BEST AVAILABLE TECHNIQUES FOR

Indian Iron and Steel Sector

Green Rating Project (GRP)
CENTRE FOR SCIENCE AND ENVIRONMENT
New Delhi

December 2012

The Centre for Science and Environment (CSE) is a public interest research and advocacy organisation based in New Delhi. The Centre researches into, lobbies for and communicates the urgency of development that is both sustainable and equitable.

The scenario today demands using knowledge to bring about change. In other words, working India's democracy. This is what we aim to do.

The challenge, we see, is two-pronged. On one hand, millions live within a biomass-based subsistence economy, living at the margins of survival; the environment is their only natural asset. But a degraded environment means stress on land, water and forest resources for survival. It means increasing destitution and poverty.

The opportunity to bring about change is enormous. But it will need a commitment to reform – structural reform – in the way we do business with local communities.

On the other hand, rapid industrialisation is throwing up new problems – growing toxification and a costly disease burden. The answers will be in reinventing the growth model of the Western world so that we can leapfrog technology choices and find new ways of building wealth, which will not cost us the earth. This is the challenge of the balance.

Our aim is to raise these concerns and to participate in seeking answers and more importantly, in pushing for the answers to become policy and then practice. We do this through our research and by communicating our understanding through our publications. We call this knowledge-based activism. We hope we will make a difference.

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1. INTRODUCTION

This document briefly lists the best available techniques (BAT) for design, technology and operational performance of the Indian Iron and Steel sector. For each technique under different iron and steel manufacturing processes, the Indian best practice and the global best practice has been presented. The Indian best practice figures represent the values observed from the Centre for Science and Environment's Green Rating Project (GRP) study of the sector in India for the year 2009-10. The global best practices and figures represent the best achieved so far, however, there is further scope of improvement. The global best practice data have been referenced from latest documents as mentioned along with the text.

The document summarizes the best practices in India and the global in Iron and Steel sector under following headings:

- Raw material handling and storage
- Iron ore agglomeration
- Coke making – byproduct recovery and non-recovery
- Iron making - Blast furnace route, Coal DRI route, Gas DRI route
- Steel making - Basic Oxygen Furnace route, Electric Arc Furnace route, Electric Induction Furnace route
- Overall resource use

SCOPE OF THIS DOCUMENT

Iron and steel plants have numerous products manufactured based on their customers' demand after the liquid steel making stage. Hence, in order to compare the performance across industries, the scope of the BAT document is limited till crude steel making stage only. Within that, the BAT study covers the major process stages in iron and steel making, as applicable.

Upstream activities like mining and associated processes such as lime plant, air separation unit are also not included in the study. Downstream activities beyond crude steel making like hot strip mills, cold rolling, ferro-alloys etc., are also not included in the scope.

This is Version 1 of the BAT document and will be updated regularly. Comments/ suggestions/queries can be addressed to Mr. Sanjeev Kumar Kanchan, Programme Officer, Green Rating Project, Centre for Science and Environment, Tughlakahabad Institutional Area, New Delhi-110062 (email : sanjeev@cseindia.org)

2. RAW MATERIAL HANDLING AND STORAGE

Producing one tonne of primary crude steel requires 4 to 5 tonnes of solid raw materials. The raw materials include iron ore (lumps and fines), process coal (coking coal, blast furnace injection coal, non-coking coal for sponge iron making), boiler coal, limestone, dolomite and coke. The handling of large quantity of dry and powdered raw material leads to significant fugitive dust emissions.

The material handling areas which generate high fugitive emissions include: a) unloading areas of railway rakes/ trucks/ barges/ ships; b) stockpiles and storage area; c) crusher and screening area d) during transfer through conveyor belts/ bucket elevators/ vehicles and e) vehicular movement. The fugitive dust emission from raw material handling area is a major pollution issue in Indian steel plants.

Raw material storage areas also have a significant impact on soil, groundwater and surface water, especially during rainy season. The run-off from material stockpile areas contains high suspended solids. Besides, the loss of valuable raw-materials also adds as cost to the company.

The Green Rating of Indian iron and steel found the lack of serious efforts for proper raw material handling and management by the steel plants. The relevant standards are either not prescribed, or where notified are lenient. The industries meanwhile do not make enough concerted effort to meet the dust emission norms. A major reason could be that the monetary loss through fugitive emission is negligible for certain type of raw materials. In addition, as the material handling is mostly done by contract and daily wage workers, serious effort is not undertaken due to poor liability of companies on the workers' occupational health and safety. The weak regulatory enforcement pressure on arresting dust emission from material handling is another cause.

A large number of Indian plants informed that the fugitive emissions from raw material handling is unavoidable or have blamed the meteorological conditions of the region. However, globally steel plants are handling raw materials efficiently and meet the stringent pollution norms as well. Generally a combination of technological solutions and best practices are used to settle, capture and recover the air borne raw material dust particles.

The best practices of raw material handling may include the following:

2.1 RAW MATERIAL UNLOADING AREA EMISSION CONTROL

The air borne dust emission during unloading can be controlled by creating negative pressure for dust collection and passing the dust laden air through bag filter for gas cleaning. Water sprinkling and dry fog system also minimize the fugitive dust emission.

Almost all Indian iron and steel plants were not measuring dust emission concentration in air near the raw material unloading area. Where measurements have been undertaken by pollution control boards it shows non-compliance with the notified suspended particulate matter (SPM) concentration norm of 2000 µg/Nm^3.

Indian best practice: Dry fog dust suppression systems are installed in Essar Steel Hazira at the iron ore pellets unloading area and in Tata Steel Jamshedpur at coke unloading area. Many Indian plants also use suction hood with bag filters and water sprinkling for dust suppression.

Global best practice: The integrated iron and steel plants in European Union (EU) are installed with several emission control equipments in raw material unloading area[1]. Dry fog systems are installed for fugitive dust emission reduction. Vacuum systems along with bag filters are extensively installed for fugitive dust capture and gas cleaning purpose. Frequent cleaning of spillages is done to maintain good housekeeping. Workers are provided with proper dust control masks and personal protection equipments.

2.2 RAW MATERIAL STORAGE AREA EMISSION CONTROL

Most of the Indian plants have open storage of major raw materials including iron ore, coal and coke. Uncovered and unsystematic storage of raw materials is susceptible to heavy material loss and dust emission during high winds.

Systematic and covered storage, paved and impermeable storage surface area (wherever applicable) and appropriate drainage system minimise the material loss, dust emission and leaching problems.

Use of large stackers and reclaimers instead of smaller loading machines (shovels, backhoe loader, etc.) reduces dust emission in raw material storage area. Similarly, paved floors with interceptor catch and proper drainage help to control surface run-off and leaching of raw materials to ground water. Green belt around the raw material storage areas also help significantly in preventing dust emission in ambient environment.

Indian best practice: Tata Steel Jamshedpur uses tarpaulin sheet to cover raw material stockpiles. The plant also stores pulverized injection grade coal under a shed to control the emission and moisture content. JSW Steel Vijaynagar Works has installed wind curtains to minimise the material dust getting air borne.

Global best practice: Raw material storage areas in EU steel plants are provided with boundary enclosures over stockpiles[2]. Raw materials are stored in covered storage yard. Open stockpiles are stored perpendicular to the direction of prevailing wind to reduce the volume of raw material exposed to the wind.

The drop heights are small during stacking and transfer of raw materials. Storage areas are provided with impermeable paving, interceptor catch and proper drainage systems are made for runoff control for leachable raw materials. Thick green cover of trees is provided around the raw material storage and handling area.

Figure 1: Iron ore storage and loading facility

Source: http://www.ppm.com.au/index.php?widget=casestudy&id=9 (as viewed on October 26, 2012)

2.3 EMISSION CONTROL DURING RAW MATERIAL TRANSFER

The unloaded raw materials are transferred to preparation areas (crusher/screener and basemix yard) before finally sending to the particular process units. The material is transported mainly using open or closed conveyor belts and vehicles (dumpers).

Transfer through closed conveyors is preferred over other alternatives. Maximum use of covered conveyor is deemed best in order to control dust emission and material loss. Enclosed transfer points and smaller dropping heights are also put in place to prevent dust emissions from covered conveyors.

Indian best practice: SAIL Rourkela, Essar Steel, Hazira and Tata Steel, Jamshedpur use entirely covered conveyors for raw material transfer within the plant.

Global best practice: The global best practice is to install 100 per cent covered conveyors. Lesser drop heights are ensured during raw material transfers[3]. Building enclosures and dust suppression systems are installed for every transfer point. The roads are properly paved to reduce the dust emission from vehicle movement. Plants undertake regular spillage cleaning using vacuum system and maintain good housekeeping.

3. COKE MAKING PLANT

In the modern coke-making process, there are broadly, two methods: by-product recovery type and non-recovery type coke making. In the by-product recovery type, the off-gas is cleaned of tar and other hydrocarbons and used as cheap piped fuel for heating different applications in the rest of the steel plant. In the non-recovery (also called as heat recovery) type, the off-gas is burnt and used for steam-based power generation.

For ensuring an emission-free environment and safe working conditions, new by-product coke ovens are not being installed in the USA. The United States Environmental Protection Agency (USEPA) has, in fact, banned greenfield by-product coke ovens; only non-recovery coke oven technology is being promoted. India too has to push towards modern non-recovery coke ovens - a declared clean technology for coke making.

Till 2009-10, India however operated 45 byproduct coke oven batteries with aggregate capacity of 22.98 million tonnes per annum (MTPA) gross coke as per GRP survey. The primary purpose of using byproduct technology is for the cheap and 'rich in energy' coke oven gas available as heating fuel. The following section discusses the BAT for the byproduct recovery coke plants

A. Byproduct coke plant - In an integrated steel making plant with byproduct recovery coke oven units, the coke plant is the most highly polluting section. It is a major source of air, water and hazardous wastes pollution in the steel industry. The best available technology (BAT) for byproduct coke oven focuses on design and technology, operational improvement and pollution monitoring and control.

The byproduct coke making facility may include the following into best practices:

3.1 CARBONIZATION CHAMBER HEIGHT AND COAL HOLDING CAPACITY

Higher capacity of the coke oven chamber is an important parameter for byproduct recovery type ovens. As larger amount of coal is held in an oven, it significantly reduces the number of pushing per day and hence emissions per tonne of coke produced. Besides, it also reduces space, machinery and handling operations for per tonne of coke produced[4].

Higher oven chamber height maximizes the battery capacity. For example, the annual output of two 4.5 m tall top-charged batteries is equivalent to a 7m tall top charged battery.   In India, chamber height for coke ovens are found in the range of found 4.5 m-7.0 m.

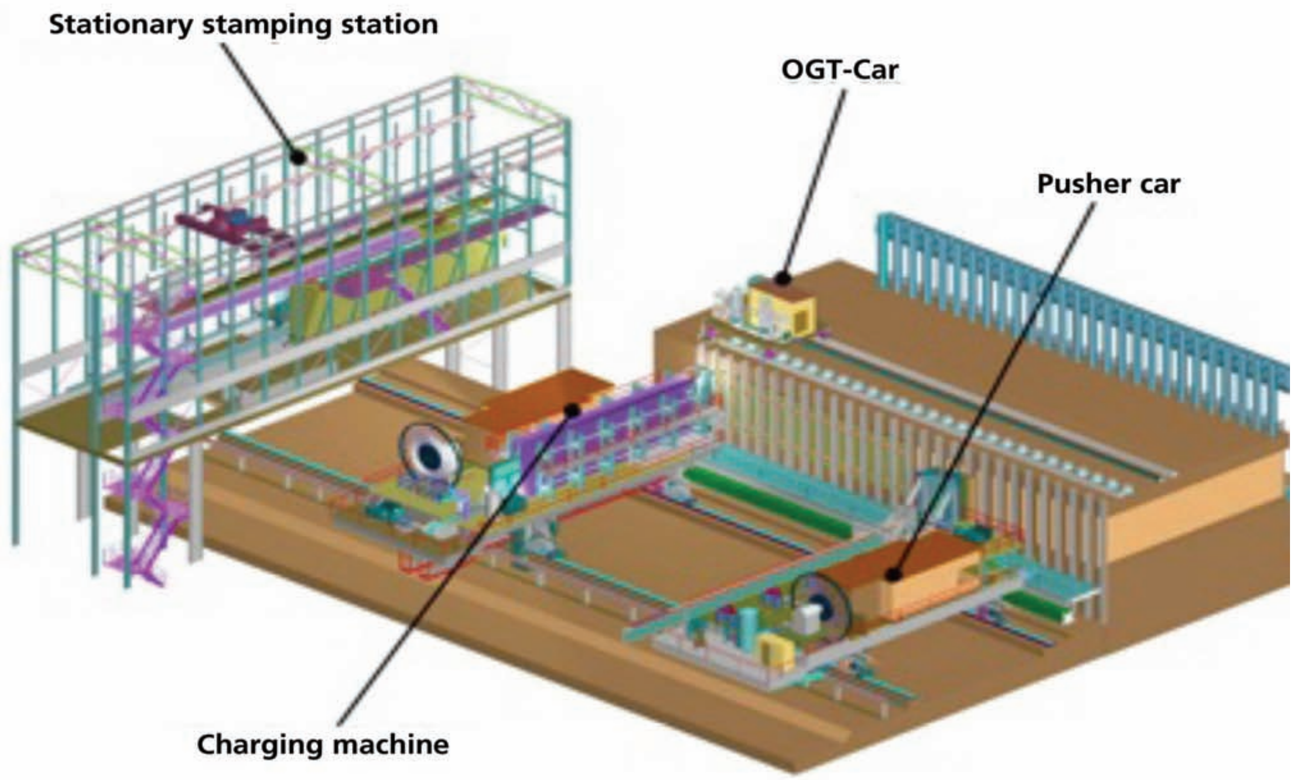
Indian best practice: The tallest carbonization chamber height for coke oven in India (till 2010-11) was found at 7.0 m. The integrated steel plants such as Vizag steel (battery#1 to battery#4), Neelachal Ispat, SAIL Bhilai (battery#9, #10) have installed 7.0m height coke ovens for coke making. Nearly 31.6 tonnes of coking coal (dry basis) can be charged at a time in a 7.0m tall coke oven.

Global best practice: The Duisburg-Schwelgern (Germany) coke plant of ThyssenKrupp Steel AG integrated steel plant has the tallest oven with 8.3 m batteries. The plant has a capacity of 2.5 million tonne metallurgical grade coke per annum. These ovens have the capacity to hold nearly 70 tonnes of coking coal (dry basis) per oven charging[5].

3.2 STAMP CHARGING (applicable for both recovery and non-recovery type coke ovens)

The stamp charging has significant advantages over conventional top charging of coking coal into coke ovens. It can produce high quality coke from low quality coking coal. The compactness of the stamp charge is normally 20-50 per cent higher than conventional charging. While the top-charging facility produces coal compactness of 765 kg/m^3 only, the stamp charging technology gives compactness of 1150 kg/m^3. By using stamp charging, more charge can be fed at a time in the oven compared to the top charging process. Therefore, the stamp charging also reduces door leakage and charging and pushing emissions. It enables better and efficient coke oven operation as well[6].

Figure 2: Diagrammatic representation of stamp charged coke oven battery



Source: Coking plant technology, FLSmidth http://www.flsmidth.com/en-US/Products/Product+Index/All+Products/Coking+Plant+Technology/Coking+Plant+Technology/Stamping+Technology (as viewed on 26 October 2012)

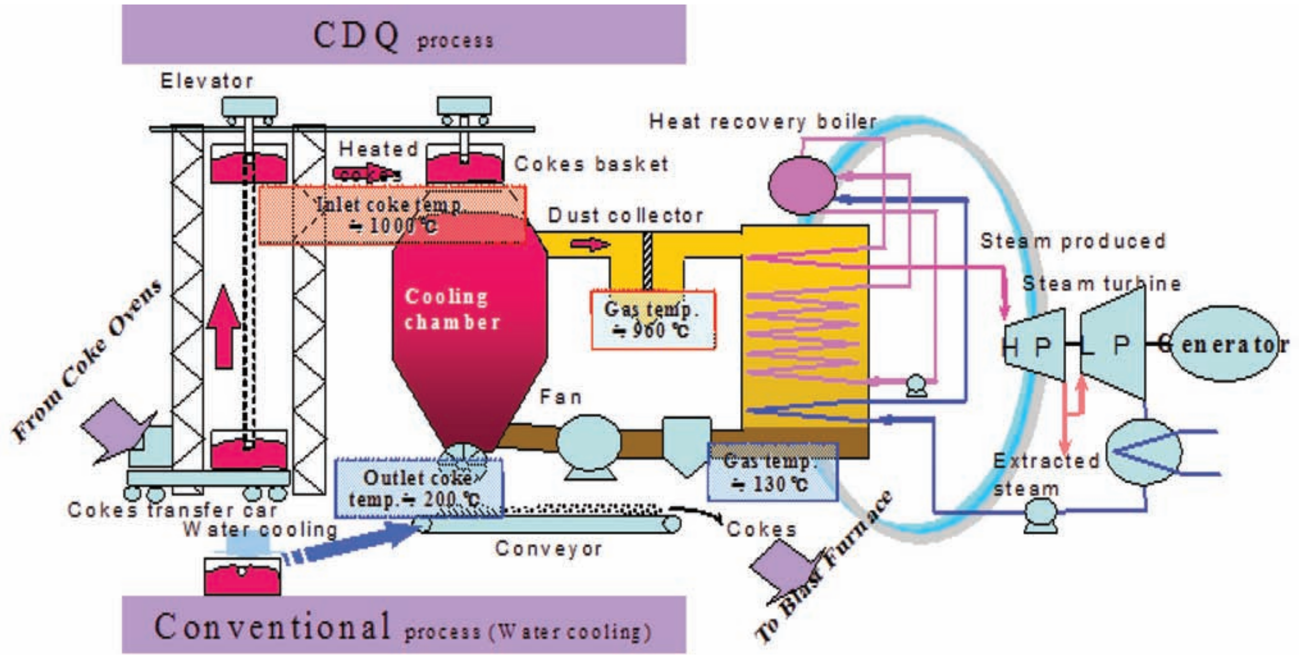
Indian best practice: Stamp charging facility has been installed in some integrated steel plants in India such as Tata Steel (in battery#8 and battery-#9) and JSW Steel (battery#3A #3B, #3C and #3D)

Global best practice: Stamp charging facility for coke oven has now been adopted widely across the globe. Example - Tangshan Jiahua (BCCW) Coking & Chemical Company, China has stamp charged battery for 6.25 m tall batteries with 46 ovens per battery[7].

3.3 COKE DRY QUENCHING (CDQ) (applicable for both recovery and non-recovery type coke ovens)

Coke making process involves quenching of red hot coke produced from coke oven. In case of wet quenching, significant quantity of water is lost during quenching. Besides, waste water is also generated and heat is lost in the environment. Dry quenching method saves water (around 0.5-1.0 m^3/tonne of gross coke), reduces water pollution as well gives opportunity for waste heat recovery of around 0.286 GCal/tonne gross coke[8]. Stable coke quality and energy efficiency of the process are key driving forces for this technology.

Figure 3: Schematic representation of Coke Dry Quenching



Source: Anon 2010, 'The State-of-the-Art Clean Technologies (SOACT) for Steelmaking Handbook', p31, http://asia-pacificpartnership.org/pdf/Projects/Steel/SOACTHandbook-2nd-Edition.pdf, as viewed on October 25, 2012

Indian best practice: As of 2009-10, only two integrated plants in India had installed CDQ facilities - Vizag steel (for all four batteries) and Neelachal Ispat Nigam Limited (for one battery).

Global best practice: Many plants across the world have installed CDQ facilities. By March 2008, the number of CDQ plants (chambers) in operation was: 104 in East Asia, 12 in Central Asia, 5 in South America and 21 in Europe. In Europe, five are in Hungary, three in Finland, four in Poland, four in Romania and five are in Turkey[9].

3.4 HIGH PRESSURE AMMONIA LIQUOR ASPIRATION SYSTEM (HPLA)

During charging of coal in coke ovens high sooty emission is released. A localized vacuum is created by injecting high pressure ammonia liquor in a jet spray system in the gas collecting mains pipe to collect the gas. This helps not only to collect the high calorific value coke oven gas but also reduces charging emission by around 60per cent[10].

Charging Gas Cleaning (CGC) system is installed with stamp charge batteries which do not use HPLA system but the gas is collected cleaned and burnt. However in this process, significant amount of coke oven gas is lost. Therefore, HPLA with charging gas transfer system (CGT) is preferred for stamp charged batteries. This checks the pollution issue and also increases coke oven gas yield. CGT is considered best practice for stamp charging coke oven plants.

Indian best practices: HPLA systems are installed in a few integrated steel plants in India such as Neelachal Ispat (one battery), Tata Steel Jamshedpur (for battery#8 and #9), Vizag Steel for battery#4, and few SAIL plants – SAIL Rourkela (battery #1, #4 and #5), SAIL Bhilai (battery #3,#4,#5, #6 and #10), Bokaro Steel (battery #5), etc.

Global best practices: Many coke plants across the world have installed HPLA system, example - Duisburg-Schwelgern (Germany) coke plant of ThyssenKrupp SteelAG integrated steel plant.

3.5 SELF SEALING DOORS

Positive pressure generated during coking process in the coke oven forces the off-gas to leak through the doors. The leakage could be huge if sealing of doors is not complete. The self sealing doors manage to maintain the lower pressure in the oven and enables formation of tar gasket along the doors for self-sealing. It helps to minimize the emissions during the coking cycle[11].

Indian best practice: Self- sealing doors are applied in many coke oven plants in India such as – Vizag steel (battery#4), SAIL-Rourkela (battery##1 and #4), Tata Steel (battery#5, #6, #7, #8 and #9) etc.

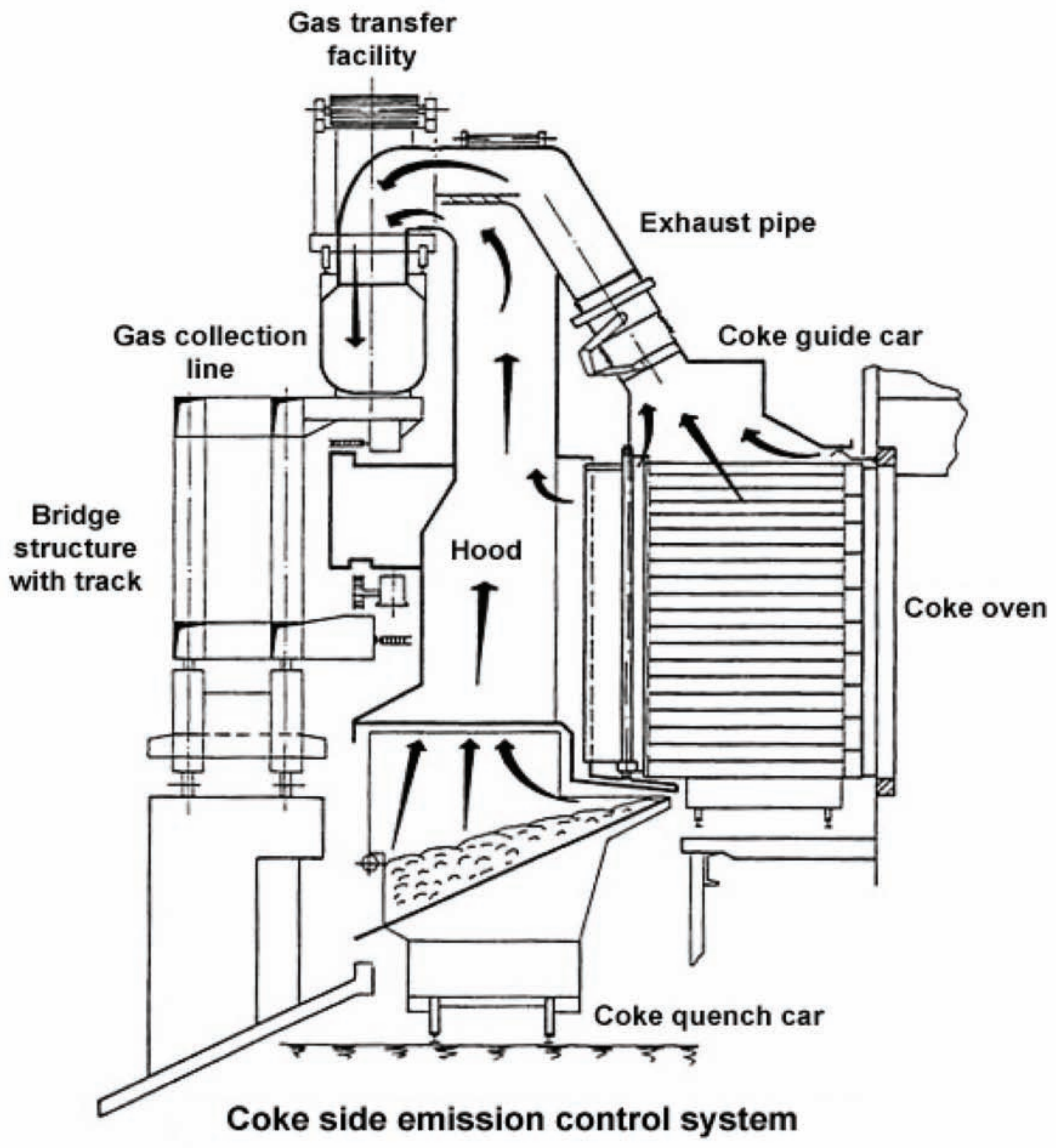
Global best practice: The integrated steel plants such as Corus, Ijmuiden (The Netherlands), Hüttenwerke Krupp Mannesmann, Duisburg-Huckingen (Germany), BHP Steel (Australia), ArcelorMittal Fos-sur-Mer and Dunkirk (France) etc. have installed self sealing doors in the coke oven[12].

3.6 STATIONARY LAND BASED PUSHING EMISSION CONTROL

After completing the coking cycle, the red hot coke is pushed out from the oven into an open container. The high diffuse emission generated during this process is arrested using a suction hood installed at the container car. The gas is later collected in a pipe and cleaned in a bag filter before release in the environment.

The installation of the stationary land-based pushing emission control system in new and renovated (rebuilt) batteries has been mandated in India by the MoEF as per the GSR 46 (E) notification.

Figure 4: Stationary land based pushing emission control system



Source: Anon 2012, 'Integrated Pollution Prevention and Control (IPPC) – Best Available Techniques Reference Document', European Commission, p 266, http://eippcb.jrc.es/reference/BREF/IS_Adopted_03_2012.pdf , as viewed on October 25, 2012

Indian best practice: Vizag Steel (battery # 4), Tata Steel (battery # 8, # 9) and JSW Steel (all four batteries) etc. have installed this clean technology.

Global best practice: Many steel plants across Europe such as ArcelorMittal- Ghent, (Belgium) and Dunkirk, Fos-sur-Mer, Seremange (France), Mannesmann Hüttenwerke Krupp, Duisburg-Huckingen (Germany), Corus, IJmuiden (The Netherlands) have installed stationary land pushing emission control system[13].

3.7 WET OXIDATIVE DESULPHURIZATION OF COKE OVEN GAS

Sulphur is present in raw coke oven gas as hydrogen sulphide (H_2S) in the concentration of 1,800-4,000 mg/Nm^3 in Indian coke plants. To minimise sulphur dioxide (SO_2) emissions during burning of the coke oven gas, the H_2S content has to be minimized. A standard of 800 mg/Nm^3 of sulphur concentration in coke oven gas (after by-product recovery unit) has been stipulated by the MoEF as per the GSR 46 (E) notification. Conventionally, sulphur is removed by absorbing H_2S with ammonia scrubbing[14].

There are number of wet oxidative desulphurization process in use such as Stretford, Takahax, Thylox, Perox etc. based on the chemicals used for scrubbing and regeneration of the sulphur[15].

Indian best practice: JSW Steel Vijaynagar has installed wet desulphurization process for coke oven gas to achieve post cleaning H_2S concentration of less than 200 mg/Nm^3.

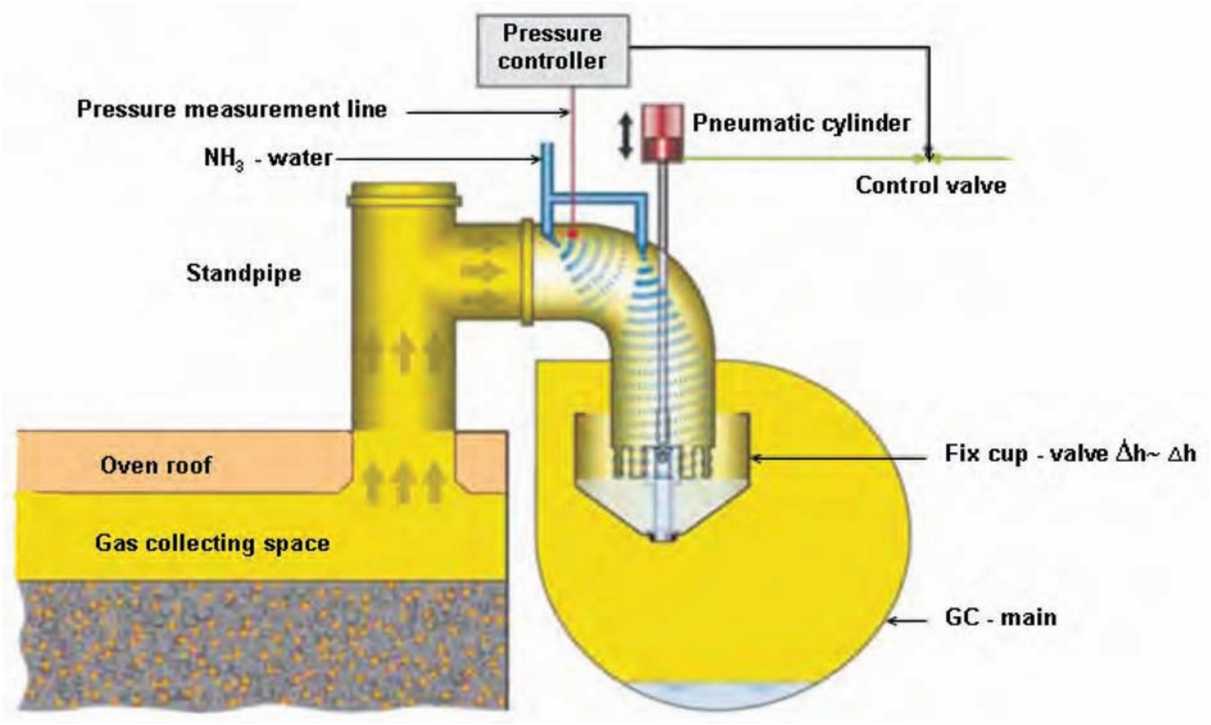
Global best practice: Many plants across the globe such as ArcelorMittal, Hamilton (Canada) and Lorraine (France), POSCO (Korea) have installed Stretford process, Nippon Steel plants (Japan) have installed Takahax process[16].

3.8 VARIABLE PRESSURE REGULATION TECHNOLOGY

Higher pressure build-up during charging of coal in coke ovens results in leakage through doors and lids – causing high diffuse emissions and loss of the valuable coke oven gas. The pressure build-up peaks (up to 35 mm water column) during charging and remains slightly positive (10-15 mm water column) for a large part of the coking duration of 14-28 hours[17].

In the conventional manual method, a fixed high and low pressure regulation is used for pressure control. Through the advanced variable pressure regulation technology, the coke oven pressure is lowered to just above atmospheric pressure during charging. This enables drastic reduction of all diffuse emissions (charging, doors, lids and gas off-take joints). The dust, PAH emissions and coke particulate emissions are also reduced drastically using this technology.

Figure 5: Variable pressure regulation technology



Source: Anon 2012, 'Integrated Pollution Prevention and Control (IPPC) – Best Available Techniques Reference Document', European Commission, p 250, http://eippcb.jrc.es/reference/BREF/IS_Adopted_03_2012.pdf , as viewed on October 25, 2012

Indian best practice: None of the Indian plants have so far installed the variable oven pressure control technology for charging emissions control.

Global best practices: This pressure regulation system has been operating since 2003 at the new coke plant in Duisburg, Duisburg-Schwelgern (Germany), thereafter at several coke ovens plants in Brazil, China and South-Korea, etc.[18]

3.9 HIGH COKE OVEN GAS COLLECTION RATE

Coke oven gas is rich in calorific value (3800 to 4200 kCal/Nm^3) and is used as an important fuel for high temperature heating applications in the different units of steel mills. It can also be mixed with other lean calorific value waste gases so that the leaner waste gas can also be used suitably. The coke oven gas collection rate reflects the extent to which the waste energy is recovered from the coke oven battery.

Indian best practices: Among Indian integrated steel plants, Vizag Steel was observed to have the highest coke oven gas recovery rate at 340 Nm^3/tonne dry coal charged. Vizag Steel uses low ash Australian coking coal with ash content of 10per cent and volatile matter of 26.1per cent.

Global best practices: The best practice in EU integrated steel plants is coke oven gas recovery rate of around 388 Nm^3/tonne dry coal charged using the same Australian grade coking coal[19].

3.10 LOW SPECIFIC THERMAL ENERGY FOR BATTERY

The coke battery refractory walls are heated up to 1350°C by using waste gas fuels (e.g. coke oven gas, blast furnace gas or a mixture of both). The waste fuel gas is used to heat the bricks underneath each oven. The specific thermal energy consumption per tonne of gross coke produced indicates the overall energy and operational efficiency of the battery.

If the refractory walls of the oven chambers have cracks and deformations, then additional amount of under-firing will be required for heating the brick walls.

Indian best practices: SAIL Bhilai plant battery #5 was found having the lowest specific thermal energy consumption among Indian plants at of 726 kcal/kg gross coke.

Global best practices: At Kawasaki Steel, Mizushima (Japan) battery #4 was reported to have the lowest specific thermal energy consumption at 650 kcal/kg of gross coke[20].

3.11 HIGH GROSS COKE YIELD

The amount of gross coke produced per tonne of dry coal charged is an important parameter. It shows whether coal charged in the oven is efficiently being converted into coke or being over burnt (over coking) in the coking process which may lead to the energy loss. Some Indian plants also add pet coke to enhance the coke yield as well as to improve the strength of coke output.

Advanced control technologies including infrared sensors and computer diagnostics need to be installed to minimise over coking. Non-recovery type coke ovens have lesser coke yield compared to the byproduct recovery type.

Indian best practices: SAIL Burnpur was found having the highest gross coke yield of around 76per cent. The reason was the high use of imported coal to indigenous coal (60:40) resulted in high gross coke yield. The indigenous coal is used from Chasnalla (Jharkhand), Jitpur and Ramnagore area and imported coal from Australia. However productivity of this coke oven plant (0.558 t gross coke/m^3 inner volume) and BF-coke to gross coke ratio (89per cent) was found low compared to the other similar plants in India.

For the non-recovery type coke ovens highest coke yield was 72.9per cent at Bhushan Power and Steel, Sambalpur as per GRP survey.

Global best practices: Among the EU integrated steel plants, the gross coke yield was found as high as 81per cent for Australian grade coking coal[21]. For the non-recovery type coke ovens, the global best practice has been considered at 76per cent in GRP survey.

3.12 HIGH BF (MET) COKE PRODUCTION EFFICIENCY

The coke obtained after quenching is screened and crushed to obtain different size fractions. BF-grade coke of size between 25-70 mm is the desired product for the blast furnace operations. The other small and powdered coke is deemed as waste and used in sinter plants, partly added in the blast furnace, sold or even recycled back in the coking process. Higher the BF-grade coke produced, better the operations of the coke plant. Byproduct plants in India have typical BF coke production efficiency of 79-84 percent as per GRP survey.

Indian best practice: JSW Steel, Vijaynagar was found having the best BF coke production of 91.9per cent in India. The Coking coal is mainly imported from Australia and South Africa with some quantity from USA and China.

Non-recovery type coke ovens had relatively high BF grade coke production efficiency. Green Rating project found Jindal Steel and Power Limited (JSPL), Raigarh and Bhushan Power and Steel, Sambalpur with the BF coke production efficiency as high as 90 to 92 percent as per GRP survey.

Global best practice: The highest BF grade coke efficiency, globally, was considered as 92 percent as per GRP survey.

3.13 BENZO(A)PYRENE MONITORING

In coke ovens, the emissions during the entire charging and coking cycle primarily arise out of the volatile hydrocarbons present in the coal mass. The hydrocarbons in coal are typically around 25 per cent by weight and vary slightly across plants depending on the coal blend. The off-gas collected or released from charging and coking operations predominantly appear in the form of polycyclic aromatic hydrocarbon (PAH) compounds due to partial burning. PAHs are persistent organic compounds released during incomplete combustion of fossil fuels, as done during the coke making process. Prolonged human exposure to emissions of PAH group of compounds is known to lead to cancer. Thus, the health of workers in by-product coke oven battery area is a major concern.

To monitor the extent of emissions of PAH group of compounds, the concentration of benzo(a) pyrene compound is measured and used as an indicator for the entire PAH family. The other organic compound measured in coke ovens is benzene.

As per the European Integrated Pollution Prevention Control (IPPC) document, the average daily value for the emission rate was estimated to be in the range of 5 – 35 mg BaP/tonne of coke.

The GRP survey found that the compliance monitoring and reporting of B(a)P emissions was poor and in many cases non-existent among Indian integrated steel plants.

Indian best practice: Vizag Steel has reported the purchase of B(a)P emissions monitoring equipment in March 2011, thus becoming the only Indian plant to have in-house monitoring facility. The frequency of monitoring should be as frequent as possible, atleast once in a month. The B(a)P norms in ambient air in India is notified at 1 ng/m^3 as per National Ambient Air Quality (NAAQ) 2009 standards.

Global best practice: In Australia, the PAH emission concentration is measured every six days using Gas

Chromatography-Mass Spectrometry (GCMS) as per ‘Other Approved Method 1 means measurement of PAH using a certified extraction and analysis procedure based on USEPA method 8270, and reporting results as speciated PAH, including benzo(a)pyrene’.[22]

The threshold limit of B(a)P is 1 ng/m^3 for ambient standards in Australia. As per Australian EPA, where levels of B(a)P exceed 1 ng/m^3 an assessment to determine the likely reason for the elevated PAH level must be made of :

- weather data (including provision of a wind rose showing wind speed and direction for the period of the monitoring);
- operating conditions and;
- other relevant factors.

Reporting: For each monitoring site graphical presentation should include the 12 month averages for PAH and benzo(a) pyrene for the current licensing (consent) year plus the preceding years (where such data exists). This graph must include a trendline and a line showing relevant guideline criteria for benzo(a)pyrene.

3.14 SPECIFIC WASTEWATER INFLUENT TO ETP

Moisture in charge coal, which is evaporated in ovens and condensed in the gas collecting mains, is the main source of waste water in a by-product recovery plant. The excess waste water generated in the process is sent to an effluent treatment plant for treatment followed by recycling or discharge. Higher moisture content in coal (with higher quantity required for stamp charge preparation) may lead to higher waste water pollution load. Overall, if moisture content in charge coal is in the range of 8-15 per cent, this leads to wastewater generation of 0.1 to 0.17 m^3/tonne of coke as per GRP survey.

Indian best practices: Among Indian plants Vizag Steel (0.2 m^3/tonne of gross coke) and Tata Steel (Tata Steel- 0.27 m^3/tonne gross coke) had the lowest wastewater generation to ETP. Vizag Steel is equipped with top charging facility whereas Tata Steel has stamp charging facility.

Global best practices: The best practice of waste water influent sent to treatment plants is in EU coke oven units at 0.1 m^3/tonne of gross coke[23].

3.15 MULTI-STAGE WASTEWATER TREATMENT AT COKE OVEN PLANT

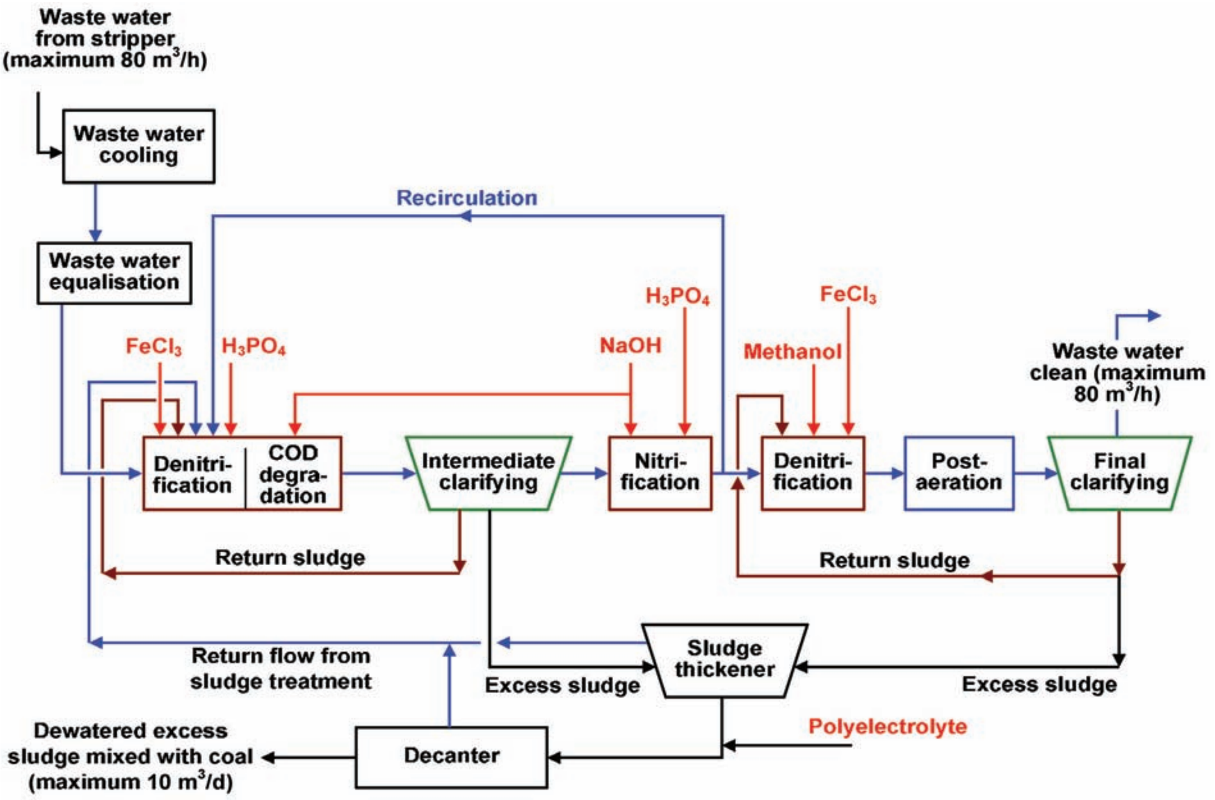
Recovery type coke making process is highly water polluting. The wastewater generated from the process contains high concentration of nitrogen and cyanide compounds and hydrocarbons. This wastewater can be treated either using biological treatment method or chemical one.

The wastewater generated end pipe undergoes ammonia stripper (for removing ammonia) and then directed to aerobic biological treatment with activated sludge system and if required then nitrification system or nitrification-denitrification system for further treatment. Biological treatment method is the most common which includes tar removal from the wastewater followed by biological treatment using microorganisms. The contaminants such as phenols, cyanides and aromatic hydrocarbons are biologically degraded and heavy metals are partially removed by adsorption to the activated sludge.

Activated sludge systems with a low food/microorganism ratio (F/M) are preferred from an environmental point of view. A low F/M ratio also enables biodegradation of heavily biodegradable organic compounds.

In case where further ammonia removal is required, biological treatment can be followed by nitrification process. Where complete nitrogen removal is required, additional pre-denitrification- nitrification efficiently works.

Figure 6: Multi-stage treatment of coke oven wastewater



Source: Anon 2012, 'Integrated Pollution Prevention and Control (IPPC) – Best Available Techniques Reference Document', European Commission, p 164, http://eippcb.jrc.es/reference/BREF/IS_Adopted_03_2012.pdf , as viewed on October 30, 2012

Indian best practices: Many of the Indian coke oven plants such as from Vizag Steel, Tata Steel, JSW steel, SAIL Rourkela etc. have installed biological wastewater treatment system with nitrification-denitrification system. Tata Steel has biological treatment system with pre nitrification system which removes extra ammonia from the effluent. However, in the initial GRP survey most of the plants found failed to comply the coke oven wastewater pollutant concentration norms.

Vizag steel has installed Mechanical Biological Chemical (MBC) effluent treatment system which is recently provided with reverse osmosis (RO) system. This MBC system includes physico-chemical processes ending with ultra filtration (UF). Ultra-filtration system is followed by RO system. RO treated water is used as make-up to circulation water system for captive thermal power plant whereas RO reject is used for ash transportation. This saves nearly 11MLD fresh water in the plant. Ammonical nitrogen concentration has been achieved in the range of 18-45ppm against the norm of 50ppm.

Global best practices: Coke oven waste water treatment plant at Hüttenwerke Krupp Mannesmann in Duisburg (Germany) is designed as a multistage biological system at coke oven plant. It includes ammonia/hydrogen sulfide stripper, 1st denitrification, activated sludge process, nitrification, 2nd denitrification, post aeration and clarifier. Coke oven waste water treatment plants using the pre-DN/N concept have been installed at ArcelorMittal, Ghent (Belgium) and Seremange (France), ZKS, Dillingen (Germany), Hüttenwerke Krupp Mannesmann, Duisburg-Huckingen (Germany).

A wastewater treatment system with pre-denitrification-nitrification system can achieve COD as low as 74mg/l, phenol less than 0.1mg/l, cyanide 0.1mg/l, SCN 0.8mg/l, ammonical nitrogen 0.28mg/l.[24]

Rivagroup Taranto (Italy) has installed additional ammonia stripping system.

3.16 HIGH SPECIFIC CRUDE TAR COLLECTION

Wastewater generated from coke oven plant contains tar. As it is relatively hard to degrade, it is removed by gravity separation, as much as possible, before it enters the effluent treatment plant. The specific crude tar collection rate gives a good indication of how well the tar has been removed by gravity separation prior to the overflow flushing liquor entering the ETP.

Indian best practices: Among the Indian steel plants, Neelachal Ispat which uses 100 percent imported Australian grade coking coal, reported the highest crude tar collection at 42 kg/tonne of gross coke from the coke plant.

Global best practices: The EU coke oven plants using the same Australian grade coking coal have recovered as high as 48 kg of crude tar per tonne of gross coke[25].

B. Non-recovery coke ovens

Worldwide, the use of non-recovery coke oven technology is rising, both in integrated steel plants and by merchant coke producers. By 2010, almost one-third[26] of the coke oven output of US and 8per cent of total coke production in China[27] was from non-recovery type. However, the EU member states have not initiated the use of non-recovery coke oven technology as of 2009-10[28]. In India, non-recovery coke oven technology accounted for more than a fourth of the 32 MTPA coke production capacity in 2009-10[29].

Non recovery type coke ovens are considered cleaner than byproduct recovery type, as the off-gas generated from the process (high in calorific value) is burnt completely and used for steam and subsequent power generation. This way no pollutants are generated from treatment of coke oven gas and subsequent recovery of by-products. Therefore, as mentioned earlier, the USEPA since mid 1990s has effectively banned greenfield by-product recovery coke ovens and only non-recovery coke oven technology is being promoted as a clean technology for coke making.

Stamp charging, higher coal holding capacity and coke dry quenching (CDQ) are considered as the best practices for non-recovery type coke ovens as well. The former two technologies are already adopted in Indian plants such as Visa Steel, JSPL, Raigarh and Bhushan Power and Steel, Sambalpur. None of the non-recovery coke oven plants in India have installed CDQ yet.

3.17 EQUIVALENT WASTE HEAT POWER GENERATION IN NON-RECOVERY COKE OVENS

The heat from the hot flue gases generated in the non-recovery coke making process is used for power generation. The waste gas is burnt to heat the oven chambers and the hot flue gas is sent to a gas fired boiler to generate steam and subsequently power. The steam and power is further used in various units of the plant to maximise energy savings.

Indian best practice: Visa Steel Kalinganagar has reported the highest equivalent waste heat power generation at 341 kWh/tonne gross coke[30].

Global best practice: The global best practice has been reported at 500 kWh/tonne gross coke in the standalone 1.6 MTPA non-recovery coke oven facility of Tata Steel, Haldia, West Bengal, India[31].

4. SINTER PLANT

Iron ore fines are agglomerated into blocks before use in the blast furnace process so as to obtain the required permeability for the flow of reactant gases. In BF-BOF plants, sintering process is adopted for agglomeration whereas for sponge iron (DRI) process pelletization is used. Higher proportion of agglomerated iron ore in blast furnace helps improve the energy efficiency and productivity[32].

The sintering process involves fusion of iron ore particles at a temperature just below the melting point of iron. The fuel used for the fusion process is coke dust, also called coke breeze. The fused mass of iron ore particles appears as blocks of size ranging from 5 to 50 mm

The sinter plant is also called the scavenging unit of a steel mill as a wide range of wastes can be mixed with fresh raw material in sinter making. The design and technology, operational performance improvement and air emission control are important aspects to be considered for BAT in sinter plants.

4.1 LARGER SINTER MACHINE SURFACE AREA

Sinter machines with larger surface area enable installation of all energy conservation technologies such as sinter cooler waste heat recovery and thus help in minimising specific energy consumption of sintering process. The specific energy consumption of a sinter machine with larger surface area retrofitted with all the relevant waste energy recovery devices is 40-50per cent less than the conventional smaller sized sinter machines[33].

The average sinter machine size in India, in 2009-10, was 195 m^2 reaction area whereas the average sinter machine size reported in Japan was 342 m^2 (2005 data) and 234 m^2 in the European Union's 27-nation block (2009 data)

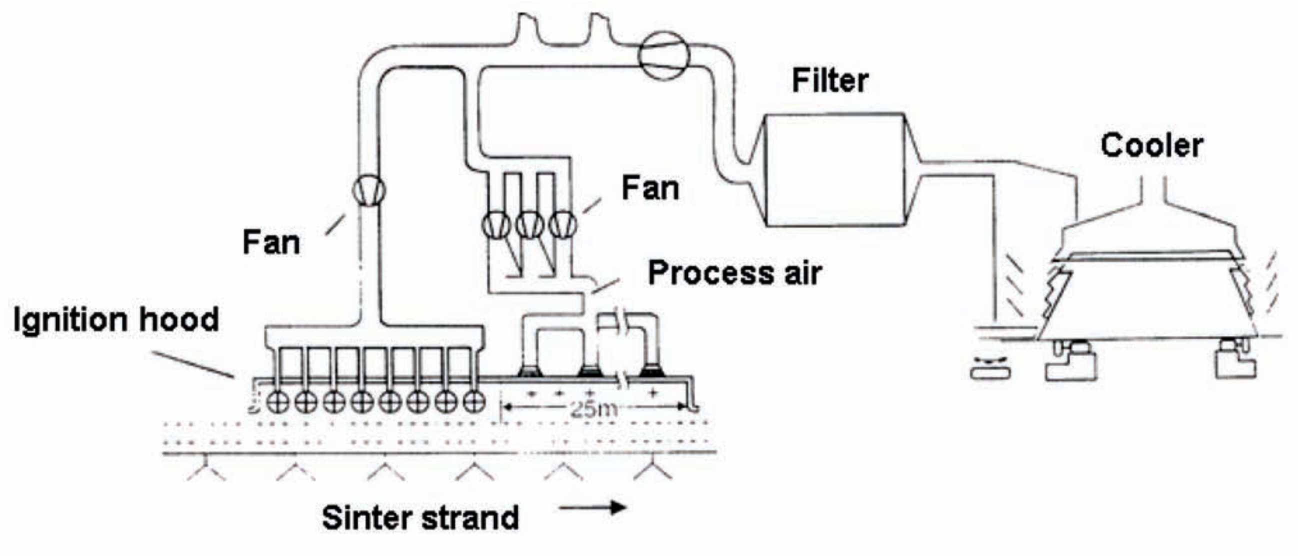
Indian best practice: In the year 2010-11, JSW Steel Vijaynagar has installed India's largest sinter machine of 496 m^2 reaction area for its sinter plant #3. This machine can produce 5.75 MTPA of sinter.

Global best practice: The world's largest sinter machine from Outotech has the size of 600 m^2 [34]. This can produce as high as 6.5 MTPA sinter.

4.2 SINTER COOLER WASTE HEAT RECOVERY

The hot screened sinter needs to be cooled before it is dispatched to the blast furnace section. A part of the waste energy recovered can be used in annealing hood. The hot air generated can also be supplied to the ignition hood burner of sinter strand, thereby minimising the waste fuel gas (BF gas, coke oven gas) consumption for ignition purposes. To further enhance recovery, steam can be generated for use in process or power generation. The annealing hood and pre-heated air together can gainfully use only 20per cent of the waste energy available. Further, steam generation can help in energy recovery of up to 30per cent of the waste energy available.

Figure 7: Sinter cooler waste heat recovery scheme



Source: Anon 2012, Outukompu Sintering Technologies, http://www.outotec.com/28621.epibrw (as viewed on October 26, 2012)

Indian best practice: A number of sintering plants in India such as at SAIL Rourkela (sinter plant #2), Tata Steel (sinter plant #2, #3 and #4), JSW Steel Vijaynagar (sinter plant #1, #2), Ispat Industries etc. have installed partial waste heat recovery system of annealing hood and preheating ignition hood. However, significant amount of heat is still wasted and hence further heat recovery is possible for applications such as steam generation.

Global best practice: In Philippine Sinter Corporation plant of Japanese steelmaker JFE Steel (Philippines), for a sinter strand of 495 m^2 and which produces 5.5 MTPA of sinter, 18 MW of waste heat power is generated from sinter cooler waste heat recovery. The power plant accounts for 73 per cent of the sinter plant's electrical energy demand[35].

4.3 SINTER EXHAUST GAS LOW TEMPERATURE RECOVERY

The sinter exhaust gas carries low temperature heat which is diluted with fresh air and released to atmosphere. This sensible heat of the waste gases can be recovered through a heat recovery boiler before being passed to the electrostatic precipitators (ESP) and stack.

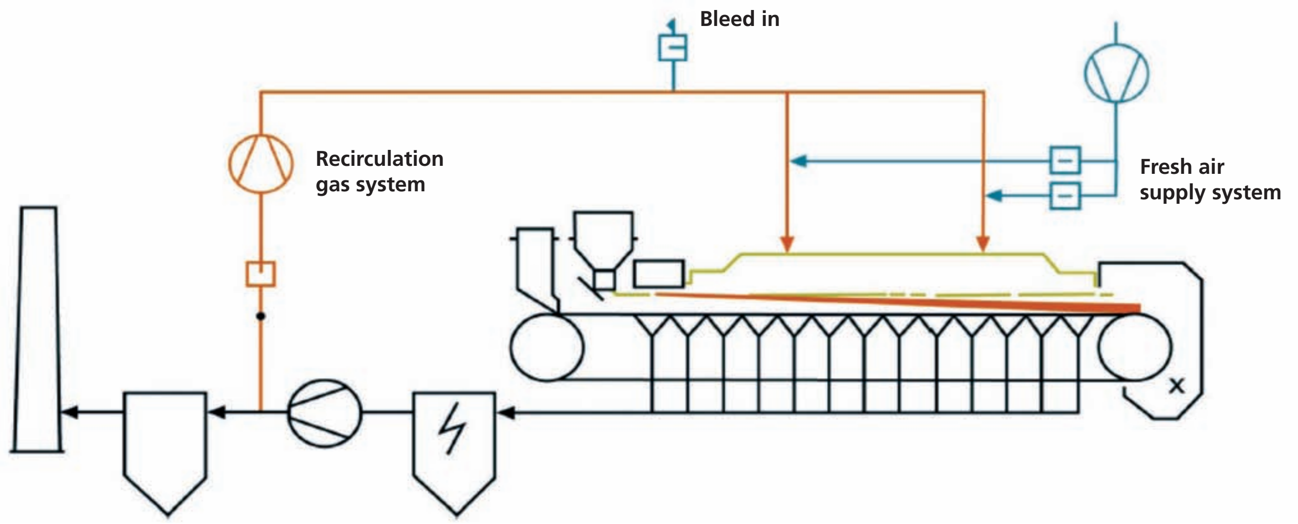
Indian best practices: None of the Indian plants have installed low temperature waste heat recovery.

Global best practices: Sinter plants in Japan have installed this technology. In 1995, it was reported that nearly 43per cent Japanese sinter machines had installed low temperature gas heat recovery from stack exhaust gas.

4.4 SELECTIVE WASTE GAS RECYCLING

Hot waste exhaust gas from wind boxes is collected and re-circulated back to the sinter bed to minimize the solid fuel energy required in the bed. An enclosed hood is provided on the top of the sinter bed to maintain sinter bed temperature. This can reduce the coke breeze consumption by 10-15per cent and reduces exhaust gas flow by 50per cent and corresponding air pollution as well[36].

Figure 8: Selective waste gas recirculation technology for sinter plants



Source: Anon 2010, 'The State–of-the-Art Clean Technologies (SOACT) for Steelmaking Handbook', Asia-Pacific Partnership on Clean Development and Climate, p 35, http://asiapacificpartnership.org/pdf/Projects/Steel/SOACT-Handbook-2nd-Edition.pdf, as viewed on October 30, 2012

Indian best practices: Till 2009-10, none of the Indian sinter plants had installed selective waste gas recycling (SWGR) technology. However, one upcoming sinter plant of JSPL Patratu, Jharkhand (430 m^2 reaction area) has proposed to install this technology.

Global best practices: The technology has been installed in five plants in Japan (including Tobata sinter plant #3, Yawata Works, Nippon Steel Corporation) and one steel plant in Europe Corus IJmuiden (The Netherlands)[37].

4.5 INTENSIVE MIXING AND NODULISING

The raw materials which contain iron ore fines and flux agents from different mining sources have varying characteristics and need to be blended to form a homogenous mixture. Moreover, some of the sinter plants do not have blending and bedding yards and charge raw materials directly to sinter plants.

The intensive mixing and nodulising technology helps in homogenizing the raw material feed. A high-speed mixer and drum mixer are used to produce granulated ore. This helps in significantly improving energy efficiency and productivity as well as reducing large space required for the mixing and blending yard. Besides, it also helps in re-use of other metallurgical wastes of the plant by homogenizing the sinter feed mixture.

Indian best practice: Sinter plants at several integrated steel plants in India such as Vizag Steel, SAIL Rourkela, Tata Steel, JSW Steel and Neelachal Ispat have adopted this technology.

Global best practice: Several sinter plants in the world such as Wakayama Steel Works (sinter plant #4), Sumitomo Metal Industries (Japan), Voesalpine Donawitz (Austria) and Dragon Steel Corporation (Taiwan) use the intensive mixing and nodulising technology.[38].

4.6 TWIN LAYER CHARGING

With a uniform layer charging on sinter strand, the higher temperature on the grate could lead to fire and damages. This may also restrict downdraft air flow and increase carry-over of the coke breeze, thereby affecting heating operations.

In twin-layer charging, smaller grain size charge materials with higher concentration of coke material is charged in the top layer. Larger grain size material (ore, sinter return) with lower coke concentration is charged at the bottom layer. This ensures proper passage of heat in the lower layers, high permeability and efficient use of fuel.

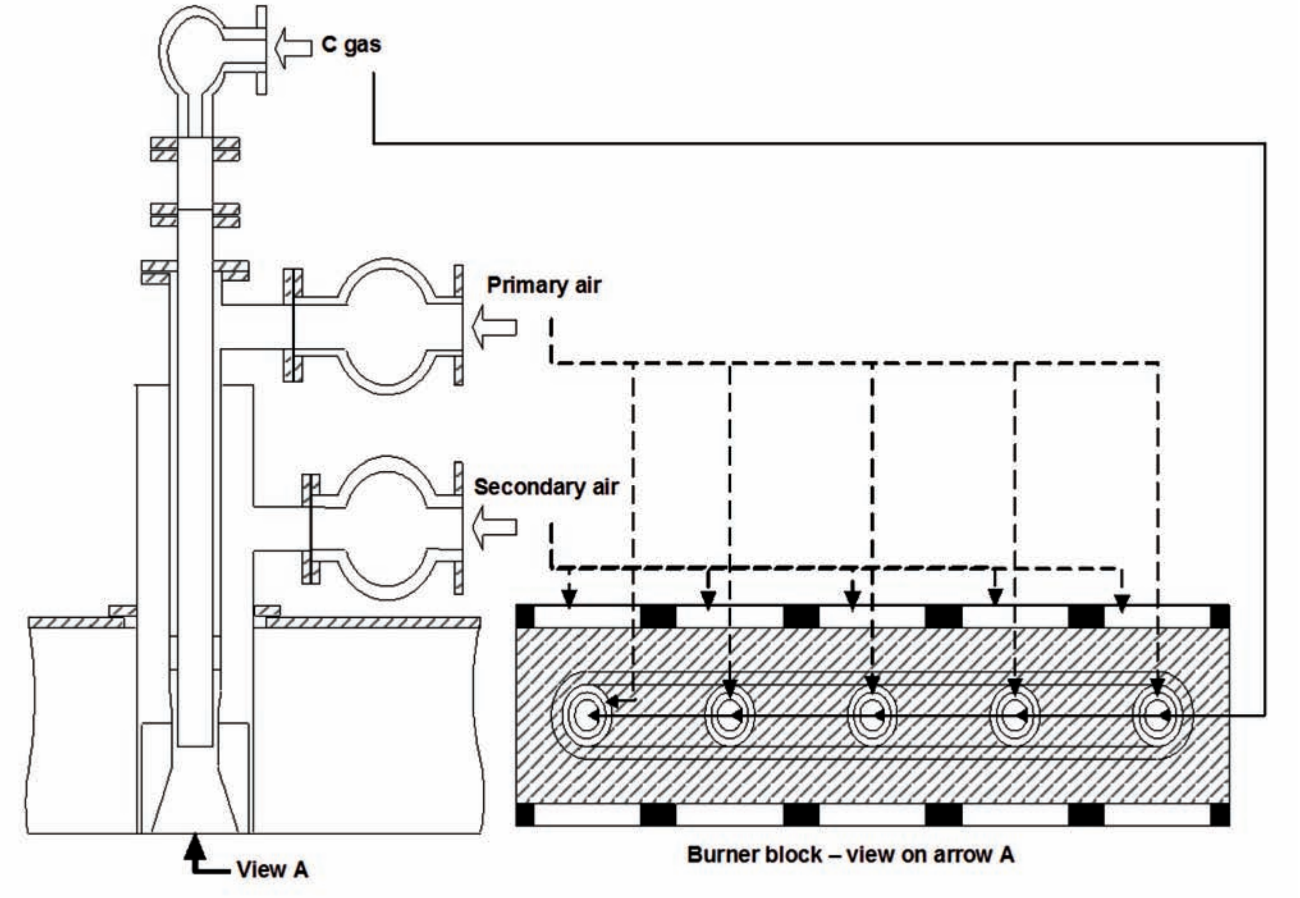
Indian best practice: Sinter plants in India such as at Tata Steel Jamshedpur and JSW Steel Vijaynagar have installed twin layer charging facility.

Global best practice: Several steel plants in the world such as Dragon Steel Corporation (Taiwan) have adopted this technique[39].

4.7 MULTI-SLIT BURNER

In the sinter plant, the flame stability of the burner is essential to ensure faster heat of the sinter feed bed. Multi-slit burners help produce a single wide large stable flame which eliminates no-flame areas and supplies minimum heat input for ignition, thus saving energy input in the ignition hood by about 30 per cent[40].

Figure 9: Multi-slit burner outline



Source: Anon 2010, 'The State–of-the-Art Clean Technologies (SOACT) for Steelmaking Handbook', Asia-Pacific Partnership on Clean Development and Climate, p 40, http://asiapacificpartnership.org/pdf/Projects/Steel/SOACT-Handbook-2nd-Edition.pdf, as viewed on October 30, 2012

Indian best practice: As per GRP survey, several sinter plants in India such as those of SAIL plants, Tata Steel, Ispat Industries etc. are equipped with multi-slit burners.

Global best practice: The burners have been installed in Sumitomo Metals (Wakayama Steel Works) Japan and many steel works in China and other countries[41].

4.8 HIGH SINTER PRODUCTIVITY

Higher productivity of a sinter plant per square metre of strand surface area enables lower energy consumption per tonne of sinter produced. Apart from the operational techniques and performance, the factors which affect sinter machine productivity are the raw material quality, rate of unusable powdered sinter fines produced, the consistency of blend of raw materials prior to charging, the dimensions of sinter bed, waste heat recovery and the effectiveness of suction under the strand.

Indian best practice: Tata Steel Jamshedpur sinter plant #3 and #4 and JSW Steel Vijayangar Sinter plant#2 (each of 204 m^2 grate area) had the highest productivity of 1.50 tonne sinter/m^2/hour.

Global best practice: The global best sinter strand productivity is reported at 1.80 tonne sinter/m^2/hour[42].

4.9 LOW SPECIFIC COKE BREEZE CONSUMPTION

Coke breeze, generated from coke making process is used as fuel and a fusion source in sinter making. It is a major source of thermal energy for sinter plant. Coke consumption largely depends on raw material quality and waste energy recovery measures in sinter plant. Coke is the dominant fuel source in sinter plants accounting for 85-90 per cent of thermal energy input, with the remainder coming from waste gas fuel. Higher the coke breeze consumption, higher the specific energy consumption of the sintering process.

Indian best practice: Sinter plant #1 of JSW Steel Vijaynagar has reported the lowest coke breeze consumption of 55.5 kg/tonne sinter in India. This sinter machine is equipped with waste heat recovery and uses preheated air in the strand's ignition hood. The coking coal used is low ash coal imported mainly from Australia while the iron ore fines is from the nearby Bellary mines.

Global best practice: Sinter plants in EU have achieved coke breeze consumption of as low as 39 kg/tonne sinter (in year 2004, as surveyed by European Blast Furnace committee)[43].

4.10 LOW SPECIFIC THERMAL ENERGY CONSUMPTION

Coke breeze accounts for bulk of the energy consumption in sinter plants accounting for close to 90 per cent of thermal energy input, with the remainder coming from waste gas fuel. The specific thermal energy consumption depends on the operational techniques, quality of raw material feed and extent of waste energy recovery recycled back to the sinter machine.

Indian best practices: Lowest specific thermal energy consumption of 0.40 GCal/tonne sinter was observed at JSW Steel Vijaynagar Sinter Plant #1.

Global best practices: EU sinter plants have reported the best thermal energy efficiency at 0.30 GCal/tonne sinter in plants accompanied by technologies such as waste gas recycling, sinter cooler waste heat recovery, etc.

4.11 HIGH SOLID WASTE RECYCLING IN SINTER PLANT

Different solid wastes from blast furnace and steel melting process stages are recycled through the sinter plant by mixing with the fresh raw material feed. It may include metallurgical wastes, dust captured from air pollution equipments and small quantity of slag from steel melting.

Indian best practice: Ispat Industries, Raigad was found having highest waste recycling in sinter plant at 122 kg/tonne sinter in India. It recycles gas cleaning plant and flue dust from blast furnace, electric arc furnace and gas based sponge iron units (69.5 kg/tonne product sinter), mill scale (35.2 kg/tonne product sinter) and electric arc furnace slag (17.2 kg/tonne product sinter).

Global best practice: The global best practice also corresponds to the Indian best practice of Ispat Industries, Raigad at 122 kg/ tonne sinter.

4.12 ADVANCE SINTER PLANT DUST EMISSION CONTROL

Reddish dust emission from a sinter plant is one of the largest air pollution sources in a steel industry which largely comes from sinter crusher area, raw material and lime proportioning area and other sinter shed areas. ESP is the most common dust abatement device used at sinter plant. Wet ESP is also used in some plants.

For good performance, ESP is used with pulse energisation technique in which high voltage pulse is repeated at up to 200pulses/seconds frequency. This performs efficiently even with high resistivity dust. Use of Moving Electrode Electrostatic Precipitator (MEEP) is another method which can counter insulating effect of dust layer at plates and removes highly adhesive dust effectively. In this technique group of ESP plats move on a caterpillar track and rotating brushes keeps the plates clean. Electrostatic space cleaner is also used with ESP which enlarges the gap between the plates and allows higher voltage for higher dust control efficiency. Use of various programmable logics and use of up to five fields with ESP, efficiency of ESP can be improved. Use of alkali in ESP and waste gas re-circulation system also has additional advantages.

These techniques give 95-99 per cent of dust emission reduction at sinter plant. A MEEP can reduce dust emission to 25-30 mg/Nm^3. With energisation technique, ESP can reduce the dust emission to 43 to 77 mg/Nm^3. With electrostatic space cleaner dust emission control is reported less than 40 mg/Nm^3.[44]

Indian best practice: Sinter plants in India are majorly equipped with dry type dust control systems with space de-dusting system. However, GRP survey found high dust emission from most of these sinter plants. Sinter plant installed at Ispat Industries Limited which uses BF gas and natural gas for ignition hood and carry waste gas recirculation for preheating, dust emission was found comparatively low.

Global best practice: ArcelorMittal, Ghent (Belgium) using ESP equipped with micropulse discrimination have achieved emission reduction to 20 – 42.7 mg/Nm^3. Energy pulse superimposition has been installed at many sinter plants such as Gwangyang Works, Posco (South Korea), Thyssen Krupp Stahl, Duisburg (Germany), ArcelorMittal, Dunkirk and Fos sur Mer (France) and Ghent (Belgium) etc.

A MEEP has been installed at Riva, Taranto (Italy) and ArcelorMittal, Eisenhüttenstadt (Germany). An electrostatic space cleaner super (ESCS) has been installed at the sinter plant of Nippon Steel Corporation, Yawata Works in Japan.

4.13 CONTROL OF DIOXINS AND FURANS

Sinter plants are a major source of polychlorinated dibenzop- dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), formally known as dioxins and furans, respectively.

PCDDs and PCDFs are listed among the 12 most persistent organic pollutants (POPs) under the Stockholm Convention due to their environmental persistence and their high accumulation ability in biological tissues.

A whole range of measures such as use of activated carbon in flue gas stream, minimising chlorine content in the feed and use of fabric filters with catalyitic oxidations systems need to be adopted to minimise dioxin-furan emissions.

Indian best practice: None of the Indian plants have adopted any measure to reduce dioxin-furan emissions.

Global best practice: Sinter plants in EU such as ArcelorMittal, Ghent (Belgium), Thyssen Krupp Stahl in Duisburg (Germany) and Hüttenwerke Krupp Mannesmann, Duisburg (Germany) use activated carbon system[45]. Further, plants such as ArcelorMittal Bremen (Germany) and Voestalpine Stahl GmbH, Donawitz (Austria) use the bag filter system in combination with reduction and oxidation agents.

5. BLAST FURNACE

Blast furnace (BF) process accounted for more than 90per cent of iron making in the world in 2011. In India, BF process contributed to about 65 per cent of iron making; with the remaining 35 per cent accounted by the Direct Reduced Iron (DRI) route.

In the BF process, agglomerated ore in the form of sinter (or pellet) along with lump ore are the major raw material feed. Coke is added that acts as a reducing agent as well as energy source.

Improvements in design and technology, operations, pollution control systems, waste management and health and safety are the focus areas of best practice in BF process.

5.1 LARGE WORKING VOLUME FURNACE

Larger working volumes of blast furnace shell enables the installation of clean technologies such as pulverised coal injection, high top pressure and higher hot blast temperature, thus minimizing coke consumption. The consumption of coke in large blast furnaces can be reduced by up to 50per cent in large volume blast furnaces, thus also reducing coke demand and hence, environmental impacts in the upstream coke making.

Indian best practice: In 2010-11, the largest size blast furnace was installed at JSW Steel Vijaynagar BF #3 and #4. Each blast furnace has working volume of 3445 m^3 with hot metal capacity of 2.8 MTPA. These BFs are installed with clean technologies such as pulverized coal injection, bell less top, high top pressure etc.

Global best practice: Blast furnace in Japan such as Nippon Steel Oita Works is reported to have the largest working volume at 5000 m^3 with unit capacity of 5.0 MTPA hot metal[46].

5.2 BELL LESS TOP

In this design, the charge material from hopper passes through two valves – gate valve and sealing valve operating alternatively, before entering the rotating feeder system. Thus, a two-valve mechanism is used instead of the conventional double-bell system. This enables uniform distribution of materials, maintaining uniform temperature and reaction zones and minimising coke consumption.

Indian best practice: Of the 43 blast furnaces considered under GRP till 2009-10 and for which data was available, 29 had bell-less design type for charging.

Global best practice: The bell less charging is a common practice in advanced countries –for example, 40 of the 49 BFs in Western Europe have installed this technology[47].

5.3 PULVERISED COAL INJECTION (PCI)

High grade coal (such as anthracite) is powdered and injected through tuyeres at the bottom of the blast furnace. Oxygen supplied in the hot blast tuyeres enables faster burning of this coal. This alternate fuel injection system reduces coke consumption in the blast furnace. Around 0.85-0.95 kg metallurgical coke production is avoided for every kilogram of pulverised coal injected into the blast furnace. Higher the PCI, lower the coke consumption and better is the energy efficiency.

Indian best practice: Tata Steel Blast Furnace #H had highest PCI rate at 135 kg/tonne hot metal (thm) in 2009-10. The furnace has a working volume of 3230 m^3.

Global best practice: PCI is a common technology adopted in blast furnaces globally. The highest PCI rate of 255 kg/thm has been achieved by Corus, Ijmuiden #6 (The Netherlands). However depending on the carrying capacity of the coal and thermochemical condition of furnace, maximum theoretical PCI of 270 kg/thm can be achieved. To maintain the combustion for high PCI, oxygen enrichment is provided in the furnace[48].

5.4 HIGH TOP PRESSURE AND TOP PRESSURE RECOVERY TURBINE (TRT)

While the raw material charge in a blast furnace descends by gravity in the reactor shell, the hot blast air is forced upwards. The counter-current direction of hot blast air is important to speed up the interaction of the reductant gases (carbon monoxide) with the iron burden to enable faster removal of the oxides from the ore. Hence, high top pressure needs to be maintained to enhance the productivity and minimize coke and hence, energy consumption.

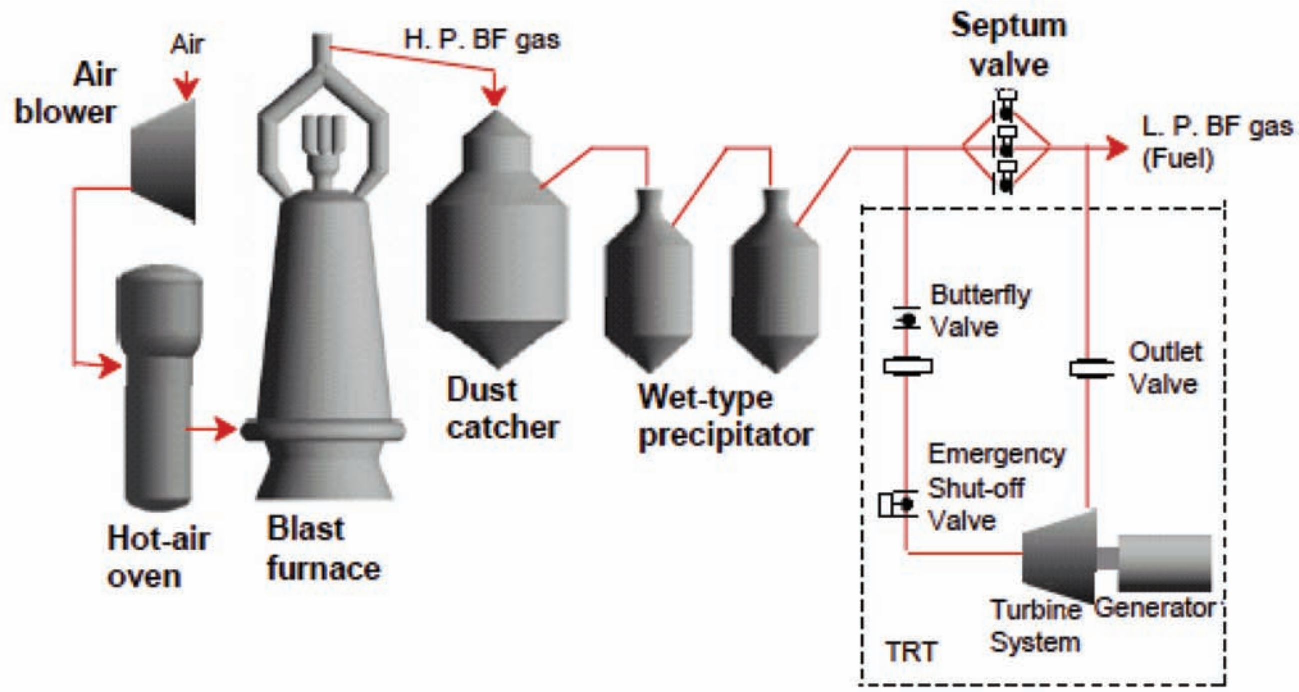
High top pressure (above 1.5bar g) blast furnaces also provide an ideal opportunity for recovering energy from the large volumes of pressurised top gas. As per International Energy Agency (IEA, 2007), a top-pressure recovery turbine (TRT) can be used to generate electricity from this high top pressure. A TRT can produce 15 – 40 kWh/thm[49].

Indian best practice: The furnaces equipped with TRT technology in India are Vizag Steel (BF # 1 and # 2 – each with 12 MW generator capacity), Tata Steel (BF # G – 8.0 MW and BF # H – 13.5 MW), JSW Steel (BF # 3 – 12.4 MW) and Ispat Industries (BF # 1 – 5.5 MW). The Indian best practice for power generation was 23 kWh/ tonne steel in Vizag Steel in 2009-10.

Global best practice: Several blast furnaces in the world run at high top pressure for improved efficiency. High top pressure of these furnaces is around 3.0 bar (g)[50].

TRTs are widely used in Japan and Europe. In China, 66 blast furnaces representing nearly half the total production capacity were equipped with TRT in 2004. Japanese BFs have achieved as high as 40-60kWh/thm power from top pressure[51].

Figure 10: Top Pressure Recovery Turbine system



Source: Anon 2010, 'The State–of-the-Art Clean Technologies (SOACT) for Steelmaking Handbook', Asia-Pacific Partnership on Clean Development and Climate, p 40, http://asiapacificpartnership.org/pdf/Projects/Steel/SOACT-Handbook-2nd-Edition.pdf, as viewed on October 30, 2012

5.5 DRY GAS CLEANING

In wet gas cleaning around 0.4-8 m^3/thm of fresh water is used. This also leads to extensive waste water generation to treatment plants. Presently, the latest technology that is used for gas cleaning has 100 per cent dry gas cleaning approach, minimising wastewater generation and freshwater consumption.

Indian best practice: Bhushan Power and Steel, Sambalpur is the only plant in India equipped with dry gas cleaning technology with its blast furnace. This is for a BF of 860 m^3 working volume bell-less type blast furnace with 3 internal type hot blast stoves, PCI facility and 1.5 bar (g) design top pressure.

Global best practices: Dry gas cleaning for BF gas is common among Chinese and Japanese blast furnaces[52].

5.6 CAST HOUSE SLAG GRANULATION

For ensuring that all the slag that is generated has cement-making properties, it has to be rapidly quenched with a high pressure jet of water at the blast furnace cast house itself so that it breaks down into tiny granules. This is known as cast house slag granulation.

Indian best practice: Out of the 43 BFs in India covered under GRP till 2009-10, 33 had installed cast house slag granulation system.

Global best practices: Blast furnace of EU plants such as Thyssen AG, Duisburg (Germany) and Corus plants at Port Talbot and Scunthorpe have installed cast house slag granulation with fume emission control[53].

5.7 WASTE HEAT RECOVERY FROM HOT BLAST STOVES

The waste flue gases (exhaust) from the hot blast stoves are released to the atmosphere at around 350°C. This waste heat can be utilised for preheating the incoming cold blast (combustion air). It can also be used for heating the waste gas fuel itself before it is used for burning. Energy savings is estimated up to 0.07 GCal/thm.

Indian best practice: Many Indian BFs - Tata Steel (BF #G, #H), Ispat Industries, Jindal Steel and Power (BF#2), Jai Balaji, Durgapur have installed waste heat recovery from hot blast stoves.

Global best practices: Many blast furnaces across the world have adopted waste heat recovery from hot blast stoves. Plants such as ThyssenKrupp Steel AG, Duisburg (Germany), Blast Furnace # 7 of Corus, Ijmuiden (The Netherlands), ArcelorMittal, Ghent (Belgium) and ArcelorMittal, Gijón, (Spain), Voestalpine Stahl GmbH, Linz and Donawitz (Austria) have installed energy saving system from hot blast stove exhaust[54].

5.8 BLAST FURNACE PRODUCTIVITY

The productivity of a blast furnace is defined as tonnes of hot metal produced per m^3 working volume per day. Higher the productivity of a blast furnace, lower the coke consumption and higher the energy efficiency. Productivity of a blast furnace depends on a number of factors such as raw material quality, high top pressure, oxygen injection and hot blast temperature.

Indian best practice: Among medium and large sized BFs in India, Tata Steel BF #H has the highest productivity at 2.6 thm/ m^3 working volume/ day. Amongst mini blast furnaces, BF #1 and #2 of Jai Balaji, Durgapur plant have achieved high productivity of 3.4 thm/m^3 working volume/day.

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Global best practice: Corus IJmuiden BF#6 has achieved the productivity as high as 4.0 thm/m^3 working volume/day. This BF has the working volume of 2328 m^3, having all the clean technologies installed and highest PCI of 255 kg/thm[55].

5.9 HIGH AGGLOMERATED IRON ORE RATIO IN IRON BURDEN

Agglomerated ore has advantages of higher bed permeability, higher porosity and self-fluxing burden – all of which enable faster reaction of iron ore with reactant gases. With high ratio of agglomerated iron ore in the form of sinter and pellet in iron ore charge in the blast furnace, higher productivity can be achieved.

Indian best practice: The highest ratio of agglomerated ore in blast furnace iron burden was reported at Ispat Industries, Raigad, Maharashtra at 86 per cent (sinter 1146 kg/thm + pellets 302 kg/ thm with total burden of 1717 kg/ thm).

Global best practice: It is reported that agglomerated iron ore ratio in the charge of blast furnace can be achieved as high as 90per cent at Corus Ijmuiden with equal use of pellets and sinter[56].

5.10 COKE RATE IN BLAST FURNACE

Coke is the source of energy as well as reducing agent for blast furnace operation. Lower the coke consumption lower is the energy consumption. The coke is not only a costly concern for the plant but it also puts major environmental impact during production at coke oven. Therefore, lesser coke consumption not only saves cost and increases energy efficiency but also lowers the environmental impact from the plant.

Indian best practice: Lowest specific coke consumption has been achieved by Ispat Industries at 394 kg/thm. The same furnace has the highest rate of substitute fuel - pulverized coal injection in India, at 126 kg/thm.

However, the gross thermal specific energy consumption was found lowest at Jindal Steel and Power, Raigarh at 4.22Gcal/thm[57]. This is a 1462m^3 working volume blast furnace with 3 internal type of hot blast stoves. The specific coke consumption is 410kg/thm and PCI of 130kg/thm.

Global best practices: The lowest coke consumption has been achieved at 250kg/thm[58] whereas the lowest gross specific thermal energy consumption has been achieved at 4.0Gcal/thm.

5.11 LOW BLAST FURNACE GAS GENERATION

The blast furnace gas is generated as waste gas during blast furnace iron making process. It has the calorific value of around 700 to 900 kCal/ m^3. The lower the BF-gas generated the lower would be the energy released as waste during blast furnace operations.

Indian best practice: Blast furnace #G of Tata Steel, Jamshedpur has lowest BF gas generation at 1200 Nm^3/thm. This is a BF with working volume of 2308 m^3, bell-less design with 4 external type hot blast stoves.

Global best practice: The global lowest BF gas generation rate has also been noted to that of Indian BF at 1200 Nm^3/thm[59].

5.12 HIGH HOT BLAST TEMPERATURE

Higher the hot blast temperature, lower will be coke consumption in the blast furnace. It also leads to lower specific energy consumption in blast furnace operations.

Indian best practice: Blast furnace #H of Tata Steel, Jamshedpur has achieved the hot blast temperature of 1,188°C. The blast furnace #G of the Tata Steel has shown lowest hot blast volume requirement at 920m^3/thm.

Global best practice: Blast furnace at Nippon Steel (Japan) has achieved the highest hot blast temperature of 1300°C[60]. The global best for the lowest volume of hot blast achieved so far is 900m3/thm[61].

5.13 HIGH HOT BLAST STOVE EFFICIENCY

The hot blast stove efficiency is defined as the ratio of thermal energy of hot blast and input waste gas fuel supplied. The higher the blast stove efficiency the higher will be the temperature delivered, thus minimising coke consumption as well as waste gas generation.

Indian best practice: Blast furnace#4 of SAIL Bhilai has achieved highest hot blast stove efficiency of 67per cent. There are 4 internal type hot blast stoves installed with this 1491 m3 working volume blast furnace. Oxygen enrichment is provided in the hot blast.

Global best practices: In EU steel plants, as high as 90per cent stove efficiency has been reported[62].

5.14 LOW SLAG GENERATION RATE

The impurities in blast furnace operation are collected as slag. Higher the blast furnace slag generation rate, higher will be the energy required for heating up the slag in the blast furnace to molten metal temperature, leading to higher coke and energy consumption.

The blast furnace slag generation rate primarily depends on the quality of iron burden and the ash content in coke or pulverised coal.

Indian best practice: Among small BFs in India, Visa Steel has been found having lowest slag generation rate of 210kg/thm in a 250 m^3 blast furnace. The iron burden consists of 100per cent lump ore sourced from Orissa Mineral Corporation with 63.49per cent Fe, very low Silica (0.48per cent) and alumina (0.57per cent) content. No pulverized coal injection is adopted here.

Among medium and large BFs, Neelachal Ispat has the lowest slag rate at 273 kg/ thm. The company has a BF of 1670 m^3 working volume which is currently purchasing iron ore from Daitari/Banspani mines of Orissa Mining Corporation and 100per cent coking coal from Australia.

Global best practice: European blast furnace have achieved slag rate as low as 150 kg/thm. These plants use high quality iron ore and have major proportion of agglomerated iron in the iron burden[63].

5.15 LOW SPECIFIC IRON ORE CONSUMPTION

Specific iron ore consumption depends on the ore quality grade which is determined by its ferrous content and the impurities. The impurities mainly are alumina and silica content. Indian blast furnaces normally use iron ore fines with high alumina at 3.0-3.5per cent when compared to less than 2.0 per cent globally.

Indian best practice: Lowest specific iron ore consumption in India was observed at Vizag Steel at 1.53 tonne/tcs. The blast furnace uses 75per cent agglomerated iron ore as iron burden. Iron ore lump and fines are sourced from NMDC, Bailadila, Chhattisgarh. Sinter used in process has 55.4per cent Fe, 6.5per cent Silica and 2.32per cent Alumina whereas lump ore contains 66.69 per cent Fe, 1.6per cent Silica and 0.94per cent Alumina.

Global best practice: European blast furnaces have achieved the lowest iron ore consumption of 1.4 tonne/tcs[64].

5.16 SPECIFIC EQUIVALENT COKING COAL CONSUMPTION

Coke consumption in blast furnace and the coke making efficiency on a plant boundary level is easily reflected in the specific equivalent coking coal consumption per tonne of crude steel in an integrated steel plant. This single indicator gives a clear measure of how efficiently the plant is managing its energy use.

Indian best practice: Lowest equivalent coking coal consumption of 656 kg/tcs was reported at Ispat Industries. The plant also has lowest specific coke consumption of 394 kg/thm. On the other hand, the plant uses maximum substitute fuel of pulverized coal injection at 126kg/thm.

Global best practice: The global best for plant level coke consumption is as low as 250 kg/tcs[65].

5.17 CAST HOUSE DEDUSTING SYSTEM

When the blast furnace tap hole is opened intermittently for tapping the molten iron, a huge amount of fumes and graphite dust particles are released. Further, as the molten iron travels along the open sand pathways to the insulated vessel (ladle), huge fumes and dust emissions are again released.

Hence, to ensure proper working conditions for the blast furnace workers and minimise heat loss, the fumes, dust and graphite particles need to be collected through properly designed suction hoods and bag filter/ ESP system.

Figure 11: Cast house dedusting at Bhushan Power and Steel, Sambalpur, Odisha

Source: Green Rating Project, 2011

Indian best practice: Of the 43 BFs surveyed under GRP in India, only 12 had installed cast house dedusting system.

Global best practice: As per the European Union IPPC document, cast house dedusting system has been installed at Blast furnace #7, Corus, IJmuiden (The Netherlands); blast furnaces #5, #6 and #A, Voestalpine, Linz (Austria); blast furnace Thyssen Krupp Stahl AG, Duisburg-Schwelgern (Germany); ArcelorMittal, Drbrowa Górnicza (Poland); SSAB (Sweden) and Rivagroup, Taranto (Italy)[66]. The dedusting system is for tap holes, runners, skimmers and torpedo ladle charging points.

5.18 ADVANCED CARBON-MONOXIDE MONITORING SYSTEM FOR GAS LEAKAGE DETECTION

The BF-gas and other waste gas fuels are found to leak from the gas scrubbing area, blast furnace top, hot blast stove area and other areas in the blast furnace operations. The BF-gas contains around 26 per cent carbon monoxide and hence is extremely lethal. The leakage of BF-gas has been reported to be a major cause of fatalities in steel plants, as per GRP survey. During the GRP survey, it was found that employees were not carrying portable carbon monoxide meters (an indicator and proxy for gas leakage measurement) in the blast furnace area of many plants. Further, many online carbon monoxide monitors installed in different locations were not found working. More attention is required for gas leakage tracking and accessibility of monitors for plant personnel, including contract workers.

Indian best practice: The alarm level for BF-gas leakage detection was found normally kept at 30-50 ppm carbon monoxide.

Global best practice: The global best practice is exposure to carbon-monoxide of less than 5 ppm in 8-hour shift as per standards in advanced countries and with nil gas leak accidents.

5.19 BF GAS CLEANING AND METALLURGICAL WASTEWATER TREATMENT

Blast furnace gas after coarse dust separation is directed to gas scrubbing using scrubber or wet ESP. Scrubbing water, reddish in colour, contains higher concentration of carbon particles and heavy metals such as iron, lead and zinc. Whereas coarse dust is reused in sinter plant, sludge from wet gas cleaning, settled at settling tank, is difficult to reuse because of having high lead (0.8-2.0per cent) and zinc content (1-10per cent). The low zinc sludge is separated from high zinc sludge and is reused in sinter whereas high zinc sludge is stored and disposed off. Sedimentation process at settling tank is improved by using flocculation agents such as anionic polyelectrolytes, mixed polymers or activated silicic acids. Over flow of the sedimentation step is generally cooled and used back in gas scrubbing[67].

Use of low quality ore may generate high impurity off gas resulting in higher impurities such as alumina, silica, salt content and alkali compounds in scrubbing water which may result in increase in water requirement for scrubbing, reduction in GCP efficiency and recyclability of treated water. Higher cyanide concentration in scrubbing water is observed especially during starting or restarting phase of blast furnace.

Overflow from the scrubbing water circuit ranges 0.1 – 3.5 m^3/thm whereas the gross water requirement for off gas cleaning ranges 0.4 – 8 m^3/thm depending on the raw material quality and water availability.

Indian best practice: Indian blast furnaces such as at Ispat Industries, Jindal Steel and Power Limited and Jai Balaji, are able to recycle 100 per cent of treated GCP wastewater. GCP sludge generated is entirely reused in sinter plants. However in many other blast furnaces in India, GRP survey found metallurgical wastewater being released as overflow to the drains. Due to inefficient filtering and dewatering equipments and their poor maintenance, the recycling was poor and contaminated wastewater was being discharged into the environment.

Global best practice: BF gas treatment is widely applied at blast furnaces around the world which can achieve the residual dust concentration of 1 – 10 mg/Nm^3. Low pressure drop (0.07-0.14 bar) and high efficiency gas cleaning system is preferred in modern plants. The older scrubber at the blast furnace however can also be replaced with the modern one but in consideration with the top gas pressure turbine.

Corus, IJmuiden (The Netherlands); Thyssen Krupp Stahl AG, Duisburg (Germany) have installed hydrocyclonage to separate zinc rich sludge (20-40per cent by weight) as overflow and separate it for stockpile/landfill.

For cyanide treatment at ArcelorMittal, Bremen, formaldehyde is added to scrubbing water before sedimentation process to produce glyconitrile which is oxidized by adding hydrogen peroxide solution to form glycol to lower the environmental impact[68].

6. COREX PLANT

The COREX process uses a melter-gasifier which gasifies non-coking coal to produce reducing gas which is used in reduction shaft for reduction of iron ore (lumps and pellets) for making direct reduced iron (DRI). The process is called smelting. The hot gases produced in the melter-gasifier are further used to melt the hot DRI produced from reducing shaft.

The improvised form of COREX process is FINEX which can use iron ore fines directly. In India, JSW Steel, Vijaynagar has been using COREX technology till 2011, however few other steel plants such as Essar Steel, Hazira are adopting the COREX technology as well.

The market penetration of COREX technology is limited and it has certain shortcomings as well. The major limitations include:

- The limited unit-wise capacity of the COREX module (maximum 1.0-1.5 MTPA hot metal per module)
- High oxygen requirement (almost 10 times the requirement in BF)
- Frequent breakdowns which affect production
- Strictly controlled charge quality requirement for smooth operations.

The best practices for COREX process operations have been reported for lower off-gas generation, minimised solid fuel and hence gross energy consumption, lower oxygen consumption and lower COREX slag generation rate[69].

The other clean technologies of BF such as cast house slag granulation, cast house dedusting, low slag generation, lower coal and coke consumption etc. are also applicable to COREX process.

7. COAL DRI PLANT

The coal based iron making process involves direct reduction of iron ore to solidified iron in a rotary kiln. The process uses non-coking coal which acts both a reducing agent and an energy source. Lump ore (and increasingly ore pellets) is used as iron burden.

In the coal based direct reduced iron (DRI) process, a part of the non-coking coal and the entire lump iron ore (both of size 5-20 mm) are fed at the higher end of the kiln. Limestone or dolomite is also added for removing the sulphur present in coal. Combustion air is fed at the discharge end, and by special fans located throughout the length of the kiln shell. The product appears in the form of spheroids with sponge like appearance. This process is also called coal based sponge iron process.

The reaction gases coming out from the kiln is burnt in an after burning chamber (ABC) for removing traces of carbon monoxide. The flue gases are finally passed through an ESP to capture the dust before release through the stack.

The coal DRI process is extremely polluting by nature. The major air pollution sources are the kiln exhaust gases and the cooler discharge/production separation areas. The other significant sources of air pollution are the coal and iron ore storage and handling areas. Further, the process also generates large amounts of solid wastes, which are not recyclable and hence land-filled, mostly outside plant premises.

The coal DRI process urgently needs overall improvement in raw material quality, operational performance, control of air emissions and management of solid waste disposal, among others.

The following are few of the best practices in coal DRI process.

7.1 HIGH KILN CAPACITY

Large size kilns allow economies of scale in installing advanced air pollution control and waste heat recovery equipments and minimize space requirement. The kilns of maximum 350 TPD and 500 TPD capacity are considered the best practice in India. Above 500 TPD kilns are reported unstable due to higher accretion formation and maintenance problems[70]. A typical 500 TPD kiln produces 0.15 MTPA coal DRI.

Indian best practice: Many Indian coal DRI plants such as Godawari Power and Ispat (Kiln #3 and #4), Jindal Steel and Power (DRI Unit II - Kiln #7, #8 , #9 and #10), Visa Steel and Bhushan Power and Steel, Sambalpur etc. have installed 500 TPD kilns.

Global best practice: For coal DRI process, the global best practice corresponds to the Indian best practice.

7.2 PREHEATING RAW MATERIAL FROM HOT FLUE GASES

As per GRP survey, utilizing waste heat from kilns for power generation leads to substantial thermodynamic and system losses. Hence, it is not considered as best practice. Rather the waste heat can be used to preheat the incoming raw materials.

In this technique, the raw materials, which are otherwise fed at ambient temperatures, are preheated using waste heat (900 Deg C) from the outgoing hot flue gases. The raw materials get preheated upto 700 Deg C. This reduces the coal consumption in kiln required for heating the charge. The energy saving may range from 12.5per cent to 20per cent[71].

Indian best practice: Raw material preheating, using hot flue gas waste heat is practiced at 100 TPD kilns of Hare Krishna Metallics Private Limited, Karnataka[72]. This plant uses the iron ore lumps from Bellary mines along with South African coal for the coal DRI process.

Global best practice: For coal DRI process, the global best practice corresponds to the Indian best practice.

7.3 PNEUMATIC ESP DUST COLLECTION SYSTEM

In conventional sponge iron kilns, ESP dust is loaded onto trucks manually, which contributes to high air emission. The pneumatic ESP dust transfer system is a 100per cent dry dust collection system using pneumatic transfer in fully enclosed hoppers and pipelines. The dust is disposed off from the silo to the truck directly. This leads to significantly lower emissions with no water requirement for dust control and also significantly improves the housekeeping of the kiln area[73].

Indian best practice: As per GRP survey**,** pneumatic ESP dust collection is in practice at DRI Unit II at Jindal Steel and Power, Raigarh and Godawari Power and Ispat, Raipur (Kiln #3 and #4).

Global best practice: For coal DRI process, the global best practice corresponds to the Indian best practice.

7.4 ADVANCE DUST CONTROL IN PRODUCT BIN SEPARATION AREA

To control the dust emission from product separation and transfer point area, a custom-made suction hood with bag filter mechanism needs to be installed. The dust laden air from the transfer points are continuously collected using a localized vacuum and sent to the bag filter, which can capture all the dust before releasing the air to the atmosphere.

Indian best practice: In India, only Jindal Steel and Power's DRI Plant II has installed advance dust control systems in cooler discharge and product bin separation area. None of the other plants have installed this technology.

Global best practice: For coal DRI process, the global best practice corresponds to the Indian best practice.

7.5 USE OF 100 PER CENT PELLETS AS IRON BURDEN

Higher pellets ratio in charge gives higher (25per cent higher) productivity. This also reduces coal consumption, improves kiln campaign life, improves better metallization of pellets, reduces fines generation and iron ore loss and improves work environment. It helps in conserving the natural resource through higher use of ultra fine ores which is normally discarded. Net energy savings of 1.0 GCal/tonne DRI can be achieved over conventional kilns where lump ore is used**.** The specific coal consumption is thus lower by around 15-20per cent.

Indian best practice: As per GRP survey, Godawari Power and Ispat Kiln #3 and #4 and Jindal Steel and Power (DRI Unit II) have started using 100per cent pellets from 2010-11 onwards.

Global best practice: For coal DRI process, the global best practice corresponds to the Indian best practice.

7.6 LOWER SPECIFIC THERMAL ENERGY CONSUMPTION

The coal-based DRI process inherently has poor energy efficiency due to the poor reaction of reducing gases with iron ore, formation of unburnt coal (as char) and high amount of energy lost through exhaust gases. Lower specific energy consumption represents better efficiency, saving of coal, higher energy recovery in the plant. As per the GRP survey, the specific gross thermal energy consumption (on input basis) of Indian coal DRI kilns was found high in the range of 6.0- 9.0 Gcal/t DRI.

Indian best practice: Jai Balaji, Durgapur plant had lowest specific thermal energy consumption of 6.0 Gcal/tonne DRI in India. The plant has 100 TPD capacity kilns and uses low-ash high grade coal from Mahanadi Coalfields Limited (MCL) and Eastern Coalfields Limited (ECL) with fixed carbon close to 40 percent.

The Jindal Steel and Power, Raigarh DRI Kiln#2 of 350 TPD capacity has specific gross thermal energy consumption of 6.4 GCal/ tonne DRI. The plant uses iron ore from Barbil, Orissa and washed non coking coal with 38per cent fixed carbon post washing.

Theoretical best practice: Best achievable specific thermal energy consumption for coal DRI is reported close to 5.0 GCal/tonne DRI[74].

7.7 KILN CAMPAIGN LIFE

Fusion of coal ash in the kiln at temperature above 1050°C range creates accretion. The fused ash gets stuck in the form of a ring on the kiln inner circumference and severely affects flow of charge materials across the kiln length leading to gradual loss of output.

The non-coking coal with low-ash fusion temperature promotes formation of accretions in the kiln. Coal with high volatile matter (VM) lead to high-temperature formation in the kilns, which further leads to accretion formation.

Lower the campaign life (number of days for which a kiln operates continuously before a shutdown for removal of accretion), higher the shutdown period required, which affects energy use. It also implies higher opening of the after burning chamber (ABC) cap, directly leading to sooty emissions. Campaign life of Indian coal DRI kilns was found in the range of 29-225 days.

Indian best practice: The DRI kilns at Usha Martin, Jamshedpur has highest campaign life of 225 days. These are 350 TPD capacity kilns and use better quality non-coking coal with fixed carbon content of 34 to 40per cent and calorific value of 4500 kCal/kg. Some kilns of Jindal Steel and Power, Raigarh have reported kiln campaign life of close to 300 days.

Global best practice: For coal DRI process, the global best practice corresponds to the Indian best practice.

7.8 SPECIFIC CHAR GENERATION AND UTILIZATION

Higher the unburnt coal (char) discharged from the kiln, higher the amount of solid waste generated, leading to significant impacts on environment and local community. The high coal char generation may result in higher specific coal consumption which results in poor energy efficiency performance. Char generation in Indian plants was found significant in the range of 225-461 kg/ tonne DRI.

Char contains moderate calorific value of 1500-1600kCal/kg due to having unburnt carbon in it. It does not have any volatile matter therefore cannot be used as independent fuel. It is washed to free the impurities, mixed with coal fines, pulverized and then used as fuel in Fluidized Bed Combustion Boilers (FBC).

Indian best practice: Jai Balaji, Durgapur’s DRI kiln had lowest char generation of 225 kg/tonne DRI. The plant has 100 TPD capacity kilns and uses low-ash high grade coal from Mahanadi Coalfields Limited (MCL) and Eastern Coalfields Limited (ECL) with fixed carbon close to 40 percent.

Most of the plants are India used to dump the maximum char into low lying areas. Godavari power and Ispat has little higher calorific value char i.e.1800-2000 kCal/kg, therefore, almost 70 per cent of it is burnt in-house in boilers or sold to external agencies as fuel. The remaining 30 per cent is dumped outside the plant in abandoned stone mines. Similarly, Jai Balaji plant also recycles and reuses the char in its captive thermal power plant.

Global best practice: The best achievable char generation quantity is considered as low as 180 kg/tonne DRI. It is expected to not to dispose but to reuse the generated char entirely (100per cent) by the plant. The char can either directly be used as fuel or can be mixed with coal fines to convert into briquettes to be used brick kiln[75].

8. GAS DRI PLANT

Gas based Direct Reduced Iron (DRI) production process uses natural gas instead of coal as a source of energy and reducing agent. Natural gas which mainly contains methane is converted into reducing gas - a mixture of carbon monoxide and hydrogen, using reformer. The reformed gases are used in shaft furnace for reduction of iron ore in DRI.

The gas based process produces DRI with high degree metallic iron and it also enables lower specific energy consumption and lesser pollution problems. MIDREX and HYL are two different gas based DRI production technologies installed in Indian plants. Limited natural gas availability and high price has been a major reason behind limited capacity addition of gas based DRI plants in India.

Technologies for achieving better energy efficiency and air pollution control have been the key aspects for consideration in the gas based DRI plants globally.

8.1 HIGH TEMPERATURE DRI TRANSFER TO ELECTRIC ARC FURNACES

Hot DRI (650 Deg C) produced from modules are directly transferred to the steel making unit (EAF) using either pneumatic pipelines or transfer vehicle. The technology reduces overall energy requirement and improves overall productivity.

Indian best practice: Hot DRI transfer vehicle is used for hot DRI transfer at Essar Steel. This technology saves energy of around 100 kWh/tcs which is equivalent to 20per cent of energy consumed in EAF based steel making process at Essar Steel[76].

Global best practice: There are some other gas DRI plants in the world which have installed this technology. Hadeed Steel’s gas DRI plant in Saudi Arabia has installed pneumatic hot DRI transfer technology[77].

8.2 HIGH PRODUCTIVITY

The productivity of a module is defined as tonnes of gas DRI produced per day per m^3 reduction volume of the module. Higher productivity implies lower energy consumption per tonne of gas DRI produced.

Indian best practice: In Midrex process, Essar Steel’s gas DRI module#5 has achieved the highest productivity of 10.65 tonne DRI/m^3 volume/day. The module has pellet ratio in iron burden at 83per cent.

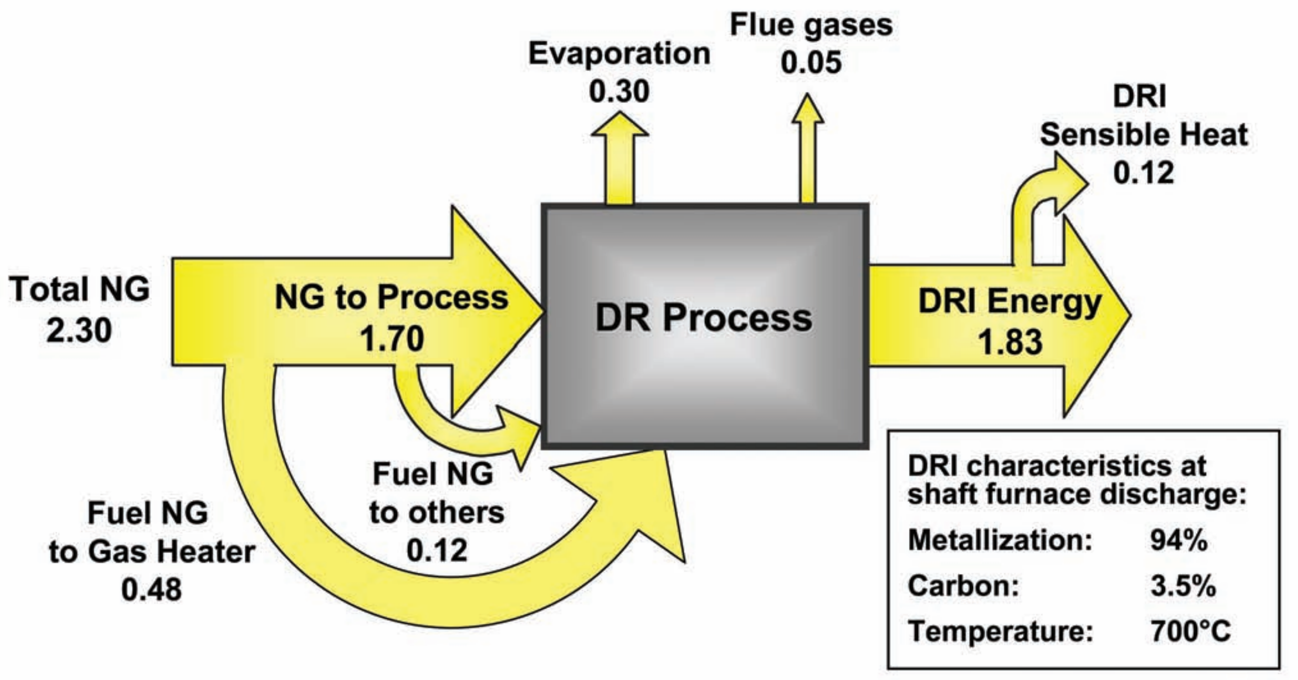
Global best practice: Midrex technology reports the highest achievable productivity of 14 tonne DRI/ m^3 volume/day[78].

8.3 SPECIFIC THERMAL ENERGY CONSUMPTION

Natural gas acts both as a source of reductant and energy. Some plants uses naphtha and propane in addition as auxiliary fuel source. Specific natural gas consumption is found in the range of 296-341 m^3/tonne DRI among Indian gas DRI plants.

However pellet making also requires energy so total specific thermal energy required for gas DRI making was found in the range of 2.8-3.2 GCal/ tonne DRI which is comparatively low compared to the other metallurgical routes of BF coal based DRI route as per GRP survey.

Figure 12: Energy balance in MIDREX gas DRI making



Source: P Duarte 2007, 'ENERGIRON Direct Reduction Technology – Economical, Flexible, Environmentally Friendly', Argentina, p 8, http://www.tenovagroup.com/pdf/exhibition/ENERGIRON%20Direct%20Reduction%20Technology%20%20Economical%20Flexible%20and%20Environmentally%20Friendly.pdf, as viewed on November 2, 2012

Indian best practice: Essar Steel has achieved lowest specific thermal energy consumption at 2.44 Gcal/ tonne DRI. This includes the advantage of having hot DRI transfer facility with this plant which saves power nearly 100kWh/tcs.

Global best practice: The global best specific thermal energy consumption is reported as 2.3 GCal/ tonne DRI[79] (see energy balance below).

9. BASIC OXYGEN FURNACE

This is the most popular primary steel making process in the world which utilises oxygen for steel making. This process, named the basic oxygen furnace or BOF process (also Linz Donawitz or LD process) enables production of high quality steel in a batch cycle of less than 60 minutes duration. As of 2010, this accounted for 70 percent of steel making route in the world[80]. In India basic oxygen furnace route accounted for 46per cent of steel making in 2010-11, with the rest being accounted by electric arc or induction furnaces.

The process requires continuous supply of hot molten iron from BFs which is mixed with coolant materials (steel scrap, iron ore lumps etc.) and lime agents. The molten iron is supplied with pure oxygen to achieve the higher temperature required for steel making which can be further purified to achieve desired quality. Steel slag generated from steel making is one of the biggest problems besides the air and water pollution issues.

The process has major pollution issues in India like secondary emissions, metallurgical wastewater discharge and slag disposal. Hence, there is significant potential of adopting best practices in BOF steel making in India.

9.1 LARGER SIZE CONVERTER

The converter size or unit capacity is defined as tonne of liquid steel produced per batch cycle and is a key design feature for steel melting shops (SMS). Larger converters enable installation of waste energy gas recovery systems and advanced pollution control equipments. The converter size in Indian plants was found in the range of 66 to 300 tonnes /heat.

Indian best practice: SAIL Bokaro SMS #2 unit has the largest size converter of 300 tonne/heat. This has the capacity to produce 2.16 MTPA of liquid steel. The converter is equipped with combination oxygen blown facility and operates at 26 heats per day.

Global best practice: The largest LD converter was found at 375 tonne/ heat at ILVA Spa (Italy)[81].

9.2 DOGHOUSE FOR EMISSION CONTROL

Huge amounts of fugitive emissions are released during oxygen lancing and when coolant materials such as iron ore and scrap are fed to the converter during each blowing cycle. To address the pollution problem, a total housing or enclosure system for each converter vessel is available and it captures the entire emissions from the enclosure. This technology is called doghouse. The dust-laden doghouse air is cleaned in bag filter or electrostatic precipitator (ESP) before being released to the atmosphere.

Indian best practice: Tata Steel (SMS#2) and JSW Steel (SMS# 1 and SMS #2) are the two integrated steel plants in India which have installed doghouse technology for fugitive emission control in SMS area.

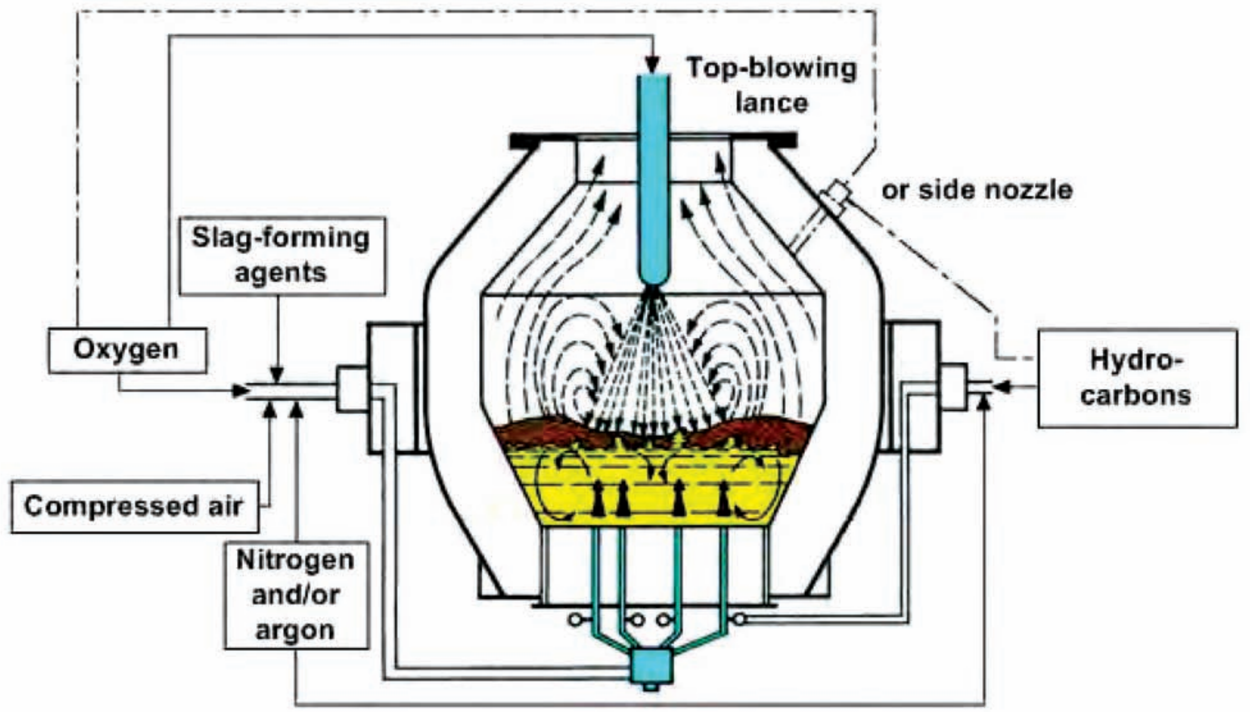
Global best practice: Installation of doghouse is common in BOF units of steel plants in EU and advanced countries[82].

9.3 COMBINATION BLOWN CONVERTER

Oxygen blowing is required for faster reaction in LD converters. In conventional converters supersonic oxygen jet lancing is done from the top which has low penetration in depth at the same time bottom oxygen blowing has issues of intense heat generation and affect on refractory life. The new technology- Combination blown system can blow oxygen from the bottom which maximizes oxygen interaction with hot metal and speeds up the reaction without compromising the refractory life and intense heat issue.

Oxygen injection can also be supplied through Multi holes oxygen lancing into molten bath. This in ensures further speed up of reaction and better interaction of oxygen with molten metal.

Figure 13: Combination blown converter



Source: Anon 2012, 'Integrated Pollution Prevention and Control (IPPC) – Best Available Techniques Reference Document', European Commission, p 358, http://eippcb.jrc.es/reference/BREF/IS_Adopted_03_2012.pdf, as viewed on November 2, 2012

Indian best practice: Most of the Indian steel plants have installed multi hole lancing facilities for oxygen enrichment. Integrated steel plants such as Vizag Steel, JSW Steel, Tata Steel (SMS#2) etc. have installed combination blown converters for steel making.

Global best practice: Combination blown converters are preferred and widely installed in steel plants in advanced countries.

9.4 STATIC DYNAMIC PROCESS CONTROL

In the conventional BOF steel making method, the total charge mix, oxygen blowing duration and the oxygen required are computed prior to the start of the process. This method does not help predict the process variations as a function of time during the lancing process. Hence, it leads to delayed time for achieving the desired steel quality, leading to lower energy efficiency and low waste energy recovery.

In the dynamic process model, the Static dynamic process control enable process operator to compute reaction even when the reaction is going on. Accordingly, operator can ensure precise supply of oxygen and control various process parameters[83]. Production time per batch is reduced so productivity is increased.

Indian best practice: Till 2009-10, only JSW Steel had installed Static dynamic process control for its 5 converters spanning SMS #1 and # 2.

Global best practice: As per the EU IPPC document**,** most EU plants apply online sampling and dynamic modeling process[84]. Other plants which have adopted this technique include Nanjing ISCO (China), Taiyuan ISCO (China) US-Steel Kosice (Slovakia), Maanshan ISCO (China) and Mittal Steel Vanderbijlpark (South Africa).

9.5 SUB-LANCE

Using sub-lance technology, metallurgical samples from the converter can be withdrawn and check for its desired qualities without tilting the converter and within 90 seconds. Sub-lance system along with dynamic process control minimises oxygen re-blows and increase the lancing precision[85]. Emissions to air are also reduced as it is not necessary to tilt the BOF.

Indian best practice: None of the Indian steel plants have installed the sub-lance system to the converters.

Global best practice: Steel plants in European Union member states have adopted sub-lance technology for its converters. As per Vortrefflich (2010), more than 30 steel shops in China have installed over 90 sublance systems producing in excess of 200 Million Tonne of liquid steel per year[86].

9.6 SEMI-DRY GAS CLEANING

Off gas scrubbing at BOF may require 0.5 to 1.0 m^3/ tcs water. Using semi-dry technique of gas cleaning system water demand can be reduced by nearly 50per cent, thereby, reduces effluent generation as well. Dust removal efficiency of particles >1µm of this technology is up to 99per cent.[8].

Indian best practice: None of the Indian steel makers have adopted this process for off gas cleaning in India.

Global best practice: This has been adopted in many steel making plants in Europe.

9.7 NUMBER OF HEATS PER DAY

The tap-to-tap time reflects the entire time duration required for completion of one batch of oxidation cycle in a converter to achieve the desired steel quality output. Faster the tap-to-tap time, lower the energy loss and faster is the batch cycle of steel melting. Tap-to-tap time of Indian converters was found in the range of 40 to 99 minutes/cycle.

Lower tap-to tap time also ensures higher number of heats per day. Higher the number of heats (batch cycles) per day, higher will be the overall efficiency of BOF plant operations. The higher heats per day ensure proper scheduling of the upstream blast furnace operations and hence lower energy losses at the blast furnace unit. Number of heats per day in Indian plants was found in the range of 14 to 34.

Indian best practice: LD converter #1 of capacity 150 tonne/heat at Tata Steel has the lowest tap to tap time of 40 minutes. The same converter, therefore, has highest number of heats of 34 heats/day.

Global best practice: Baosteel (China) has achieved lowest tap to time of 34 minutes. Average tapping temperature remains 1610-1700 DegC[88]. Mittal Steel Sparrows Point plant (USA) has achieved highest tap to tap time of 40heats/day with its 295tonne/heat converters[89].

9.8 LOW SPECIFIC OXYGEN CONSUMPTION

Lower the oxygen consumed for steelmaking in BOF operations, lower the energy that is required for oxygen supply. This leads to improved energy efficiency of the BOF process operations.

Apart from hot metal quality, the specific oxygen consumption depends on the stirring and homogenisation of the bath. Higher stirring helps in increased oxygen interaction and ensures early completion of the steelmaking cycle. Oxygen consumption in LD converters in Indian plants was found in the range of 47 to 65 Nm^3/tonne of liquid steel (tls).

Indian best practice: SMS#2 of Tata Steel Jamshedpur consumes lowest oxygen at 47 Nm^3/tls for its 160 tonne/heat converter.

Global best practice: The lowest oxygen consumption of 47 Nm^3/tls at Tata Steel Jamshedpur also corresponds to the global best as per GRP survey.

9.9 HIGHER LD GAS COLLECTION & REUSE

The off-gas from BOF process is rich in energy at 1800 kCal/m^3 and can be used for reheating and power generation purposes in a steel plant. Nearly 2-4per cent of the energy required in steel plant is supplied by LD gas. Higher LD gas collection and reuse enables better energy efficiency and lower air emission. LD gas collection and reuse in Indian steel plants was found in the range of 0 to 107 Nm^3 / tcs.

Indian best practice: JSW Steel has achieved highest LD gas collection at 107 Nm^3 / tcs from SMS#1 which has 3 x 130 tonne/heat capacity converter.

Global best practice: The highest LD gas collection and reuse has been reported at 130 Nm^3 /tcs[90].

9.10 LOW LD SLAG GENERATION

The impurities in molten bath in the BOF process are collectively separated and removed as slag. Lower the slag generation rate, higher will be BOF process efficiency and lower solid wastes generation. LD slag generation rate was found in the range of 96-180kg/tcs.

Indian best practice: Vizag Steel in India has achieved the lowest LD slag generation of 96 kg/tcs with its 150 tonne/heat capacity converters. The charge consists of hot metal of 1005 kg/ tonne liquid steel, scrap of 83.4kg/tonne liquid steel and fluxes of 18.6 kg/tonne liquid steel.

Global best practice: European steel plants have achieved LD slag generation as low as 85 kg/tcs[91].

9.11 LD SLAG REUSE

Recycle and reuse of LD slag is a complex issue for the steel industry. It contains lime or calcium oxide (48-55 per cent), ferrous oxide (18-22 per cent), silica (10-15 per cent) and traces of alumina, other metal oxides, phosphorus and heavy metals.

Due to high iron oxide content LD slag is not used in cement making but some quantities are used as liming agent in the sintering process where its limiting factor is phosphorous content which in high quantity affects the sinter chemistry.

Road and rail making ballast are the main sources of LD slag reuse. However it is also used as component of cement raw mix, sea shore protection, pavement bases, storage yard, heavy vehicles parking loads etc. The hazardous components of LD slag and their impacts on environment are yet to be explored.

Indian best practice: Ispat Industries, Raigad have started metal recovery from the LD slag. JSW Steel states that around 20 per cent LD slag is gainfully reused in process i.e. around 14 per cent through metal recovery and 6 per cent using a lime agent is sinter plant# 2. Essar steel has started using the LD slag in heavy vehicle parking spaces, ceramic tiles making, filling low lying area and boundary wall of the compound.

Global best practice: In Europe, considerable amount of LD slag is also used as fertilizer (nearly 3per cent) and lime agent for agriculture due to its high lime (CaO) content. Use of LD slag reuse as sulphur containing soil conditioner has also been reported.

In EU plants, nearly 45per cent LD slag is reported to be use in road construction, 17per cent as interim storage, 14per cent internal recycling, 11per cent final deposit and remaining in hydraulic engineering, fertilizer, cement production and other uses[92].

9.12 HIGH VESSEL LINING LIFE

The faster deterioration of refractory materials leads to frequent shutdown of the BOF vessels for repair. This in turn affects the scheduling of hot metal demand from blast furnace and hence overall plant energy efficiency. The average vessel life lining of LD converters in India was found 5000 heats/campaign.

Indian best practice: In 2009-10, JSW Steel Vijaynagar SMS#1 was reported to have the highest vessel lining life of 8177 heats/campaign.

Global best practice: Highest average vessel lining life is reported for Baosteel (China) at 9908 heats/campaign[93].

9.13 THIN SLAB CASTING (also applicable for electric steel making)

This is a new technology that integrates casting of liquid steel and the subsequent stage of hot rolling in one process. In conventional continuous casting process, the liquid steel is cast into slabs (50-90 mm thick) and then they are left to cool. For the next stage, the cooled slab is again heated in reheated furnaces in hot strip mill area to make steel sheet coils.

The casting of molten steel into near net shape or thin slabs without the intermediate use of reheating furnace is called thin slab casting. Typical dimensions for thin slab casting are lower, between sizes of 15-50 mm. In the near net shape strip casting leads to a strand thickness of below 15 mm and thin strip casting to less than 5 mm. This measure helps in lowering primary energy used in the reheating stage by 0.5 GCal/tonne finished steel when compared with the conventional continuous casting method.

Indian best practice: None of the BOF plants in India has installed thin-slab or near net shape technology for casting process. Ispat Industries, Raigad which has CONARC furnace is equipped with thin slab casting.

Global best practice: Thin-slab casting has been installed at ThyssenKrupp Nirosta, Bochum, Germany (400000 tonnes/year); Nucor Crawfordsville, Indiana, US (400000 tonnes /year) and Nippon Steel, Japan[94].

10. ELECTRIC ARC FURNACE

In this process, the raw material charge could include scrap, Direct Reduced Iron (DRI), hot metal and pig iron. Electricity is used as energy source to melt solid charge, remove carbon and produce steel. Electric steel making process is growing worldwide as it is not only used by merchant steel makers but also by integrated steel plants. The process causes a heavy burden on electric grid and also a prominent air emission source. The electric arc furnace (EAF) process accounted for 24 percent of steel making in India in 2009-10.

The best available techniques for EAFs in India comprise of reduction of air polluton and energy consumption and increasing productivity.

10.1 HIGH FURNACE CAPACITY

In Indian integrated steel plants, EAF unit size was found in the range of 40-190 tonne/heat. The larger size EAF vessels enable economies of scale to install advanced pollution control and energy efficiency technologies.

Indian best practice: Ispat Industries, Raigad, has CONARC type arcing steel making facility. Among Indian electric arc furnaces, it has the largest capacity of 190tonne/heat, each of 0.9MTPA capacity. Many plants in India have installed DC type furnaces including Ispat industries.

Global best practice: Tokyo Steel (Japan) has installed the largest 420 tonne /heat capacity arc furnaces. It is a DC type twin arc furnace with 2.6MTPA steel production capacity[95].

10.2 SPECIFIC TRANSFORMER RATING

The specific transformer rating is the total apparent power supply in kilo volt ampere (kVA) installed for melting one tonne crude steel. Use of high transformer rating furnaces enables faster melting of solid charge material thereby decreasing the tap-to-tap cycle time. The range of transformer rating among Indian EAFs is found in the range of 500-1227 kVA/tcs.

Indian best practice: Essar Steel has installed highest transformer rating EAF at 1227 kVA/tcs. Each furnace has capacity of 150 tonne/heat with 1.15 MTPA crude steel production capacity.

Global best practice: The highest specific transformer rating is reported at 1500kVA/ tcs for a 120 tonne/ heat capacity EAF[96].

10.3 FOAMY SLAG PRACTICE

Oxygen injected with granular coal or carbon produces carbon monoxide (CO) which entraps and forms bubbles foaming the slag. It helps in shielding the arc and molten steel liquid, minimizes heat transfer losses. Thermal efficiency of the plant increases by 40-60 percent.

Indian best practice: Essar Steel, Hazira, Ispat industries, Raigad and Jindal Steel and Power, Raigarh have adopted foamy slag practice.

Global best practice: Foamy slag practice is common practice among EAFs in advanced countries.

10.4 COHERENT JET OR SHROUDED JET LANCING

Oxygen enrichment is also used through Coherent jet or shrouded jet lancing. Oxygen jet is shrouded with a fuel flame so that the supersonic jet travels to at least 1.5 times the depth in the molten bath. This helps in reducing overall energy consumption significantly. It also helps in lower oxygen consumption[97].

Indian best practice: Indian steel plants such as Ispat Industries, Raigad, Usha Martin, Jamshedpur, Jindal Steel and Power Limited, Raigarh etc. have adopted Oxyfuel burner for oxygen enrichment in arc furnaces. They are also equipped with Coherent or shrouded jet lancing facility.

Global best practice: These oxygen enrichment technologies are commonly adopted in EAFs of advanced countries.

10.5 BOTTOM STIRRING

Poor movement of the molten bath implies higher cycle time required for completing reactions to remove carbon and other impurities. This leads to higher energy consumption. Hence, similar to BOF converters, bottom stirring system in EAF utilises additional gases such as argon or nitrogen jets for injecting through a direct or indirect contact plug from the bottom of the furnace to stir the molten bath in the EAF.

In direct contact plug, the plug is in contact with molten metal, whereas in indirect the plug is not in direct contact with molten metal but embedded in a porous bottom refractory.

In indirect plug, the argon or nitrogen gas enters the bath via the porous refractory hearth resulting in stirring over a larger area when compared with direct plug. The bottom stirring helps in better homogenisation of the molten bath and balances the temperature. It also improves the slag-metal equilibrium[98].

Indian best practice: Among Indian arc furnaces, Ispat industries' CONARC type furnaces have installed bottom stirring facility.

Global best practice: This technology is common among EAFs installed in advanced countries.

10.6 SCRAP PREHEATING SYSTEM

Nearly 20 per cent of the EAF energy is released through waste off-gas, representing 130 kWh/tcs. Efficient utilisation of this energy can be done by pre-heating the scrap charge.

As per the EU IPPC document (2012), scrap pre-heating using the off-gas from EAF is a technology which can recover chemical and heat energy from the off-gas. Scrap pre-heating can be performed in a specially designed system (scrap charging basket or charging shaft furnace or specially designed scrap conveying system for continuous charging). In some cases, additional fossil energy is used for scrap pre-heating. This measure reduces energy consumption by 40-60 kWh/tonne depending on the scrap pre-heat temperature. The scrap can be pre-heated to 800°C before charging to the furnace.

Indian best practice: None of the Indian EAF based steel plants have installed scrap preheating system.

Global best practice: Globally many plants such as ASW, Montereau (France), Severstal AG (Russia), Habas, Aliaga (Turkey), Stahl Gerlafingen (Switzerland) etc. have adopted this practice[99].

10.7 DRI CONTINUOUS CHARGING

Continuous feeding of DRI is accomplished by conveying the materials from a storage silo located at the top of the melt shop. This ensures uninterrupted steel making process and increased productivity as well.

Indian best practice: All the arc furnaces in the integrated steel making facilities in India are practicing continuous DRI and scrap charging as per GRP survey.

Global best practice: Continuous charging of scrap is practiced by several EAF based plants in EU such as TSW, Trier (Germany), ORI Martin, Brescia (Italy) and Acciaierie Arvedi, Cremona (Italy).

10.8 ECCENTRIC BOTTOM TAPPING

The eccentric bottom enables to arrest the primary slag. Eccentric bottom tapping reduces steel tap times, temperature losses and slag carryover into ladle. The strip producing plants are equipped with eccentric bottom tapping in electric arc furnaces.

Indian best practice: All the arc furnaces in the integrated steel making facilities in India are practicing eccentric bottom tapping as per GRP survey.

10.9 OFF GAS POST COMBUSTION

Carbon monoxide (CO) gas is produced in large quantities in EAF which must be combusted either in the furnace freeboard or in the 4th hole evacuation system conveying the off-gases from the furnace to the bag house.

The oxygen jet lancing injectors in the furnace also act as a post combustion system. Injecting the oxygen in the furnace burns the generated CO gas into carbon dioxide. The generated heat is an energy source for the EAF. If the CO gas is burned in the EAF, it is possible to recover the heat while reducing the heat load on the off-gas system. Beside energy recovery it also controls emission of PCDD/F matters in off gas.

The post combustion heat recovery enables recovery of 35-60 per cent of the energy in the offgas whereas the typical electric energy savings are about 4 kWh/Nm^3 of oxygen injected[100].

Indian best practice: Steel plants such as Bhushan Power and Steel Limited, Sambalpur, Essar Steel, Hazira, Usha Martin, Jamshedpur etc. have adopted post combustion system.

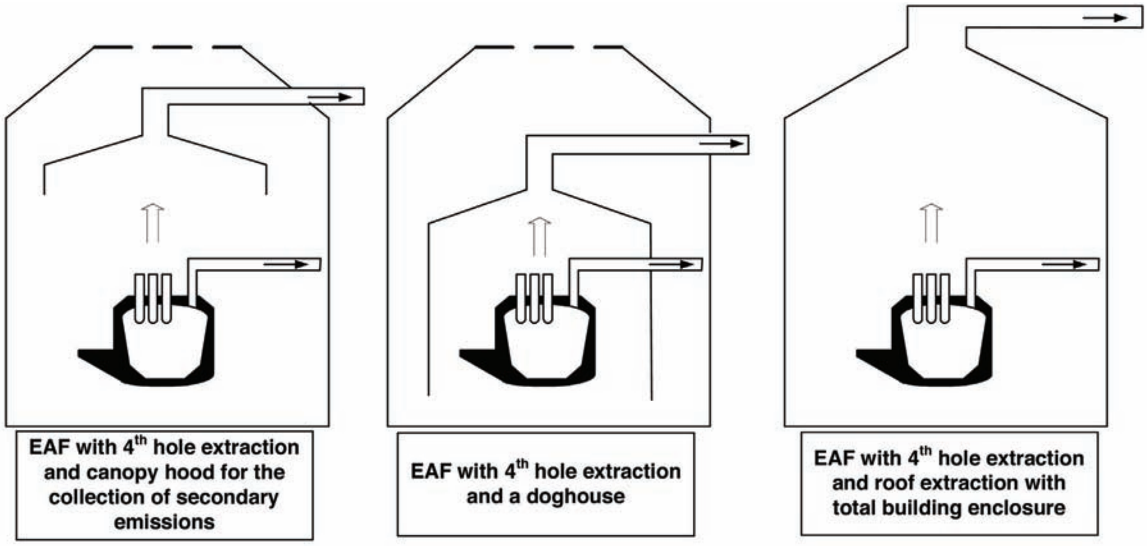
Global best practice: This technology is common among European Union based arc furnaces.

10.10 EAF OFF GAS EMISSION CONTROL: 4TH HOLE, DOG HOUSE, TOTAL BUILDING ENCLOSURES

Nearly 95 per cent of EAF emission is primary off-gas emissions of which 85per cent can be captured using the 4th hole system in the case of three-electrode AC furnaces or from the 2nd hole in the case of one-electrode DC furnaces.

Secondary emission from the process can be captured effectively using Doghouse and total building enclosures. The gases need to be cleaned using a bagfilter, before releasing to the atmosphere.

Figure 14: Off gas emission control techniques



EAF with 4th hole extraction and canopy hood for the collection of secondary emissions

EAF with 4th hole extraction and a doghouse

EAF with 4th hole extraction and roof extraction with total building enclosure

Source: Anon 2012, 'Integrated Pollution Prevention and Control (IPPC) – Best Available Techniques Reference Document', European Commission, p 431, http://eippcb.jrc.es/reference/BREF/IS _Adopted_03_2012.pdf, as viewed on November 5, 2012

Indian best practice: Most of the Indian EAF process based steel plants have adopted combination of off-gas collection and treatment systems. However, the fugitive emissions from these plants were still observed high because of non-functional emission control systems.

Global best practice: Combination of canopy hood, building enclosures and 4th hole is installed among good plants in European Union and across the globe.

10.11 HIGH PRODUCTIVITY

Higher productivity implies lower energy consumption per tonne of liquid steel produced. EAF productivity however depends on number of factors- charge mix and clean technology installation status. Maximum available electrical and chemical energy also improves productivity. In Indian EAF productivity was found in the range of 49.6-176.5 tls/m3 hearth volume/day.

Indian best practice: Jindal Steel and Power, Raigarh has achieved highest productivity of 176.5 tonne liquid steel/m^3 hearth volume/day.

Global best practice: EU steel plants have shown productivity of close to 200 tonne liquid steel/m^3 hearth volume/day.

10.12 NUMBER OF HEATS PER DAY

Similar to the BOF steel making process, the higher the heats per day, the higher will be the productivity and hence, lower the energy use. In Indian EAFs, number of heats was found in the range of 8.5-30 heats/day.

Lower the tap-to-tap time, higher the number of heats per day. High transformer rating such as ultra-high power EAFs reduce the melting duration and therefore, decrease tap-to-tap time.

Indian best practice: Jindal Steel and Power (which uses 50per cent hot metal and 50per cent coal DRI) has the highest number of heats at 30 heats/day for its 100 tonne/heat capacity arc furnace. The same furnace has the lowest tap-to-time of 45minutes.

Global best practice: Nucor steel plant, Texas has achieved highest 50 heats /day with lowest tap-to-tap time of 30-32 minutes. The best results achieved so far was a tap-to-tap time of 28 minutes which allows the production of 50 heats per day[102].

10.13 LOW SLAG GENERATION RATE

Similar to BOF steel making process, slag generation quantity and quality in EAF plants depend on the raw material input as well as desired quality of steel. Higher impurities in the charge mean higher slag generation

Indian best practice: Jai Balaji plant, Durgapur has achieved the lowest slag generation of 140 kg/tonne liquid steel at its EAF plant. This is a 60 tonne/heat furnace which produces 0.5 MTPA of liquid steel. This plant has used both hot metal and coal DRI as feed to the EAF.

Global best practice: European Union states' EAFs have achieved as low as 60kg/tls EAF slag[103].

11. ELECTRIC INDUCTION FURNACE

In the Electric Induction Furnace (EIF) process steel is produced by melting the charge material using the heat produced by electromagnetic field. These furnaces are smaller and the product qualities do not match those of EAFs. EIF is generally used in small scale units. It is a low cost investment and preferred by small producers and merchants but is highly polluting in terms of air pollution and solid waste disposal. Around 31 percent of crude steel in India was produced by induction furnace route in 2009-10.

11.1 LARGER FURNACE SIZE

Larger the furnace size, lower the energy losses, and hence higher the energy efficiency of steel production. Induction furnace size in India has increased from 1.0 tonnes/heat batch melting capacity in the 1980s to up to 18 tonnes/heat[104].

Indian best practices: Jai Balaji, Durgapur plant has largest 18tonne/heat size induction furnaces, each with 6MW power capacity.

Global best practices: The largest size Induction Furnace has been reported as large as 40 tonnes/ heat[105].

11.2 USE OF FURNACE LIDS OR INERT GAS BLANKET

Induction furnaces are normally kept open during the entire melting process where the workers engage in slag skimming and monitoring of the quality of molten bath. However, this leads to significant heat loss and hence special covers or lids need to be installed for reducing heat losses. In particular, reducing the time the lid is kept open while melting, can lead to energy savings. A new technology has come into use, where an inert gas, Argon, shield is used to cover the top of the induction furnace. This is expected to lead to around 25 percent energy savings, improved refractory life and overall higher productivity[106].

Indian best practice: None of the Indian plants have installed this technology.

11.3 PREHEATING OF CHARGE MATERIALS AND LOWEST SPECIFIC ELECTRICITY CONSUMPTION

Similar to charge preheating in other iron and steel making processes, pre-heating scrap by using the hot gases and other means such as hot DRI charging can substantially reduce the energy requirement and also increase the tap-to-tap time.

Indian best practice: Jai Balaji Plant, Durgapur uses 18-20 percent hot metal in EIF charge. Therefore this plant also reports lowest power consumption for EIF at 760 kWh/tcs in India.

11.4 SPECIFIC ELECTRICITY CONSUMPTION

Electricity is the only energy source for steel melting in EIF. The specific consumption was found in the range of 760-850 kWh/tcs among Indian induction furnaces.

Energy saving can also be achieved using proper compaction of charge materials which is important to ensured uniform and rapid heating process[107].

Similarly minimizing the overheating of molten bath also saves energy. Once the melting is complete, the slag is skimmed off. However, it is found that electric current is still being supplied leading to overheating of the molten steel bath. This leads to energy losses. Hence, proper power control systems with potentiometer adjustment need to be provided for minimising energy losses due to overheating.

Indian best practice: Jai Balaji plant, Durgapur has lowest power consumption for EIF at 760kWh/tcs as per GRP survey. None of the Indian induction furnaces have adopted either use of compact charge materials nor have initiated minimization of bath overheating practices.

Global best practice: The best theoretical electricity consumption reported as 351.5 kWh/ tcs whereas the best achieved in US based plants is 538.1kWh/tcs[108].

11.5 ADVANCED DUST EMISSION CONTROL SYSTEM

Huge amounts of hot fumes and gases are released from the open furnace vessels during induction furnace operations and spread across the shop floor, affecting the health of workers. The fumes have to be captured by a properly designed suction hood mechanism. The hood should draw the entire exhaust gases which should be further cleaned through a bag filter before being let out into the atmosphere. The suction hood mechanism could be side, swivel or canopy hood type.

However, as induction furnaces are operated in a less organised way with little management focus with most of the workers being unskilled, their health and safety is compromised. The suction hood mechanism for all plants was not found working properly during the GRP survey.

Indian best practice: None of the Indian plants have installed proper air pollution control systems.

Global best practice: The best practice is to draw the fumes and dust in suction hoods on the arc furnace and passes it through a bag filter for gas cleaning, before releasing it to the atmosphere.

12. OVERALL RESOURCE USE

Apart from the key raw material of iron ore, primary iron and steelmaking operations consume large quantities of major natural resources such as water, energy and land. Increasingly energy sources need to be imported, whereas water and land are site-specific resources and hence their efficient use is of significant importance.

The plant boundary level use of key input resources - energy, water and land are the key benchmarks for assessing resource efficiency of Indian steel industries.

12.1 SPECIFIC WATER CONSUMPTION

Traditionally, the iron and steel sector in India has benchmarked water use across all process stages till the crude steelmaking stage. This is because different steel plants produce different downstream steel products and power could be generated in-house or imported from the grid. Besides, some plants do not have townships for their employees, and this creates a slight inconsistency in benchmarking. Thus, to provide a uniform yardstick for measuring water conservation performance across plants, specific water consumption is estimated till crude steelmaking alone.

However, for many steel plants, the figure is highly distorted by arbitrarily excluding many water demand areas and categorising them as service zone, domestic use (drinking water) within the factory or reservoir loss. The plants create this distortion in order to show compliance with the Charter on Corporate Responsibility for Environmental Protection (CREP) guidelines.

To maintain the consistency in the comparing the water consumption, it should be compared till crude steel making both including and excluding downstream water requirement. As the Indian electricity grid largely rests on coal-based power generation, the specific water requirement for grid power is considered at an average of 5 m^3/MWh of grid power imported.

Hence, measurement and reporting under best practice for specific water use in Indian steel plants should include both the following indicators:

1) For process stage till crude steel making alone – i.e. excluding downstream rolling mills, power generation and township, expressed as m^3/ tcs
2) All inclusive or total – i.e. including downstream, power generation and township, expressed as m^3/ tcs

As per GRP survey, weighted average specific water consumption till crude steel making process stage (excluding downstream rolling mills, power generation and township) in Indian BF-BOF plants is found to be 4.0 m^3/tcs, whereas for DRI-based plants it has been found to be 2 m^3/tcs.

For all inclusive or total weighted average –specific water consumption of the entire sector – was 11.8 m^3/tcs in 2009-10. For BF-BOF process plants, the all-inclusive specific water consumption has been found to be weighted average of 14.9 m^3/tcs, whereas for DRI-based plants it is 6.75 m^3/tcs.

Indian best practice: As per GRP survey, following were the results

Indicator	**Plant name and configuration**
Specific water consumption till crude steel process stage alone excluding downstream rolling mills, power generation and township	**Large steel plant:** Ispat Industries, Raigad has the lowest specific water consumption of 2.1 m^3/tcs. The 3.6 MTPA integrated steelmaking plant has a configuration as follows: one 1.6MTPA gas based DRI plant, 2151 m^3 working volume Blast Furnace, one 204 m^2 grate area sinter machine (2.0 MTPA capacity), two twin-shell Electric Arc Furnaces each shell of 190 tonne/ heat capacity and thin slab casting technology[109]. **Small/medium plant:** Godawari Power and Ispat, Raipur at 0.2 m^3/ tonne crude steel which has a 0.5 MTPA coal DRI plant and induction furnaces
Specific water consumption all inclusive (or total) – i.e. including downstream, power generation and township:	**Large steel plant:** JSW Steel Vijaynagar at 8.8 m^3/ tonne steel plant which had a 6.8 MTPA BF-BOF plant **Small/medium plant**: Godawari Power and Ispat, Raipur at 1.5 m^3/ tonne crude steel which has a 0.5 MTPA coal DRI plant and induction furnace

Global best practice: Excluding downstream operations, the global best specific water consumption for BF-BOF plants is reported at 2.0 m^3/tcs as per a survey by Worldsteel Association[110]. This is for 2.4 MTPA crude steelmaking plant with following configuration: cokemaking 0.7 MTPA, sintering 2.5 MTPA, blast furnace 2.0 MTPA and BOF 2.4 MTPA.

Including downstream operations, power and township, the global best practice for BF-BOF plants has been reported at 5.0 m^3/tcs as per a survey by Worldsteel Association[111]. This is for a 4.3 MTPA integrated steel plant with following configuration: cokemaking 1.5 MTPA, 2.6 MTPA sintering, Blast furnace 4.0 MTPA, BOF 4.3 MTPA, Casting 4.3 MTPA, hot rolling, 3.2 MTPA, cold rolling 1.5 MTPA and finishing 1.4 MTPA.

12.2 LAND USE EFFICIENCY

Poor land planning in Indian steel plant implies that solid waste is being dumped outside the premises in an ad-hoc manner, severely affecting the local communities and ecology. On the other hand, many Indian steel plants have townships and huge unoccupied area or vacant lands. Hence, comprehensive measuring and reporting of best practice of land-use is considered important. The best practice for efficiency of land use can encompass four indicators:

1) Total land (including township) occupied per MTPA of installed capacity.
2) Total production area occupied per MTPA of installed capacity
3) Whether solid waste dumping occurs outside premises?. If yes then poor land-use pattern
4) Green Belt Development as per CPCB guidelines

Indian best practice: Essar Steel, Hazira had achieved highest land-use efficiency at 65 hectares (ha) /MTPA capacity (including township) and 54 ha/MTPA considering only production area (i.e. excluding township). The Essar Steel, Hazira facility is a gas based DRI-EAF based integrated steel making plant. It has 5 gas DRI modules of total 5.0MTPA DRI capacity, 4 DC type EAFs of total 4.6MTPA crude steel capacity with a 600MW gas based captive power plant. The entire plant is just set-up in 300 hectares of land. It is currently under expansion from 4.6 MTPA to 10 MTPA capacity of steel making.

However, the green belt development of the plant as per CPCB guidelines needs significant improvement.

Global best practice: For a conventional type integrated steel plant The global best practice for land use efficiency has been considered as 150 ha/MTPA considering production area alone (i.e. excluding township) . This includes land for solid waste dumping and green belt development. The green belt development with thick canopy trees should be at least 15per cent of the occupied area for production (excluding township) and along the periphery. For total land requirement including township, the global best practice has been considered at 200 ha/ MTPA

12.3 SPECIFIC ENERGY CONSUMPTION

Each steel plant produces different types of downstream steel products to cater to its individual customer segments, with each product requiring varying degrees of energy use. Further, some plants purchase intermediate products such as coke, etc. Hence, comparing the total specific energy of one plant with another does not allow for consistent assessment.

Therefore, for consistent measurement and reporting of best practice for energy use in steel plants should be based on primary energy assessments till crude steel making alone.

Natural gas based plants had lowest specific energy consumption. In coal based processes, conventional BF-BOF process had better specific energy consumption pattern than coal DRI-Electric furnace based steel making route.

Indian best practice: Among DRI based plants, Ispat Industries, Raigad was observed as the best energy efficient plant with specific primary energy consumption at 5.4 GCal/tcs. Ispat Industries is a 3.6 MTPA integrated steel plant with gas DRI process, blast furnace and electric arc furnace.

Among coal based BF-BOF integrated steel plants, Tata Steel, Jamshepdur had achieved the best specific energy consumption at 6.2 GCal/tcs. Tata Steel, Jamshedpur is a 6.8MTPA capacity steel plant (2009-10) with 7 BFs of total 7.3 MTPA hot metal capacity, 4 sinter plants (8MTPA), 9 coke ovens (total 2.3MTPA gross coke), 2 SMS shops (total 6.8MTPA) and a captive power plant (757 MW).

Global best practice: The global best achievable specific energy consumption for a coal based BF-BOF plant is reported at around 4.5 GCal/tcs for a Netherlands and a France based plant[112].

12.4 CARBON EMISSION INTENSITY

The iron and steel sector is the third highest emitter of carbon emissions after the thermal power and cement sectors in India. Carbon emission intensity is higher in coal based processes. The sector emitted around 135 million tonnes of carbon dioxide (CO_2) in 2008-09, with average emission intensity at 2.4 tonne CO_2/tcs[113]. Carbon emissions intensity has close relation to specific primary energy consumption, varying only due to the type of major fuel used (coal or natural gas). Indian grid is dominated by coal based power plants and hence, in case plants import power, the emission factor of power continues to remain high at 0.85 kg CO_2/kWh. Within coal, the emission factor for CO_2 expressed as tonne CO_2/GCal of energy supplied varies depending on the net calorific value and total carbon content of the fuel. While coking coal has an emission factor of 0.44 tonne CO_2/GCal, the non-coking coal sourced from India has an emission factor of 0.38 tonne CO_2/GCal.

Indian best practice: Among integrated steel plants, the carbon emission intensity has been observed lowest at 1.4 tonne CO_2/tcs at Essar Steel Hazira which is natural gas based DRI-EAF plant.

For an integrated coal based BF-BOF based integrated steel plants, 2.7 tonne CO_2/tcs is the lowest carbon emission intensity which is at Tata Steel, Jamshedpur.

Global best practice: For carbon emissions intensity of primary steel making, the global best practice corresponds to the Indian best practice, i.e. Essar Steel, Hazira at 1.4 tonne CO_2/ tcs. The plant is a natural based DRI - EAF based integrated steel plant with power sourced from a natural gas based combined cycle power plant.

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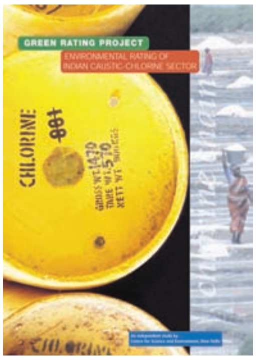

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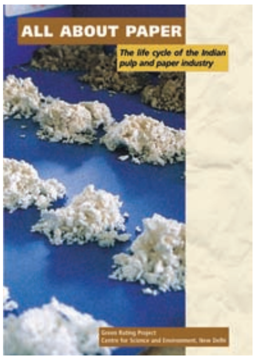

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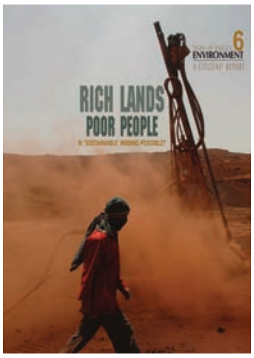

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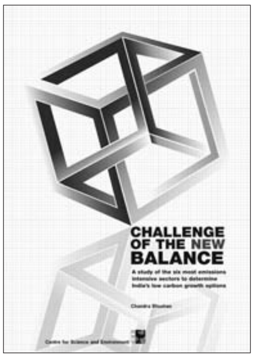

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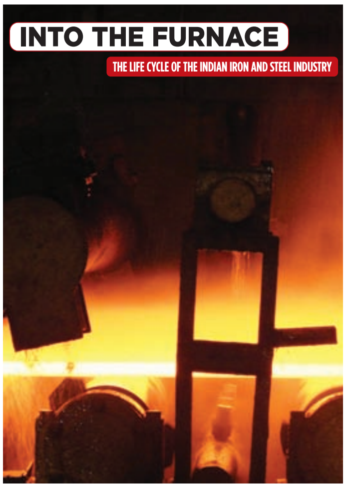

Into The Furnace: Green Rating of Indian Ironand Steel Sector (2012)

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