

A ROADMAP

for
Research & Development
and
Technology
for
Indian Iron and Steel Industry



Ministry of Steel
Government of India
www.steel.nic.in

www.chiranjin.com



Ministry of Steel
Government of India
www.steel.nic.in

FOREWORD

The Indian Steel Industry rides high on the wings of optimism. It now the fourth largest steel producer in the world. Its spiraling growth rate at 9-10% is poised to grow at an even faster rate. Production level is soon expected to cross the 100 million tonnes mark leveraged by developmental needs of the burgeoning Indian economy – currently the second fastest growing economy in the world. Apart from a large domestic market, India’s steel industry has also benefitted from indigenous availability of key raw materials such as iron ore. Entrepreneurs in the steel sector added 57 million tonnes of capacity in the last two decades of deregulation.

The last two decades have also seen far reaching changes in the contours of the industry in more ways than one. The new units brought in new technologies to this century old industry in India. Existing units in both private and public sectors have undertaken extensive programmes of modernization, expansion and debottlenecking. Most commendably, the new age entrepreneurs have shown a rare foresight in embracing state-of-the-art technologies and have innovated with alternate and mixed routes of production in keeping with the exigencies of raw material availability. With all these structural changes, the globalized industry has proved its resilience during economic downturns of 2002 and 2008.

Time has now come for the industry to consolidate the gains made in the last two decades, to sustain and further add to the growth momentum generated by favourable changes in the economic environment and policy shift towards liberalization. This would also mean course correction wherever needed, based on critical evaluation of its performance so far. We believe that the second push to the Indian steel industry must come from within through focused efforts to enhance efficiency in all areas of operation- from mining of raw materials to finishing of the final products. This must come in two ways – firstly, by improving operational efficiency of steel production through bench marking to best practice levels globally; secondly, and more importantly, by continuous and concerted R&D efforts to add to the body of existing knowledge and adapting such knowledge for application in India’s steel industry. Last but not the least, all such efforts for upgrading of technology profile of this resource-intensive industry must centre around and calibrate issues of sustainability and economic development.

The merit of the current document lies in its attempt to contextualize the R&D needs of this industry in which small units co-exist with large and very large producers. This report presents an inventory of technologies in use in each of the sub-segments from processed inputs such as Sponge Iron/ Pellets through non-specialised mild steels to value added sophisticated end products. It compares the performance parameters of each sector with the global best practice norms and diagnoses the possible reasons for such divergences. It also takes into account quality issues and lists various remedial measures to overcome the lapses. The report does all this in the perspective of the problems particular to the Indian Steel Industry relating to quality of raw materials, characteristics of the market for different products and status of in-house R&D initiatives in different segments of the industry. As an epilogue, it also enumerates the different systems of state support to R&D initiatives available currently to producers and other national or sector level organisations engaged in research in iron & steel.

Hitherto, R&D efforts, whether sponsored by the Government or by the corporate have been sporadic and mainly in the field of product engineering. Little attention has been paid towards better utilization of domestic raw materials for increasing efficiency of Indian steel plants. The new publication therefore sets out a roadmap to channel research with a focus on beneficiation of our own raw materials thereby leading to higher efficiency and productivity. Currently the



efficiency of the Indian Steel Industry is low when compared with many other steel producing countries. This is also because enough attention has not been paid by the Indian steel industry towards Research and Development.

The Roadmap, we hope, will provide a focus for the Indian Steel Industry for increasing R&D in their organisations thereby reaping the benefits of improved productivity and efficiency in the long run. In an increasingly globalised and competitive market place, we believe that such efforts are necessary for the survival and growth of the individual producers. We hope this technology compendium will lead to better understanding of the imperatives of operational discipline and need to adopt, adapt and improve existing technologies to stay ahead in the race for market space.

At the same time, we hope that the report will provide important insights to policy makers in devising an appropriate technology and R&D policy for the Indian steel sector aimed at maximizing economic welfare of the nation at large for the present and for future generations.

We, sincerely hope that this volume will serve as a roadmap to the immense possibilities of technological improvement through R&D efforts and suitable policy interventions in that direction. Through this we also strive to contribute to the cause of Indian steel in its pursuit for excellence and social relevance.



(Shri. P.K. Mishra)
Secretary
Ministry of Steel
Government of India

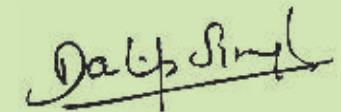
New Delhi,
30th September 2011

ACKNOWLEDGEMENT

The Ministry of Steel, Government of India felt the need to take a stock of the present status of Research & Development (R&D) and adoption of Technology in the iron & steel sector in the country, so as to identify the gaps and suggest critical areas for pursuing R&D and Technology intervention. Its aim to address these critical areas has led to the publication of this coveted Report on “A Roadmap for Research & Development and Technology for Indian iron & Steel Industry.”

This valuable publication traces the varied avenues of Technology and R&D scenario in our country vis-à-vis its international counterparts and offers valuable ideas on the innovation and R&D initiatives that can fortify the steel industry in the days ahead. The Roadmap emphasizes research with a focus on beneficiation of raw materials used in iron and steel making i.e. particularly iron ore and coal.

The Roadmap is a significant effort and I acknowledge the valuable contribution of the Industrial Adviser and his team in bringing out this useful publication. The effective guidance rendered by eminent experts and CEOs of the steel industry in formulating the report is worth mentioning. I also appreciate the valuable suggestions of Secretary, Department of Science and Technology and senior officials of Ministry of Steel for their useful inputs in the making of the Roadmap.



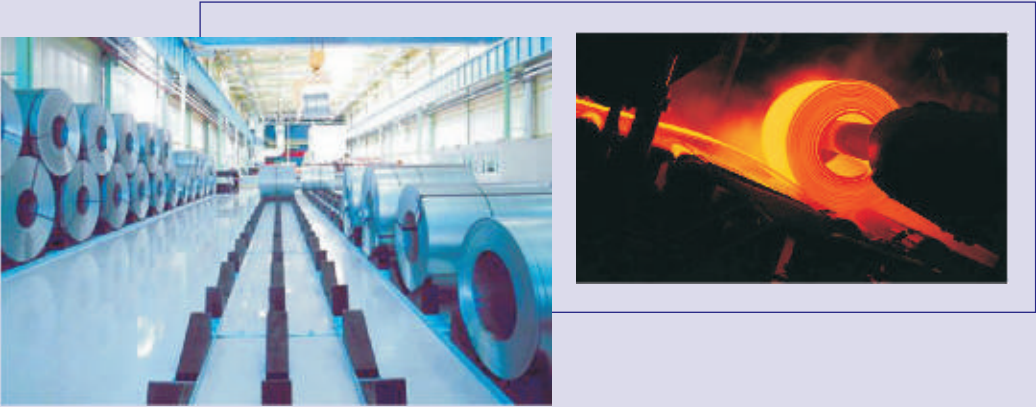
New Delhi,
30th September 2011

(Dr. Dalip Singh)
Jt. Secretary
Ministry of Steel
Government of India

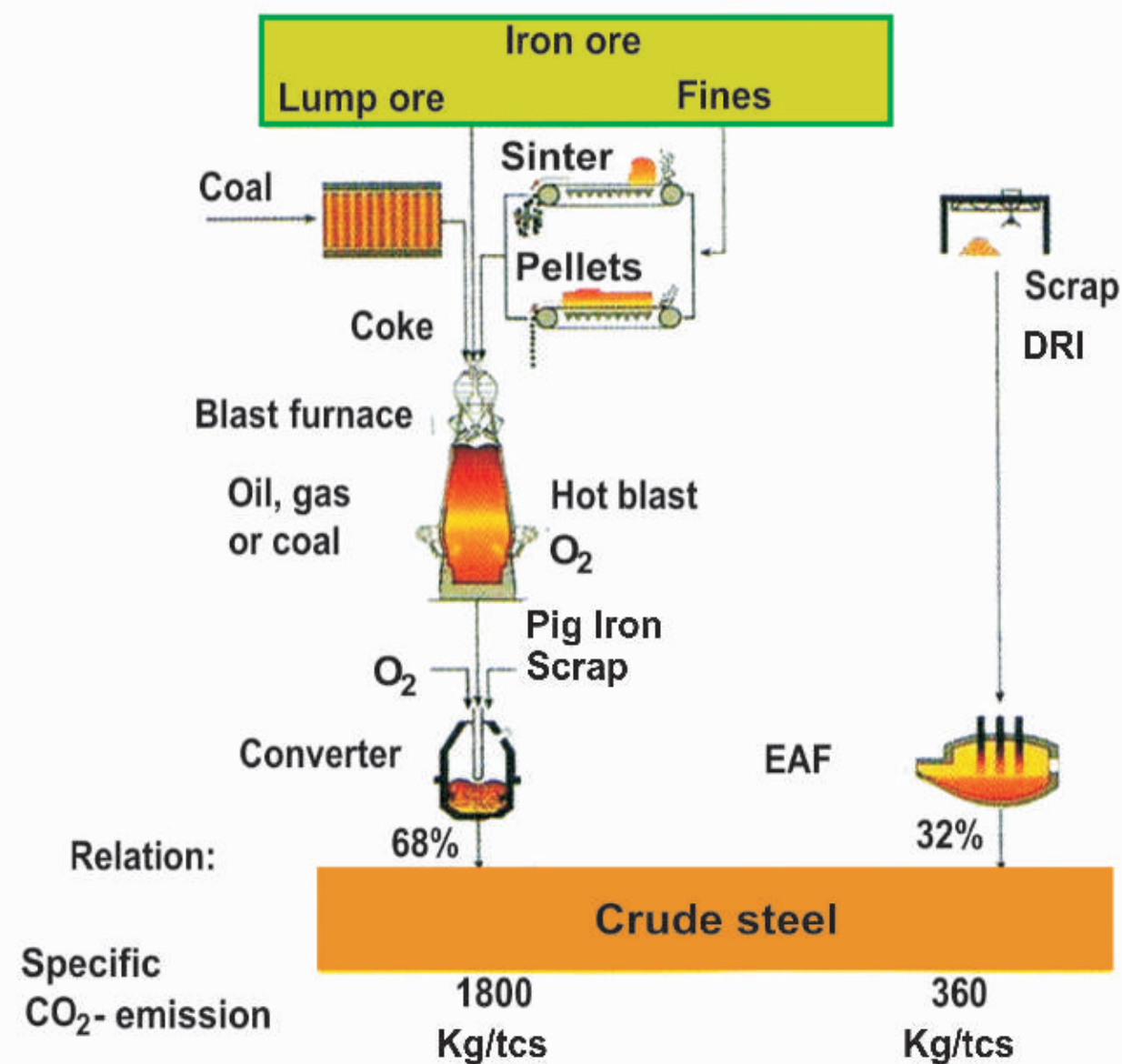


CONTENTS

Chapter	Subject	Page
1.0	Overview	1-2
2.0	Technology Profile of Indian Steel Industry	3-21
3.0	Assessment of Techno-Economic Parameters	22-26
4.0	Status of Beneficiation and Agglomeration of Raw Materials	27-32
5.0	R&D Needs and Thrust Areas	33-43
6.0	Conclusion and Recommendations	44-49
Annexures		
Annexure I	Status of Emerging Technologies	50-52
Annexure II	Highlights of R&D Work by the Industry	53-56
Annexure III	R&D Projects with funding from SDF	57-61
Annexure IV	R&D Projects with funding from Government	62-64



Greenhouse Gas Emissions in steel making



Iron and Steel have played an important role in the development of human civilization over the years. Essentially, steel is composed of iron and small amount of other elements like carbon, manganese, silicon etc. Steel by itself is one of the most environment friendly products used in our daily life. Steel has been a material of choice for innumerable applications all along in the past, and it is likely to continue to be an important material for use in the foreseeable future.

The world steel production has been increasing from year to year and has already crossed the 1 billion tonnes mark for the first time in 2004. During the intervening period, steel production has grown very fast, and in 2010, global steel production has exceeded 1.4 billion tonnes. The rapid increase has been led by China accounting for more than 45% of world steel production. China is not only the largest producer of steel (627 million tonnes), it is also the largest consumer of steel (576 million tonnes) followed by the United States and India.

An analysis of the Technology Profile of World Steel Industry shows that 70% steel is produced through the Basic Oxygen Furnace (BOF)/LD Converter route, 28.8% through Electric Steel Making route and the balance 1.2% through the open hearth (OH). The open hearth route of production is almost extinct from the world map except in some of the erstwhile CIS countries like Russia, Ukraine etc. Another technical feature of the world steel industry is its increasing output of continuously cast steel thereby phasing out the obsolete ingot-casting route. In several countries the continuous casting ratio is as high as 100% and in most of the technologically advanced countries, the ratio varies in the range of 90-95%, global average being 95% approximately.

Iron and steel industry is a major contributor of green house gases (GHGs), particularly carbon dioxide (CO₂) gas which is one of main contributors for climate change and hence is a major concern of the world iron and steel fraternity. Naturally, the main agenda of the steel producers across the globe is directed towards development of strategies and technologies to substantially reduce consumption of coal and/or bypass the use of carbon (coal & coke) in iron and steel production as far as possible. Towards this objective, steel companies all over the world are investing in the state-of-the-art iron and steel making technologies, and practices and uneconomic plants are being phased out. China has also evolved a strategic agenda to close smaller, energy intensive units.

The Indian steel industry is characterized by a mix of old and new technologies exhibiting poor to excellent techno-economic performance parameters. The origin of the modern iron and steel industry in India dates back to pre-independence era when the Tata Iron & Steel Co Ltd (TISCO) was set up in 1907 at Jamshedpur. At the time of independence in 1947, the country had three ore based steel plants (TISCO, IISCO, VISL) and a few Electric Arc Furnace (EAF) based mini steel plants. Between 50-70s, large integrated steel plants were set up in the public sector at Bhilai (BSP), Durgapur (DSP), Rourkela (RSP) and Bokaro (BSL), and Steel Authority of India (SAIL) came into being as the largest steel producer in the country. Plants like Rourkela Steel Plant (RSP) adopted the state-of-the-art technologies of the time, namely the LD steel making. Another green-field public sector plant i.e Visakhapatnam Steel Plant (VSP) was set up in the 90s with quite a few modern technologies and practices of the day.

The economic liberalization of the 90s, witnessed the entry of several large integrated steel plants in the realm of private sector (Essar Steel, JSW Ispat Steel and JSW Steel). The country experienced rapid growth in steel making capacity mainly owing to two factors – new players streaming in to join the race and modernization and expansion of existing plants. During this

OVERVIEW

period, a large number of coal based sponge iron plants and electric induction furnace based steel making plants came into existence. With these, production capacity of steel increased from 21 million tonnes (crude steel) in 1990-91 to over 78 million tonnes in 2010-11. Table-1 depicts the year-wise growth in production and consumption of steel in India in post 90s.

Table-1 : Year-wise Steel production and consumption

Period	Crude Steel production(%) (MT)	Growth (%)	Finished Steel Consumption (MT)	Growth (%)
1991-92	17.1	-	14.38	-
1996-97	26.5	9.2*	23.3	10.1*
2001-02	31.9	3.8*	28.5	4.1*
2006-07	50.8	9.7*	46.8	10.4*
2007-08	53.8	6.0	52.1	11.4
2008-09	58.4	8.5	52.4	0.4
2009-10	65.8	12.7	59.3	13.4
2010-11	69.6	5.7	65.6	10.6
2006-11		8.4*		9.6*

* 5-Yearly Growth (CAGR)

In 2010, India produced 68.32 MT crude steel and was ranked 4th largest steel producer in the world, after China, Japan and the US. The industry is growing fast @ 9-10% and such a growth rate is considered necessary to sustain the economic development of the country. Per capita steel consumption in India is low at 55 kg as against the world average of 200 kg. This justifies the need for a rapid increase in capacity and production of steel in the years to come. As per the present projections, it is expected that India will emerge as the 2nd largest steel producer within the next 2-3 years. With such rapid growth continuing, it is projected that India’s ambitious target of 200 MT steel production by 2020 may also get fulfilled.

The green-field steel plants set up in the 90s or thereafter, have adopted most of the modern, state-of-the-art technologies. Within a very short span of time, most of these plants have expanded their capacities many-fold adopting thereby clean and green state-of-the-art technologies. Plants like Tata Steel Ltd have made special efforts in the last two decades to gradually replace most of the older facilities thereby checking obsolescence to a great extent. However, the pace of modernization, renovation, and expansion in other older plants remained slow resulting in technological passé in the plants. This, together with constraints in raw material quality, summarily explains the poor techno-economic performance of these steel plants in the country. This is particularly true for older production facilities in public sector plants of SAIL and also in the Mini Steel sector.

To improve the technological face of the existing plants and also to sustain the projected high growth rate, there is a massive need for concerted technology development and research & development (R&D) programmes in the iron and steel sector in India.

Technology Profile of Indian Steel Industry

Globally, there are two main process routes for steel making, i) the "primary or integrated route" based on Blast furnace (BF) and Basic oxygen furnace (BOF)/LD Converter using iron ore as the basic raw material and ii) the Electric Arc Furnace (EAF) route using steel scrap as basic raw material with/without sponge iron. In India, steel is produced adopting three main process routes - Basic Oxygen Furnace (BOF), Electric Arc Furnace (EAF) and Electric Induction Furnace (EIF). The interesting feature of the Indian steel industry is that about 32% of total crude steel production comes from the electric induction furnace (EIF) sector. This is the one of outcomes of liberalization and is hardly found in any developed or developing countries. With 23% steel being produced through

the EAF route, proportion of total electric steel making in India has crossed 55%. Only the balance 45% steel is being produced through the BF-BOF route with marginal quantity from the Twin Hearth Furnace (THF). Metallic iron inputs used for steel making through the three process routes vary widely from plant to plant. Hot metal produced in Blast Furnace and Corex Furnace is the predominant source followed by direct reduced iron (DRI) produced in gas based or coal based plants and the last but not the least is the steel scrap (Figure-1). In these processes, scrap has a dual role to play- while in BOF it serves mainly as a coolant, in stand alone Electric Furnaces; it is the chief source of metallic iron for direct melting.

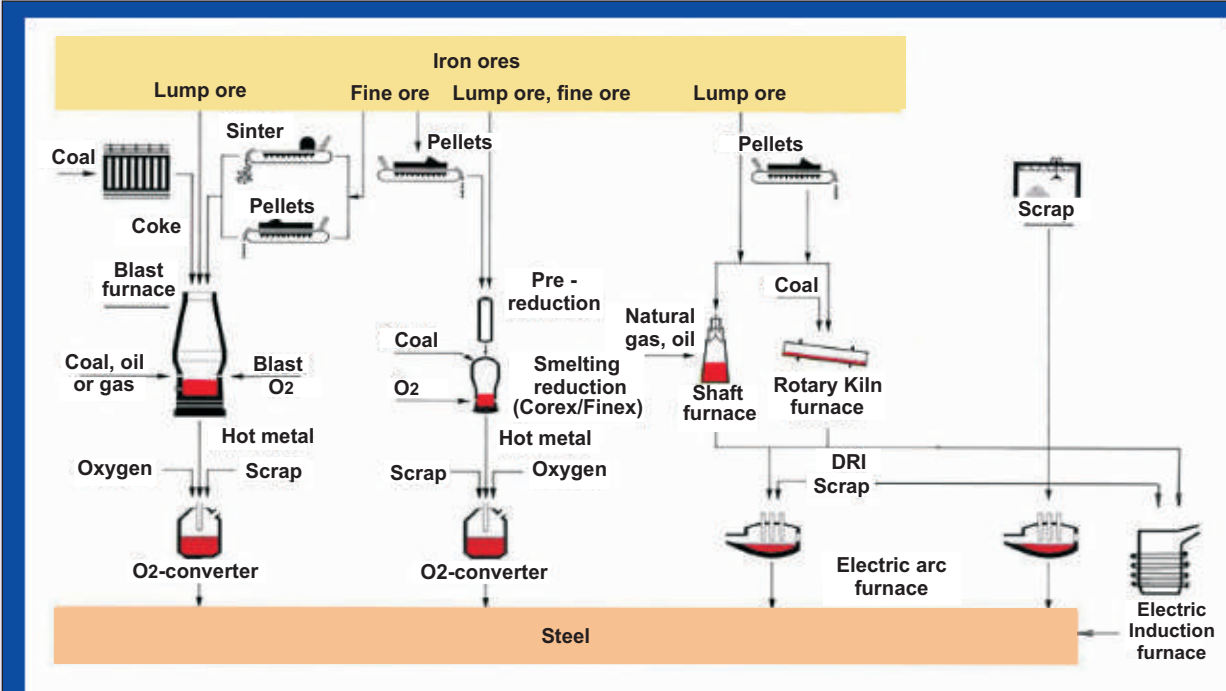


Figure- 1: Crude steel production methods adopting three main process routes
Source: [312, Dr. Michael Degner et al. 2008] &
(European Best Available Techniques (BAT) Reference Document)

Structure of the Indian iron and steel industry therefore, is quite diverse. On the basis of inputs/feed-mix used in iron & steel making/processing, profile of Indian steel industry has been summarised under the following sub-groups:

- a. Integrated steel plants comprising Coke Oven – sinter plant - Blast Furnace (BF) – Basic Oxygen Furnace (BOF)/Twin Hearth Furnace (THF): using coking coal and iron ore (lumps/sinter) as basic inputs.
- b. Integrated steel plants comprising Pellet Plant - Corex Furnace – Basic Oxygen Furnace: using primarily non-coking coal/ weak coking coal and iron ore (lumps/pellets) as basic inputs.
- c. Integrated steel plants comprising gas based Direct Reduced Iron (DRI) plant/Blast Furnace – Electric Arc Furnace (EAF): using natural gas, Coke/Coal and iron ore (lumps/pellets) as basic inputs.
- d. Integrated plants comprising coal based Direct Reduced Iron (DRI) plant– Electric Arc Furnace (EAF)/ Electric Induction Furnace (EIF): using non-coking coal and iron ore (lumps) as basic inputs.
- e. Integrated plants comprising coal based Direct Reduced Iron (DRI)/ Blast Furnace (BF) - Electric Arc Furnace (EAF)/ Electric Induction Furnace (EIF): using iron ore, non coking coal and coke as basic inputs for steel production using hot metals from Blast Furnace to partially substitute DRI in EAF to optimize power/ electrode consumption.
- f. Mini Blast Furnace (MBF) – Energy Optimizing Furnace (EOF): using coke, iron ore lumps and scrap as basic inputs.
- g. Stand alone Electric Arc Furnace (EAF) / Electric Induction Furnace (EIF) units: using steel scraps and purchased DRI.
- h. Stand alone Mini Blast Furnaces (MBFs): using mostly iron ore lumps and coke as basic inputs producing pig iron mostly for iron castings.
- i. Stand alone gas/coal based DRI Furnace: using iron ore lumps/pellets and natural gas & non-coking coal.

- j. Stand alone Hot Rolling/Rerolling Mills: using purchased/imported semis as basic inputs for production of mostly long products.
- k. Stand alone Cold Rolling Mills/Processing Mills: using purchased/imported HR/CR coils as basic inputs for production of CR/Coated flat products.

Designing, engineering and manufacturing capability of iron and steel plant equipments in India is limited. Therefore, in most cases, technology is imported from abroad, and equipments / machineries are designed and fabricated out of India. This is particularly, true for large plants viz, the integrated steel plants. Hence, the capital cost of any such ISPs is excessively high. The high Capex is one of the major deterrent for growth and development of Indian steel industry. It is also one of the primary reasons for small /medium/first generation steel entrepreneurs for selecting cheaper routes of steel making viz. the induction furnace route with /without captive sponge iron facilities.

With the setting up of new/green-field steel plants based on modern state-of-the-art technologies and also gradual phasing out of old/obsolete facilities in the course of modernization and expansion of existing plants, the technological profile of the Indian steel industry has been continuously changing for the better ensuring higher productivity, improved quality and competitive cost.

Since availability of high grade iron ore as well as lumpy ore is limited, processes such as beneficiation and agglomeration are receiving prominence. Energy conservation and environment friendly measures like recovery of waste heat from hot blast stoves, sinter cooler, coal based sponge iron, Pulverised Coal Injection (PCI), Coke Dry Quenching (CDQ), Top pressure Recovery Turbine (TRT) etc and charging of hot DRI and hot metal in EAF are drawing attention of the industry. The industry has started thinking beyond conventional continuous casting towards Thin Slab casting in pursuit of excellence.

Salient features of major iron & steel making

technologies, particularly in the context of integrated steel plants are highlighted here under:

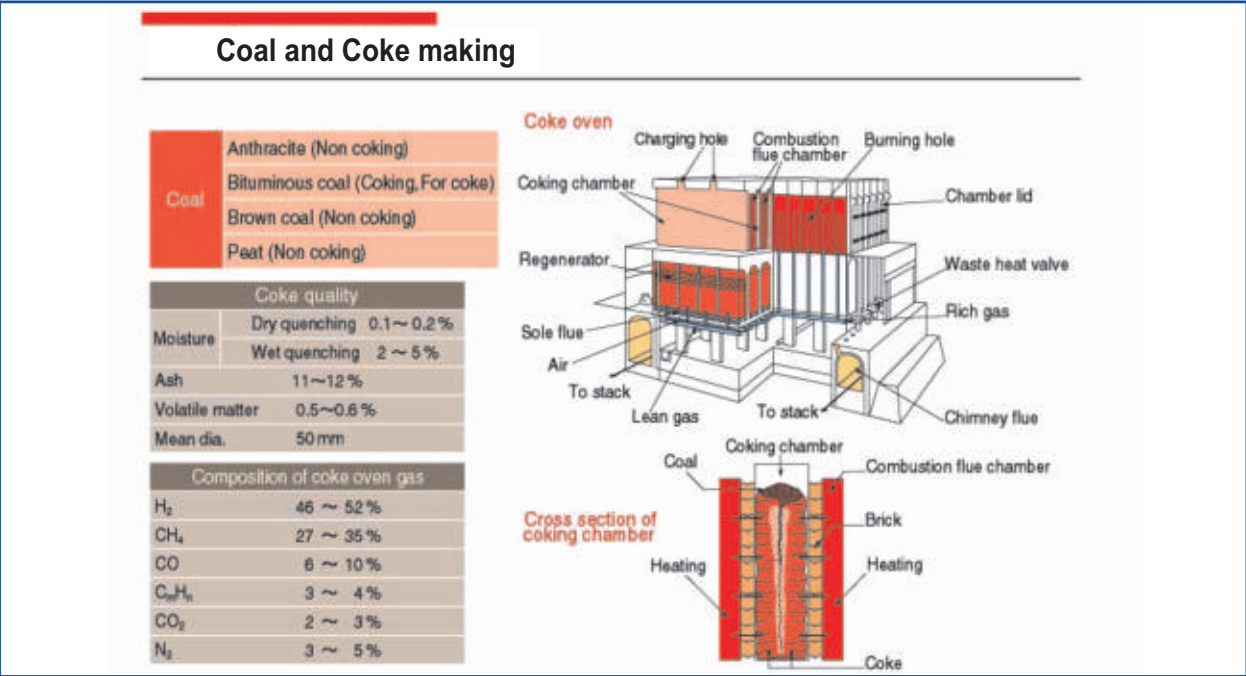
Coke Making

Coke making is a high temperature dry distillation process that removes and captures the gaseous chemicals in coal leaving thereby a residue of solid and porous lumpy mass of carbon known as coke. Coke serves four basic functions in the blast furnace iron making. Besides being the sole reductant to reduce iron ore into iron, it is the chief source of heat required for the reduction process. Solid coke also provides the required permeability inside the blast furnace to enable gases to pass through the bed and supports the heavy column of material in the furnace.

The pre-requisite physical and chemical characteristics call for adoption of relevant technology for production of coke of required property. Generally, coke for metallurgical applications is produced in by-product coke ovens and in non-recovery/heat-recovery coke ovens. Most of the integrated plants in India have set up top charged by-product coke oven batteries and some like JSW Steel Ltd., Jindal Steel & Power Ltd. (JSPL) and Tata Steel Ltd. (TSL) have set up non recovery/heat recovery ovens. Further, a few plants

have4 adopted CDQ in their quest for achieving the environment norms.

The scenario of coke making has been changing over the years on techno-economic and environmental considerations. From the conventional top charged, low/medium height coke oven batteries, the present trend is to go in for taller batteries and leak proof oven doors to economize on land use, increase productivity and reduce environmental pollution caused due to oven leakage. SAIL, RINL, Neelachal Ispat have installed 7 m tall batteries. Bhushan Steel is in the process of setting up a 7.6 m tall battery which may be tallest in the country. Several plants have adopted pre and post carbonization techniques to enable economic production of coke using inferior/weak/cheaper coking coal in an environment friendly manner. Towards these objectives, Stamp Charging and Partial Briquetting of Coal Charge (PBCC) have been adopted respectively by Tata Steel and SAIL plants, particularly with an aim to improve productivity and quality of coke even with relatively inferior coal. RDCIS, SAIL has developed a computerized coke oven heating system, which ensures consistent coke quality, reduced energy consumption, improved battery life and avoids wrong pushing. The system has been incorporated at COB#3 of BSP and COB#1 of DSP. An upgraded



version is now being implemented at COB#4 of BSP and COB#3 of RSP.

The above Technological innovations like Stamp Charging & Partial Briquetting of Coal Charge (PBCC), Tall ovens/batteries, Leak Proof Doors, Coke Dry Quenching (CDQ), on-line heating control technology etc. may be considered for extensive adoption for enhanced productivity, improved quality and reduced pollution. Other technological developments recommended for adoption are:

- Development of suitable models to optimize the coal blend in consideration of total cost, coke quality, oven health and easiness of pushing.
- Improvement in automation to facilitate improvement in productivity and quality i.e. level-1 or level-2 depending on the need
- Refractory welding for quick repair
- Energy conservation programme

SCOPE 21, a revolutionary coke production process, which is being developed by Nippon Steel, Japan, expected to reduce energy consumption and also boost production efficiency. Dry-cleaned and Agglomerated Pre-compaction System (DAPS) is a new coal pretreatment process for coke making to enhance coke strength and suppress dust occurrence to improve the environment friendliness of coke making by drying coal, separating fine coal from lump coal and forming the fine coal into agglomerate. The DAPS decreases the heat consumption of coke making due to lower moisture content of coal and productivity. The heat consumption decreases by approximately 15% compared to the conventional wet coal charging process at the same production rate. These are futuristic technologies and Indian plants need to keep an eye on these developments.

Life of by-product recovery coke oven in India remains much lower as compared to Japan or other western countries. Some of the by-products released during coke making are carcinogenic. This is an area of concern and hence control on emission and by-product recovery are considered very important. Some of the steel plants in India like Tata Steel have made special efforts to reduce the stack

and other emission in top charged as well as stamp charged batteries.

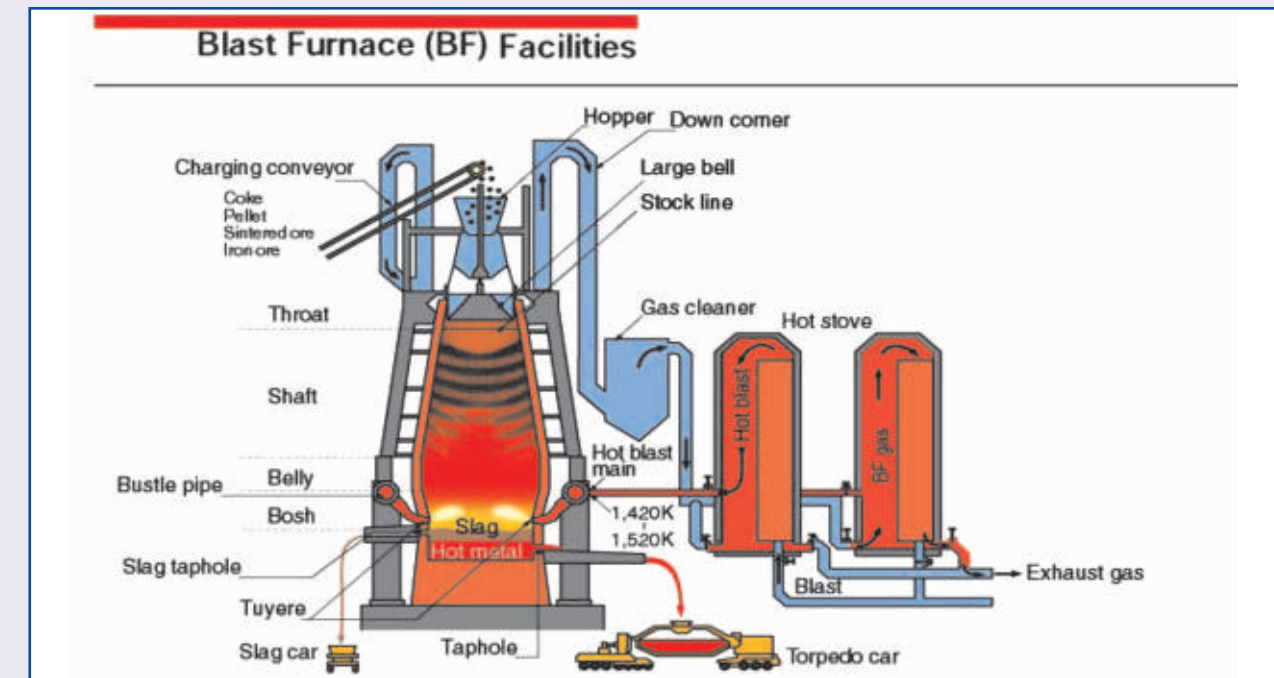
Due to environmental concerns, several companies have adopted non-recovery coke ovens equipped with modern innovations like vibro-stamp-charging and co-generation of power. No doubt, these have helped in reducing pollution normally associated with the by-product of coke ovens but these plants suffer from strong technological de-merits in the context of integrated plants, viz. non-availability of high calorific value coke oven gas for steel plant operation, lower productivity and large space/land requirement etc. Similarly, CDQ technology has also its merits (in terms of energy efficiency) and demerits in terms of problem in discharging waste water from coke oven (which is presently being used in wet quenching of coke).

Iron Making

Iron making is the science of extracting iron from iron ore (oxides). This is primarily done in the blast furnace using coke made from coking coal, which is the most widely adopted technology for iron making in view of its scale of operation and thermal & chemical efficiency. BF iron is supplemented by Direct Reduced Iron (DRI) produced in gas based or coal based plants. Of late, Smelting Reduction processes like Corex and Finex have been developed to supplement the production of iron. The salient features of three routes in the Indian context is highlighted hereunder:

BF Iron Making

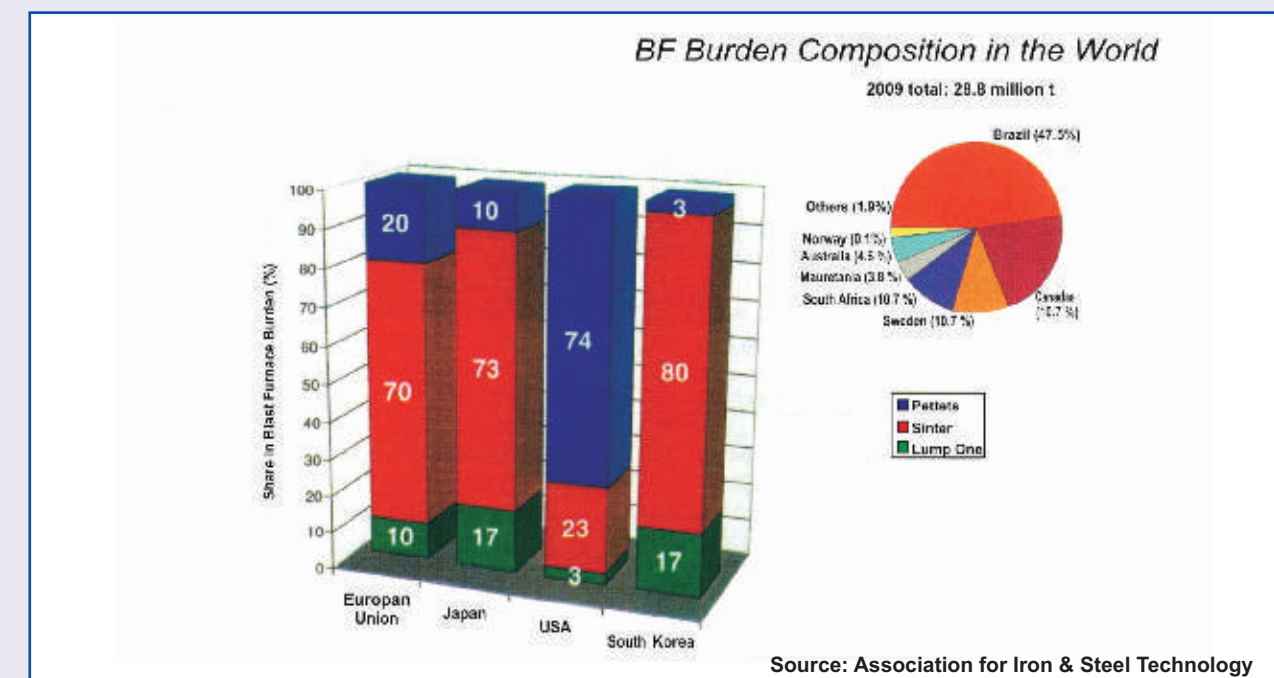
Blast Furnace is the main unit where primary reduction of iron ore takes place leading to production of liquid iron, also called hot metal. There are around 50 large and medium sized blast furnaces in India; and their sizes till recently varied in the range of 530 M3 - 3200 M3. Over the years, quite a few older furnaces have been phased out or renovated/ upgraded to be equipped with some of the latest technological innovations such as Bell-Less Top charging, Coal Dust Injection, Oxygen enrichment, High Top Pressure, higher hot blast temperature, etc. Recently, several larger blast



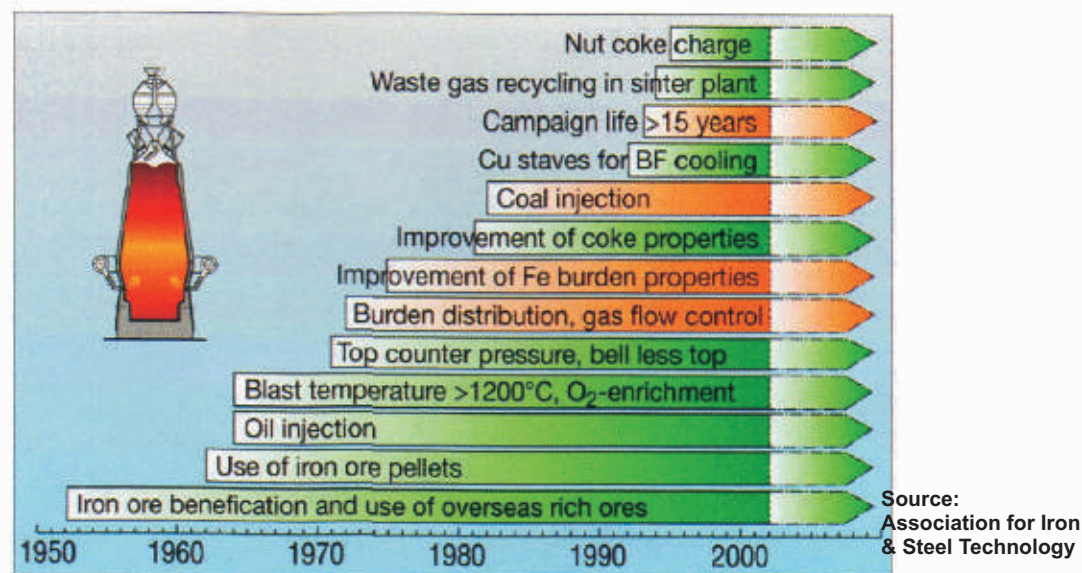
furnaces (3800 m3 and above) with state-of-the-art technologies have been installed. Such furnaces have achieved much higher hot metal productivity (upto 2.8 t/m3/day) with lower coke rate, higher coal dust injection, lower slag rate and higher oxygen enrichment. SAIL is setting up a 4060 M3 Blast Furnace at IISCO Steel Plant (ISP), Burnpur and one Blast Furnace each of similar capacity shall be setup at RSP, Rourkela and BSP, Bhilai. It is also satisfying to note that reduction of coke rate by injection of coal or other substitutes is gradually becoming the main

agenda of Indian blast furnaces to substitute the use of scarce and costlier coking coal.

However, overall scenario in the BF sector in India, particularly the older installations, is pretty bleak and a lot needs to be done to improve the level of technology and techno-economic parameters through well defined technology intervention programmes. Since the availability of lumpy ore is very limited, there is a need for charging prepared burden (sinter & pellets) in place of lumps. Successful use of pellet in BF is also expected to



Technical Development in BF Ironmaking



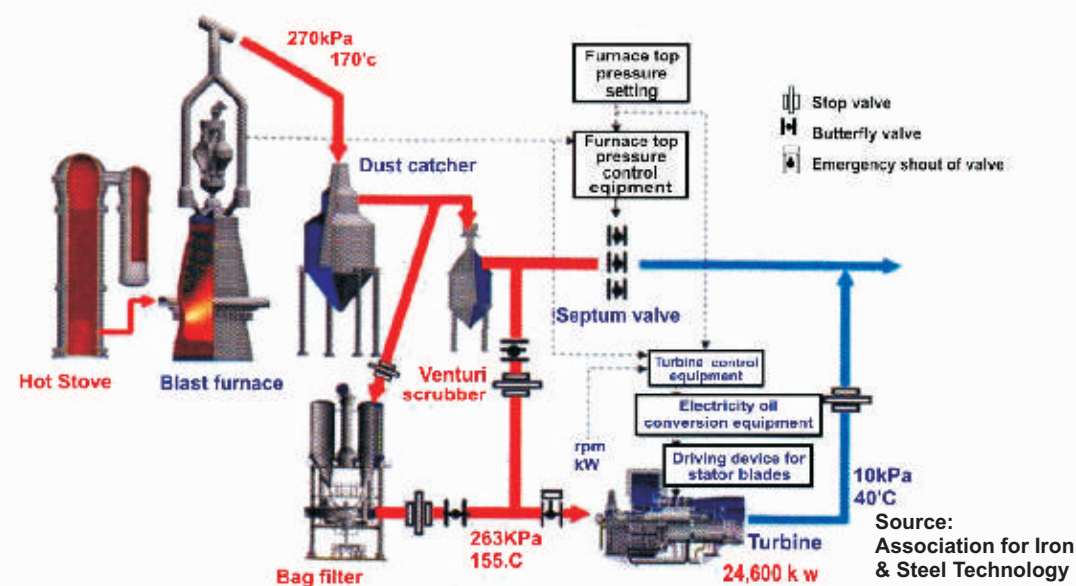
increase bed permeability inside BF which not only improves furnace operation, but also enables higher coal injection thereby reducing coke rate. Besides increased use of prepared burden, some of the technological innovations that need to be considered under Indian conditions to improve the productivity and quality of hot metal and to reduce the consumption of fuel are:

- Process improvements viz. revamping/conveyorization of stock house and increasing screening efficiency of ore, sinter and coke,

strengthening stoves capacity, increasing blast volume and flow rate, increasing oxygen enrichment of blast, higher hot blast temperatures of at-least 1100° C, application of close circuit water for better cooling efficiency, increasing the inner useful volume by the use superior quality refractories (by 150-200 M³).

- High level of alternate fuels injection to drastically reduce coke rate, incorporation of technologies for injecting pulverized/granulated coal (+200 kg/thm), oil (100

TOP Gas Recovery Turbine



kg/thm), Natural gas (100 kg/thm) and waste plastics granules have to be seriously considered.

- Adoption of energy efficiency measures in existing and new blast furnaces e.g. Top pressure Recovery Turbine, use of waste heat stove gas for preheating of gas, high efficiency stoves etc.
- Increase in campaign life by introduction of various measures like copper staves, Silicon carbide and monolithic linings in stack and bosh, closed circuit demineralized water and provisions for regular monitoring of heat flux all along the furnace height and cross-section, use of titanium bearing material as a regular hearth protection measure etc.
- Application of sophisticated probes (under and overburden probes, vertical probes etc), models and computerized expert system for process analysis, control and optimization are very important tools for bringing about quantum jump in productivity levels of Indian blast furnaces.
- Efficient casting practice through up-gradation of cast house equipment, clay mass and liquid disposal system, incorporation of powerful mud gun and drilling machines etc.

In post liberalisation era, a large number of Mini BF_s (175 M³—350/400 M³), mostly stand-alone units, based on Chinese Technology have been set up in the country. There are also a few tiny Blast Furnaces (50 M³). Smaller BF_s normally suffer from poor thermal and chemical efficiency and hence inferior consumption norms and higher environmental pollution. China, who were the pioneer in adopting/supplying MBF_s has been gradually pulling down the shutters of all such Mini BF based iron/steel plants under their Climate Change Programme, in spite of the fact that most of such furnaces are highly productive (productivity: more than 3 T/M³/D). In India, these MBF_s are contributing significantly in terms of optimum grade of pig iron for iron casting foundries and are also feeding hot metal to EAF_s resulting in saving in electric power consumption. However, there is

need to modernize/renovate these installations, failing which the inefficient units may be considered for closure.

On account of the spiraling prices of raw materials (especially coking coal / coke), there is increasing need to carry out research on the following to make the BF iron making cost competitive:

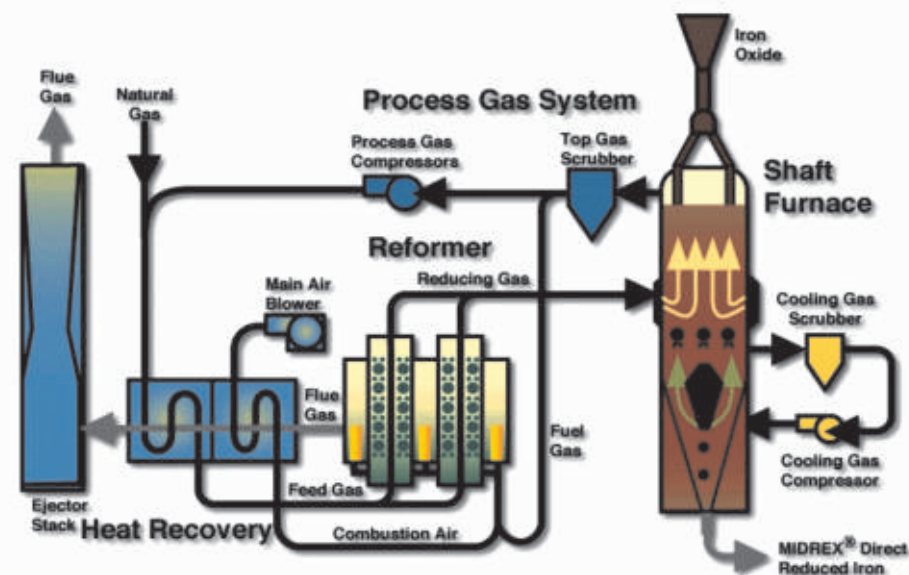
- Achieve Benchmark norms in consumption of vital raw material inputs
- Harness the thermal and kinetic energy of the entire system
- Increase the BF campaign life
- Produce good quality coke from cheaper coal blend
- Produce sinter / pellets from cheaper iron bearing materials
- Beneficiate inputs and reduce slag generation

Direct Reduced Iron (Sponge Iron) Making

DRI is the solid metallic iron obtained upon Direct Reduction of high grade iron ore. There are two established process routes: gas based process using natural gas and coal based process using non coking coal. There are further two gas based DRI processes in the world i.e. MIDREX and HYL-III (now called Energiron) and both have been successfully adopted in India. Essar has also developed and mastered the hot charging of gas-based DRI technology that remarkably reduces power consumption in EAF steel making. Since natural gas availability in India is limited besides being very costly, these processes have not found wide acceptability. To reduce the dependence on natural gas, Essar Steel is setting up a new gas based plant using Corex gas for reformer heating. JSW Steel, on the other hand, is setting up one DRI plant using Corex gas as process gas in place of natural gas utilizing the concept adopted in Saldhana, South Africa.

A revolutionary and challenging new alternative likely to be suitable in Indian conditions is non coking coal gasification by the well established coal gasification process of Lurgi and use of the synthesis

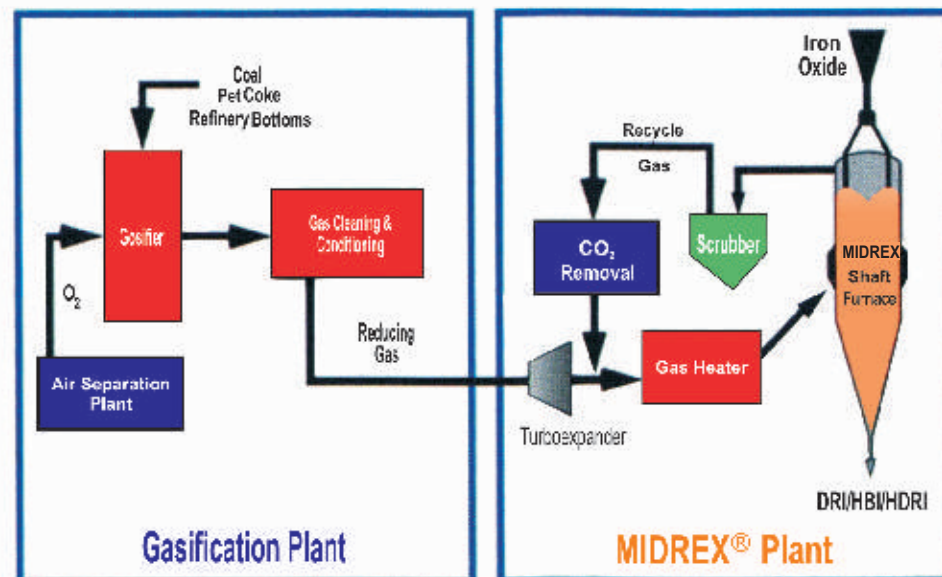
MIDREX® Direct Reduced Flowsheet



gas (syn-gas) thus generated as reductant in shaft furnace to produce gas based DRI. JSPL is putting up two gas based modules at Angul, Orissa using syn-gas produced from coal gasification. Besides all other advantages already stated above, the process is quite environment friendly.

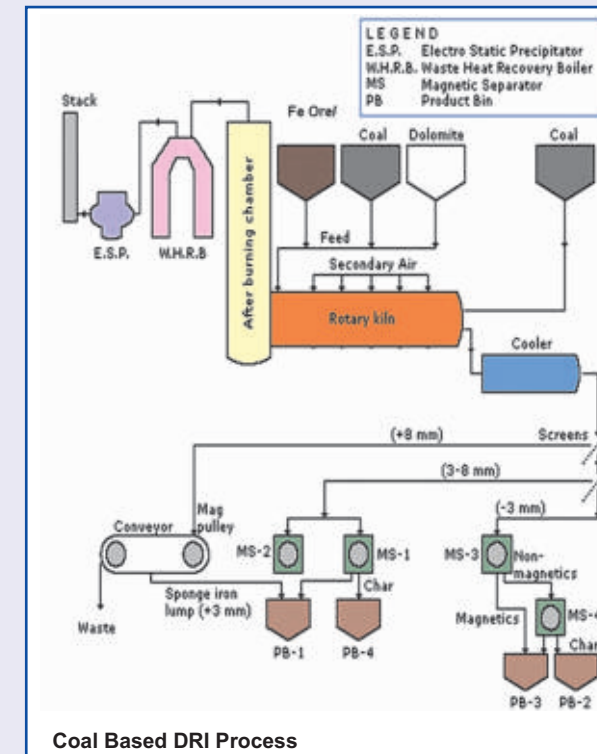
from 50/100 tpd to 500 tpd. Some of the coal based plants (Jindal Steel & Power Ltd, Raigarh , Tata Sponge and others) have also taken a number of initiatives to improve efficiency and address environmental issues so much so that today, these plants can be considered as the benchmark in coal

The MIDREX® Reducing Gas Coal (MXCOL™)



Coal based DRI process has established itself as a viable technology in India in terms of locational flexibility, productivity and kiln campaign life. There are over 350 units in India of varying module size

based sponge iron route with regard to environment efficiency, productivity, process efficiency energy efficiency or waste reduction.



Coal Based DRI Process

Today, India is the world's largest producer of sponge iron as also of coal based sponge iron. During 2010-11, total production of sponge iron is reported at around 27 million tonnes, of which contribution of coal based plants is approximately 75%.

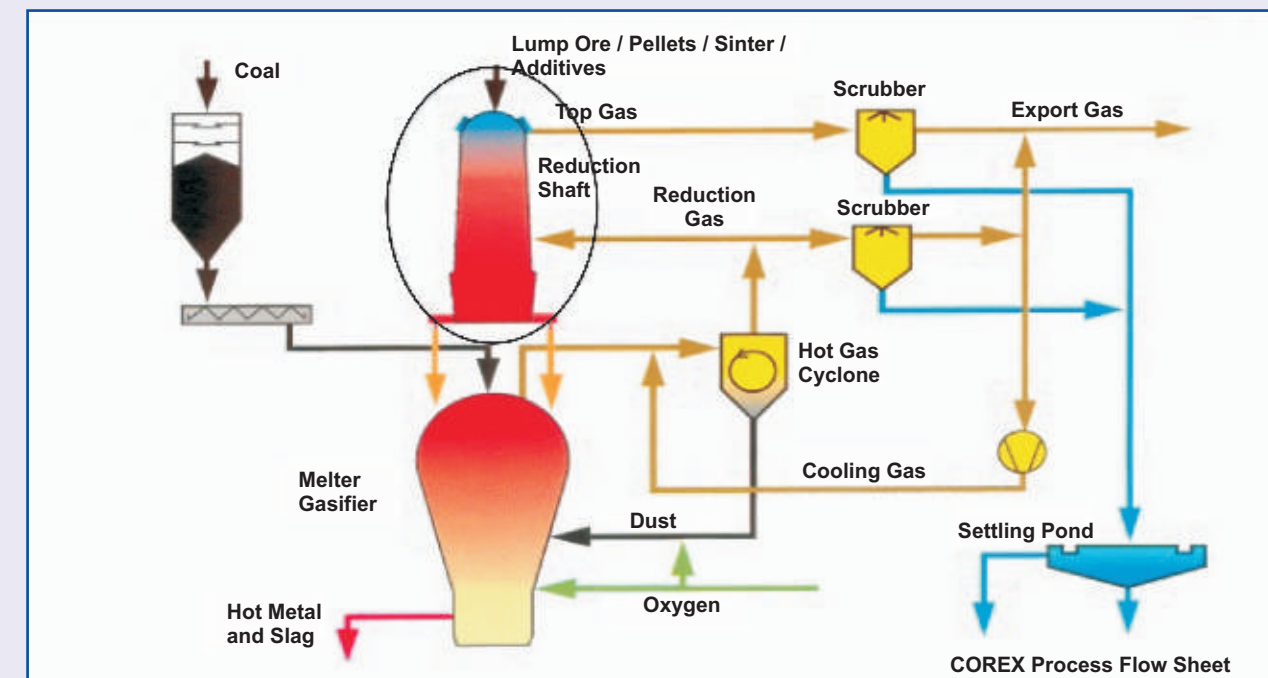
A large number of coal based plants of smaller modular size 50/100 tpd or below have mushroomed recently adopting thereby

indigenous/retrofitted technologies. These plants are trailing behind in terms of productivity, quality, energy efficiency and/or environment friendliness. To address the problem of quality, the BIS specification for coal based sponge iron needs to be revisited there by specifying a cap on the minimum level of metallization, Fe metallic and Fe total to qualify as DRI. The sector also requires stricter enforcement of pollution control measures. Complete utilization of char (Dolochar) generated from coal based plants remain a chronic problem and R&D solutions may be needed to address the same.

Alternative Iron Making Process

COREX Iron Making

COREX is a proven smelting-reduction (SR) process developed by Siemens VAI for the cost-effective and environment friendly production of hot metal from iron ore (lumps & pellets) and coal without resorting to coke making. In India, JSW Steel has successfully adopted the Corex process (C-2000 Module) in Karnataka. Initially, the plant resorted to utilization of gas in power generation but today, they are gainfully utilizing the gas mixed with BOF

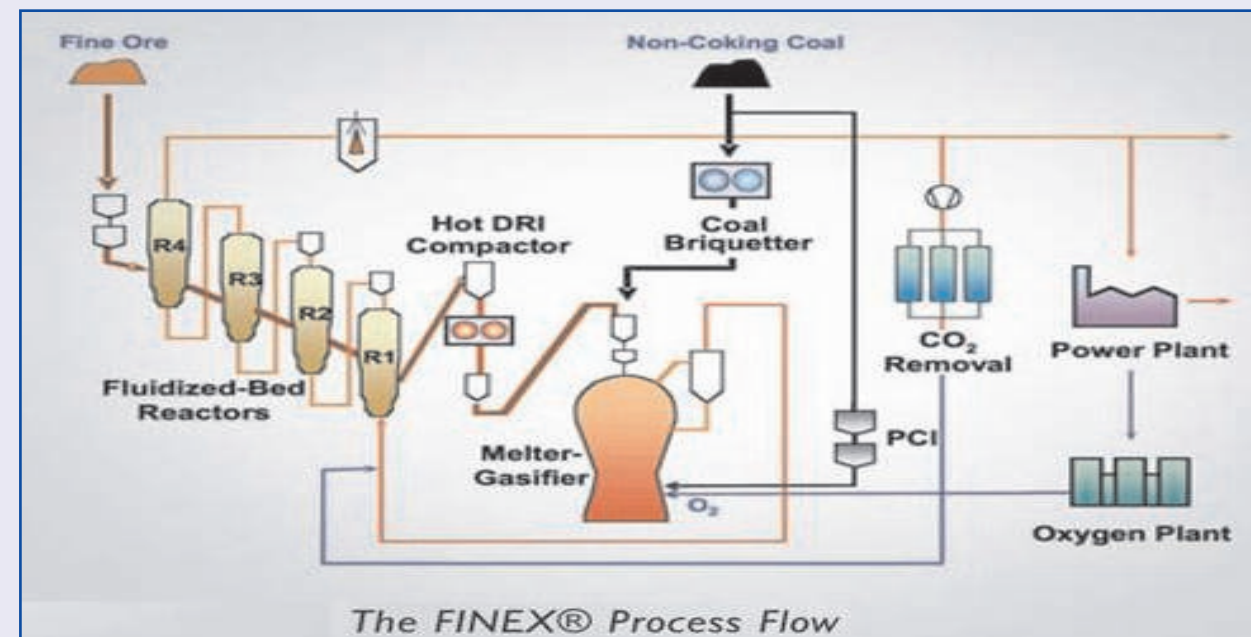


COREX Process Flow Sheet

gas for process heating in mill side. However, now JSW has decided to utilize the Corex gas for production of DRI and they are already in process of setting up the DRI plant using the Corex Gas. Essar Steel, Hazira is also installing two similar (Corex C-2000) modules shortly.

Hismelt Iron Making

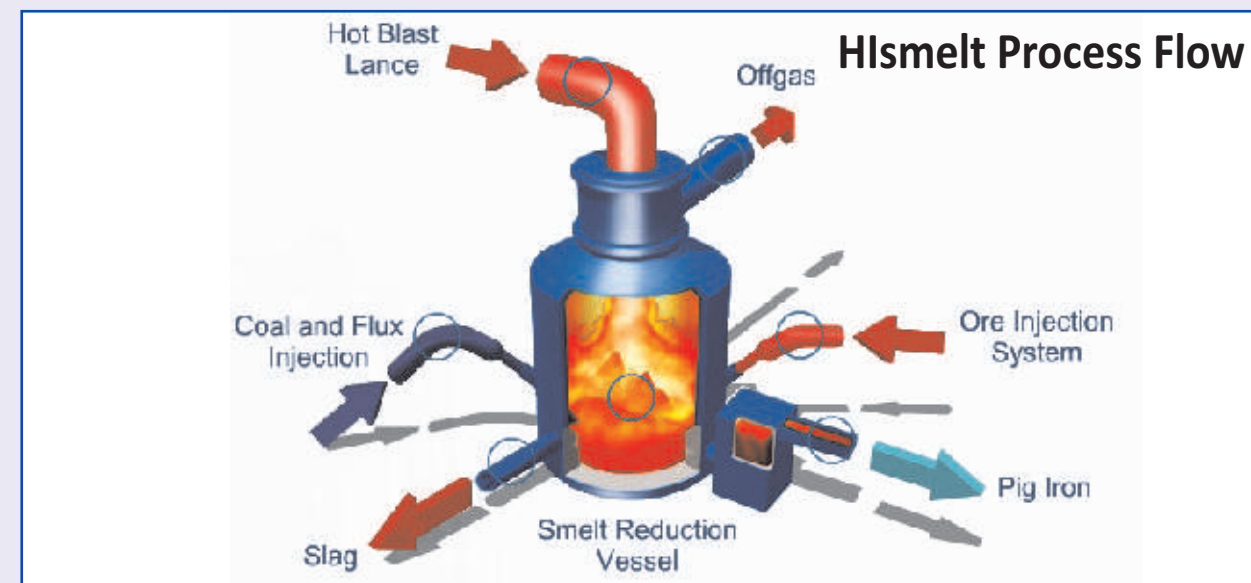
Hismelt i.e. High intensity smelting reduction is yet another promising technology for production of hot metal. Unlike Blast Furnace using hot blast of air and COREX/FINEX processes using oxygen, Hismelt



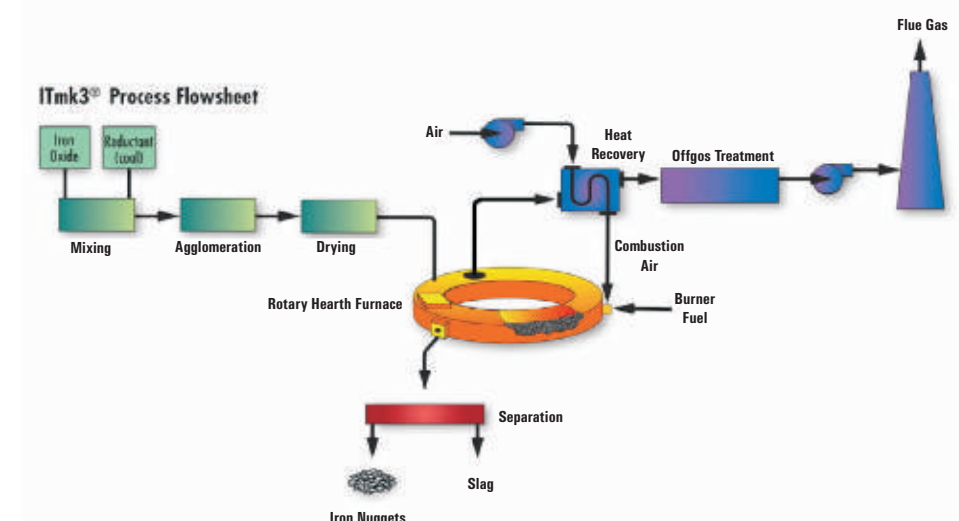
FINEX Iron Making

The limitations of the COREX process with respect to use of iron ore fines directly led to the development of FINEX process at Pohang, POSCO, South Korea. In this plant, the process has been successfully demonstrated at 1.5 million tonne modular capacity.

process uses oxygen enriched hot air blast. The process seems particularly relevant for high alumina and high phosphorous Indian Iron ores and therefore positioned to become a technology of choice for future Iron making. The first large scale demonstration plant (0.8 MTPA) was setup at Kwinana, Australia. However, before the process could be successfully demonstrated with 100%



ITmk3® Process Flowsheet



capacity utilisation, the plant was put under shutdown and is yet to be restarted.

ITmk3 Iron Making

ITmk3 process uses low grade Iron ore and non coking coal to produce high purity iron nuggets in a rotary hearth furnace. The process is relatively less energy intensive, less capital intensive and more environment friendly. The first commercial plant (0.5 MTPA) is in operation since 2005.

Beside the aforesaid process, there are several other promising smelting reduction/direct reduction technologies which are in the various stages of development. Salient features of the various emerging/promising technologies and their current status are given in Annexure-I.

Steel Making

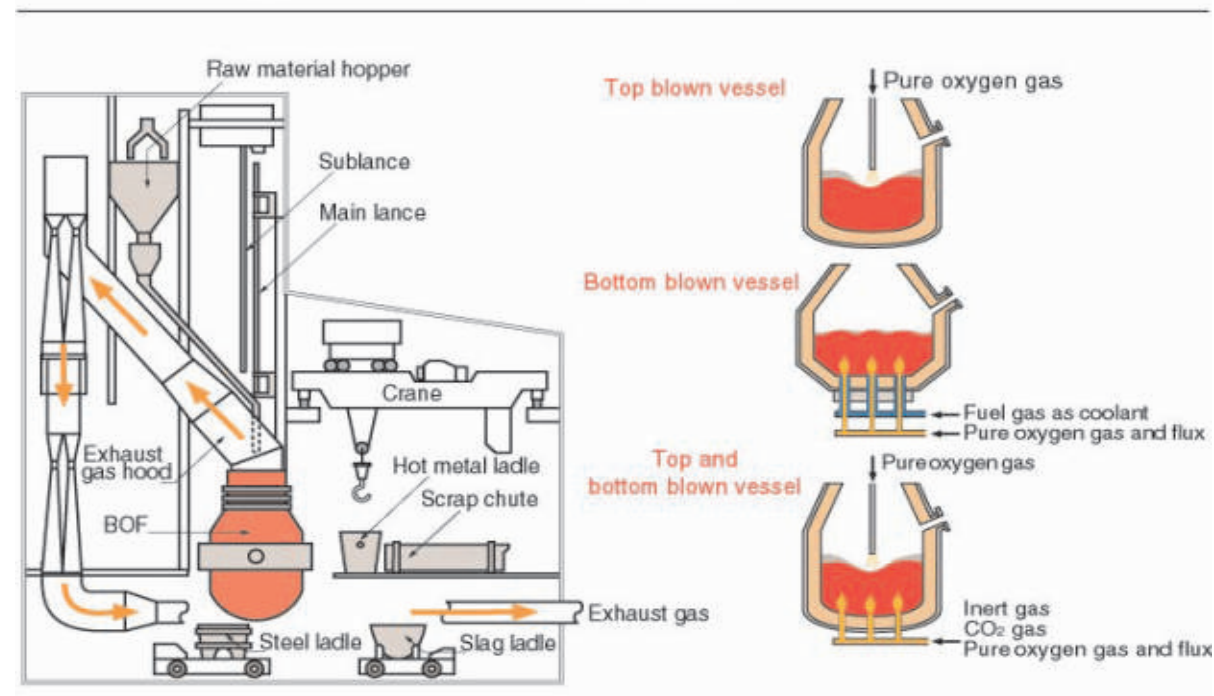
As stated above, there are three main process routes for steel making in India namely, BOF, EAF and EIF which together contribute over 98% of total steel production. While BOF and EAF processes are well established processes to produce quality steel, for high end product, EIF units are handicapped to produce high quality steel and mostly cater to the need of construction steel. Salient features of different process routes adopted in India are highlighted hereunder:

Basic Oxygen Furnace (BOF) Steel Making

In BOF steelmaking process which is commonly known as LD process, molten hot metal from blast furnace is poured into a BOF vessel where it is mixed with scrap steel. Pure oxygen is blown into the mixture through a lance. The carbon and silicon in the hot metal are oxidized generating huge quantities of heat which melts the scrap and produces molten steel. In view of its strong techno-economic merits, BOF process has practically phased out all other pneumatic steel making processes like Bessemer Process, Open Hearth Process all over the world (except in some of the CIS countries). In India also, the obsolete Open Hearth Process of steel making has been phased out in favour of BOFs. The left out OHFs have been converted into Twin Hearth Furnaces which are relatively more energy efficient and are operating at BSP and ISP. However, these are also being phased out soon.

Some of the BOFs are being equipped with the latest technological innovations like concurrent top and bottom blowing practices, slag splashing, Gas recovery system, modern automation & control facilities including dynamic Level-II control and better shop floor practices. These have led to higher productivity and lesser consumptions of costly inputs like refractories. There are gadgets such as 'smart-lance' and 'sub-lance' for the

Basic Oxygen Furnace (BOF) Facilities



prediction of end blow conditions, which facilitate higher alloy recovery, reduction in corrective blows, higher metallic yield, improved productivity and better quality. Tata Steel has recently introduced smart-lance in one of their BOF converter and some of the other plants are also planning to adopt this system in the near future.

Use of carbon bonded magnesia bricks and slag splashing / slag engineering (MgO enrichment) have led to substantial increase in refractory lining life. Over 5000 heats are consistently achieved by BOF steel producers. However, there are units which have achieved vessel life beyond 10000 heats (SAIL Bhilai achieved average converter life of 9500 heats with a campaign record of 12325 heats). The industry is engaged in finding ways and means to consistently achieve higher campaign life over 10000 heats (Benchmark) through pre-treatment of hot metal, good bottom stirring and stable foam practice.

One major problem in BOF process is the reduction of slag entry into the steel ladle at the time of tapping. Generally steel producers use 'DART' / IR camera for reducing the slag entry and their effectiveness is far from satisfactory. There is a need for the development / adoption of suitable

technology to overcome this problem. MECON has successfully developed an IR based camera system in the country which has also been demonstrated at Rourkela Steel Plant of SAIL.

Larger BOF vessel (size: 300/315t) has few inherent advantages and needs to be considered for future installations. Bokaro Steel Plant has established such a large capacity BOF vessel. Tata Steel is in the process of establishing 300 t BOF shop at Kalinganagar, Orissa.

Some of the steel melting shops /plants are still far behind in adopting modern practices and are operating at much lower level than the international benchmark. In the area of process development for handling and utilization of SMS slag and sludge in steel making process too, the Indian steel plants fail to keep pace with the international standard. Worldwide attention is being focused towards reducing the quantum of slag generation and utilizing them gainfully so that wastes become valuable materials. Besides, many processes are being mastered to use the generated solid/liquid wastes resulting in waste recycling and Zero Waste disposal. These are still areas of concern in Indian industry.

Electric Arc Furnace (EAF) Steel Making

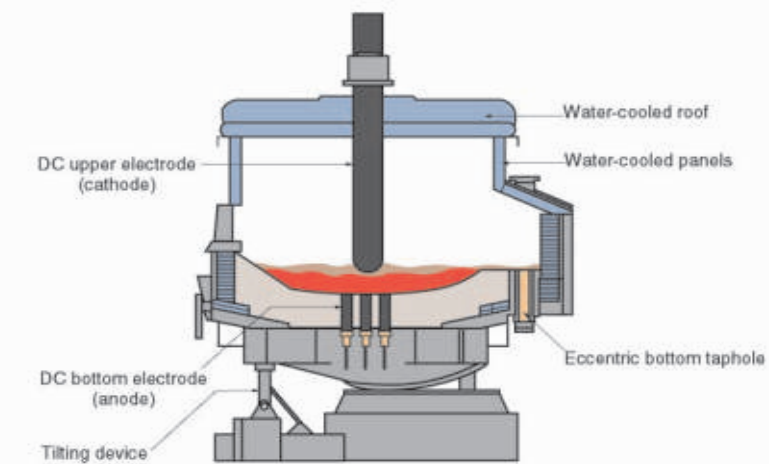
EAF is the second most predominant process of steel making contributing about 30 % of global steel production. In India, large number of EAFs have been phased out in favour of EIFs in the post-liberalisation period and today, contribution of EAF is reduced to about 23%.

Notable features of these units are geographical distribution in the country and also catering to the requirement of alloy/ special/value added steel in the country.

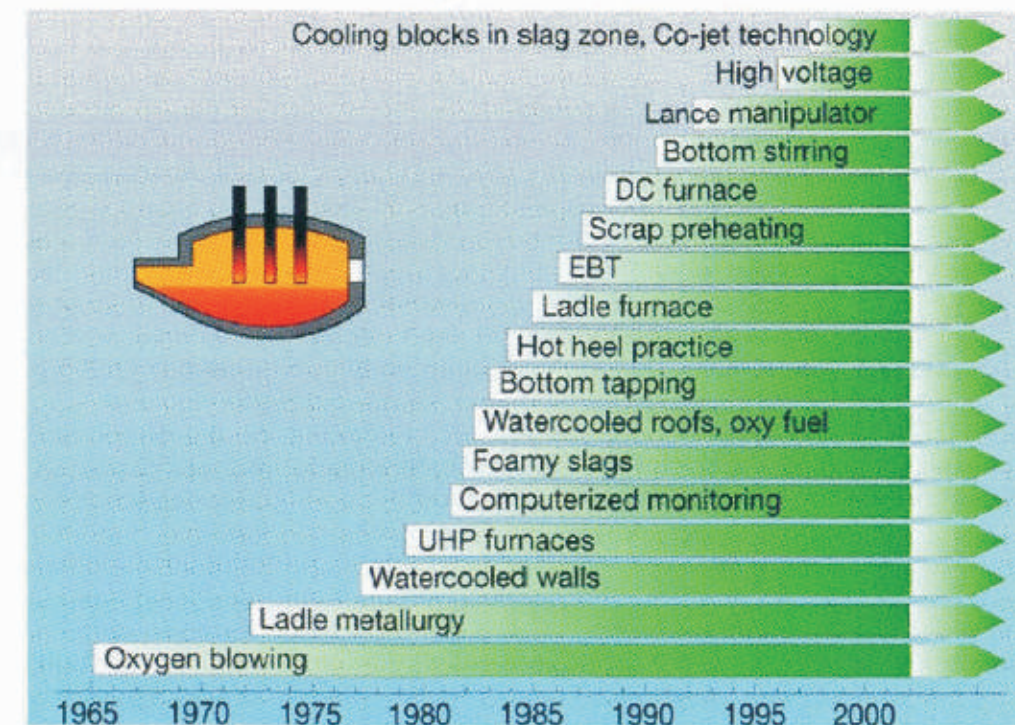
Today, there are 36 units in the EAF sector having divergent sizes and technology profile. Units like Essar, the erstwhile Ispat, JSPL and Bhushan have

adopted large, world class EAFs including DC EAFs and Con-arc Furnace fitted with most of the modern gadgets and innovations. Some of the EAF based mini steel plants too have adopted a number of latest technological features. A few units have set up mini blast furnaces for production of hot metal for use in EAF thereby utilizing the chemical/ sensible heat of the hot metal resulting in low power/electrode consumption. However, others

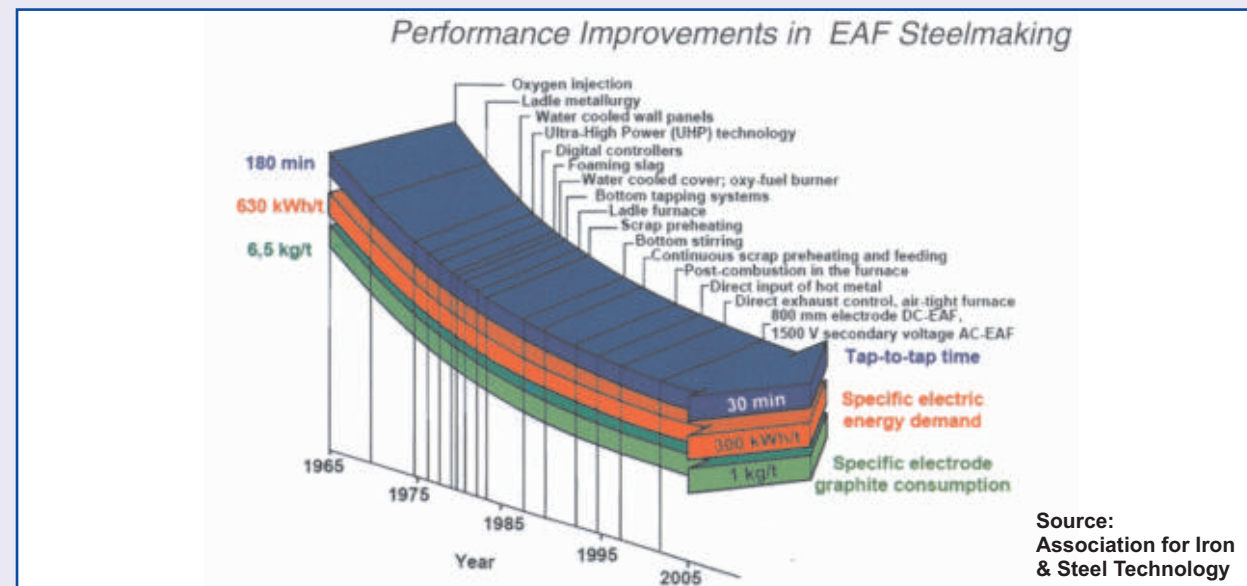
DC Electric Arc Furnace (EAF)



Technology Development in EAF Steelmaking



Source: Association for Iron & Steel Technology



particularly those in smaller sizes suffer with technological obsolescence. State-of-art-technologies like Ultra High Power (UHP) furnaces with ratings 0.9-1 MW/tonne, Oxy-fuel (side) burners, roof burners, water cooled electrode holders economizers, continuous feeding through delta region, enlarged shell for single charging, eccentric bottom tapping (for slag free tapping), electromagnetic stirrer (EMS), utilization of waste heat for scrap preheating (Finger Shaft Furnace, Echo-Arc Furnace) are some of the promising/emerging technologies which are recommended for adoption in the EAF sector in India to ensure increased productivity, reduced energy and electrode consumption and improved environment friendliness. These technologies may be considered on priority by the EAF based mini steel plants to change the technological face of the industry through technological upgradation of existing facilities or phasing out of obsolete facilities.

Electric Induction Furnace (EIF) steel making:

India is the largest producer/user of induction furnaces for production of steel. Today, there are 1074 operating Induction Furnace units with total capacity of over 24.4 million tonnes producing approximately 20 million tonnes of steel which accounts for 32% of total steel production in the country. The salient features of IF technology is that

the units are very flexible and may be set up at lower capital costs. This sector has proved to be a good source in making available structural steel at all corners of the country without the use of coking coal and iron ore with minimum emission of carbon dioxide gas or other GHGs. However, most of units have installed captive coal based DRI units thereby increasing the environmental pollution and CO₂ emission.

Induction Furnaces are primarily melting vessels in which electrical induction results in generating energy for melting scrap. These furnaces do not permit any slag to remain on the steel surface for long, and hence, no appreciable refining of the metal bath (e.g., to reduce phosphorous) is possible. Phosphorous makes the final product hard and brittle. The pickup of nitrogen during induction melting also makes the steel brittle. Over the years, quality of steel from this sector has deteriorated and most of the products contain much higher phosphorous than the prescribed limit in the relevant standards. This is mainly because of limited availability of quality steel scrap and its higher cost vis-à-vis sponge iron /cast iron which have lured the induction furnace units in using large quantity of Sponge iron and Cast iron (as high as 80%) thereby reducing the use of quality shredded scrap to the barest minimum. Owing to the large amount of phosphorous from inputs and inability of the furnace to refine the melt to remove Phosphorous like in other process routes, the

products essentially end up with higher phosphorous, making the steel brittle and unsuitable for use in critical applications like infrastructure, housing, buildings, etc.

The quality of sponge iron mostly from coal based units is also poor in terms of metallization. Considering lower metallization and higher phosphorous, its higher use in IF results in low yield and also higher energy/power consumption in the IF besides higher phosphorous in the steel. This tends to increase the cost of production which is compensated by lower price of sponge iron. Solutions to these problems need to be found out, if the IF route is to sustain.

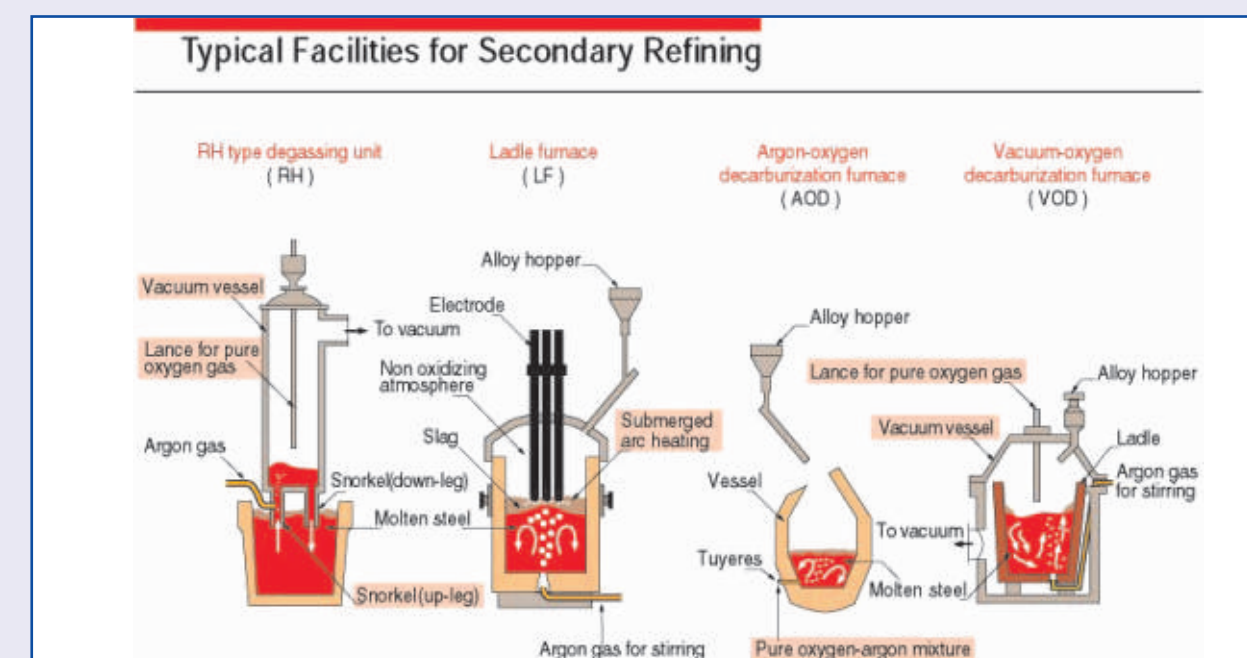
The IF industry is undergoing changes in terms of its size profile, adoption of continuous casting, adoption of secondary refining etc. However these improvements are not significant and these initiatives are needed to be adopted by others for survival of the industry. Efforts are also necessary on the part of the industry and Government to address the quality problems by suitable technological interventions. These may include finding out ways and means to refine the steel, if possible in the IF furnace proper or outside the IF (Ladle Refining Furnace/Induction Refining Furnace) to reduce the harmful elements viz Sulphur, Phosphorous, inclusions, slag entrapment etc. and thereby make quality steel as per relevant standards.

Secondary Metallurgy

The steel making process is usually followed by post-treatment including a number of diverse metallurgical operations, referred to as 'secondary refining or secondary metallurgy' to improve the quality of steel and over all productivity. Secondary metallurgical practices have been adopted by some of the integrated plants and alloy/special steel producers for the production of high quality steel. However, there are still gaps in this area because of which some of the Indian plants are unable to produce stringent quality steel for high end applications.

In view of increasing demand of quality steel by the consumers, it is apparent that the steel industry needs to pay more attention towards secondary refining and also continuous casting to improve quality of steel and also to reduce energy consumption and increase yield and thereby produce steel at reduced cost. There are several well established technologies viz. RH / RH-OB process, CAS-OB process, LF/ AOD/ VOD/ VAD/ VD for secondary refining processes which may be adopted depending on their suitability for the specific steel production units. Some of the new technologies that are worth consideration are:

- Selective use of 'Wire Feeders' to reduce variation of steel alloying elements



- 'Slag Free' tapping to improve steel cleanliness and reduce aluminum consumption.
- Improve 'Ladle Insulation' to reduce heat loss and achieve better control on super heat.

In the context of Induction Furnace, secondary refining processes are limitedly used. Secondly, there is no established process to effectively address the problem of higher phosphorous and nitrogen in steel produced in EIFs. Some companies producing Induction Furnaces claim to have developed innovative refining facilities for de-phosphorisation. The techno-economic viability of these processes is however, not yet fully established. As a result, most of the units resort to selection of appropriate charge-mix (shredded scrap and coal based DRI) matching with the composition of steel produced so as to produce quality steel.

Continuous Casting (CC)

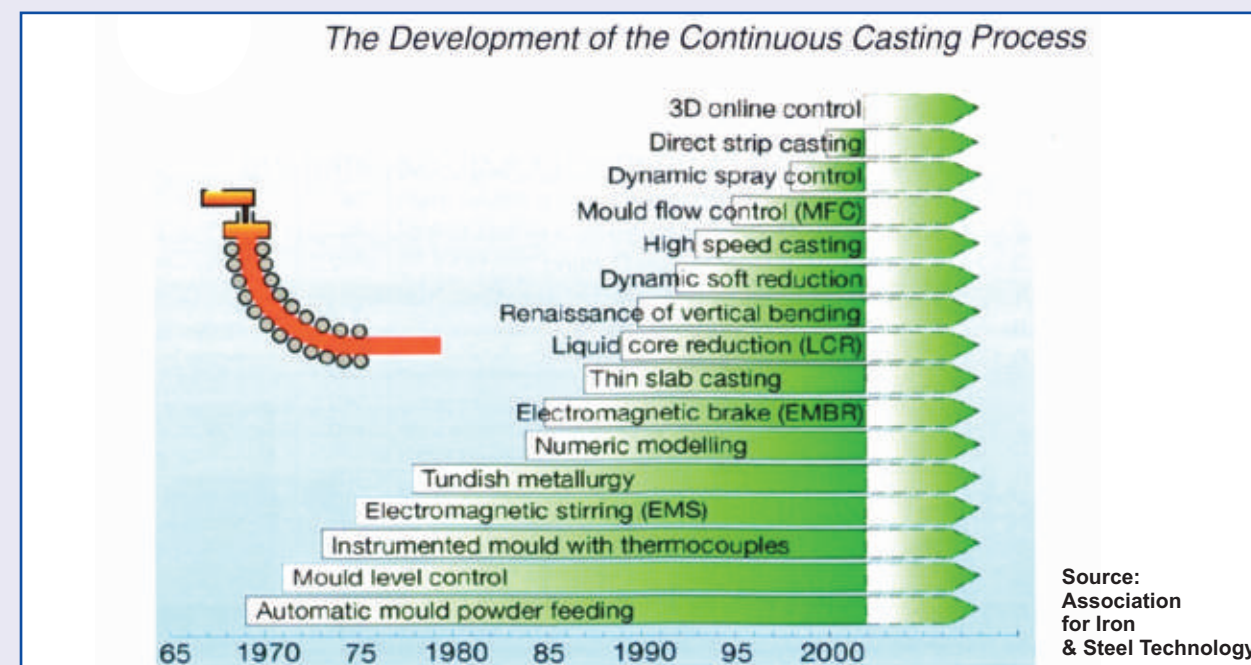
The liquid steel produced in steel melting shop is converted into solid intermediate products by casting into specific shapes- adopting the ingot-casting or continuous-casting process. Today, ingot-casting is becoming obsolete and the method of choice is continuous casting which offers several advantages viz. improved energy efficiency, reduced emissions and reduced water utilisation

due to the elimination of slabbing mills and billet mills, high yield in excess of 96 % and hence high productivity, etc.

Today, almost all steel grades for rolled products can be handled by the continuous casting route. Several innovative technologies/features like 'vertical bend mould', 'liquid core reduction', 'EMBR', 'mould and strand stirrers', 'shrouded casting', 'mould powders for high speed casting', 'water models for smooth casting' etc have been developed for improving productivity and quality of cast steel.

Most of the integrated steel plants and EAF units in India have adopted the continuous casting technology and proportion of continuously cast steel has reached 70%. Some of the plants have also adopted the modern features stated above. However, still 30% steel is cast through the obsolete ingot-casting route mainly by some of the integrated plants and most of the EIF units. In view of increasing demand for productivity, quality and consistency, the steel plants are expected to switch over to CC route and also improve the casting technology in line with the modern technological innovations. There are several technological developments in the conventional CC technology for slabs and billets, viz.

- Ladle Car Technology (instead of 'Turret System') with 'H/L' type tundish to make ladle



changeover time zero.

- 'Tundish Heating' for superior steel temperature control
- 'Auto Mould Powder Feeding' to reduce slag entrapment / uniform mould lubrication.
- 'Dynamic Soft Reduction Technology' to improve internal soundness of cast products i.e. reduction in centerline segregation
- 'Auto Scarfing and Grinding' to remove sub-surface defects and produce sliver / lamination free coils
- Higher billet casting speed (for 130 mm billets) beyond 7 m/min for high productivity, quality and efficiency.

Near Net Shape Casting

The present trend world over is to cast a profile, which is very near to the final product in size and shape (called Near Net Shapes). Casting of thin slab, beam blank, near net shape strip casting also known as direct strip casting (DSC) and thin strip casting fall under this category. The thin strip casting shortens the process from liquid steel to hot rolled sheet, therefore reducing the overall energy demand and increasing material efficiency but requires other secondary metallurgical steps. Typical dimensions for thin slab casting vary between sizes of 15 and 50 mm in thickness. Near net shape strip casting leads to a strand thickness of below 15 mm and thin strip casting to less than 5 mm. The casting process is combined with the direct hot rolling, cooling and coiling of the strips without an intermediate reheating furnace used for conventional casting techniques, e.g. continuous casting of slabs or thin slabs.

The main advantages are in terms of reduced capital cost, energy conservation, high yield and reduced land requirement. Technology for casting of thin slab, beam blank is well established today on a commercial scale. Thin slab caster coupled with on-line hot rolling stands has been available on full commercial scale producing most of steel grades and has been also implemented in India at JSW Ispat Steel formerly, Isapt Industries and Bhushan Steel. Tata

Steel and Essar Steel are in the pipeline. JSPL has commissioned two beam-blank casters. ISP (SAIL) is setting up one 4-Strand beam blank / bloom caster for production of H Beams upto 700mm.

Thin strip casting is also taking shape and demonstration plants have been set up abroad. Near net shape continuous casting of billets in an endless manner to directly produce wire rod is also another challenging area. Near Net shape strip casting is the futuristic technology and India should develop/adopt this technology.

Rolling Mills & Processing Lines

Hot Rolling Mills

Several state-of-the-art hot rolling mills have been set up by the steel plants, and others are in the process of acquisition of such mills. JSW Steel has recently commissioned one of the most modern and the widest hot strip mill (2.2 m wide) in India. Bhushan Steel and Essar Steel have set up modern hot strip mill adopting CSP route recently. Tata Steel is in the advanced stage of setting up a second hot strip mill adopting CSP technology. Essar Steel has also set up the widest (5 m wide) and one of the most sophisticated and state-of-the-art plate mill capable of producing all high quality plates including API, Q&T and normalized plates hitherto imported from abroad. The trend is continuing and in the next few years, many more state of the art rolling mills are expected in the flat and long product segment. SAIL (RSP) is already setting up a wide (4.3 m) plate mill with all modern features. In the long product segment, also, the scenario is changing. Modern bar and rod mills have been set up by JSW, JSPL, Tata Steel and others which are capable of rolling products with tight dimensional tolerances. SAIL is also setting up a universal Rail mill at Bhilai Steel Plant.

Some plants are also practicing latest techniques like Hot Charging of Slabs (though partially) in hot rolling areas and reaping benefits in terms of productivity and energy conservation. Schedule-

free rolling, high pressure de-scalers, AWC (Automatic Width Control), Use of HSS rolls, Hydraulically controlled AGC for gauge accuracy, Finishing stands with level-2 automation, Roll cross pair, Edge preheaters, Ultra Fast Cooling in ROT and edge masking system are other developments to improve the productivity, quality and rolling efficiency. Improvement in heating efficiency and reduction in fuel consumption in reheating furnace can be achieved by installation of HEC (High Efficiency Combustion) regenerative burner, which also has favourable effect on CO2 emission.

Older hot rolling mills however, are still handicapped with obsolete rolling technology and practices resulting in poor productivity, poor dimensional tolerance and higher energy consumption. The level of technology in these mills has to be changed through modernization and renovation.

Re-rolling mills in small and medium plants contributing over 20 million tonnes of finished steel production conventionally suffer with poor productivity and energy inefficiency also causing

high CO2 emission. On the initiative of Ministry of Steel, in association with UNDP, a specific energy efficiency improvement project has been taken up under which over 20 mills have been upgraded and several more units are in implementation stage. There is an urgent need to upgrade the technological face of this important sector in order to increase their productivity and energy efficiency through eco-friendly technologies.

Cold Rolling Mills

Like HRMs, CRM sector is also getting a facelift with setting up of modern, state-of-the-art mills with best productivity and quality. Till the end of 90's, most of the cold rollers with single stand reversing mills were handicapped with limited capacity, poor yield and also poor quality due to process limitations. However, the scenario has since changed substantially with setting up of several large capacity state-of-the-art rolling mills. To improve the overall yield and reduce the scrap, PLTCM (pickling line and tandem cold rolling mill) has been installed. Seeing the success of PLTCM at Tata Steel and ESSAR, many other

Steel producers such as Bhushan Steel are following suit. Tata Steel is planning to set up a wider PLTCM at Kalinganagar. JSW Steel and UTTAM Steel have established Twin Stand Reversing mill in recent times.

To improve the gauge consistency and shape, work roll bending, CVC crown, intermediate roll shifting, Feedback & Feed forward gauge control, Hydraulically operated AGC, sophisticated X Ray gauges and Level-2 automation system have been introduced. Most of the above have been adopted by the Steel Producers, who supply Steel for the high-end application.

Though some of the older plants are still operating with sulphuric acid pickling, most of the newer plants have adopted more efficient hydrochloric acid pickling. Other developments in Pickling area are Tension leveler (to loosen the scale for faster pickling), shallow / fully granite blocks, turbo pickling, acid less pickling, Acid Regeneration system, Auto Inspection etc and they facilitate quality and improved productivity.

The annealing technology in cold rolling mills has also undergone a big change in the country in the last few years. The Cold Rolling Industry was mostly using HNx gases for annealing. They had lower productivity and inferior surface finish. Almost all the Steel Producers have now switched over to the modern practice of 100% Hydrogen annealing process in last few years.

The changing customer requirements especially in the automotive segment necessitate the change in annealing process. The need for product consistency and high strength steel grades is growing and this seems to be the major driver for the introduction of Continuous Annealing Technology in the country. Tata Steel is in the process of establishing the first CAPL (0.5 million ton annual capacity) in association with Nippon Steel Corporation, Japan. Other Steel majors (ESSAR Steel, JSW Steel, Bhushan Steel etc) are also having plans for adopting continuous annealing.

Processing Lines

Finishing lines, like Galvanised and Colour- Coated have undergone a sea change for the better. Till recently, most of the Galvanizing units were producing only zinc coated steel, primarily for the

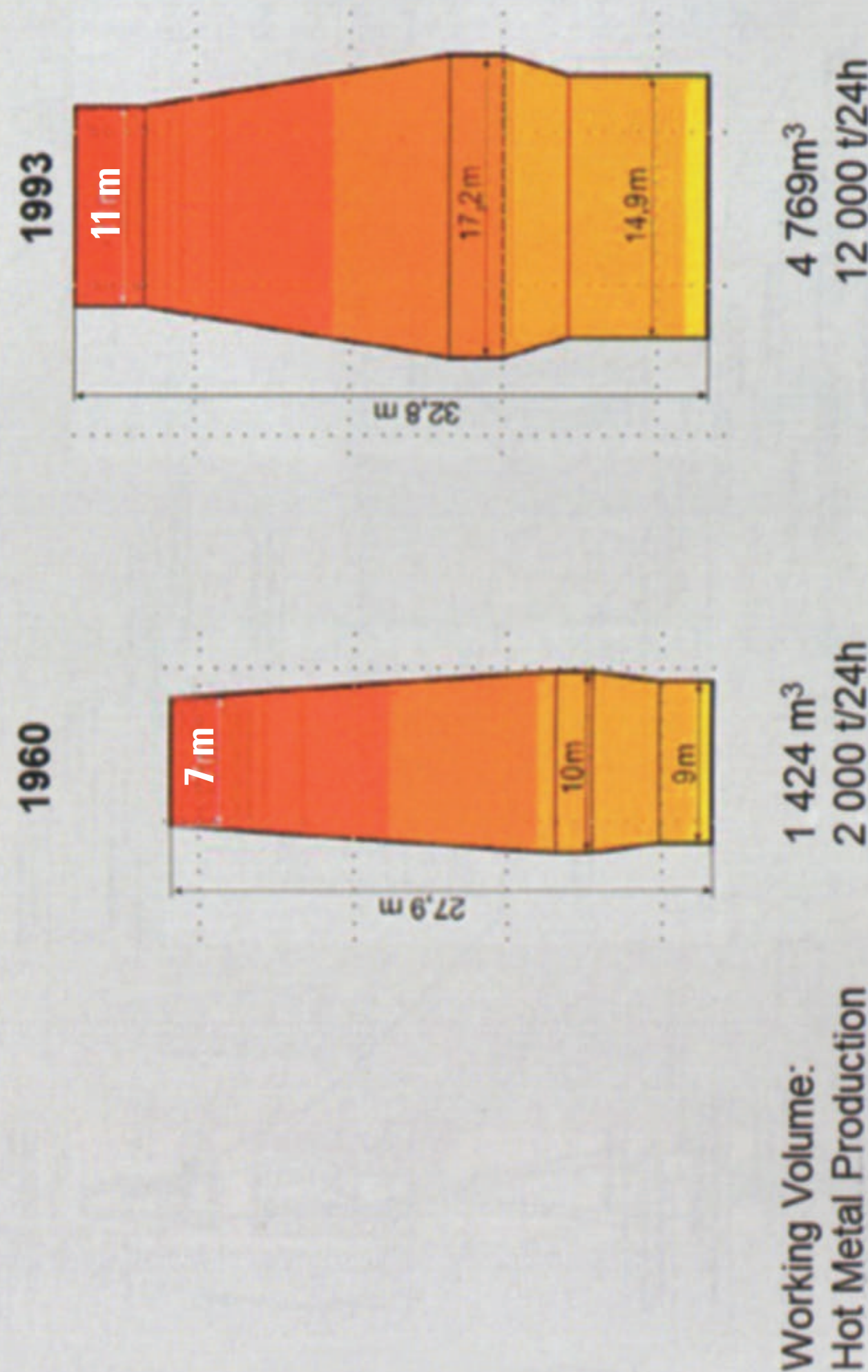
housing sector. But today, demand for galvanized steel for engineering applications is on the rise. Secondly, the galvanizers normally produce Zn-Al coatings. But today, Zn- Mg, Zn-Ni, Al-Si etc. are becoming popular and hence the Steel Producers are expected to gear up for the new requirement. Further, products like Galvalume and /Colour Coated/ Prepainted/Pre-coated steels have become popular for applications such as roofing and cladding. Several Galvalume lines and colour coating facilities have been set up (Uttam, JSW, Bhushan, Sree Pre-coatd Steel (Essar), National Steel etc), and Tata Steel – Blue Scope JV is likely to be commissioned shortly.

Galvannealing (GA) is a proven technology for the production of coated steel for automotive panels. GA sheets are considered better than GI on account of their superior weldability and hence most of the Korean and Japanese autos prefer GA to GI, in spite of the cost superiority for GI. Production of low strength grades by Galvannealing process is well

established. In India, Tata Steel has already set up facilities for production of GA sheets basically to cater to the requirements of automotive sector.

The older cold rolling mills and processing lines particularly in SAIL plants need upgradation. Extensive efforts are also needed to domestically meet niche product requirements, such as in automobile sector and in electrical steel, where India has serious constraints and most of the products are imported. The major thrust areas are improved product and productivity, increased yield, reduced energy consumption and production of high strength steel including UHS formable steel for high end applications. Production of CRGO electrical steel sheets has so far remained a challenge and technology is also not readily available from abroad. Therefore, Indian steel industry has to take up this challenge to indigenously develop the technology and produce CRGO electrical steel sheets including amorphous sheets for transformers.

DEVELOPMENT OF BLAST FURNACE IN VOLUME AND PRODUCTIVITY



Assessment of Techno-Economic Parameters

Performance of integrated steel plants is assessed by some of the common techno-economic parameters across the globe as per IISI (now World Steel Association) norms. When compared with plants in advanced countries, it is found that generally, the techno-economic performance parameters of Indian Steel plants are significantly lower, as explained below:

• BF productivity:

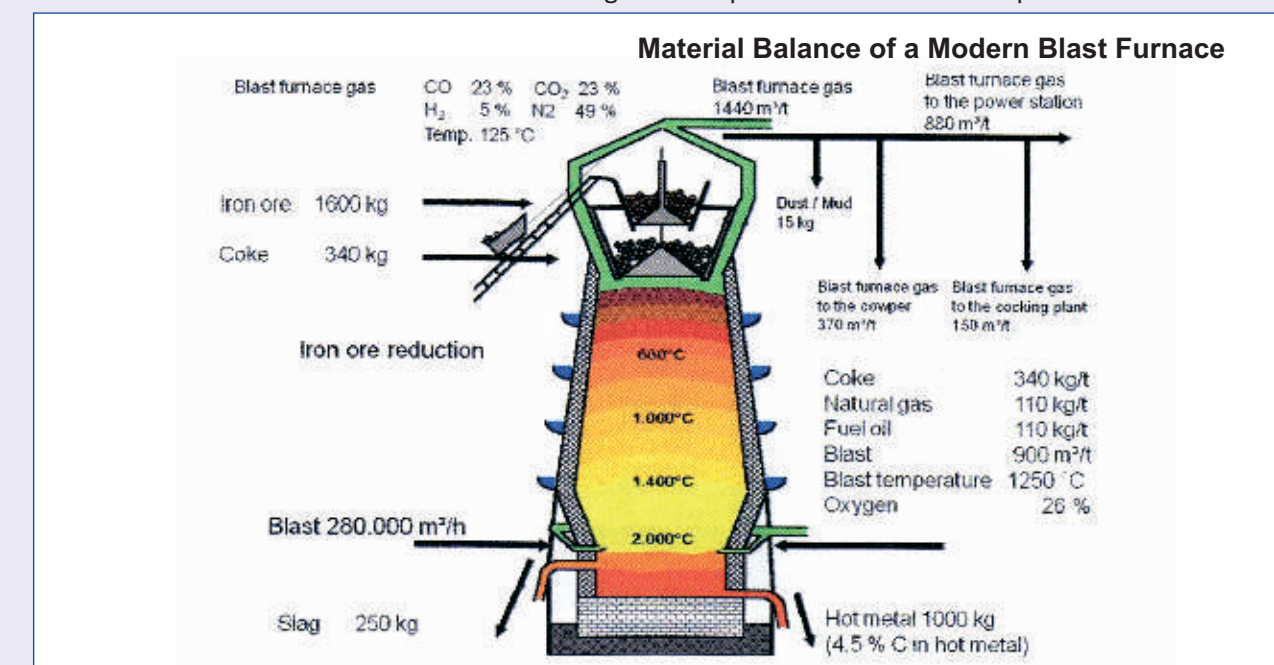
Productivity of Indian BFs varies considerably. While at RINL (commissioned in 1990s), the BF productivity level is satisfactory (around 2 T/M3/D), the recently commissioned plants (Tata Steel, JSPL, JSW, Essar etc) are fitted with world class technological features and productivity levels (2-2.8 T/M3/D) are at par with the benchmark plants abroad. However, most of the older plants suffer with very poor productivity (1.5-2 T/M3/D) which is an area of concern and needs to be tackled through

appropriate technological interventions.

The poor productivity is explained in terms of constraints in the quality of inputs/raw material charged in the furnaces viz. high gangue content (particularly alumina and silica) in input iron ore, high ash content in coking coal/coke including variation in quality of coal) and adoption of obsolete technologies /practices viz. lower hot blast temperature below 1000 °C, lack of high top pressure operation, poor level of oxygen enrichment of hot blast, limited use of agglomerated feed like sinter and pellet etc.

• Coke rate:

Coke rate in Indian Blast Furnaces is normally very high (400-520 kg/thm) and is also much higher than the international norm of 350-400 kg/thm. This is mainly because of higher coke ash, inconsistent coke quality, lack of PCI/CDI and also lower hot blast temperature in BFs. This phenomenon can be



corrected by focused technology inputs and operational practices in the plants. Adoption of auxiliary fuel injection technology is considered one of the important keys to reduce coke rate and must be considered in all BF's without any loss of time, wherever feasible. In some of the plants (Tata steel, JSW, JSPL, Essar etc) where PCI has been adopted and the plants are also equipped with latest features, the coke rate is much lower and at par with the world norm. All other plants have to bring in technological innovations and improve quality of inputs to reduce/replace scarce and costly inputs like coke.

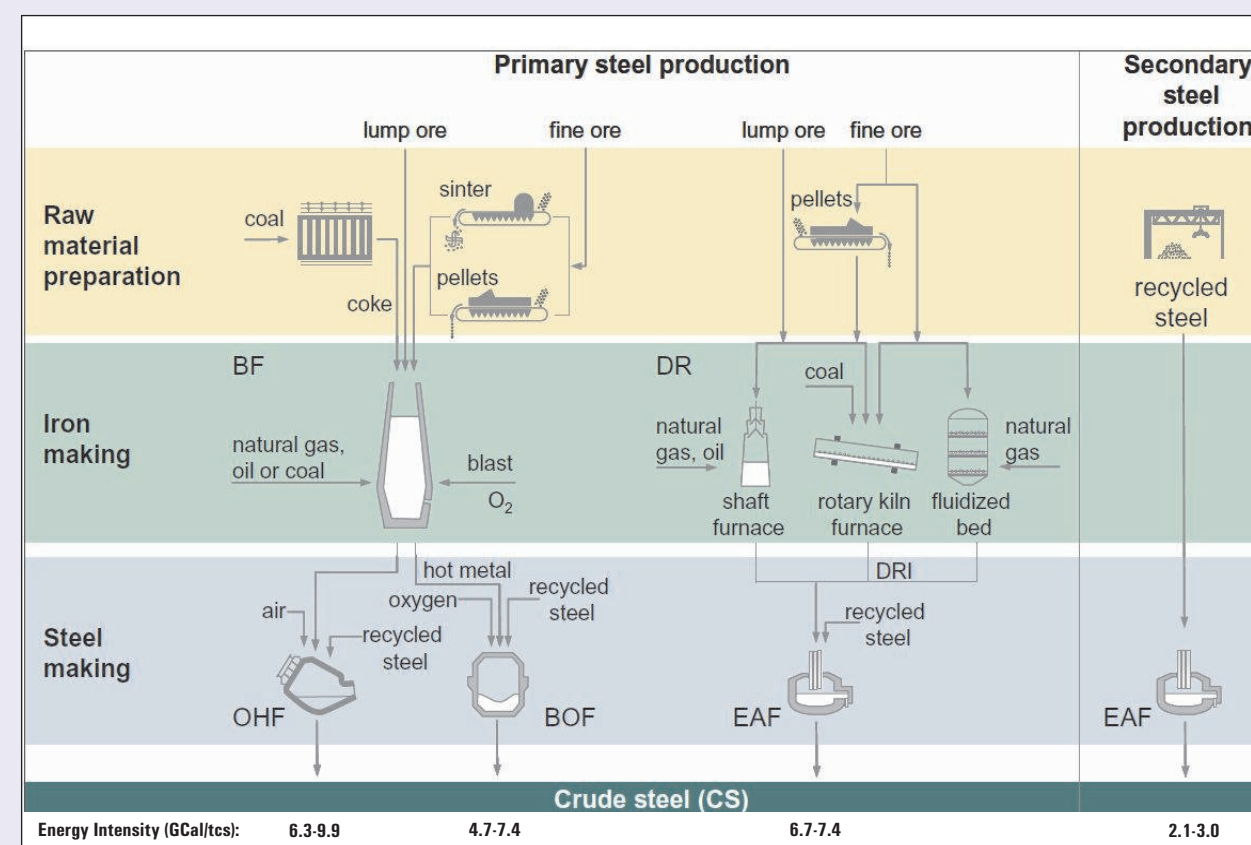
• Pulverised Coal Injection(PCI)/ Coal Dust Injection(CDI) rate:

In general, PCI/CDI technology is limitedly adopted in Indian BF's. Secondly, wherever it had been adopted, the injection rate remained limited mainly because of a number of problems, viz. inadequate hot blast temperature, poor coke quality (M40 and CSR), lower level of oxygen enrichment, very high slag rate, higher alumina content and higher viscosity of slag, poor sinter quality and wide

variation in coke quality. Lately, the scenario is changing fast. CDI rate in some of BF's in Tata Steel, JSW and JSPL is exceeding 100 kg and is likely to reach 150 kg in the near future. The technology needs to be adopted in all BF's sooner or later in order to reduce dependence on coking coal besides some other complimentary benefits.

• Energy consumption:

Energy consumption and coke /fuel rate are closely linked. Like coke/fuel rate, Energy consumption in Indian integrated steel plants is high and varies in the range of 6-6.5 Giga Cal/tcs as compared to 4.5 - 5.5 G. Cal/tcs in benchmark companies abroad. Accordingly, GHG emission is also high eg. 1.5 times when compared with similar plants abroad. This is mainly because of prevalence of obsolete technologies like ingot casting, Open/Twin hearth furnace, Pusher type reheating furnace, limited adoption of energy conservation and waste heat recovery facilities as well as poor quality of raw material specially high gangue (alumina + silica) in ore and high coke ash, low level of PCI/CDI, low level of automation/ control, resulting in higher fuel rate and hence higher energy consumption.



• LD Productivity:

LD productivity in Indian steel plants (No. of heats /operating converter/year) vary widely. Productivity in newer plants like RINL, JSW, Tata Steel is quite high in the range of 8000-9000 heats as compared to over 10,000 in the internationally competitive plants. In other plants, however, the productivity is much lower. This is mainly because of limited adoption of secondary refining facilities and constraints in quality of hot metal viz. higher silicon, phosphorous or sulphur etc requiring longer process time to remove these impurities resulting in lesser number of tappings, inadequate capacity of oxygen plants, logistics both up and down streams, and above all, poor automation and control. However, the scenario is changing gradually.

• BF Slag Volume:

BF slag volume is an important indicator of efficient BF operation and its productivity-- the lower the slag volume, the better it is both technically and economically. Indian Plants produce on an average 300-400 kg of BF slag which is 1.5 -2 times more compared to those in the developed countries. This is mainly because of poorer quality of raw materials viz. higher gangue content in iron ore used and higher ash in coke. Slag occupies a substantial volume of the Blast Furnace hearth and very adversely affects furnace operation. Moreover, slag is not free but consumes substantial energy and fluxes to form and melt. These explain lower production of hot metal per unit volume (i.e lower BF productivity) and higher fuel consumption. Continuance of such phenomenon does not have techno-economic sense and the industry must address the issue. We should not allow higher slag volume and the solution is beneficiation of iron ore and coal.

Most of the modern technological solutions are commercially available and what is needed is their adoption and adaptation in the steel plants. The new/green field plants which have been set up recently or are being set up, adopt most of the modern technologies and are reaping the benefits to the extent these are achievable with the type of ore/coal being used. Similarly, the older plants under their modernization/expansion plans are

phasing out some of the outdated technologies in favour of modern technologies. However, a lot needs to be done and the process is very slow.

In addition to the mother technologies/ equipments, there are selected technologies which primarily aim at improving energy efficiency and reducing environmental pollutions. There are large numbers of references for such energy efficient, clean and green technologies in National /International publications like State of Art Clean Technology Hand Book of APP- Steel Task Force, New Energy & Industrial Technology Development Organisation (NEDO) Handbook and EU Best Available Technology (BAT) Handbook. The Industry is well aware of these technologies but actual on-ground implementation is lacking. The Secondary steel sector also lacks knowledge about BATs relevant to the sector. Dissemination of knowledge in this regard is required and everyone is expected to adopt these. It is imperative that the steel industry makes critical assessment of these technologies and adopts them by evolving short term and long term programmes so as to improve the technological face of the Indian steel industry. Government initiatives as lately initiated in China through a combination of voluntary initiatives and deterrents/legislations are also called for.

A barrier analysis in existing plants would show that all the modern/state-of-art technologies/ facilities may not be retrofitted in the existing plants due to space constraints or design/technological constraints/impairity. Therefore, in such cases, until the whole plant is dismantled or whole shop is phased out; it may not be possible to adopt the latest / state-of-art technologies in these plants. So, under the national/international obligations under the backdrop of Climate Change initiatives, these plants have to evolve their short term and long term strategies to gradually phase out such obsolete technologies/plants in favour of modern, state-of-the-art, clean and green technologies.

Innovative technological solutions need to be evolved also for the IF sector to enable them to produce quality steel with low phosphorous and sulphur. Poor steel quality issue is a matter of concern. As a pre-requisite, therefore, this sector is

required to be fully brought in, in the national information main stream. Further, Government intervention towards pursuing/ promoting R&D or other strategies to produce high quality steel with reduced Phosphorous, Nitrogen & Sulphur content in steel produced in IF may be needed through modification/up-gradation of technology.

It is worthwhile to note that about 40% crude steel in India is produced by the mini steel plants-EAFs and EIFs. Most of these plants are ill equipped to bring in or acquire technological innovations of their own on cost considerations. There are well established technologies in EAF sector but their actual adoption in the industry is limited. Similarly in EIF sector also technological upgradation is

needed to improve their productivity, reduce energy consumption and improve the quality. Rerolling sector also requires technological intervention in the form of Scientific/ computerized design of reheating furnace to ensure higher productivity and energy efficiency. However, higher cost of all such up gradations has proved to be the deterrent and the industry is therefore following their business as usual in the pursuit of survival. To minimize the gap in technological profile of these plants, it is considered necessary to find some innovative strategy jointly by the Government and the industry.

Status of Beneficiation & Agglomeration of Raw Materials

Presently, most of the steel plants wash and (partially) beneficiate their primary raw materials particularly, iron ore and coal. But adoption of the modern or deep beneficiation techniques has been very limited. Indian coals are characterized by high ash content with very difficult washability characteristics. These coals require high precision washeries with much finer technological controls. These are not available in the washeries of Coal India Limited (CIL), which is the main supplier of washed coal in India. As a result, as against commitment of CIL to supply washed coking coal with 17% ash, actual ash content of coal being supplied is 19-20%. This has resulted in dependence on imported coking coal for more than 75% in plants like SAIL, to meet the quantitative gap and also to meet quality requirement. Tata Steel has adopted superior beneficiation technology and is producing 13-14% ash coal with good yield. Tata Steel is also pioneering towards production of 8% ash coking coal for the first time in India.

However, the overall scenario on iron ore and coal beneficiation remains unsatisfactory and requires improvement. It is the need of the hour that CIL may undertake necessary due diligence of their existing and upcoming washeries to explore the possibility of further lowering the ash content from the current level of around 20% to at-least 12-13%. This is one of the biggest challenge facing the Indian steel industry and must be addressed on priority.

Because of the specific nature of the feed materials like high gangue ore and high ash coke, Indian steel plants end up with high volume of slag resulting in poor productivity and higher energy consumption. Techno-commercial solutions of this established alibi is called for urgently; and as an example if blast furnace slag volume is below 300 kg/thm, the high Al₂O₃/SiO₂ ratio does not have significant impact.

The undesirable gangue from ore/coal needs to be removed as early as possible in the overall process, and wherever possible at room temperature. This calls for extensive beneficiation of Indian iron ore and coal by developing relevant technologies in-house.

The R&D work done in Europe and Japan and even in the United States did not concentrate so much on raw materials as they bought the best from elsewhere and contributed most significantly in world steel production. This is however, history now, and today focus of iron/steel making is shifting to developing countries like China, India and others. Naturally, we have to develop our own solutions to our perennial problems on priority as a National Policy.

There is a general belief that any ore of any impurity level can be beneficiated by selection of a suitable beneficiation process. Magnetite ores are easily beneficiated regardless of the initial iron level. Dry / Wet magnetic separation techniques are found suitable for the beneficiation of iron ores containing magnetite. However the same logic is not applicable for Hematite ores. Along with hematite, there are few iron bearing minerals such as limonite, goethite etc which have inherent lower iron values. The frequently present gangue minerals / substances with hematite are gibbsite and clay. If the iron bearing minerals containing low iron and the gangue are interspersed as fine particles in hematite, beneficiation to higher value of iron (65% and above) will become difficult. Very fine grinding of the ore to liberate the gangue particles will render the process uneconomical due to:

- Higher grinding energy
- Reduction in separation efficiency due to higher misplacement (fineness and higher surface area of particles are responsible for misplacement)

- Dewatering problems of the product and tailing.

Some of the Indian steel companies also claim that total beneficiation of raw materials (to bring them at par with the best quality) may not be economical and if this is resorted to, Indian steel may not remain globally competitive. It is also claimed that beneficiation processes involve crushing, grinding, physical/chemical separation of gangue followed by agglomeration, all of which are very expensive and make the product unviable. This is an area which needs further due-diligence to establish a balance between the optimum quality of resources/inputs and techno-economics of steel production. However, this must include the crucial issues like higher energy consumption and CO₂ emission.

Iron Ore Scenario

Over the past several decades, hematite iron ore has been used extensively in the steel industry as a prime raw material. It is estimated that upto around 60% of Indian ore mined is in the form of fines with relatively lower grade of iron and high level of impurities. It is also one of the main reasons to explain why the performance of blast furnaces in India is at lower levels in comparison with the developed countries and also some of the developing countries.

In order to increase the efficiency of blast furnace, the industry needs to ensure that high grade ore with higher iron content and minimum content of alumina & silica (2-3%) are made available and used. As against this, iron ore used in Indian steel plants suffer from several drawbacks namely, lower Iron content and high levels of impurities (Fe: 63.5-64%, Alumina +Silica: 5 - 6%) besides several unfavourable metallurgical characteristics.

The conventional iron ore processing circuits comprise two/three stage crushing, wet screening followed by processing in mechanical classifier to produce iron ore lumps (10-40 mm) and sinter fines (- 10 mm). Only in a few selected mines, the slime (- 0.2 mm) generated during the above process is treated in a cyclone and/or magnetic separator to recover enriched iron ore fines thereby reducing slime generation. However, these techniques hardly enhance the iron content by 2 to 3 per cent with marginal reduction in gangue constituents. It

has been observed that removal of alumina from the ore body by simple washing is limited to only 30-35%. So, other extensive beneficiation routes need to be adopted. Further, slimes to the tune of 15 to 20% of run-off-mine (ROM) is generated as waste causing environmental and ecological imbalances. This has to be minimized by extensive beneficiation of slimes across the industry.

Iron Ore Slimes

Most of the iron ore mined in India are generally soft and friable in nature and generate large quantities of fines and slimes during mining and processing. In India around 10 million tonnes of such fines and slimes containing around 50-60% Fe are being generated at current rate of ore consumption per year. These fines/ slimes have higher amount of silica and alumina and cannot be utilized directly in conventional furnaces of iron and steel making. Therefore, the fines/ slimes are either separately stockpiled or discarded as tailings due to lack of suitable beneficiation techniques. These fines and slimes also occupy huge space and cause environmental and ecological problems to the surrounding areas. The proportion of fines and slimes produced will steadily increase owing to the increase in iron ore mining and processing, unless appropriate technologies are developed and adopted to increase the yield of concentrates and thereby reduce the quantum of generation of slimes. Besides industry, the Government has a role to play in the area.

Considering the gradual depletion of high-grade ore reserve, it is essential to recover the additional iron values from these slimes, not only to earn additional revenue to iron ore industries but also from the conservation of mineral wealth point of view. It may be noted that today's rejects are tomorrow's input raw material.

The Indian Steel/Mining Industry is concerned about the issue and some of them are already finding out ways to beneficiate/utilise slimes, as per details given below:

- SAIL has taken up a few research projects in the area of slime beneficiation. Some of these are: a) Installation of an innovative slime beneficiation system at Dalli mines, comprising of Fluidized Bed Classifier (FBC), hydro-cyclones and Slow Speed

Spiral Classifier (SSSC). b) Installations of Stub cyclones by replacing conventional hydro-cyclones and introduction of de-sliming cyclone (Second stage) at Meghahatuburu mines for recovering concentrate from slimes. SAIL has further taken up one slime beneficiation project at Dalli mines comprising of cyclone and medium intensity magnetic separator to ensure 100% slime treatment and another ambitious R&D project for beneficiation of iron ore slimes of Barsua mines (consists of goethite and gibbsite minerals) to recover the valuable iron minerals to its maximum from the slime rejects.

- Tata Steel has also developed in their R&D laboratory an innovative method for beneficiation of slimes. They are presently in the process of setting up a pilot/bench scale plant for beneficiation of slimes from Joda mines.

- Essar Steel is also working in this area for recovery of iron values from slimes at their Bailadila and Joda mines. They propose to setup a lab scale (500 kg/hr) facility for this purpose.

- In tune with the others, JSW is also actively considering this issue seriously and detailed R&D work is being pursued.

- NMDC, NML and IMMT have also done considerable work in development of process flow sheet in beneficiating different grades of iron ore/ slimes in their R&D Centres. Such flow sheets have been supplied to many Indian companies.

Lean/Low Grade Ores

The future of Indian steel production will mostly depend on sinter or pellet making due to the dwindling of high grade ores. The major iron ore resources that would be available in future are (i) low grade ores (containing less than 55% Fe and high alumina & silica) (ii) banded hematite quartzite (BHQ)/ banded hematite jasper (BHJ)/ banded magnetite quartzite (BMQ) which typically contain 30%-40% Fe but are characterized by very low alumina but higher silica, and issues of beneficiation are different than that of conventional low grade hematite ores.

Large reserves of such banded iron ore deposits are available in India, which are currently not being exploited/used. Extensive Laboratory scale R&D

work have been done or are being done at NMDC, Hyderabad, NML, Jamshedpur, IMMT, Bhubaneswar, and companies like Tata Steel & JSW Steel Ltd. have also initiated R&D work in this area, details of which are enumerated below:

- NMDC has carried out extensive laboratory and pilot scale testing to beneficiate BHJ/BHQ available in Donimalai (Karnataka) iron ore mines of NMDC. Based on the optimum process flow sheet developed at their R&D centre, NMDC is setting up a 0.36 MTPA capacity mini beneficiation plant at an estimated cost of Rs. 150 crore to process BHJ/BHQ. This is going to be one of the first plants of its kind in India. Based on the experience at Donimalai they propose to set up similar facility for beneficiation of BHQ/BHJ at Bailadila.

- Tata Steel has already initiated lab scale work particularly to address still lower varieties of BHJ/BHQ containing 40-45% Fe. They are now going in for a bench scale facility soon.

- JSW Steel has recently setup full fledged Lab scale iron ore beneficiation facilities including BHQ/BHJ. Based on the lab scale results, they are in the process of setting up a pilot scale plant.

However, ores like BHQ/BHJ and BMQ are available in plenty in the states of Orissa, Chattisgarh, Jharkhand and Karnataka. Since these sub marginal ores are the potential future deposits, detailed and extensive R&D work including pilot scale studies are considered necessary beyond the present initiatives leading to commercial production of concentrates and pellets.

The other major challenges are the utilization of low grade ores with high alumina and silica <55% Fe, which are abundantly available in India, for sinter or pellet feed and value addition from the waste (slimes with very low Fe) generated during processing of these ores. Unfortunately, there are technological gaps and beneficiation circuits to process such low grade ores with maximum/ acceptable yield that are not available in India. As a result, Iron ore with less than 55-58% Fe is discarded as overburden or waste and is dumped. This results in reduction in mine life.

The technological challenge is to beneficiate these iron ores in order to improve their iron content to around 65% Fe by development of relevant

method of beneficiation to reduce the slime generation and to achieve reasonably high yield through recovery of iron values. NML and IMMT have done substantive R&D on several samples at laboratory scale. However, nature and characteristics of iron ore drastically vary from region to region and process developed for one may not be suitable for the other. Therefore, beneficiation circuit has to be established and optimized for all such ores in laboratory scale followed by trials in pilot/commercial scale expeditiously with special emphasis on enhancing recovery and reducing rejects. Recently Ministry of Steel has assigned a R&D project to NML, Jamshedpur to develop indigenous viable technology for effective utilization of low grade iron ore including BHJ/BHQ/BMQ, fines & slimes to produce concentrate with 65% Fe.

Further, it is worth noting that the generation of tailings cannot be fully avoided in any iron ore processing plant particularly those having to deal with low grade ore. This can be minimized to a large extent by using modern beneficiation techniques including resorting to beneficiation of slimes. Therefore, innovative use of the tailings has to be found out in areas other than iron making. IMMT, Bhubaneswar is pursuing R&D in this area to utilize tailings for building materials, ceramics, foamy bricks, waste water treatments, high value chemicals and phytoremediation, for growth of specific plants and removal of harmful components leading to zero waste concept.

Agglomeration (Sintering /Pelletisation)

Like the beneficiation of iron ore and coal, agglomeration of ore fines has also to be addressed on priority basis in all the iron and steel plants as a National Policy to reduce dependence on lumpy ore, to utilize fines including low grade fines and also to avail associated techno-economic benefits.

Sintering

Today, the integrated steel plants are equipped with captive sinter plant. The sinter plant productivity and quality in India in modern plants is very high and comparable to many in the advanced countries like Japan and Europe. However, the general, technology

profile, productivity and energy consumption of most of the sinter plants, are not comparable to modern plants abroad, mainly because of older technology, limitations in quality of raw materials and lack of energy conservation technologies. Moreover, the actual quantity of sinter produced in most of ISPs is limited thereby limiting the sinter charge in the BF to around 60-70% only. Again most of the Mini BFs have no sintering facility. Naturally, there is an increased dependence of the BF based plants on use of lumps resulting in poor techno-economic parameters in iron making in BF.

Further, a number of energy saving technologies namely, increased use of multi slit burners, proper MgO addition etc. are available which have to be introduced in the existing sinter plants to make them more energy efficient. Similarly, measures available for increase in production and productivity from existing facilities viz. use of super fines in sinter mix (e.g. HPS process), granulation equipment, high agitating mixture, extension of grate width, increased bed height/width and suction etc. have to be introduced selectively. Energy conservation and reduction and Emission Control in Sinter Plants are challenging tasks and adoption of modern energy conservation and pollution control technologies need to be considered on priority.

Since most of the iron ore fines are combination of hematite-goethite and hematite-limonite, the sinter plant and its performances are adversely affected due to high fusibility and high porosity of iron ore fines. New technology has to be developed to reduce the porosity of iron ore fines and fusibility characteristics by preheating of iron ore fines, granulation, etc.

Pellet sintering technology, which combines pre-balling and sintering process holds promise to take care of the availability of finer grade iron ore fines. This technology is extensively used in China and some preliminary work in R&D scale has also been done in India by NMDC. Recently NML has also initiated extensive R&D work with Government Budgetary Support through Ministry of Steel for developing deep beneficiation & agglomeration techniques.

Pelletisation

In technologically advanced plants abroad, the

preferred burden in BF is a mix of Sinter and Pellet (65-70% sinter and 15-25% pellets) with minimum dependence on lumps as against the Indian scenario where the BF burden comprise 60-70% sinter and balance as lumps. Pellet use in BF in India is practically missing so far, (except in JSW Steel and JSPL), mainly due to inadequate availability of pellet, comfortable availability of lumpy ore and also higher price of pellets vis-à-vis lumps. With abundant availability of high grade iron ore fines, direct sintering of these ores was considered a viable and economical option, and fine grinding of the ore for pelletisation was not considered. Thus, pelletisation of iron ore fine has not been very popular in India.

However, now having realized that reserves of high grade ore would not last long to sustain the long term growth of the Indian steel industry, complex beneficiation of low grade ore followed by pelletisation has become a prerequisite. The scenario is therefore, fast changing and several new pellet plants are being commissioned/ planned by steel companies viz. JSW Steel, JSPL, Tata Steel, SAIL, Essar Steel and RINL which will use beneficiated iron ore fines as pellet feed. Besides, merchant pellet plants are also being set up by several entrepreneurs including the iron ore miners. It is expected that Indian BFs will also use 85-90% agglomerated burden comprising sinter and pellets soon and given this, coke rate and productivity are also expected to improve.

Available technologies for production of pellets from the West are essentially in large scale, in the order of several millions of tonnes. On the other hand, the need of the hour is to have cost effective small capacity pellet plants, to suit the need of the very small mine owners. If such technologies and plants are encouraged, iron ore fines so far exported could be processed indigenously reducing dependence on export. This would also prove beneficial to coal based DRI plants which are dependent on lumpy iron ore. However, the possibility of setting up large merchant pellet plants even based on iron ore fines from a number of mine owners may also be examined mainly because of techno-economic consideration. All these issues need to be resolved on priority, for which Government intervention in the form of incentives for setting up of Beneficiation & Pelletisation

facilities, or waiver of import duty on imported technology/ equipment may be desirable.

Of late the issue of pelletisation including developing appropriate technologies for Indian ore is receiving the attention of the Indian entrepreneurs. Several units have resorted to imported Chinese technologies. Many of such units have faced acute problems in adaptation of Chinese Technologies in Indian condition and are finding solutions after extensive R&D intervention. Other players are looking at other sources for procuring pelletisation technology.

There are still technological challenges with pelletisation of certain varieties of iron ore available in the country. RDCIS, SAIL has recently taken up one R&D project for development of pilot scale pelletisation technology of Goethitic/Hematite ore. Under this project it is proposed to develop pilot scale pelletisation facilities based on comprehensive laboratory scale trials backed with theoretical exercises and development of mathematical models with an objective of setting up an appropriate commercial pellet plant under Indian conditions.

In short, there are many problems / challenges in the iron ore areas and specific programmes need to be evolved and strengths need to be built in order to address them. More specifically, the areas which need to be addressed seriously are:

- Ore mineralogy- particularly, complex and difficult to treat ores such as goethitic and limonitic, oxidized ore etc.
- Process development for beneficiation of lean grade ores, low grade ores, low grade fines and tailings/slimes
- Agglomeration including sintering and pelletisation
- Modeling and prediction of process performance
- Sustainable raw material preparation
- Pilot scale mineral processing /engg/designing facilities
- Data renovation for designing commercial concentrate
- Preparation of pre-feasibility report

Coal (Coking and Non Coking Coal)

Coking coal is used in the production of coke which in turn is used in the blast furnace for the production of pig iron or hot metal acting both as a source of heat and as a chemical reducing agent. However, the coking coal reserves constitute only about 14 % of the total coal reserves of 252 Billion Tonnes in India. Due to overall shortage of coking coal and very limited availability of good quality, low ash coking coal, imported coking coal with low ash content is being used. As a result, the cost of steel increases as it is highly sensitive to coking coal prices. The requirement of coking coal will steadily increase due to increase in steel production.

Looking into the limited reserves of coking coal in India, the scientific development of coking coal resources as well as development of appropriate cleaning technologies to ensure lower ash with higher yield assumes greater significance in the overall national interest. Since India has large reserves of non-coking coal, the possibility of utilizing non-coking coals for metallurgical coke can be considered. In order to achieve the same, the reactive components of coal which are vitrinite, pseudo-vitrinite and exinite must exist in proper proportion leaving the inert components to minimal value. Besides, anisotropic mosaic grain size has to be developed during the formation of coke. This can be achieved with thorough active research in bench and pilot level scale. New coke making technologies like Dry Cleaned and Agglomerated Pre-compaction System (DAPS) may be considered towards maximizing utilization of non-coking coal in coke making without much adverse effect on coke characteristics.

In India, the reserves of prime coking coal is very low and most of available reserves of coking coal fall under the low volatile medium coking (LVMC) coal which are not used in iron making today because of technological limitations in washing these coal, which are inherently of very high ash content (25-35%), with optimum yield in the conventional washeries. Coal India Ltd. and Steel companies must endeavour to find out some alternate / innovative method for beneficiating such coal for the use in iron and steel industry.

Tata Steel has taken up innovative steps to reduce ash in coking coal. They have already succeeded in getting

13-14% ash clean coal from high ash coking coal adopting conventional methods of beneficiation and efforts are on for reducing the ash further to around 8%. Laboratory scale studies have been completed and now they are in the process of setting up a pilot scale demonstration plant. Ministry of Steel has also recently assigned IMMT Bhubaneswar R&D project for production of low ash (10% Ash) clean coal from high ash Indian coal including beneficiation/desulphurization of North East coal and recovery of ultra fine coking coal from washery tailings.

There are other established methods/ technologies for reducing coking coal consumption in steel industry. These include production of sponge iron in rotary kiln and coal dust injection (CDI) in blast furnace. CDI drastically reduces (upto 30- 40% or even more) dependence on coking coal in iron making through blast furnace. However, the technology requires appropriate quality of non-coking coal characterized by low Ash: 12%, VM: 12-15% CSN: (-) 3%, HGI: (+) 75%, Ash Fusion Temp: IDT-1300o C and Final Flow Temp: 1500oC. Such type of coal is not readily available in India. This also requires R&D intervention to beneficiate relevant raw coal to produce clean coal for utilization in CDI fully or partly.

Extensive studies are required to develop suitable washing/cleaning technologies for Indian non coking coal as it is also difficult to wash coals with high ash and more near gravity materials.

In other words, the following are the key areas of concern and suitable action plan may be evolved to address these issues:

- Detailed characterization of coal for resources evaluation
- Improving the performance of existing coking coal washeries to enhance the clean coal yield.
- Recovery of additional clean coal from middling and fines from the coking coal washeries.
- Magnetic Carrier Technology for purifying the washery recycled water.
- Improving the floatability of ultra-fine coal.
- To produce 10% ash clean coal from high ash coking/non coking coal.
- Development of Jig control system for coal beneficiation.
- Development of advanced dewatering techniques.
- Dry beneficiation of non-coking coal to reduce ash content.

Research & Development Needs & Thrust Areas

Present Status of R&D

The first R&D Laboratory (or R&C Laboratory) in steel sector in India was set up in 1936. SAIL set up their R&D Centre in 1972. Newer plants, such as RINL, JSW, Essar, Ispat and JSPL came into being in 1990s. Most of them have R&C set up and R&D laboratories are at different stages of formation/ development. Besides these steel plants, the Government has also set up several National/ Regional Laboratories/Institutes under CSIR under the Administrative Control of Ministry of Science & Technology. Amongst them, National Metallurgical Laboratory (NML), Jamshedpur, Institute of Minerals and Materials Technology (IMMT), Bhubaneswar and to some extent AMPRI, Bhopal and ISM, Dhanbad are associated with R&D in iron and steel including minerals and fuels. In addition, Academic Institutes like IIT, Kharagpur, IIT, Kanpur and others are also engaged in carrying out sponsored research work in the area of iron and steel.

Amongst the steel companies, substantive R&D is carried out only at Tata Steel Ltd., Jamshedpur and Research & Development Centre for Iron & Steel (RDCIS), SAIL, Ranchi. Both these companies have accomplished some significant work in the area of product development. However, major focus of work in these companies generally relates to incremental technology development in order to address the present and short term needs of various production units viz. improvement in existing processes, improvement in energy efficiency, reduction in cost of production and short to medium term product development. Their contributions towards disruptive technology development like innovative/path breaking processes/technologies have not been noteworthy. No doubt, some sporadic efforts were made but

nothing notable has been commercialized. This is mainly because of limited interest and low priority accorded to R&D by the management of the steel companies, thereby resulting in limited allocation of resources-fund, time, infrastructure and dedicated manpower as well as lack of high-end visionary Research Programmes in the pursuit of development of innovative technologies.

The R&D policy/strategy also varies from company to company. For example in PSU steel plants of SAIL and RINL, the approach is mainly bottom-up. Though some projects of basic research and scientific investigation are pursued, majority of the programs at RDCIS are plant driven, focusing mainly on plant performance improvement lacking long term strategic issues.

In other plants, by and large, similar strategies and programmes are in practice, though, the approach/ strategy is changing fast as visible from the following:

- In Tata Steel, top-down approach is pursued in respect of strategic / thrust area projects under which specific projects are pursued by the R&D Centre. Tata Steel have taken up some major initiatives and have identified several thrust area projects for development of new technology to reduce ash in Indian coking coal to 8% without reducing yield, finding ways and means to utilize iron ore slimes in iron making, generation of hydrogen gas for use as fuel from the excess heat of the steel plants and developing next generation steels for light weight automobiles etc.
- JSW Steel also pursues a top-down approach. A sub-committee of the Board, monitors and reviews R&D projects. JSW Steel has also initiated programmes to develop process for beneficiation of low grade iron ores and BHQ, utilization of plant

wastes including dust, sludge and slime, briquetting of coal fines for Corex, etc.

NML, Jamshedpur, IMMT Bhubaneswar, BESU, Howrah and some of the IITs have recently taken up some innovative R&D programmes relevant to the Indian steel industry.

Highlights of R&D projects and programmes being pursued by major companies like SAIL, Tata Steel and some of the major research laboratories like NML Jamshedpur and IMMT Bhubaneswar on iron & steel and related areas may be perused in **Annexure-II**

In overall terms, the steel companies in India invest very little on R&D and actual investment varies in the range of 0.15-0.25% of the total turnover of the companies. Details may be seen in Table 2:

Table-2: R&D investment (in Rs Cr and as % of turnover) in India

Company	2005-06	2006-07	2007-08	2008-09	2009-10
SAIL	62.4 (0.19%)	76.8(0.20%)	101.86(0.22%)	118.2(0.24%)	107.3(0.24%)
RINL	10.4(0.12%)	11.7(0.13%)	17.9(0.17%)	17/4(0.16%)	12.7(0.12%)
Tata Steel	25(0.21%)	33(0.24%)	42.2(0.21%)	39.2(0.20%)	48.8(0.21%)
JSPL	1.74(0.06%)	2.76(0.07%)	3.36(0.06%)	3.14(0.04%)	3.3(n.a)
Essar Steel	2.87(0.045%)	9.9(0.11%)	13.77(0.12%)	15.14(0.12%)	18.4(0.17%)
JSW Steel	_____	_____	14.86(0.13%)	12.28(0.09%)	9.14(0.06%)

R&D in steel companies abroad

R&D scenario in Steel companies abroad, particularly, in China, Japan and South Korea quite is quite different. Not only the companies are equipped with full-fledged in-house R&D laboratory, they also have visible tie-up with external laboratories and Academic institutions with large outlay of funds

earmarked for R&D. Naturally, annual R&D investment is very high and reportedly varies in the range of 1-2% of their turnover:

- World’s top ranked company, POSCO, South Korea invested US \$ 359 million (Rs.1800 crores approximately) nearly 1.4% of its turnover in 2007. The success story of POSCO is a result of extensive research directed by the top management. The company has large dedicated manpower engaged in R&D and out of 736 people working there, 371 are Ph.Ds.
- Relatively, lesser known China Steel Corporation, Taiwan, a 12 million tonne integrated steel plant, spent US \$ 40 million (Rs.200 crores approx.). This works out to 0.65% of the sales revenue. This

company too has large manpower strength of over 300, of which around 100 are PhDs.

- Likewise, most of the top rank steel companies pursue extensive R&D programmes with substantial investments so as to sustain in the global competition even though they are dependent on imported raw material, high manpower cost besides saturated market. The details are given at Table-3:

Table-3: R&D Expenditure of Global Steel Companies as percent of sales turnover(%)			
Company Name	Country	2008-09	2009-10
Nippon Steel	Japan	0.9	1.0
JFE	Japan	1.1	1.1
POSCO	South Korea	1.2	1.3
Thyssen Krupp	Germany	0.6	0.7
KOBE Steel	Japan	1.4	1.4
Arcelor Mittal	Luxembourg	0.2	0.4
Sumitomo Metal	Japan	1.2	1.2
Boa Steel	China	1.2	1.7

Source: Department for Business, Innovation & Skills, Government of UK
www.bis.gov.uk/randscoreboard

China invests in steel R&D more than the investment made by the rest of the world put together. Based on the original Soviet model, subsequently adapted and dovetailed with national needs & plans, these institutions/organizations sustain growth and retain the competitive edge of their steel industry of more than 600 mtpa. There are more than 50 R&D institutes of the kinds, namely academic and basic research linked to universities; adapted applied and industrial research institutes under institutions like CSIR in India and focused industrial R&D institutes controlled by the Ministry concerned, to cater to the sector. Besides, large steel companies have their self-sustaining corporate R&D organisations.

No wonder, the Steel industry of India with limited R&D infrastructure, limited manpower and a minimal investment on R&D suffer with poor techno-economic parameters.

5.5 SAIL has corporate R&D centre (RDCIS) at Ranchi, but the total strength of their R&D manpower (2009) is around 267 and the numbers of PhDs were only 41. Further, their R&D investment is also very meagre. In Tata Steel, the scenario is only marginally better as in terms of their total R&D manpower of around 130, 37 are PhDs. In other plants, R&D investment or the strength of technically qualified manpower is only notional. Moreover, in most of these companies, R&D programmes are bottom driven with a nominal involvement of the top management. Naturally, R&D and technology issues or associated work do not get due priority. R&D engineers generally have poor rapport with operating personnel in the plants. Owing to their slow results & delivery, these engineers are generally thought to distract the production process.

Government Initiatives to promote R&D

R&D with Steel Development Fund

In order to augment R&D initiatives and to step up investment for it in the steel sector, the Government had decided in 1997-98 to fund upto

Rs. 150 crore per year for R&D projects in iron & steel sector, from the interest proceeds of Steel Development Fund (SDF). An Empowered Committee (EC) has been set up under the chairmanship of Secretary (Steel) and members from Ministry of Science & Technology, Steel Producers, Research Laboratories and Academic Institutes. There is a two tier structure for evaluation of R&D proposals under this scheme. An Evaluation Group (EG) comprising MOS, DST and DSIR evaluates the proposals and its recommendations are placed before the EC for consideration & approval. For large value projects, there are independent Empowered Board (EB) of experts for each project for review and monitoring progress.

The Cabinet Committee on Economic Affairs (CCEA) while approving the R&D scheme, had suggested creation of an institutional mechanism i.e Research & Technology (R&T) Mission headed by a Mission Director for evaluation of proposals, monitoring of on-going projects, and also serving as secretariat of the EC. However, the Committee of Secretaries (COS) on right sizing and downsizing of Government Departments decided other wise, and directed that Technical Wing of the MOS will function as the Secretariat of the EC. Therefore, Technical Wing of MOS has been functioning as the Secretariat of EC.

Actual R&D and investment thereof even under this Scheme over the years has not been very encouraging. This is mainly because of limited number of overall R&D infrastructure in steel companies or in Laboratories resulting in limited number of applications. In between, R&D work under the scheme also had a slow pace because of limited availability of liquid fund in the SDF. Ministry of Steel took some pro-active initiatives. However, the result is not very encouraging.

Actual status of R&D projects sanctioned and investment thereof under this scheme is given in Box-1.

Box-1: Status of SDF assisted R&D Projects

No. of projects approved since inception (1998):68	
Total cost of the 68 projects (Rs. Crore):	544
Total SDF assistance (Rs. Crore):	263
No. of Projects Completed so far:	35
No. of Projects stopped :	09
No. of Projects under implementation:	24

Under the scheme, once the R&D project is approved by the EC and sanction letter issued (by TW), Joint Plant Committee (JPC), being the Secretariat of SDF Managing Committee releases the SDF money as per terms and conditions of the sanction letter. JPC also monitors the utilization of fund later.

Since inception, Rs. 146 crore (approximately) has been disbursed from SDF on completed and ongoing R&D projects. Year-wise release of fund is given in Table-4

Table-4: Year-wise disbursement of SDF funds during last 5 years

S. No.	Year	Investment (Rs. Crore)
1	2006-07	19.41
2	2007-08	10.12
3	2008-09	7.27
4	2009-10	11.26
5	2010-11	20.65

Lists for Projects Completed, Projects in Progress and those abandoned may be referred in **Annexure III**. Some of these projects relate to basic/fundamental research whereas others relate to applied research i.e to find out ways to solve problems being faced by the industry. Research results of several R&D projects have already been implemented by plants under SAIL and in Tata Steel, resulting in improvement in productivity, reduction in energy consumption and pollution etc.

Highlights of achievement in respect of a few flagship projects:

- A high value joint project given to NML, Tata Steel and SAIL has helped in better understanding of the intricacies inside blast furnace using probing techniques for the first time in India, resulting in improved productivity and reduced energy consumption.
- A real time process simulator has been developed by NML, Jamshedpur with a purpose to facilitate better Blast Furnace operation and improve its productivity, reduce coke rate etc. This

was implemented at Bokaro Steel Plant and is also under implementation in Bhilai Steel Plant.

- Another joint project between SAIL and Tata Steel has helped them to develop Casting technology/ process to enable them to produce improved quality steel in respect of certain critical applications like forging quality steel, welding electrode quality steel, PC strand quality steel and Crank Shaft Quality steel through the adoption of EMS and closed casting route resulting in substantial savings in cost of production and significant improvement in yield and quality of such steel. This has also led to substantial savings on the part of the consumers i.e. Engineering Industry.

- A project given to RDCIS, SAIL has resulted in development of intelligent mill setup model for dynamic and adaptive control of plate mill resulting in rolling of plates with much closer tolerance.

- A project on development of customized zonal lining design and programme maintenance schedule has helped RSP (SAIL) to reduce refractory consumption in LD converter and steel ladles.

- A project on simulation of thermo-mechanical processing and hot workability of high strength steel has enabled SAIL (RSP) to produce HSLA steel with higher strength and superior impact toughness properties.

- A project on modeling and control of microstructure and mechanical properties during hot strip rolling at Bokaro Steel Plant has helped them to control quality and productivity of hot rolled strip.

- A R&D project given to Tata Steel and Jadavpur University on development and characterization of spot welding techniques has helped in recommending welding process parameters for coated steels to several automotive customers.

- A project on fatigue behavior analysis given to Jadavpur University and Tata steel has given insight in to the performance of welded high strength steels.

R&D with Govt. Budgetary support (Plan Fund):

The Government has allocated Rs.118 crore from

Plan Fund, for promotion of R&D in Iron & Steel Sector during the 11th Five Year Plan. As per the approval of the Expenditure Finance Committee (EFC) the three broad areas to be pursued under this scheme are:

- Development of innovative/ path breaking technologies for utilization of iron ore fines and non-coking coal.
- Beneficiation of raw materials like iron ore, coal etc. and agglomeration.
- Improvement in quality of steel produced through the induction furnace.

Eight R&D projects have so far been approved within the aforesaid 3 broad areas (Annex -IV) with a total cost of Rs.144 crores involving Plan Fund of Rs.96 crores (approx). Actual work in these projects started w.e.f. 2010-11. So far Rs.39.02 crores has been released and the year-wise release of fund is in Table 5

Table 5: Year-wise disbursement of Plan Fund

S. N.	Year	Fund released (₹ in crore)
1.	2009-10	4.13
2.	2010-11	27.05
3.	2011-12 (Planned)	29.00

Major projects covered under the scheme include exclusive R&D initiatives to upgrade Indian low grade iron (including BHQ/BHJ) and Indian coking/non-coking coal. Presently, these projects are at the preliminary stage of work but when completed, and if results are successful; these may go a long way in making available high quality inputs from lean ore/coal for the iron/steel industry.

R&D under Steel Research and Development Mission (SRDM)

Having noted that the outcome of SDF assisted projects was not satisfactory, the Ministry of Steel reviewed the position; after thorough brain storming and consultations with the scientists, technologists and industrialists, a task force was set up with an aim to review the existing institutional

infrastructure, identify gaps, assess present and the future needs of the industry and to suggest a blue print for pursuing innovative/path breaking technologies.

In pursuance of the recommendations the Empowered Committee approved a project for setting up a virtual Centre at Hyderabad (AP) and sanctioned Rs.50 crores as an initial corpus to sustain R&D projects and Rs. 15 crores to meet the initial establishment and running cost for the first three years upon which the centre is expected to be self-reliant. Follow up actions in this regard were being taken towards actual setting up of the centre at Hyderabad. SRDM was registered as a Society at Hyderabad. However, due to limited liquid fund availability in SDF, it was decided later in consultation with major steel producers by MOS to fund the SRDM by contributions from the steel companies as a joint research initiative/project. Later, the steel companies showed their reluctance to extend any fund for SRDM. Consequently, SRDM could not be started due to paucity of funds at that point of time and it was decided to close this venture.

Present R&D initiatives across the Globe

Steel industry across the globe, and particularly in the advanced countries have identified climate change as a major challenge for more than two decades and have been proactive in reducing energy consumption and green house gas emissions by aggressive R&D and Technology intervention adopting the clean & green and state-of-art technologies in all areas of production. In most of the advanced countries, these improvements have led to reductions of 50% (approx.) in specific energy consumption since 1975 and most of them are now operating close to the theoretical limits, leaving limited scope for any further large reductions. However, Chinese and Indian steel industry roughly account for about 50% of world steel production and are high in energy intensity and CO2 emission have also taken various steps , though a lot needs to be done to reach the level as in advanced countries.

To improve further in terms of energy efficiency or CO₂ efficiency, a paradigm shift is needed in industrial production processes to reduce or bypass the consumption of coal/coke in iron /steel making. Towards this objective, the World Steel Association launched the CO₂ Breakthrough Programme in 2003, an initiative to exchange information on regional activities all over the world. It is noted that Research is taking place for development of Concepts/Technologies in:

- EU (Ultra-low CO₂ Steelmaking or ULCOS), (Rs 360 crore project)
- US (the AISI initiative)
- Canada (the Canadian Steel Producers Association initiative)
- South America (the Arcelor Mittal , Brazil initiative)
- Japan (the CO₂ Ultimate Reduction in Steelmaking by innovative technology for Cool Earth 50 Committee or COURSE-50 initiative)
- South Korea (POSCO Breakthrough Technology)
- China/Taiwan (Baosteel and China Steel initiative), and
- Australia (Bluescope /One Steel and Hismelt Corporation)

The aforesaid R&D programmes are aimed to bring in major changes in the way iron and steel is made, within a time frame of 2020 and beyond, pursuing the following five key areas:

Coal: minimize coal consumption by adopting oxygen operation in modified BF/Smelting Reduction like Finex or similarly designed furnaces alongwith in-process CO₂ capture rather than oxy-fuel combustion and pre/post combustion capture of CO₂ and further reduction.

Hydrogen: to be used as Reducing agent in place of Coal/Coke, partly or fully.

Electron: to be used as reducing agent like Hydrogen.

Biomass: to be used to generate reducing gas.

Carbon Capture & Storage (CCS): to find out ways and means to capture CO₂ gas and Store it in deep saline aquifers, depleted oil or gas fields, in coal mines as geological storage or turned back into carbonate etc

The country/region research programmes are mostly joint collaborative research programmes involving Government, Steel producers, Consultants, Technology Providers & Equipment Manufacturers, Academic Institutions, Design Organisations and others. Highlights of Some of these programmes are:

Japan

Japanese Government through NEDO has taken up the innovative technology development programme - Course 50 in association with six Steel companies in Japan coordinated through the JISF, which aims at the development of technologies to reduce CO₂ emission by approximately 30% through reduction of CO₂ emission from Blast Furnaces as well as capture of CO₂ from Blast Furnace gas. Technology to support Course 50 includes the following:

- Development of technologies to utilize Hydrogen for reduction of Iron ore.
- Development of technologies to reform coke oven gas.
- Development of technologies to produce improved coke and Hydrogen reduction of required Iron ore.
- Development of technologies to capture, separate and recover coke CO₂ from Blast Furnace gas.
- Development of technologies to recover unused sensible heat.
- Development of holistic evaluation technologies for process.

This is a long term project to be taken up in phases-Phase one to be completed by 2020, Phase-2 by 2030 by when the technology is proposed to be developed. Subsequently, under phase-3, the

technology will be implemented. Phase-1 comprise of two steps – a budget of 10 billion Japanese Yen to be funded by the government of Japan, has been earmarked for step-1. For step-2 budget of 15 billion Japanese Yen has been estimated.

The European Union

In EU, a consortium of 48 companies from 15 European countries, have launched the cooperative R&D initiative – “ULCOS” to enable drastic reduction in CO₂ emission in steel production by at least 50%. The programme is run by a small member of partners called the core members and is coordinated by Arcelor Mittal. The programme is being pursued in two phases. Phase-1 : the research and pilot stage has already been completed in 2010 with a budget of 75 million Euro - 40% of which was contributed by EU and 60% by ULCOS consortium. The demonstration stage will take the ULCOS programme to phase-2 when techno- economic feasibility will be studied. ULCOS-2 is planned to run from 2010 to 2015. The results of ULCOS-2 can potentially be rolled out to the industry 15-20 years from now.

South Korea (POSCO)

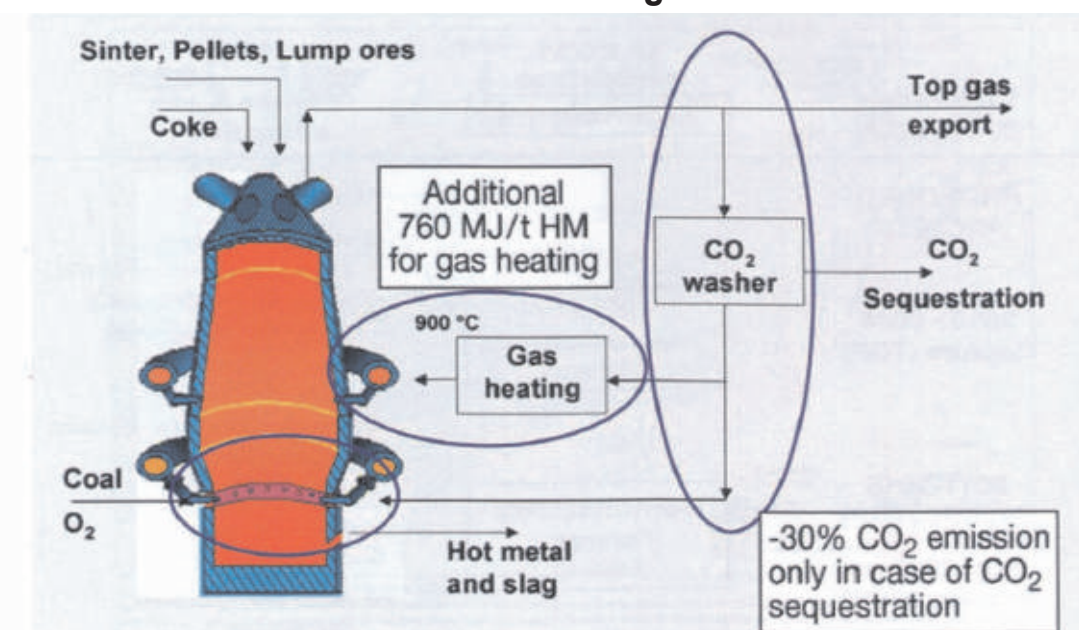
POSCO has taken up ambitious R&D programme towards its commitment to 9% reduction of CO₂ emission per tonne of steel production by 2020 investing 7 billion US dollar. The short term (2015) strategies include improvement of energy efficiency programmes. Midterm (2020) strategies include development of innovative steel making processes and the long term (2050) strategies include development of hydrogen steel making processes thereby dramatically reducing CO₂ emission.

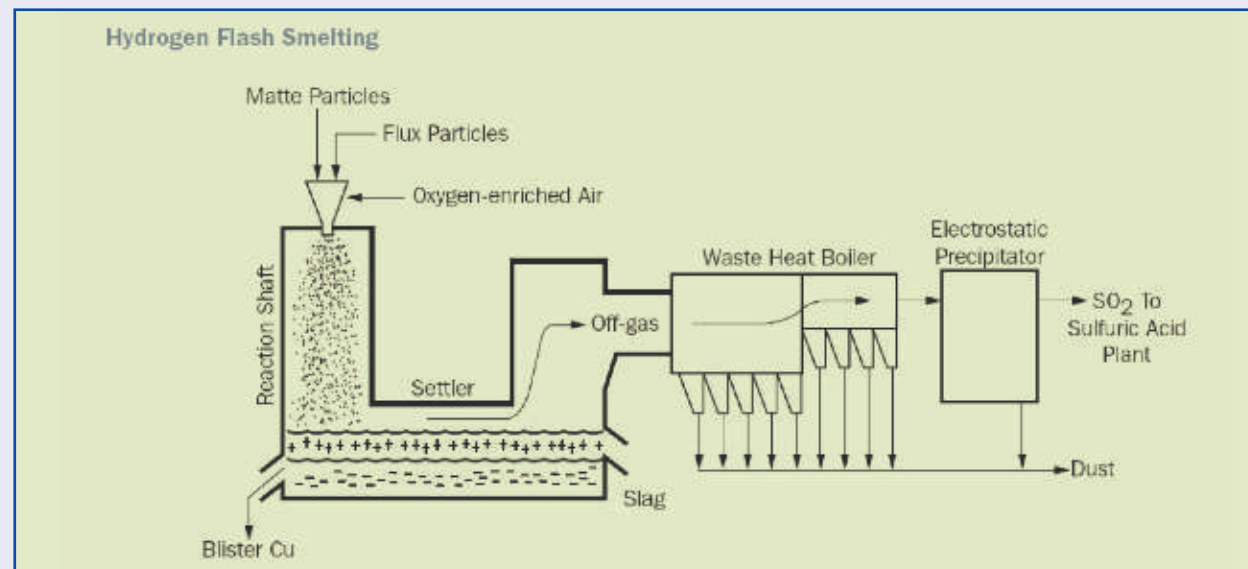
The USA (AISI)

The American Iron & steel Institute has taken up a collaborative research programme -“CO₂ Breakthrough Programme” to develop breakthrough technologies in steel making to reduce emissions by more than 50%. The three phase programmes include:

- Concept discovery and assessment (2002-2008)
- Pilot phase (2009-2015)
- Demonstration phase (2016+)

Oxygen Blast Furnace to reduce Fuel Consumption and CO₂ Emission under ULCOS Programme

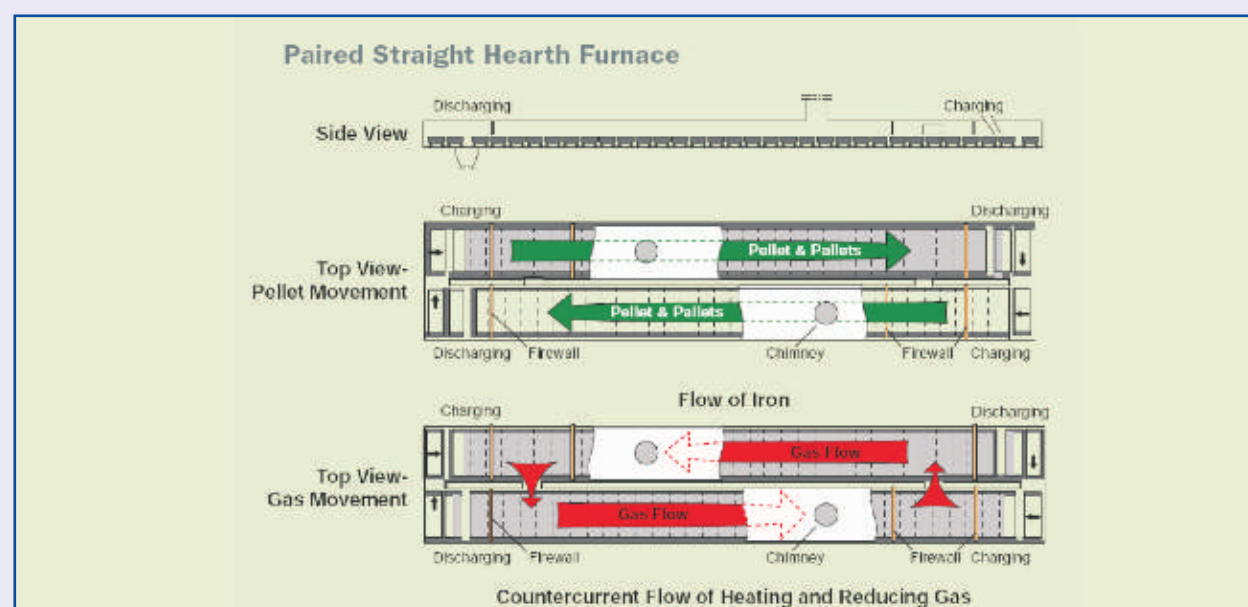




Various options being pursued under this programme include i) Technical feasibility of steelmaking by Molten Oxide Electrolysis and ii) Hydrogen Flash Smelting similar to those used in copper smelting. The budget for these two

CO2 Sequestration Technologies under the breakthrough programme.

India needs to emulate the aforesaid strategies and experiences to find unique solutions applicable for



projects is 5.6 million US dollar to be contributed by the industry.

In addition they are also pursuing a third project in the near term namely, Development of Deep Bed Reactor (Paired Straight Hearth Furnace) for DRI under funding from US Department of energy. PSHF is a high productivity, low energy iron making process that can also process steel plant waste as well as virgin iron material using coal. Additional, AISI is also pursuing development of radically new

Indian conditions particularly for its poor raw material quality having unique characteristics.

R&D Programme and Action Plan

The National Steel Policy, 2005 emphasized the need for aggressive R&D efforts to step up India's R&D expenditure and also to create state-of-the-art

manufacturing capability based on indigenous resources. With this objective in view, the Indian steel fraternity, particularly the large steel companies were requested to address the problem more seriously and endeavour to increase expenditure on R&D to 1% of their turnover, by the terminal year of the 11th Five years Plan period and to 2% by the year 2019-20. However, this has not materialized. It is felt that the individual steel companies must attach required importance to R&D and step up India's R&D investment in the Steel Sector. Government may also create appropriate environment to facilitate growth in R&D investment. Towards this objective, major steel companies must increase their R&D investment during the next five years in the 12th Five Year Plan and achieve the target of 1% of sales turnover by the terminal year (2016-17). This may be achieved through allotment of substantially increased budget by Steel companies and Government support.

Though the choice of technology will be largely determined by the entrepreneurs based on techno-economic considerations, the Government need to encourage/facilitate development and adoption of such technologies which are relevant to natural resource endowment of the country, which minimize damage to the environment, optimize resource utilization, facilitate achievement of global standards of productivity and efficiency and development of front end and strategic steel based materials. Against this backdrop, the issue of utmost importance is the R&D intervention to find out techno-economic solutions to use indigenous raw material resources. The issues have been deliberated at length in the previous chapters. Another area that requires attention is the product development to develop and produce high performance steel indigenously.

To attain these objectives the following should be the prime focus area for research and Technology development in India:

- To improve the quality of basic input/ raw materials and develop/adopt suitable beneficiation technologies to suit Indian conditions. These would include lower grade iron ores (Fe content < 55%) including slimes, high ash coking / non-coking coals

and raw materials for refractory (magnesite, bauxite and graphite) and Ferro-alloys.

- Development of alternate iron making technology suitable for indigenous raw material, including direct smelting of low grade ore using indigenous non-coking coal in view of lack of good quality coking coal and low high alumina iron ore which renders conventional iron making through Blast Furnace less attractive.

- To utilize iron ore fines including beneficiated micro fines adopting relevant agglomeration techniques like sintering and pelletisation.

- Technology for modification of coal blending covering utilization of high ash non coking coal, waste plastics for optimum coke consumption in blast furnace.

- To develop technologies to convert non coking coal into coking coal including synthetic production of coking coal.

- Emphasis on coal gasification to produce syn-gas to produce sponge iron and complete utilization of sensible heat of hot gases flowing out of iron & steel plants.

- To develop/adopt technologies/practices which have an impact in reducing energy consumption and reduce carbon dioxide emission.

- Work on alternative energy sources for Integrated Steel Manufacturing e.g. Coal Bed Methane, Natural Gas, exploratory use of hydrogen.

- Reduction of generation of waste in all stages from mining to steel making and full utilization of generated waste viz. zero waste (liquid, solid and gas) discharge.

- To focus on technologies for reducing water consumption in steel plants including programmes to ensure zero discharge of water.

- Management /recycling/utilisation of wastes including full utilisation of LD/EAF slag by designing the slag system and its chemistry through innovative approaches and/or by finding innovative applications.

- Effluent control in coke ovens through bio-chemical / microbial treatments

• Technologies have to be developed for production of high performance steel viz ultra high strength high formable steel to meet the future needs of consuming sectors like automobile, off-shore and on-shore petroleum pipe lines, CRGO Electrical Steel etc.

• Development of strategies/practices for improving rate of PCI in blast furnace to a level of at-least 100-150 kg in next five years in all blast furnaces and about 200 kg/THM including injection of natural gas, Coal Bed Methane (CBM) in next 10 years.

• Improving productivity of LD converters/EAFs including improving lining life of converter/EAF to 15000-20000 heats/1000-1200 heats respectively.

• Reduction of power consumption in EAF to below 300 KWh/tcs

• Water conservation in beneficiation and iron/steel making including exploring dry beneficiation techniques.

• Development/Adoption of compact technologies and lay out to ensure optimum use of resources and land including adaptation of technologies for Near Net Shape castings.

• Development of suitable technology/strategy for production of extra low phosphorous Ferro manganese for wide range of low carbon grades of steel by reducing phosphorous content of manganese ores.

• Development of suitable beneficiation methodology to make effective use of low grade, friable Chromite ore (less than 30% Cr₂O₃) fines, which are available in sizeable quantity in India.

• Beneficiation of raw materials required for refractories- magnesite, bauxite and graphite for use in iron/steel industry.

• Development of Mathematical modeling and simulation in process Metallurgy e.g., modeling of continuous annealing operation for IF steel strip (microstructure and texture control), integrated optimization of refining, rolling, heat treatment for enhancing properties and productivity through simulation and modeling

• Computational fluid dynamic studies for production of clean steels in ladle furnace and RH-OB

• Development of Technologies for Production of ferro-alloys using alternate technologies viz. smelting reduction of Manganese Ore, solid state reduction of Chromite ore fines/concentrates in fluidised bed reactor using natural gas.

• Development of innovative techniques for systematic use of waste refractory material for its gainful utilization in steel plants over and above the present utilization level.

• Leverage soft-ware development capability in the country and bring out optimisation packages of all activities starting from mining to out bound logistics for the steel industry - can be initiated by the R&Ds.

Keeping the Global experience in view, National programmes on R&D may cover both short/ medium term and long term strategies. The short & medium term programmes may include exploring ways and means to resolve the present problems of the industry towards improving techno-economic parameters at par with the international level through R&D and Technology intervention. The R&D projects & programmes may be industry specific and/or joint collaborative research programmes to be funded by industry with /without outside/Government funding. The long term programmes may include some of the CO₂ Break-through Concepts but relevant to Indian raw materials and purely on joint collaboration basis. Government may identify such programmes in close association with the experts and industry. Such programmes may be funded by Government to begin with and thereafter, Government assistance may taper off with balance funding from the industry. These require close cooperation between Government, Industry and experts in the field and laboratories.

R&D and Technology Development Programmes of national importance

Short-Medium Term Programmes:

a) Beneficiation/up-gradation of low grade iron ores adopting known technologies and development

of relevant technologies to beneficiate difficult-to-beneficiate iron ore including banded hematite quartzite (BHQ)/Banded Hematite Jasper (BHJ) as well as high LOI, high Blaine number ores and slimes.

b) Development of relevant technologies for Beneficiation of high ash, difficult-to-wash Indian coking/non coking coal (from 25+% to <10% ash) including low volatile medium coking coal without loss on yield, and production of better quality coke using weak/non coking coal/LVMCC.

c) Development of innovative products like CRGO electrical Steels, Amorphous Silicon Alloys (Met-glass) etc, technologies for which are not readily available from abroad.

d) Development/Adaptation of direct smelting technologies for iron making using iron ore fines and non-coking coals on line similar to Finex, Hismelt, ITmk3 or any other innovative concepts. Simultaneously, Pursuing fundamental research work for development of innovative alternative iron making technologies from low grade ore/slimes without pursuing beneficiation/agglomeration and without use of coking coal/coke like smelting reduction processes.

e) Development of appropriate beneficiation techniques for Indian magnesite (Almora & Salem sources) and bauxite (using wet leaching and firing-densification).

f) Development of niche steel products e.g ultra high strength steel with good formability and ultra fine grained steel plates/ coils/ rods (YS: 800-1000 MPa), specifically designed for Automotive Sector, Construction & Infrastructure and Energy Sector.

g) Development of suitable technologies for production of quality steel with low phosphorous & low sulphur in Induction Furnace or evolving a suitable innovative technology to produce steel economically in smaller scales of operation in place of induction furnace.

Long term Programmes:

h) Development of technology/practices for 100% recycling/utilization of LD/EAF slag.

i) Development of technology for ultra low carbon dioxide (CO₂) steel making through large collaborative programmes.

j) CO₂ sequestration in the steel plant environment starting from data base development to R&D initiatives on CO₂ sequestration through plantation and other frontier technologies through focused Government initiative along with the major companies.

k) Joint collaborative research programmes involving Government, Steel producers, Consultants, Technology Providers & Equipment Manufacturers, Academic Institutions, Design Organisations and others to pursue development of break-through technologies.

Programmes listed under short/medium term category directly concern the Indian steel industry and may be taken up on priority basis. Work in some of these areas is already in progress. More dedicated and time bound research programmes by companies as well as by the Government including joint research programmes amongst the industry with/without Government support are considered necessary. Projects like CO₂ reduction through break-through programmes are essentially very long term, collaborative research projects. Partners in these programmes should include steel companies, Technology/ Equipment suppliers/ Consultants, Research Institutions/ Universities and the Government.

Success of such joint research programmes will depend on the development of an appropriate legal, financial and governance framework and experiences from the Research Fund for Coal & Steel (RFCS) programme of Europe and COURSE50 programme of Japan could be shared. Success of such collaborative research projects would also heavily depend upon (i) clear objective, project definition, ambitious project size and corresponding fund and its support, (ii) a regular, simple 'fit for purpose' progress review mechanism directed by the designated Executing Authority on behalf of the Government, but outside the rules and regulations of the Government, (iii) nurturing a practice of successful collaboration amongst competing industry players. These may take several years to establish and it is, therefore, important that the National Policy and Programmes should be of sufficiently longer duration and there should be consistency in these matters amongst subsequent incumbents and policies.

Conclusions & Recommendations

- + Indian steel industry is trailing behind in several areas in technology and R&D which are reflected in poor techno-economic performance parameters. Main problems relate to technological obsolescence and lack of timely modernization / renovation as well as inferior quality of raw material and other inputs, inefficient shop floor practices, lack of automation & control, lack of R&D intervention. A committed effort with well thought out programme of action is, therefore, necessary to bring the Indian Steel Industry at par with its overseas counterparts. Collaborative R&D projects at national level with academic and research institutes/laboratories of repute as well as the industry to share expertise seem evident and necessary. ■■■■
- + Steel companies in developing countries, which are normally smaller in capacity, look for strategies of quick returns for further investment in production facilities. Naturally, R&D programmes which are essentially long term strategies do not get due recognition. When the industry develops in tandem with the economic growth, investment in long term options like R&D becomes considerably profitable. In Japan, US and some countries of EU, the Government investment in R&D, except for joint research programmes of national importance, is minimal. On the other hand, in developing countries like China and Russia, Government directly or indirectly facilitates R&D for all sectors of economy including steel. Indian situation is viewed similar to these developing countries and the Government support and intervention are considered logical and necessary for pursuing fundamental as well as applied research in a vital sector of economy like steel. Such a positive intervention is also considered necessary to step up R&D initiatives and investments thereof. ■■■■
- + Investment in R&D at present is very low, at only 0.15 to 0.25% of sales turnover. There is a need to increase this R&D investment to at-least 1% of total turnover in the immediate near future (by 2015-16) which may be increased to about 2% in the next 10 years (by 2020). This could be done by pursuing a few large value R&D projects/programmes at the national level which may comprise Laboratory scale, Bench scale and Large scale demonstration plants. Often it is argued that R&D investment may be expressed as a percentage of PAT or EBIT and not on turnover. The matter has been looked into and it is felt that the present system i.e. expressing R&D investment as percentage of turnover enables us to compare the R&D investment with other plants

abroad and hence it may be continued. However, R&D content and investment thereof may be uniformly defined by all companies to include all investment relating to projects for improvements and innovations. ■■■■

- + The Government of India has already allowed tax benefits under Section 35 of IT Act by which any expenditure (revenue and capital) on scientific research is eligible for deduction upto 200% from the total taxable income of the company, thereby giving relief in income tax for encouraging R&D. This method of giving incentive has not been very attractive to increase R&D investment in the steel industry, and requires streamlining with regard to its coverage of R&D content. ■■■■
- + Most of the technological challenges we face in India are 'country specific'. For example, (a) high alumina in iron ore, (b) high ash in coal, (c) low interest of academic institutions on Metallurgical Education & Research, (d) low priority on research and technology in steel industry etc., are typical Indian problems. It is, therefore, imperative that the industry must resolve to change the scenario, by finding innovative solutions to these problems by pursuing relevant R&D programmes, for its long term survival and growth. We must create and develop the required infrastructure for research, identify relevant research programmes, develop a dedicated team and provide adequate budget. ■■■■
- + Appropriate solutions to address the problem of poor techno-economics lies in phasing out old/obsolete production facilities and technologies and adoption of modern, state-of-art, relevant technologies including those specifically designed for improvement in energy efficiency and environment friendliness, commercially available elsewhere. This may be supplemented by R&D support particularly directed towards adaptation of imported technologies and /or finding out solutions to day-to-day problems faced by the industry. Towards this objective, the Japanese & Chinese approach, as under, for conservation of Energy and Environment needs to be pursued:
 - **Programmes in energy efficiency improvement and conservation technologies:**
 - Coke dry quenching technology.
 - Improved productivity of Sinter plants adopting micro pelletisation.
 - Coal moisture control, where ever necessary and relevant.
 - Hot stove waste heat recovery.
 - Waste heat recovery in sinter plant from main exhaust and sinter cooler.
 - Blast furnace top pressure recovery turbine (TRT).
 - VVVF (Variable voltage variable frequency) control for motor applications.
 - Higher efficiency operation of energy equipment.
 - High efficiency turbine in plant power generation.
 - Increased use of automation at all levels.
 - Strip Casting.

- ❑ **Utilization of waste material, Recycling, Recovery etc.**
- ❑ **Consolidation in Production by gradually phasing out small, inefficient units in the long term perspective.**



+ New plant/ facilities are being set up in the country in green-field locations. It must be ensured that all state-of-the-art and relevant technologies are adopted to ensure productivity and energy efficiency at par with international benchmark. PSU steel plants may be clearly instructed to this effect. Conventionally, production capacity and profitability have been the key considerations for planning for any brown-field or green-field expansion in India like other developing countries. It is felt that in light of global environmental concerns, the planning process needs a shift to also include important parameters like energy efficiency and environmental emission towards achievement of international benchmark.



+ Several alternative iron making (Smelting Reduction) technologies have been developed and commercialized which directly use non-coking coal and iron ore fines, viz. FINEX, FASTMET/FASTMELT or ITmk3. These or similar concepts/technologies are relevant to India in view of indigenously available resources viz. non coking coal and also abundant iron ore fines. New concepts/ technologies like ROMELT, HI-SMELT /HYSARNA seem particularly relevant for Indian iron ore containing high alumina and high phosphorous which are strong deterrents for cost effective production of iron and steel in India. There are problems and issues with regard to optimum size plants, Capex and Revenue expenditure of these technologies. Apart from Finex, the global success rates of fluidized bed technology development for iron ore has not been of a very high order. Relevance of some of these technologies including their suitability to treat Indian raw materials must be examined by designated expert or experts group before considering or taking decision towards adoption of these technologies in India. Such efforts may also require extensive R&D intervention. Generally speaking, smelting reduction is a relevant area for R&D in India. We may therefore, encourage a national programme for such development of relevant iron making technology suitable to the Indian conditions and applicable to Indian raw materials.



+ Electric induction furnace industry is plagued with technological constraints and are generally ill-equipped to produce quality steel, particularly with low phosphorous level as per standards. The Government may consider encouraging and helping this sector to find out innovative solutions to produce quality steel by pursuing /adopting R&D and other technological solutions. Towards this objective, industry and the IF manufacturers may consider evolving suitable schemes for up-gradation of the technology in the sector in collaboration with the Government, if necessary. Such schemes may also be developed for EAF units & Re-rolling Mills to upgrade their technology to improve upon techno-economic parameters.



+ With the growth of Indian steel industry @ 8-10% per year, demand on iron ore and coal is bound to rise many fold. On the other hand, availability of high grade iron ore or low ash coal is very limited and increasing dumps of low/lean grade ore as well as slimes are causing environmental hazards, besides wasting valuable resources. Therefore, relevant beneficiation techniques need to be developed with the help of R&D intervention. There are similar but critical issues with regard to cleaning of high ash coking and non coking coal (25+% ash) and beneficiation of other minerals required by the steel industry. These have been the long cherished wish of the Government and the industry. It is high time that the industry takes up this programme high on its agenda. Government assistance, if any, may be extended to pursue such initiatives. This should also include adequate production facility for beneficiation and agglomeration of beneficiated fines through pelletisation or innovative sintering processes. Some of the issues are complex and may require long term programmes, or joint collaborative programmes.



+ Today, climate change and global warming are the prime areas of concern in the realm of growth and development of iron and steel industry. India has already committed to reduce its emission intensity of GDP by 20-25% over the 2005 level by the year 2020, through pursuit of pro-active policies. Programmes for energy efficiency improvement and CO2 reduction for steel industry are therefore, not only desirable but necessary to pursue the low carbon, green growth strategy. It is therefore, essential for the Government and industry to address these key issues together by planning programmes through joint collaborative research programmes. CO2 breakthrough or similar programmes pursued by international communities may be referred to in order to evolve such programmes in India. Studies on Carbon foot print analysis need to be initiated urgently on chosen production paths so that the role of CO2 emission is clearly emphasized.



+ The Government is supplementing R&D in the iron and steel sector in the country through the SDF and Government budgetary support. However, most of the projects under SDF have been directed towards problem solving approach with incremental benefits and disruptive/ path breaking innovation is lacking. It is, therefore, important to modify the strategy and include large value innovative/ breakthrough programmes for raw material beneficiation for the benefit of the steel industry. In line with the above objective, several important projects are being pursued under the Government budgetary support scheme.



+ A fresh look is also required for the present institutional mechanism for evaluation and approval of R&D proposals and monitoring of ongoing projects. The ongoing system seems inadequate and an empowered and dedicated institutional mechanism seems

necessary for identification, selection of projects, monitoring of progress and ultimately implementation of research results in the industry. The emphasis has to shift from R&D to innovation with an associated business model. Against this backdrop the institutional mechanism like the R&T Mission earlier approved by CCEA or the Steel Research and Development Mission seems to have their relevance and it may be worthwhile to revive either of these or any other similar mechanism. ■■■

- + There are in-house R&D establishments in some of the major steel companies, though with limited focus and programmes. This position calls for a change. R&D establishments in the steel sector, particularly in Steel PSUs, have to be revamped and fortified rendering due importance to R&D experts with attractive promotional and higher financial packages in order to encourage people joining and working in R&D Centres. Recruitment of qualified manpower (experts) having R&D aptitude and qualification, through direct recruitment including lateral entries, seems essential to change the present state of affairs. It must also be recognized that in addition to suitable compensation, the need for job satisfaction, motivation, appropriate working condition, and comfort must be provided to attract and retain the best candidates once they join. ■■■

- + It is ardently felt that R&D Centres must be headed by a full time R&D Manager/CEO of National/ International repute who may directly report to Chairman/CMD and preferably be a member of the Board. Further, at-least one of the Board members must be an Expert/Technologist preferably, in iron & steel making or related areas capable of guiding /directing the company/plants on R&D and technology matters. R&D programmes in most steel companies are rarely directed by the top management or the Board Room. The scenario needs a change. R&D and technology issues must be top driven to get due attention at the plant level. ■■■

- + Development of Human Resources is essential to sustain the growth of Iron and Steel Industry and to pursue R&D in steel sector. A positive involvement of the Government in association with the industry to set up centres of excellence for development of manpower for iron and steel including R&D is the dire need. This particularly requires attracting metallurgical engineers to work in iron & steel industry and/or to peruse higher studies viz. M Tech, PhD etc., to support the faculty base in academic institutions and also R&D in the industry. Today, the scenario is sadly dismal with acute shortage of qualified technical manpower to join the steel industry or for pursuing higher education. ■■■

- + There is considerable dilution of metallurgical education in India on the whole. Even the premier institutes have converted Metallurgical Engineering into Material

Engineering and lack faculties with expertise in Metallurgy. Most of them are engaged in Material Science. Consequently, engineering graduates need extensive training to become useful for working in steel industry or to pursue R&D for steel sector. The situation needs to be reversed with suitable Government intervention. Definite steps are required urgently to modify the curriculum in the Indian engineering colleges to suit India's need rather than teach the students subjects that are irrelevant or more applicable to other countries where iron & steel production is no longer a priority. There is a need to have dedicated customized courses on iron and steel making in engineering institutes. China's example is noteworthy here as they have customized courses at graduation and post graduation levels. On similar lines, specialized courses or dedicated specialization from currently available graduate courses can be modeled for IITs/NITs. Russia has also dedicated courses/programmes on specific process areas e.g. blast furnace operation, steel making etc. which can also be emulated. ■■■

- + India has limited designing /engineering /manufacturing capabilities which at times have very adversely affected the timely and cost effective growth of the Indian industry. Once the a latest technology is bought it becomes obsolete with the passage of time. Again the steel industry must look to the foreign shores for upgradation. How long can this approach be sustained? A paradigm shift is necessary to reverse this trend. A concerted approach is necessary in India for development of indigenous capabilities for designing /engineering and manufacture of complete plants/projects by involving competent and reliable designers and consulting engineers from India/abroad. Design and engineering capabilities are very essential to convert the knowledge gained in the laboratory into a commercial products or processes. ■■■

References

1. State-of-the Art Clean Technologies (SOACT) for Steel making Handbook of Asia pacific Partnership on Clean Development & Climate.
2. European Steel Technology Platform, vision 2030: Report of the Group of Personalities, March, 2004
3. Evolution of Iron making Technology: by Takuya Negami Director (Engg) & Advisor, Kobe Steel Ltd, Japan.
4. American Iron and Steel Institute Technology Roadmap Research Programme for the Steel Industry.
5. European Commission Best Available Techniques Reference Document on the Production of Iron & Steel, December, 2001

Status of Emerging/ Promising Technologies

Process/ Technology	Process Characteristics	Merits/Demerits	Status
COREX	Corex is a two-stage process: in the first stage (Reduction Shaft), iron ore is reduced to DRI using the reduction gas (65-70% CO + 20-25% H ₂) from the Melter Gasifier and in the second stage (Melter Gasifier), DRI produced in reduction shaft is melted to produce hot metal.	<p>Since, coking and sintering plants are not required for the Corex process, substantial cost saving (up to 20%) can be achieved in the production of hot metal. Environmental emissions (NO_x, SO_x, Dust, Phenols, Sulphides and Ammonium etc) are also substantially reduced. Furthermore, waste-water emissions from the COREX process are far lower than those in the conventional blast furnace route.</p> <p>The process suffers from certain in-built drawbacks like; limited modular size (largest corex plant is of 1.5 million tonne capacity), need for lumps/pellets, dependence on partial requirement of coke and weak coking coal for optimum operation, high consumption (cost) of oxygen, necessity of gainful utilization of Corex gas for process economic viability etc.</p>	<p>COREX is a proven smelting-reduction (SR) process developed by Siemens VAI for the cost -effective and environment friendly production of hot metal from iron ore (lumps & pellets) and coal without resorting to coke making. The process is well established in India and abroad.</p> <p>In India, JSW Steel has successfully adopted the Corex process (C-2000 Module) in Karnataka. Essar Steel, Hazira is also installing two similar (Corex C-2000) modules shortly.</p>
FINEX	FINEX is the name for an innovative iron making technology developed by Siemens VAI and POSCO. Like Corex, Finex also involves two reactors- Fluidised Bed Reactors (FBR) and Melter Gasifier (MG). In the FBR, iron ore fines are reduced to sponge iron fines which are compacted to produce Hot Compacted Iron (HCI). The HCI is then charged in MG where non coking coal briquettes (65%) are also charged to ultimately produce hot metal/pig iron. The balance (35%) coal is injected in the MG as PCI. The top gas from the FBRs is treated to remove CO ₂ and part of gas (30%) is re-cycled	<p>The Finex process has removed the limitations of the COREX process with respect to use of iron ore fines- the process directly use iron ore fines. However, this process has some other limitations eg:</p> <p>i) Necessity of inputs in melter gasifier largely in lumpy form (lumps/ briquettes) requiring compaction of reduced ore at the high operating temperature and reducing atmosphere requiring substantial additional energy /cost apart from operating and maintenance difficulties.</p> <p>ii) Need of either lumpy coal or coal briquettes. Briquetting calls for use of binders and suitable processing technology to get strength levels of coke. The</p>	<p>The FINEX process has been successfully demonstrated at Pohang, POSCO in two modules- at 0.75 MTPA and 1.5 MTPA. Adoption of this process is also being considered for POSCO's venture in Orissa. SAIL has signed an MOU with POSCO to incorporate the technology under JV for creating a 2.5 – 3.0 additional capacity at Bokaro Steel Plant.</p>

	in the for use in the FBRs. The process is characterized by significant reduction of SO _x , NO _x and dust emissions.	Finex plant at Pohang reportedly uses coal injection thereby lowering need of high strength briquettes. Similarly, need of relatively coarser iron ore fines is yet another issue. iii) Like Corex gas, Finex gas is also of high calorific value and needs to be utilized gainfully to make the process economically viable. iv) The claims on lower CO ₂ emission vis-à-vis Blast Furnace route is yet to be fully established and needs further investigation.	
Hismelt	This process differs from Corex or Finex in that it makes direct use of iron ore and coal fines in a single step reactor. The salient feature of the process is that it involves moderate to high degree (70% and above) of post combustion. The gas generated during the reactions is post combusted to around 50% just above the bath and the heat energy of the post combustion is transferred back to the main process through the liquid fountain of molten iron bath, instead of recovering it as export gas. This reduces the coal and oxygen requirement of the process.	A distinguishing feature of the process is oxidation level of the slag bath (5% FeO in slag), which helps in partitioning of a large portion of phosphorous to slag. Further, silicon is practically absent, making the hot metal an ideal feed for BOF. Additionally the process is characterised by greater flexibility in terms of raw material and operation, low capital/operation cost and low environmental impact vis-a-vis conventional coke oven- sinter plant - BF iron making process. Therefore, this process seems to have considerable promise in Indian context.	The first demonstration plant of 0.8 MTPA was commissioned in 2005 at Kwinana, Western Australia. The Plant had a major shut down in February, 2006 for modification. Since its restart in March, 2006, the Plant achieved a production rate of about 60% of its capacity. There were further plants to scale up the size (internal diameters) of the Smelting Reduction vessel from 6m to 8m for achieving a production of 2 MTPA from the single module. However, during the market softening in 2008, the demonstration unit was put down without any definite plan for restart. JSPL recently signed an agreement with RIO Tinto for the transfer of the existing demonstration plant to JSPL site to take the development forward. The technology is still at the demonstration stage and would be available for the commercialization, once the teething problems are sorted out.
FASTMET/ FASTMELT	This process envisages reduction of ore-coal composite pellets in rotary	This process may be attractive for small to medium iron producing units This	The process was successfully demonstrated by

	<p>hearth furnace (RHF). Various carbon sources such coal, coke breeze and carbon bearing waste can be used as a reductant in this process. The DRI product with high degree of metallization can be charged in conventional iron & steel making furnaces or can be smelted in Electric Iron Furnace (EIF) to produce hot metal directly from the Hot DRI adopting the FASTMELT Process.</p>	<p>process as developed by Kobe has remained as a method for the recovery of iron value from steel plant waste materials. The total energy efficiency of this process is not very high as compared with the blast furnace or other coal based technologies for production of iron. The techno-economics of this process in Indian condition will have to be judged after an in-depth study of the process vis-à-vis other established process for production of DRI or Hot Metal.</p>	<p>MIDREX Corporation, USA jointly with Kobe Steel Ltd., Japan and subsequently, a demonstration plant was set up at Kobe Steel Ltd's Kakogawa Works. MIDREX Corporation is currently marketing the FASTMET process for mill waste oxides. Several commercial FASTMET units have been installed at Kobe Steel and Nippon Steel. Iron Dynamics, a subsidiary of Steel Dynamics currently operates a rotary hearth furnace to produce 85% reduced iron pellets which are subsequently melted in a sub-merged arc furnace to produce hot metal for use in a EAF shop.</p>
ITmk3	<p>Developed by Kobe Steel, Japan, the process uses a rotary hearth furnace to turn green dry pellets made from low grade iron ore fines and pulverised coal into solid iron nuggets of superior quality (97% Fe) to DRI but similar quality to pig iron, suitable for use in EAF, BOF and foundry applications. The process is unique in that nearly all of the chemical energy of the fuel used is consumed and no gas credit is exported from the system.</p>	<p>The process has a very good separation between iron (realized as metallic nuggets) and slag and the purity of iron is also very good. Recovery of iron value from the iron bearing material is expected to be very high. RHF may be one of the processes by which the recovery of iron value using the mine wastes such as iron ore slime and Jhama coal may be done efficiently. It is claimed that the process is more energy efficient (consuming 30% less energy compared to BF-BOF route), more environment friendly with 40% less emissions and involves less capital and operating cost, which make the process attractive for consideration for steel plants in the small and medium sector. However, considerable percentage of coal 'S' gets into metallic nugget and hence the use of the product in place of scrap in steel making is likely to be restricted.</p>	<p>A commercial plant of capacity 500000 tpa was set up by Mesabi Nuggets at Minnesota, USA. The success of the plant will pave the way for rapid commercialization of the process. SAIL has entered into an agreement with Kobe Steel under JV to set up a 0.5MTPA facility in Alloy Steel Plant, Durgapur.</p>

ANNEXURE-II

1. HIGHLIGHTS OF R&D WORK AT RDCIS (SAIL), RANCHI

A DEVELOPMENT OF SPECIAL STEEL PRODUCTS

- A1 Development of Special Steel Products (IS:10748 Gr.IV & V with Nb/SAE 1541/Ti Bearing High Strength Formable Quality etc.) at RSP
- A2 Development and Commercialisation of Fe 600 Rock Bolt, HCR & IS-1786 D TMT Rebars at ISP
- A3 Development of Improved Quality Corrosion Resistant Galvanized Sheets at RSP
- A4 Development of Hot Rolled High Strength Quality Steel Grades at BSL

B PLANT PERFORMANCE AND PRODUCTIVITY IMPROVEMENT

- B1.1 Optimisation of Naphthalene Crystalliser Performance in TDP #1 to improve Naphthalene Yield at BSP
- B1.2 Development of a Process for Determination and Grading of Cross Leakage in a Coke Oven Battery at BSP

B2 IMPROVEMENT IN PRODUCTIVITY AND QUALITY OF SINTER

- B2.1 Development of Magnetic Plate Sinter Mix Charging System at SP #2 at DSP
- B2.2 Development of Low Moisture Sintering Operation at Sinter Plant at BSL

B3 PRODUCTIVITY AND PERFORMANCE ENHANCEMENT IN BF

- B3.1 Optimisation of Slag Chemistry in BF at BSL

B4 PRODUCTIVITY & QUALITY IMPROVEMENT OF STEEL

- B4.1 Development of Process Technology for Production of Aluminium Killed Special Quality Bloom at DSP
- B4.2 Improvement in Deoxidation and Ladle Refining Practice for Reduction in Consumption of Deoxidisers at SMS #1 at RSP
- B4.3 Optimisation of Slag Skimming Efficiency at De-sulphurisation Unit at BSP

B5 ENHANCEMENT OF CASTER PERFORMANCE AND CAST PRODUCT QUALITY

- B5.1 Stabilisation of Continuous Tundish

- Temperature Measurement in SMS-II at RSP
- B5.2 Improvement of Cast Structure in Blooms through Optimisation of EMS parameters at BSP

B6 DEVELOPMENT AND IMPROVEMENT OF REFRACTORIES

- B6.1 Improvement in Availability of Soaking Pits by Using New Generation Monolithics in its Walls at BSP
- B6.2 Improvement in Lining Performance of EAF (#8) using High Retained Carbon MgO-C Bricks at ASP

B7 IMPROVEMENT IN PRODUCTIVITY AND QUALITY OF ROLLED PRODUCTS

- B7.1 Enhancement in Rail Quality by Evaluation of Qualifying Criteria Test of Rails at BSP
- B7.2 Improvement in Roll Cooling of Light Structural Mill at ISP
- B7.3 Centralised Mill Monitoring System for Wire Rod Mill at BSP
- B7.4 Improvement in Roll life at Skelp Mill at DSP
- B7.5 Reduction in Zinc consumption in Galvanizing Lines at RSP
- B7.6 Development of Auto Slow Down Scheme for Improvement in Productivity at Pickling Line-1, CRM at BSL

B8 REDUCTION IN ENERGY CONSUMPTION

- B8.1 Introduction of Energy Efficient Ignition System in SP#1&2 at DSP
- B8.2 Improving Thermal Efficiency of Ladle Heating System of BF at BSL
- B8.3 Introduction of New BF Gas Burner in one Russian boiler of PBS, Power Plant #1 at BSP
- B8.4 Combustion System for New in-house Built Normalising Furnace of Plate Mill at BSP

B9 REDUCTION IN DOWNTIME OF UTILITIES THROUGH AUTOMATION

- B9.1 Performance Improvement of one Wagon Tippler and Auto-Operation of Pump House 55 at RMHP at BSL

C BASIC RESEARCH

- C1 Feasibility Studies on the Development of a Next Generation high Nitrogen steel (HNS) with Improved Corrosion Resistance for Structural Applications at RDCIS

C2 Study of Low Cycle Fatigue and Ratcheting Behaviour of Rail Steel at RDCIS

D SCIENTIFIC INVESTIGATION/TESTING

D1 Study of Softening-Melting Characteristics of Iron Ore Pellets and its Combination with Ferrous Burden of Blast Furnace at RDCIS

D2 Development and Installation of Co-axial Lance in BF #5 at BSP

D3 Simulation Studies of Fluid Flow and Solidification Pattern in Slab Caster Mould through CFD Techniques at BSL

D4 Simulation of Roller Straightening of Rails by Using Finite Element Method at RDCIS

D5 Investigation of Surface Defects and Genesis to Minimise IU Generation of Rails in R&S Mill at BSP

D6 Improving Processing of Low Nickel Stainless Steel through Simulation Studies at SSP

D7 Development of Electro-sonic Process for Treatment of Steel Plant Effluent Containing Long-chain Organometallic & Organic Compounds at RDCIS

2. HIGHLIGHTS OF R&D WORK AT TATA STEEL LTD., JAMSHEDPUR

- A new thin organic coating (TOC) and a novel application process for continuous application on galvanised (GI) tubes has been developed with Tata Steel's Tubes Division at Jamshedpur. The objective was to further improve the corrosion resistance and sustainability. The plant implementation is currently being carried out jointly with Tubes Division.
- An eco-friendly copper-free coating on electrode wires for the CO₂ gas metal arc welding process has been developed. The process has been successfully implemented in the plant and commercialisation of this product is actively being pursued.
- An improved snout atmosphere using wet H₂Nx injection system in the continuous galvanizing line has been developed. The design and installation of the wet H₂Nx system has shown substantial improvement in the surface quality of our automotive skin panel material by reducing the surface defects.
- In an effort to reduce the Zn consumption during hot dip galvanising of tubes, a CFD study was

developed to simulate the entire process using a heat transfer model in association with surface wave model. The recommendation on the process parameters from this study has been implemented in the galvanising plant in Tubes Division and has resulted into a reduction in Zn consumption.

- A novel "Self-healing" coating has been developed on CRCA steel sheet for automotive applications. In addition to its self-healing properties, the coating has also substantially improved the corrosion resistance. The lab scale development is completed and upscaling of this process to pilot scale level is being pursued with our pilot coating line.
- A new process has been developed and is being demonstrated in a pilot plant for recovering pellet grade concentrates from the ultrafine fraction of iron ore slimes. The project has received the prestigious Tata Innovista Promising Innovation Award in July 2010.
- A new coal pretreatment technology has been developed in the laboratory and up-scaled for pilot-scale demonstration for producing 8% ash clean coal from high ash Indian coals.
- A new binder has been identified for improving the coal cake stability for improving the throughput, energy consumption and quality of coke from stamp charged coke making process.
- Quick Tap Model has been implemented at Steelmaking Shop # 2 (LD2) for prediction of phosphorus.
- In December' 2010, a team from R&D Jamshedpur & Europe, together with colleagues from G Blast Furnace and RMIMTG successfully conducted trajectory probe measurements at G BF. The results of measurement will help in knowing the exact location of the material trajectory in the stock level of the blast furnace. This will generate important data to tune the mathematical model for blast furnace burden distribution.
- The new pellet chemistry from new 6 MTPA pellet plant is optimized for blast furnace applications at Jamshedpur. The optimization trials are being carried out using facilities at Tata Steel Europe R&D.
- Product validation trials were carried out for sponge chrome, a new product developed at R & D for production of ferrochrome, using Electric Arc Furnace facility at National Metallurgical

Laboratory, Jamshedpur. The results have confirmed that the use of sponge chrome in production of ferrochrome can reduce the specific power and increase the SAF productivity. A work is in progress to prepare and assess the opportunity of a 10,000 TPA technology demonstration plant at Ferrochrome Plant of Tata Steel at Bamnival in Orissa.

- New chromite pellets were developed for ferrochrome production in submerged arc furnace. The pellets will reduce the specific energy consumption and thereby CO₂ emission at Ferrochrome plant. Further plant trials will be carried out.
- New hydro-metallurgical process is developed for production of pure MnO₂ using GCP sludge of FeMn plant.

3. HIGHLIGHTS OF R&D WORK AT NATIONAL METALLURGICAL LABORATORY (NML), JAMSHEDPUR

- NML, a premium R&D organization of CSIR is engaged in extensive R&D in all facets of metals and minerals namely, mineral processing, metal extraction / characterization / evaluation / forming / processing, corrosion testing and prevention, waste utilization etc. Some of the significant projects and outcome thereof undertaken in 2009-10 are:
 - Installation and commissioning of 150 tonnes/day sillimanite beneficiation plant at Indian Rare Earths at Chavara.
 - Development of commercial floatation reagents for iron ore in collaboration with M/s Somu Organics
 - Development of complete technology packages in collaboration with MECON for iron ore beneficiation plants at Gua and Bolani
 - Development of complete technology packages in collaboration with MECON for a four million iron ore pelletization plant at Gua
 - Baryte beneficiation plant at Mangampet, Cuddapah, Andhra Pradesh
 - Reduction in galvanizing losses of Zn in several galvanizing industries
 - Transfer of technology for a portable Automatic Ball-indentation system

- Transfer of technology for the recovery of Pb from Zn leach residue
 - Development of new NDE protocols for damage assessment
 - Development of rejuvenation protocols for Ni-base super alloys (Udimet 520)
 - Development of magnetic sensor and sensor devices
 - Development of steel foams
 - Carrying out site trials of the Real Time Process Simulator developed by NML in the blast furnaces of Bokaro Steel Plant
- ii). Major programmes which are continuing in the current year are:

Major programmes on recycling of electronic waste, processing of ocean nodules, direct reduction iron making processes, smelting of ferroalloys, electro-thermal extraction of Na, coal mine-water reclamation, processing of light metal alloys, failure analysis, creep property evaluation and fatigue & fracture behaviour database for a wide range of materials, rapid solidification processing of magnetic alloys, bio mimetic materials, corrosion evaluation and mitigation, industrial waste processing and standard reference materials.

- NML has also been involved in CSIR Network Projects in the Tenth and Eleventh Five Year Plan. NML is also the nodal agency for such two projects namely:
 - Technology for assessment and refurbishment of engineering materials and components in association with CGCRI Kolkata, CEMEMRI Durgapur, IMMT Bhubaneswar, NAL Bangalore, NPL New Delhi & SERC Chennai.
 - Nano-structured advanced material involving inter-related research on biomaterials ceramics composites and hard coatings, magnetic material and structural material in collaboration with NAL Bangalore, NCL Pune, IMMT Bhubaneswar, CGCRI Kolkata, CMERI Durgapur, CEERI Pilani & AMPRI Bhopal.
- Additionally, NML has initiated one Supra Institutional Project for development of Special Steel titled "Development and Forming of Performance Driven Steels" for Automotive, Aerospace, Power, Construction, Railways, Shipbuilding & other sectors poised for rapid growth. The scope of work covers:
 - Ultra high strength steel (QHS),

- High strength high formable steels,
- Advanced joining and surface modification protocols,
- Steel foams and
- Virtual platforms for process and material optimization

4. HIGHLIGHTS OF R&D WORK AT IMMT, BHUBANESHWAR

MINERAL BENEFICIATION

IRON ORE

- Pilot plant demonstration of column floatation for processing of iron ore tailings
- Development of energy efficient and eco-friendly processes for utilization of iron ore resources
- Commercial process flow sheet for beneficiation of low grade iron ore fines for pelletization
- Beneficiation of low-grade iron ore fines and blue dust for pelletization
- Integrated flow sheet for complete utilization of low grade iron ore
- Beneficiation of low grade iron ore fines by high gradient magnetic separator
- Beneficiation of iron ore fines for Finex process of iron making
- Beneficiation of low grade siliceous iron ore fines to produce quality concentrate
- Laboratory investigations on the characterization of Dolochar waste generated in sponge iron industries

CHROME ORE

- Commercial chromite plant with IMMT technology
- Roasting studies on chromite concentrate in fluidized bed reactor
- Beneficiation of low grade chromite ore lumps

LIMESTONE

- Beneficiation studies on low grade limestone from polished stone mines

- Reduction of silica content from Sattankulam limestone by VSK separator

MINERAL CHARACTERIZATION

- Exploration, characterization and beneficiation of low-grade Sundergarh manganese ore
- Characterization and beneficiation of low-grade Hosur manganese ore
- Characterization and beneficiation of low-grade manganese ore from Joda-Barbil sector

BIO-MINERAL PROCESSINGS

- Studies on microbial desulphurization of calcined petroleum coke
- Screening of potential micro algae from West Bengal and Orissa coasts and pilot scale demonstration of algae oil production
- Bio-beneficiation of low grade iron ore
- Biological reduction of iron oxides

THERMAL PLASMA TECHNOLOGY

- Plasma processing of materials
- Hydrogen plasma smelting reduction of iron
- In-fight processing of metallised limonite
- Preparation of mullite and zirconia toughened mullite from sillimanite
- Plasma smelting of red mud for production of pig iron and alumina rich slag

MICROWAVE PROCESSING OF MATERIALS

- Microwave processing of iron ore

PROCESSING OF MATERIALS

- Mechanical behaviour under non-stationary process of deformation
- Oxidation behaviour and microstructural degradation in 2.25Cr-1Mo steel

EXTRACTIVE METALLURGY

- Extraction of metal values from poly metallic nodules leach liquor
- Preparation of electrolytic manganese dioxide from manganese cake
- Utilization of leached residue as catalyst for fine chemicals

STATEMENT OF R&D PROJECTS WITH FINANCIAL ASSISTANCE FROM SDF

Sl No.	Name of the project & Implementing organization	Total cost of (Rs. in crore)	SDF contribution (Rs. in crore)	Remarks/ achievements
1	Energy efficiency improvement in secondary steel sector in India: by MECON Ltd., Ranchi. (F.No.11(7)/SDF/94-TW)	0.6000	0.6000	Project completed.
2	Chemical modification of lignite based additives and its application in beneficiation of iron ore fines and slimes: by RRL, Jorhat. (F. No. 23(1)/SDF/95-TW)	0.1120	0.0920	Project completed.
3	To improve coking characteristics of non coking Chandrapura Coal of Western Coal Field Ltd.: by IIT, Delhi & Usha Ispat Limited. (F.No.11(2)/SDF/96-TW)	0.0800	0.0178	Project completed.
4	Introduction of new mining methods and techniques for grounds control to enable mining of rich Manganese ore under very poor to fair grounds Conditions: by National Institute of Rock Mechanics and MOIL. (F.No. 10(2)/SDF/96-TW)	0.4000	0.1600	Project completed.
5	Development of on line expert system for continuous cast products (Billets/Blooms/Slabs): by MECON Ltd. & Modern Steel Limited. (F.No. 11(1)/SDF/98-TW)	0.2800	0.1400	Project completed.
6	To achieve refractory consumption of international bench mark level in integrated steel plants: by RDCIS, SAIL, Ranchi. (F.No.11(11)/SDF/98-TW)	8.7000	3.3835	Project completed
7	Simulation of Thermo-mechanical Processing of steels and Hot Workability studies of High strength steels: by RDCIS, SAIL, Ranchi (F.No.11(12)/SDF/98-TW)	10.0000	6.3069	Project completed
8	Development of welding consumables and assessment of weldability index for micro alloyed steels: by Jadavpur University, Calcutta in consultation with Hyderabad Industries. (F.No.11(21)/SDF/98-TW)	0.2059	0.1555	Project Completed
9	Development of Cast & forged microalloyed steel: by IIT, Kharagpur and Kharagpur Metal Industries. (F.No.11(17)/SDF/98-TW)	0.1546	0.1470	Project Completed
10	Documentation and development of iron making process used by Tribals of India: by National Metallurgical Laboratory, Jamshedpur. (F.No.11(5)/SDF/99-TW)	0.1400	0.0350	Project Stopped
11	To study various tolerable Indian non-coking coal sources with the aim of maximizing the usage of domestic non-coking coal in the COREX process: by Jindal Vijayanagar Steel Ltd. (F.No.11(20)/SDF/98-TW)	3.3500	0.9440	Project Completed
12	Production of CC Billet/Bloom of quality suitable for single-stage conversion into special Bars Tata Iron & completed Steel Co. Ltd. and RDCIS, SAIL, Ranchi. F.No. (11(4)/99-TW)	71.1000	27.0905	Project

13	Desulphurisation of Assam Coal: by Centre for Energy Studies, IIT, Delhi (F.No. 11(2)/98-TW)	0.0980	0.0463	Project Completed
14	Teaching Package on Structural Steel Design for Department of Civil/Structural Engineering: by: Institute for Steel Development and Growth (INS DAG), Calcutta, IIT, Madras and Anna University, Chennai. (F.No.11(25)/98-TW)	0.6960	0.5195	Project Completed
15	Maximisation of blast furnace productivity with Indian iron ore: by National Metallurgical Laboratory, Jamshedpur, Tata Iron & Steel Co. Ltd and RDCIS, Steel Authority of India Ltd., Ranchi. (F.No.11(23)/98-TW)	80.4900	34.7675	Project Completed
16	Utilisation of solid waste materials generated at Steel Plants by physical beneficiation techniques: by RRL, Bhubaneswar in consultation with TISCO and RDCIS, SAIL, Ranchi. (F. No.11(6)/98-TW)	0.1395	0.0845	Project Completed
17	Macromodeling of heat transfer and inclusion management in continuous and ingot casting of steel by Indian Institute of Technology, Kharagpur in consultation with Mukand Limited. F.No.(11(16)/98-TW)	0.1550	0.0759	Project Completed
18	Improved leak proof design of door in coke oven battery at Rashtriya Ispat Nigam Ltd., Visakhapatnam: by MECON Ltd. (F.No.11(14)/99-TW)	0.1000	0.05	Project Stopped
19	Design and development of TRIP aided ferrite-bainite steel for structural application: by B.E. College, Shibpur. (F.No. 11(6)99-TW)	0.1330	0.0980	Project Completed
20	Cold Briquetting of Iron Oxide: by Ispat Metalics India Ltd. (F.No.11(15)/99-TW)	1.1000	0.2433	Project Completed
21	Development of ultra high strength steel in as rolled condition through thermo mechanical controlled processing: by B.E. College, Howrah (F.No.11(23)/99-TW)	0.2550	0.2239	Project Completed
22	Damage assessment and integrity of welded components: by Jadavpur University, Kolkata. (F.No. 11(15)/2000-TW)	0.0378	0.0358	Project Completed
23	Mixing and mass transfer in steel making ladles stirred with dual porous plug: a physical and mathematical model investigation: by IIT, Kanpur (F.No.11(9)/2000-TW)	0.1121	0.1043	Project Completed
24	Setting up of a semi pilot demonstration plant (30kg/ Hr capacity) for production of synthetic rutile, pig iron & high pure ferric oxide from east coast ilmenite using thermal plasma technology: by NMDC, Hyderabad. (F.No.11 (16)/2000-TW)	1.1850	0.4090	Project Completed
25	Development of process for advanced hot dip coated products: by RDCIS, SAIL. (F.No. 11(14)/98-TW)	8.2380	4.5256	Project Completed
26	Smelting reduction of chromite for ferro chrome/ charge chrome making: by RRL, Bhubaneswar. (F.No 11(10)/2000-TW)	3.0000	0.2331	Project Completed
27	On-line Implementation of Indigenously developed expert system for continuously cast products in billet caster of Modern Steel, Mandi Gobindgarh: by MECON Limited. (F.No 11(1) 2001-TW)	0.7500	0.0700	Project Stopped
28	Development of Micro Alloyed Steel Structural products in Secondary steel sector through Induction	0.0600	0.0400	Project Completed

	Furnace and Controlled Rolling Route: by National Institute of Secondary Steel Technology (NISST) and All India Induction Furnace Association (AIIFA). (F.NO. 11(6)/2002-TW)			
29	Setting up a Mini Sinter Plant to utilize waste generated out of pig iron produced through Mini Blast Furnace (MBF):by Tata Metalicks, Kharagpur (F.No. 11(18)/2001-TW)	3.7500	0.25	Project Stopped
30	Development of intelligent Mill setup model for dynamic and adaptive control of plate mill by RDCIS, SAIL, Ranchi. (F.NO. 11(2)/SDF/2003-TW)	26.3100	11.9600	Work in progress
31	Pilot Scale Smelting and pre feasibility Studies on Nickel-Chromium-Cobalt bearing Magnetite ores for commercial production: by Govt. of Nagaland with the help from National Metallurgical Laboratory, Jamshedpur. F.No.11(8)/SDF/2002-TW)	0.8811	0.3111	Work in progress.
32	Research proposal on Development & Characterization of Spot Welding Techniques for Coated Steel Sheets: by Jadavpur University, Kolkata F.No.11(1)/SDF/2003-TW)	0.1738	0.1138	Project Completed
33	Extension of project proposal on Documentation and development of iron making process used by Tribals of India: by National Metallurgical Laboratory, Jamshedpur.(F.No.11(5)/SDF/99-TW)	0.1485	0.1485	Project Completed
34	Development of Value added refractory products for Indian bauxite by Central Glass & Ceramic Institute	0.7720	0.1600	Project Completed
35	Modelling and control of microstructure & mechanism properties during hot strip rolling by RDCIS, IIT Kharagpur & IISC Bangalore. (F.No 11(8)/SDF/2003-TW)	3.6840	1.0000	The work is in progress.
36	Documentation of traditional iron smelting by Agaria community by Bappa Ray Production, New Delhi. (F.No 11(5) /SDF/2004-TW)	0.1400	0.14	Project Stopped
37	Development of Coke Dry Cooling Technology (CDCT) for Non-Recovery Coke ovens: by MECON Ltd., Ranchi (F.No.11(5)/SDF/2005-TW)	0.9500	0.4647	Project Completed
38	High Efficiency High Temperature Top Fired Stoves. : by MECON Ltd., Ranchi (F.No.11(6)/SDF/2005 –TW)	0.3900	0.2569	Project Completed
39	High Efficiency Copper Stave Coolers : by MECON Ltd., Ranchi (F.No.11(7)/SDF/2005 –TW)	0.4700	0.4175	Project Stopped
40	Indigenous Development of Mini Pellet Plant of 0.5 Mt/yr for utilization of iron ore ultra fines: by MECON Ltd., Ranchi (F.No.11(8)/SDF/2005 –TW)	1.3000	1.04	Project Stopped
41	To set up a Steel Research & Development Mission (SRDM) (F.No.11(12)/SDF/2005 –TW)	65.0000	65.0000	Scheme could not take off
42	Secondary Steel Making and Vacuum Automation Reckoner (SVAR): by Kalyani Carpenter Special Steel Ltd. Mundhwa, Pune-411036 (F.No.11(16)/SDF/2005-TW)	0.7600	0.2140	Work is in progress
43	Prevention of Grain Growth in 38 MnS6 Micro alloyed steel: by Kalyani Carpenter Special Steel Ltd (KCSSL). Mundhwa, Pune- 411036 (F.No.11(17)/SDF/2005TW)	0.3700	0.1090	Work is in progress
44	Indigenous Development of Models for Dynamic BOF Process automation system at RSP: by RDCIS, SAIL,	7.0507	4.4007	Work is in progress

	Ranchi. In association with IIT,Kanpur. (F. No. 11(22)/SDF/2005-TW)			
45	Production of Ferro-Chrome from Chrome Ore Fines and concentrates by solid state reduction in fluidized based reactor with use of natural gas: by Facor Alloys Ltd. (F.No. 11(15)/SDF/2005-TW)	0.3000	0.1500	Project Stopped
46	Quality Improvement of Low Grade Iron Ore: by RDCIS, SAIL, Ranchi (F.No. 11(1)/SDF/2006-TW)	7.3000	4.1000	Work is in progress
47	Development of Integrated treatment process for coke oven effluents: by RDCIS, SAIL, Ranchi. (F.No. 11(2)/SDF/2006-TW)	7.1800	3.6400	Work is in progress
48	An integrated approach to fatigue behaviour of spot-welded, laser-welded and adhesive bonded high strength steel sheets: by Jadavpur University, Kolkata. (F.No. 11(3)/SDF/2006-TW)	1.8315	1.5413	Work is in progress
49	Smelting reduction of manganese ore for manufacture of Ferro-Manganese: by RRL, Bhubaneswar. (File No. 11(13)/2005-TW)	0.4083	0.1152	Work in progress.
50	Development and Implementation of Slag Detection System for Converter and Castor: by MECON Ltd., Ranchi. (F.No. 11(5)/SDF/2006-TW)	1.4300	0.9525	Project Completed
51	Development of continuous NOx monitoring system: by MECON Ltd. Ranchi (F.No. 11(6)/SDF/2006-TW)	0.5450	0.4885	Project Completed
52	Characterization and utilization of Dolochar from Sponge Iron Industries: by Regional Research Laboratory, Bhubaneswar in association with West Bengal Sponge Iron Manufacturers Association (WBSIMA) (F.No. 11(10)/SDF/2005-TW)	0.1026	0.05132	Project Stopped
53	Installation of demonstration plant of Continuous Induction Furnace (CONTIFUR) for production of Iron and Steel using iron ore fines and slimes: by Electrotherm (India) Ltd., Ahmedabad. F.No. 11(1)/SDF/2005-TW)	36.0000	11.7	Work in progress.
54	Reduction of Coke rate using probing and modeling techniques in BF No. 6 and BF No. 7 of Bhilai Steel Plant by RDCIS, SAIL, Ranchi & Bhilai Steel Plant and NML, Jamshedpur. (File No. 11(1)/2007-TW)	116.9420	23.2220	Work is in progress
55	Develop Procedures for Friction Stir Spot Welding (FSSW) of formable quality, high strength and advance high strength steel sheets and characterize the welding joints: by Jadavpur University, Kolkata. (F.No. 11(2)/2007-TW)	2.0886	1.8801	Work is in progress
56	Development of Synthetic Flux through Self Propagating Sintering of LD Sludge: by National Metallurgical Laboratory, Jamshedpur.(F.No. 11(4)/2007-TW)	0.7445	0.7245	Work is in progress
57	Creation of Steel Research Centre: IIT, Kharagpur. (F.No. 11(4)/2004-TW)	20.2586	16.2069	Work is in progress.
58	Creation of Chair of Prof and Five Scholarship to undergraduate students of Metallurgy in institutes teaching metallurgy. (F.No. 11(23)/2005-TW)	7.9380	7.9380	Work is in progress
59	Study of the requirement of manpower at different levels: by IIM, Kolkata.(F.No. 11(23)/2005-TW)	0.1150	0.1150	Project completed

60	Processing of Vanadium – bearing Titaniferrous –Magnetite Ores of Eastern India: by Jadavpur University. (F.No. 11(6)/2007-TW)	0.2159	0.2159	Work is in progress
61	Investigation of Deformation and Damage Mechanism in Bare and Coated Automotive Steels through In-Situ Scanning Electron Microscope: by Jadavpur University and Tata Steel (F.No. 11(7)/2007-TW)	3.3755	3.2666	Work is in progress
62	Process for Direct Reduction of Pig Iron Ore Fines using Thermal Plasma Route: by Institute of Minerals & Materials Technology, Bhubaneswar.(F.No. 11(8)/2007-TW)	0.8887	0.5606	Work is in progress
63	Development of Thermo Electrically Cooled /Heated Helmet for Industrial Applications: by MECON Ltd. (F.No. 11(17)/2008-TW)	1.3222	1.2000	Work is in progress
64	Development of High Strength Low Carbon Multiphase Steels: by Bengal Engineering and Science University, Shibpur, Kolkata.(F.No. 11(3)/2008-TW)	6.5320	6.0000	Work is in progress
65	A comprehensive water modeling facility for steelmaking process analysis and design: by Indian Institute of Technology, Kanpur-208016	0.77896	0.6190	Work is in progress
66	To develop welding/joining conditions and evaluate joint performance of sheet/tubes of formable/HS/AHS Steel using different processes: by Tata Steel Limited, Jamshedpur	21.3500	10.6750	Work is in progress
67	Development of Continuous Multi Gas Monitor: by MECON Limited, Ranchi	1.0200	0.5100	Work is in progress
68	Infrared Camera Based Ladle Condition Monitoring System: by MECON Limited, Ranchi	1.8500	0.9250	Work is in progress
	Grand Total	544.3394	263.3825	

R&D projects under Government Budgetary Support Scheme

1. Improvement in sinter productivity through deep beneficiation and agglomeration technologies for rational utilization of low grade iron ores and fines by NML.

Prime objective: To develop indigenous viable technology for effective utilisation of low grade Indian iron ores, fines and slimes by the following steps:

- Development of process for beneficiation of low grade ore/fines/slimes/BHJ/BHQ/BMQ to concentrate with 65% Fe
- Development of process for micro-pelletization of fine grained iron ore concentrate at laboratory, bench and pilot scale and bulk preparation of micro-pellets.
- Development of process for sintering of micro-pellets on laboratory and bench scale
- Studies on techno-economic feasibility of the process

Cost of the project: Rs. 12.56 crore (Govt. funding Rs. 12.56 crore)

Background: The current practice of washing of iron ore produces slimes (below 150 microns in size) which are presently discarded as waste. It is estimated that on an average, for every five tonnes of iron ore washed, about one tonne of slimes is generated and poses severe environmental problem. Moreover, during mining, there is huge generation of iron ore fines, which cannot be used for sintering and is hence discarded.

Deliverable: Will utilize low grade iron ore /fines/ slimes which are hitherto dumped and will help in conservation of natural resources and address the severe environmental pollution problems.

2. Alternate complementary Route of Iron/Steel making with reference to Indian raw material viz low grade iron ore and non coking coal by NML

Prime objective: To develop indigenous viable technology for developing an effective alternative steel making technology for small & medium sectors utilizing beneficiated iron ore fines and coal fines by the following steps:

- Study of cleaning potentiality of suitable coking and non-coking coals by detailed washability investigations followed by pilot plant studies by adopting different physical and physico-chemical processes aiming at about 12% clean coal ash
- Development of process for micro-pelletization of fine grained iron ore concentrate and /or coal concentrate suitable for charging in coke oven battery
- Development of process for reduction of micro pellets in coke oven with excess carbon (using coking and/or non-coking coal) to form ferro-carbon.
- Development of process for Smelting of ferro-carbon in SAF for steel making.

Cost of the project: Rs. 8.58 crore (Govt. funding Rs. 8.58 crore)

Background: Large scale iron & steel making through BF/BOF route requires huge investment and cannot use low grade iron & coal reserves, limiting the medium & smaller players. The alternate route of coal based DRI also requires high quality iron ore and coal whose reserves in India are limited.

Deliverable: Innovative iron making technology to utilize indigenous low grade iron ore & coal.

3. Production of low Phosphorus Steel using DRI through Induction furnace route adopting innovative fluxes and/or design (refractory) changes by NML

Prime objective: To explore possibility of phosphorus removal from liquid metal in induction furnace in laboratory scale by:

- 1) Development/ Selection of appropriate flux for slag making.
- 2) Suitable process modification
- 3) Improvement in the furnace design, including furnace lining.

Cost of the project: Rs. 2.37 crore (Govt. funding Rs. 2.37 crore)

Background: In India around 20MT steel is produced through DRI + Induction Furnace

route. The average phosphorus content in steel produced through DRI + Induction Furnace route is in the range of 0.06 to 0.1%. The required phosphorus content in any structural steel should be below 0.06%. Conventional Induction Furnace has limitation in refining of liquid metal to lower phosphorus content.

Deliverable: Low phosphorus steel in Induction Furnace.

4. Development of futuristic Technology for carbon free iron production using alternate reductants like hydrogen with minimum or no CO2 emission. Smelting reduction of iron ore/fines by hydrogen plasma and elimination of CO2 emission by IMMT

Prime objective: To conduct laboratory and bench scale experiments for single stage production of carbon free liquid iron from iron ore/fines in a prototype smelting reactor of 50kg capacity, using thermal plasma of hydrogen as a heating as well as a reducing agent.

Cost of the project: Rs. 9.90 crore (Govt. funding Rs. 9.90 crore)

Background: Conventional Iron making processes with multiple steps have high CO2 emission and energy consumption. The elimination of multiple stages of iron making will result in considerable saving in energy consumption and use of hydrogen will eliminate CO2 emission making the process environment friendly. Since there is no involvement of coal, the product will be free of carbon and sulphur thereby producing better quality iron than conventional process. Iron ore fines can be used directly in this process promoting utilization of fines generated in the mining process.

Deliverable: Single stage production of high quality Iron with lower energy consumption and zero CO2 emission.

5. Beneficiation of Iron Ore slimes from Barsua and other mines in India by RDCIS

Prime objective: To develop liberation technique for Gibbsite and Goethitic iron ore slime with a minimum yield of 50% under the three mine specific tasks:

- Reduction in slime losses from 28% to 14% through introduction of slime beneficiation

system at Barsua mines of SAIL by setting up of demonstration plant of 100 t/hr.

- Beneficiation of iron ore slime of very fine size (<45 micron) to produce concentrate with 1.5-2.0% alumina content at Joda mines of Tata Steel by setting up of demonstration plant of 10 t/hr.
- Recovery of iron values from iron ore beneficiation plant tailings from Bailadila & Joda mines of Essar Steel at lab scale 500 Kg/hr.

Cost of the project: Rs. 48.29 crore (Govt. funding Rs. 23.03 crore)

Background: Gibbsite and Goethite interlocked in hematite (typical to Barsua mines) makes it a very difficult to liberate the Fe content and that readymade technology is not available. It is estimated that on an average, for every five tonnes of iron ore washed about one tonne of slime is generated. Accumulation of slime generated over the years creates severe environmental pollution problems.

Deliverable: Beneficiation and utilization of iron ore slime will help in conservation of natural resources and address the severe environmental pollution problems.

6. Development of pilot scale pelletization technology for Indian Goethitic/ hematitic ore with varying degree of fineness by RDCIS

Prime objective: To determine relevant technological parameters for producing heat hardened pellets from Goethitic/ Hematite and other types of Indian iron ores with cold compressive strength > 250 kg/pellet through:

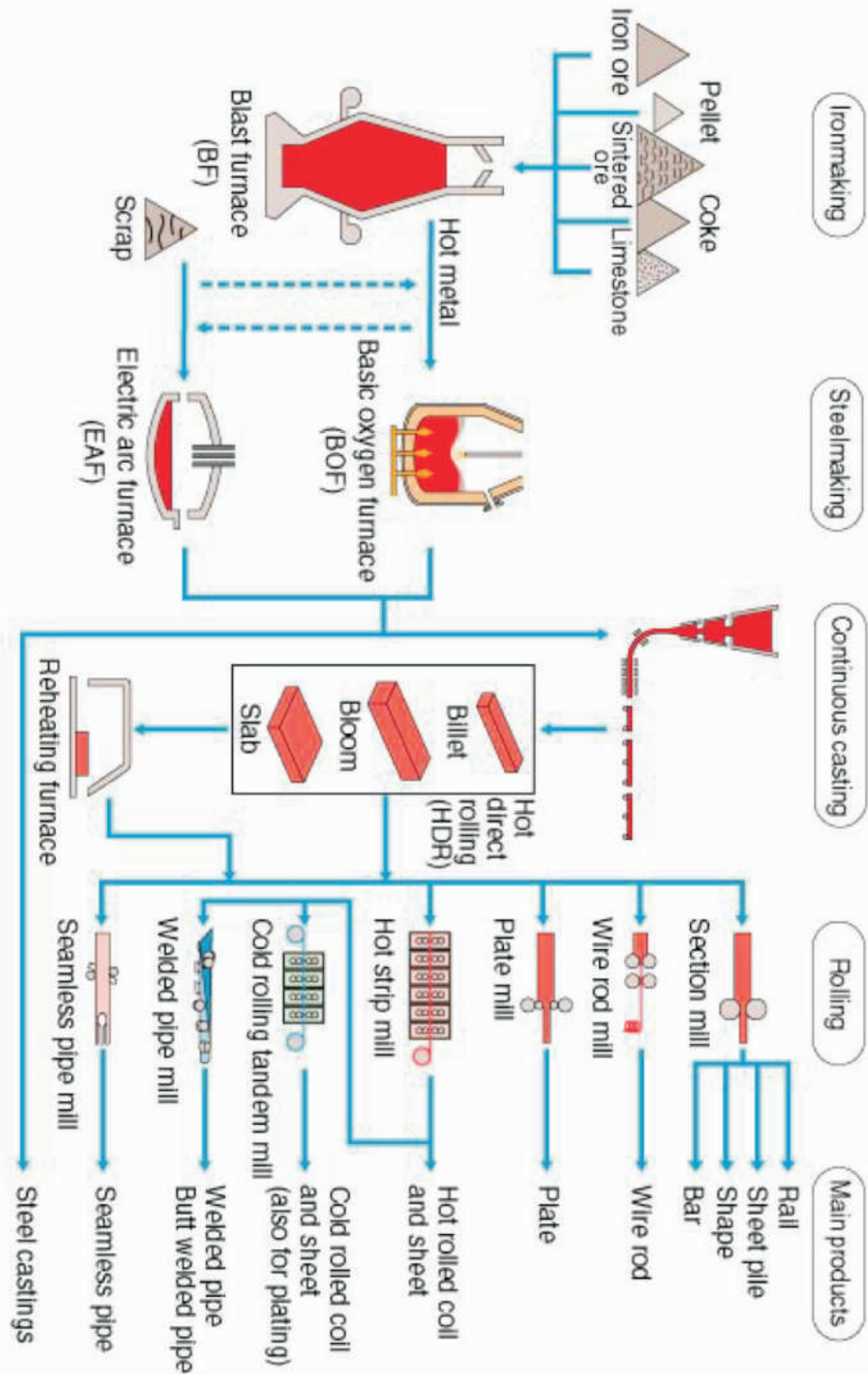
- Lab scale studies and development of a pilot-scale pelletization facility of capacity 40-60 kg/batch.
- To reduce LOI from 4-10% to 1-1.5% from high goethite content fine iron ore concentrate using fluidized bed roasting.

Cost of the project: Rs. 41.89 crore (Govt. funding Rs. 22.06 crore)

Background: Pelletisation from Goethitic/ Hematite ores fines has not been tried so far as no suitable technology is available. The high LOI of goethitic ore creates difficulty in the induration process.

Deliverable: Will develop a suitable technology for pelletisation of Goethitic iron ore fines which will

Flow Diagram of Processes and Products of Iron & Steel



result in utilization of dumped waste, pollution control and increase in the productivity of mines.

7. CO2 abatement in Iron and Steel production by process optimization by IIT Kharagpur

Prime objective: Development of a general purpose data driven BF model which optimizes its performance in terms of:

- Reduction in CO2 emissions
- Reduction in energy consumption
- Operating cost optimization through reduction in raw material consumption

Cost of the project: Rs. 0.84 crore (Govt. funding Rs. 0.84 crore)

Deliverable: Minimizing the percentage of CO2 in the top gas of iron making zone of steel plant which will reduce its impact on the environment and also reduce energy consumption.

8. Production of Low Ash (10%) clean coal (coking and non coking) from high ash Indian coals including Beneficiation/ Desulphurization of North East Coal & recovery of Ultra Fine non coking coal from washery tailings by IMMT

Prime objective: To develop viable indigenous

technology for producing clean coal through the following steps:

- To reduce the ash content to ~10% from high ash medium coking and low volatile coking coal from Eastern India by combination of physical/chemical and biological processes.
- To reduce the ash content to ~10% from high ash Indian non-coking coal as well as washery tailings by combination of physical/chemical and biological processes.
- Large scale removal of sulphur (both pyritic and organic), from NE coal by innovative microbiological processes.

Cost of the project: Rs. 19.43 crore (Govt. funding Rs. 16.88 crore)

Background: Most of the coal reserves in Gondwana region has poor washability characteristics and ash content cannot be considerably reduced by washing alone. NE coal is not being used in the steel industry because of high sulphur present in organic form.

Deliverable: Will utilize high ash coking/non coking coal from Gondwana region and also high sulphur NE coal, abundantly available in India in the steel industry thereby lowering the dependence on imported coal.