction reactor/shaft kiln
- Reducing gas heater
- CO_2 removal unit
- Reducing and cooling gas compressors
- Cooling water circuits for equipment and for process gas

- Boiler feed water system
- Inert gas generation system
- Raw materials and product handling systems
- Instrumentation and control system

11. Technological developments by Midrex in the gas refoming system has enabled them to eliminate certain equipment like steam generation system, auxilliary boilers, boiler feed water treatment system, reformed gas quenching system, CO_2 removal system and reducing gas heaters.

12. The basic capital equipment required for the coal based processes is:

- Raw materials handling and feeding system
- Rotary kiln with air injection and coal blowing systems
- Rotary cooler
- Product separation and handling system
- Waste gas cleaning system
- Briquetting system
- Electrical system
- Instrumentation and control system

13. According to the information available, the value of the imports of capital goods amounted to Rs.10.63 crores for OSIL plant and Rs.18.616 crores for BSIL plant. These amounted to 51.2% and 53% respectively of the total equipment cost.

14. As far as gas based plants are concerned, the design and manufacture of non-proprietary items, except for the critical items like process gas compressors and briquetting machines can be done indigenously. As indicated by MECON, some proprietary items can also be manufactured indigenously based on basic design from the proprietors. In respect of coal based plant, capability has been developed in the country for manufacturing almost 100% of equipment required for plants upto capacity of 1,00,000 TPA sponge iron.

15. The capital investment made by existing DRI plants is summarised below:

Plant	Capacity TPA	Year of commissioning	Investment Rs. crores
SIIL, Unit 1	30,000	1980	11.8
SIIL, Unit 2	30,000	1985	8.2
OSIL	1,35,000	1984	39.8
IPITATA	90,000	1986	35.0
BSIL	1,50,000	1989	112.0

The present requirement of capital investment for smaller size (up to 60,000 TPA) coal based plant adopting indigenous technology varies between Rs.6500 to Rs.8000 per ton of yearly installed capacity. Thus, the capital investment for 30,000 TPA plant based on this technology has been indicated to be varying between Rs.45 crores to Rs.49 crores. The operating costs of the plants comprises variable costs like costs of raw materials, fuel, power, stores etc. and fixed costs for salaries and wages of employees, repair and maintenance, depreciation, interest and others. The present day typical cost of production of sponge iron is Rs.2,954 per ton (including Rs.1,754 per ton variable cost and Rs.1,200 per ton fixed cost) for coal based plant. A reduction upto about 3% in cost of production is possible by utilising some of the waste products. The present selling price of coal based sponge iron is reported to be varying between Rs.3500/t to Rs.4100/t.

16. The existing coal based sponge iron units in the country include the plants of SIIL, OSIL, IPITATA, BSIL AND SISCL. The total installed capacity of the existing coal based plants is 5.85 lakh TPA. The gas based plant of Essar Gujnarat based on Midrex technology having a capacity of 8.8 lakh TPA comprises two modules. The first module was commissioned in March '90 while the second was commissioned in July 1990. Most of the existing plants have plans to expand their capacities. The additional planned capacity of existing coal based plants is 5.2 lakh TPA while EGL's plant is planned to have an additional capacity of 7.2 lakh TPA. Grasim Industries, Goldstar, Ispat Group, Bharat Forge, Usha Rectifier, Jindal and Mukand are some of the other companies having proposals for putting up large capacity new plants. Thus, the installed capacity of sponge iron at present including

that of EGL plant is 14.65 lakh TPA. The capacity is likely to go over 6.6 million TPA by 1994-95.

17. Sponge Iron India Limited : SIIL selected SL/RN DR technology for their plant. They absorbed the imported technology through R&D efforts carried out in course of overcoming some of the initial problems in their first unit of 30,000 TPA installed in 1980. Beside this SIIL were also able to carry out number of innovations in process and equipment design to improve productivity and product quality and to reduce raw material consumption levels. This enabled them to engineer, erect and commission their second D.R. kiln in 1985. Today SIIL is equipped with all the R&D facilities for testing of raw materials and an Engineering Division capable of providing complete services for design, erection and commissioning of coal based DR plants.

EXISTING DRI PLANTS IN THE COUNTRY

Plant	SIIL	OSIL	IPITATA	BSIL	SISCL
Location	Polancha, A.P.	Keonjhar, Orissa	Joda, Orissa	Chandil Bihar	Warthi, Bhandara Road, Maharashtra
Installed capacity (TPA)	2 units of 30,000 each	1,35,000	90,000	1,50,000	1,50,000
Commissioning	1980 and 1985	1984	1986	1989	1989 (lightup)
Technology	SL/RN	ACCAR	TDR	SL/RN	CODIR
Sources of Iron Ore	Bayaram, Hospect Bailadilla etc.	Banspani Sector, Orissa	Banspani Sector, Orissa	Banspani Sector, Orissa	NMDC, Bailadilla & Banspani Sector, Orissa
Non-coking Coal/gas	Manuguru, Yellandu	Eastern Coalfields - Raniganj etc.	ECL-Amritnagar, CCL-Hutar, Religora	CCL-Ray, Bachra Bhurkunda Hutar	Balgi, Korba
Capital Investment Rs.crores	Unit 1 - 11.80 Unit 2 - 8.20	39.80	35.00	112.00	NA

Plant	SIIL	OSIL	IPITATA	BSIL	SISCL
Production:					
Period	1989-90	1987-88	1988-89 (15 months)	1990-91 (7 months)	No commercial production
Tonnage	52930	89000	68937*	71.300	
Cap. Utilisation %	88.0	65.9	61.0	81.0	
Av. Metallisation %	90+_2	90	90	91-92	
Consumption /ton of DRI					
Iron ore t	1.90-1.95	1.45	1.54-1.77	95% yield	
NC Coal t	1.50-1.55	1.1 to 1.15	1.20-1.53	0.45 CFix/Fe ratio	
Water Cum	10.0	7.0	7.0	-	
Power kwh	155-170	141	140	80	

*Since August '90, production higher than rated capacity

18. Orissa Sponge Iron Limited : The OSIL plant is based on ACCAR technology of Allis Chalmers Corporation of USA. The technology uses non-coking coal and HSD. The installed capacity of plant was 150,000 TPA. During the initial years of operation, OSIL faced a number of problems in plant operations, but with dedicated research and development, they have been able to solve many of the problems and in the process, were successful in absorbing the technology. The main problems faced were the accretion or ring formation in the kiln, poor metallisation of the product and higher coal consumption. OSIL were successful in overcoming the problem of accretion and poor metallisation by controlling the raw material feed and the temperature profile of the kiln. For reducing the high consumption of coal, OSIL modified their coal feeding system by introduction of coal slinging from the kiln discharge end and achieved the desired results.

19. Ipitata Sponge Iron Limited : Ipitata is the first plant where indigenously developed direct reduction technology was put on commercial scale. The plant was commissioned in 1986 and since then there had been a number of problems in the plant operations. The main

problem faced was continuous failure of kiln refractories. With continued efforts for improvisation and technical assistance from Lurgi, Ipitata were able to overcome all the problems. Presently, Ipitata is achieving production levels of more than the rated capacity indicating that the TDR technology has now been fully proven.

20. Bihar Sponge Iron Limited : BSIL plant at Chandil, Bihar is based on SL/RN technology of Lurgi, GmbH, West Germany. The plant was commissioned in April 1989 and during the first year of operations, there were no major problems in respect of the process and the desired quality of the product was obtained. During the current year, the plant is operating with capacity utilisation of over 80%. BSIL technical personnel have been fully trained and have absorbed the imported technology.

21. Sunflag Iron & Steel Company Limited : The plant belonging to SISCL has an installed capacity of 1,50,000 tonne per annum and is based on CODIR process. The plant production is planned to be used in the Company's own downstream EAF facility. The plant was started in August 1989. The plant operations are yet to be stabilised. Constant efforts are being made to adapt the technology to local conditions especially those of highly variable quality of the raw materials.

22. Since, the development of DR processes in late 50's. there had been tremendous growth of sponge iron industry all over the world. The process licensors have utilised their long operating experience to remove the initial technical lecunae and brought the technologies to near perfection. Through constant research and development work, many improvements in technologies have also been brought about, such as :

i) Hojalata Y. Lamina, S.A. (HYLSA) developed moving bed HYL-III technology and converted a few of the plants based on earlier fixed bed or HYL-I technology. The total installed including under construction capacity of plants with HYL technology is over 11 million tonne per annum today.

ii) Midrex technology is the commercially most successful DR technology today and has to its credit installed annual capacity of over 20 million tonne.

iii) The new developed techniques of top gas recycling, stoichometric CO_2/H_2O reforming, waste heat recovery etc. have gone a long way to drastically reduce fuel consumption in the process. Midrex has also developed usage of coal based and other alternate fuels. The improvised product, Hot Briquetted

Iron (HBI) has opened new avenues to DRI like oxygen steel making and foundaries. Many of the Midrex plants also have achieved capacity utilisation of over 100%.

iv) SL/RN technology of Lurgi GmbH is the most favoured coal based technology and 31 units at 10 different places with a total annual installed capacity of over 4.8 million tonne are operating on this technology.

v) Lurgi after comprehensive development work have modified their heating technology. The new system involves partly feeding of coal through the kiln discharge end. This is done by pneumatic injection of fine and coarse coal through two separate tubes. Air injection in preheat zone is done through air nozzles as well as tubes while in reduction zone air is introduced through tubes only.

vi) Submerged air injection to the charge bed, newly developed pneumatic coal injection from discharge end of the kiln, waste gas system and recovery of sensible heat, injection of iron ore fines through discharge end are some of the salient features of the process.

23. The other coal based processes, namely CODIR process of Krupp MDH. DRC process of Davy Mckee, ACCAR process of Allis Chalmers/Boliden and indigenously developed TDR technology have only limited commercial application. Out of these, CODIR process, which had only one plant to its credit in South Africa, has some commercial success recently. SISCL's plant based on this technology has just been commissiosned and two more plants are under construction and would be ready in 1991 and 1992 respectively. Only one plant each is operating on DRC (Scaw Metals, S.A.), ACCAR (OSIL, India) and TDR (Ipitata, India) processes. Jindal Strips Limited are installing plant based on their recently developed coal based technology.

24. Most of the available DR technologies both the coal based and gas based have been so far imported in the country. The gas based plants on imported technology have been commissioned recently but the plants based on solid reductant technologies have been erected, commissioned and operated for quite some time and the plant operators had good opportunity of technology absorption. They have been able to overcome the technological problems in the initial stages and bring about certain improvements in the operations. Sponge Iron India Limited, the first entrants in the sponge iron field, have also engineered, erected and commissioned the second DRI unit and with

this experience they are offering technology and engineering services for setting up coal based DRI plants up to 30,000 TPA capacity with 98% indigenous equipment.

25. Indigenously developed TDR process have now been proven and the technology is available for setting up of plants up to 90,000 TPA capacity. Indigenously developed technology of Jindal Strips Limited is being adopted at their Rigarh plant in M.P. Jindals are also using 100% indigenously manufactured equipment. The capacity of each of the two units being installed is 100,000 TPA. This indicates that there are no technological gaps in respect of coal based technologies especially for the plants of capacity up to 100,000 TPA DRI. As regards the gas based plants, the reforming of natural gas with steam is not new to Indian industry and the knowhow for engineering, erection and commissioning of the same is available in the country. But technology for gas reforming by reactor top gas used in Midrex process is not available in the country.

26. The following conclusions relating to sponge iron industry could be drawn from the present study :

i) To meet the country's demand of 31.0 million tonne per annum of finished steel by the end of the century, substantial contribution is expected from mini steel industry. For the purpose, it is necessary that mini steel industry upgrades the technology for minising energy consumption and improving productivity and product quality.

ii) To overcome the shortage of scrap, mini steel industry should establish facilities so as to use maximum proportion of DRI in the charge.

iii) Replacement of scrap by EAFs is possible to the extent of 20% to 30% when charged in batches. With provision of continuous feeding arrangements, the proportion of sponge iron can be increased to 40% to 50% in the charge. With UHP furnaces, use of sponge iron exceeding above limits is possible.

iv) Power generation by utilising waste heat of the DR process and utilising the same in arc furnaces will help ease the problems of power shortage to mini steel industry.

v) Most of the existing coal based DR plants have now been stabilised and the plant operators have successfully absorbed the imported technologies. TDR the indigenous technology has also been proven to be successful now. EGL's plant based on gas based Midrex technology, though commissioned recently, has achieved rated capacity in a short time.

vi) The installed capacity of sponge iron is expected to exceed 6.5 million tonne per year by 1994-95 with about 70% contribution by gas based plants.

vii) SIIL, IPITATA and Jindals have developed capabilities of providing completely indigenous technologies for coal based DRI plants. Indigenous machinery manufacturers are also capable to supply almost 100% equipment indigenously. However, technology for reforming of NG by reactor top gas and certain equipment for gas based plants are not available in the country.

27. The following recommendations are made to ensure the desired growth of the industry:-

i) Adopting indigenously available technologies for settingg up of coal based DRI plants.

ii) For gas based, technology may have to be imported. In that case negotiations may be held for maximum indigenisation of the equipment and time bound arrangements of technology transfer.

iii) Increasing pellatisation capacity of the country based on large iron ore deposits with high proportion of fines/blue dust.

iv) Long term policy in respect of allotment and pricing of natural gas and coal to sponge iron industry.

v) Coal authorities should pay special attention for production of superior grade noncoking coal to cater to the needs of sponge iron industry.

vi) Incentives to new integrated Direct Reduction Electric Furnace (DREF) units and for modernisation of existing steel units.

vii) For testing of raw materials for new projects, facilities of laboratory and pilot and demonstration scale plants available with SAIL, SIIL and other organisations, may be utilized.

viii) Provision of emergency power in new plants and power generation units based on waste heat utilisation in DR process plants.