5.2

Electric arc furnace

This process of steelmaking needs a lower capital investment, has higher operational flexibility and is easily adaptable to market demand for different kinds of steel products. The technology has also constantly improved, geared to reduction of use of electrical energy, electrode consumption and cycle time. This process is now being used around the world. However, the environmental performance of EAFs in India is below par

An alternate method to basic oxygen furnace (BOF) steel-making is the use of high current electric arcs to generate heat for removing the carbon content in iron. Unlike a BOF process, the electric arc furnace (EAF) does not require molten iron for making steel. In the EAF process, a wide range of ferrous-based scrap material as well as iron in the form of direct reduced iron (DRI) and pig iron can be used. The quality of steel produced in EAF matches that of the BOF route and is even used to make precise grade steel[1]. EAF has been installed by both merchant steelmakers and integrated large iron and steel plants. Merchant steelmakers generally used scrap and DRI/pig iron to make steel. However, due to increased price of scrap over the last decades, its use by large steelmakers has reduced. They are feeding EAF with coal/gas DRI and melted iron, all produced in-house, to manufacture steel[2].

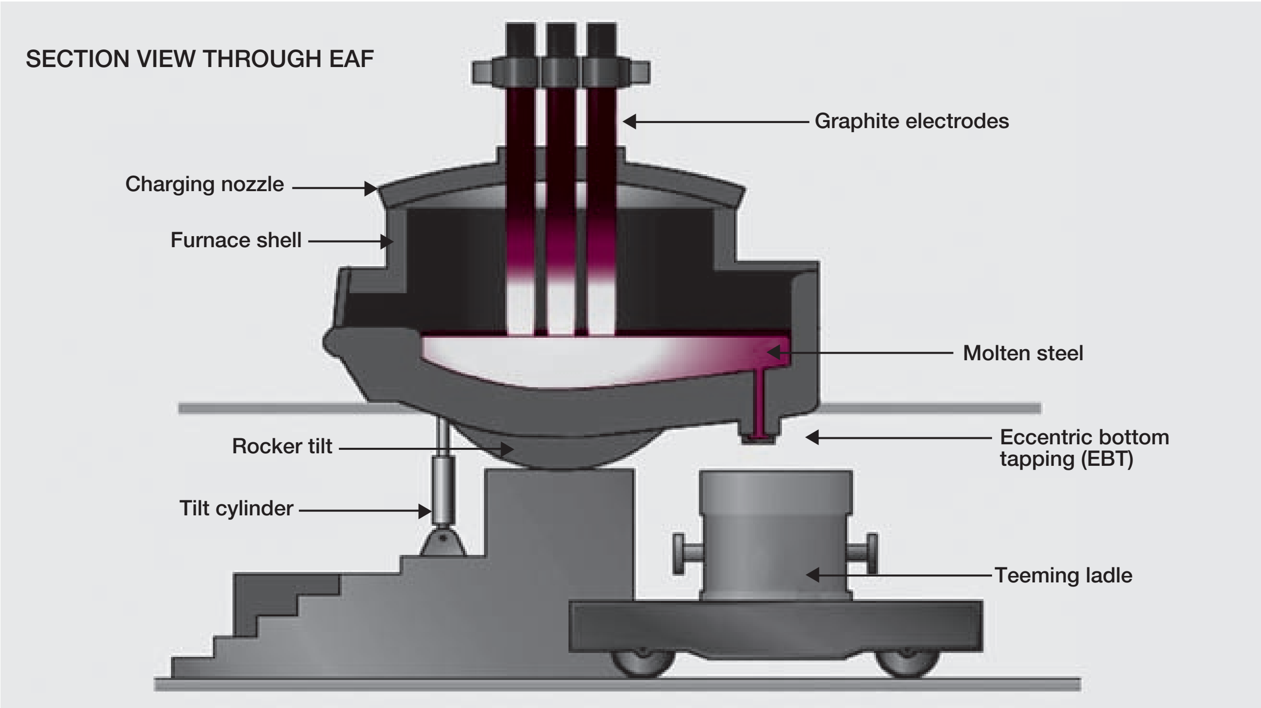
EAF steel production has been growing around the world[3]. However, there are disadvantages to standard alternating current (AC) type EAFs. There are high noise levels between 125 to 139 dB(A) during the process and the electric arcs may affect power grid networks[4]. It is also energy intensive, compared to BOF.

EAF PROCESS AND CAPACITY

An electric arc furnace (see Figure 5.2.1: *Electric arc furnace process*) consists of a spherical hearth at bottom, cylindrical shell and a swinging water-cooled dome-shaped roof. There

Figure 5.2.1: **ELECTRIC ARC FURNACE PROCESS**

A typical alternating current arc furnace configuration with eccentric bottom tapping facility



Source: 'Steel University Organisation, Furnace Layout', World Steel Association, http://www.steeluniversity.org/content/html/eng/default.asp?catid=25&pageid=2081271948, as viewed on March 25, 2012 can be one to three graphite electrodes clamped with the roof and inserted into the furnace through individual holes. The consumable graphite electrodes can be independently lifted and lowered. During charging, the roof with the electrodes is swung aside and the charge is fed into the furnace from top. The electrodes in water-cooled holders transmit high electric current which comes through water-cooled cables to supply heat for steel melting. The furnace is mounted on a tilting mechanism for tapping the molten steel through a tap hole.

The conventional electric arc furnace operates as a batch melting process producing batches of molten steel. Each batch is called heats and the operating cycle is called tap-to-tap cycle. Depending on the desired quality of steel output, charge materials such as DRI, hot briquetted iron, pig iron, steel scraps, hot metal and fluxes are charged into the furnace in different proportions.

- **Charging:** After charging, the roof and electrodes swing back into place over the furnace. The roof is lowered and then the electrodes are lowered to strike an arc on the charge. This commences the melting portion of the cycle. The number of chargings are reduced to minimise furnace opening and the resultant energy loss.
- **Melting:** EAF is a direct arc furnace, where the electric arc strikes between the graphite electrodes and the metallic charge. The temperature reaches around 4,000°C and is used to heat the bath by radiative heat transfer. The melting process starts at low voltage (short arc) between the electrodes and the charge. Nearly 15 per cent of the charge is melted during the initial bore-in period. In the beginning, the arc is unstable but it stabilises when the electrodes reach the liquid bath. At this point, voltage can be increased (long arc). The remaining 85 per cent of the charge is melted in this stage.

  During melting, chemical energy is also supplied in the furnace through oxygen and fuel burners and oxygen lancing. Oxy-fuel burners use natural gas or oil in presence of oxygen and the generated heat is transferred into the charge by radiation and convection and within the charge by conduction. Oxygen lancing oxidises the iron in the charge and other components such as aluminum (Al), silicon (Si), manganese (Mn), phosphorus (P) and carbon (C) in the liquid bath, generating intense heat for melting. The oxides that are formed are absorbed by oxidising slag and the gaseous products such as CO and CO_2 are removed by the exhaust system.
- **De-slagging and Tapping:** Samples are taken from the liquid bath to ensure that the desired chemical composition of steel is achieved. Once the bath chemistry and its temperature are attained, the furnace is tilted to allow the slag, which is floating on the surface of the molten steel, to be poured off. Next, the furnace is again tilted, but in the other direction and the molten steel poured (tapped) into a ladle, where it either undergoes secondary steel-making or is transported to the caster.

The unit capacity of EAFs may range from 40 tonnes/heat cycle to as much as 400 tonnes/heat cycle, with up to five furnaces in a steel-melting shop[5]. Modern operations aim for a cycle time of less than 60 minutes. Some twin-shell furnace operations have been achieving cycle times of 35-40 minutes[6].

EAF capacity and size distribution

India produced 65 million tonnes per annum (MTPA) crude steel in the year 2009-10, out of which 45 per cent was produced through the blast furnace-basic oxygen furnace route, 24 per cent by EAF route and 31 per cent by induction

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Secondary emissions release from arc furnace operation at Bhushan Power and Steel, Sambalpur

Table 5.2.1: EAF DESIGN CAPACITY AND INSTALLED ANNUAL CAPACITY, 2009-10

Arc furnaces in large plants are largely adapted to using hot metal and DRI

Plant name	Charge material	Plant nomenclature	Size (tonne/heat)	Individual capacity (MTPA)	Total (MTPA)
Jindal Steel and Power Limited (JSPL), Raigarh	Coal DRI + hot metal + scrap	EAF # 1	100	1.2	2.4
		EAF # 2	100	1.2	
Essar Steel, Hazira	Gas DRI + scrap	EAF # 1	150	1.15	4.6
		EAF # 2	150	1.15	
		EAF # 3	150	1.15	
		EAF # 4	150	1.15	
Ispat Industries, Raigad	Gas DRI + hot metal + scrap	EAF # 1	190	0.9	3.6
		EAF # 2	190	0.9	
		EAF # 3	190	0.9	
		EAF # 4	190	0.9	
Bhushan Power and Steel Limited (BPSL), Sambalpur	Coal DRI + hot metal + scrap	EAF # 1	90	0.45	2.0
		EAF # 2	90	0.45	
		EAF # 3	100	0.55	
		EAF # 4	100	0.55	
Usha Martin, Jamshedpur	Coal DRI + hot metal + scrap	EAF # 1	40	0.175	0.95
		EAF # 2	40	0.175	
		EAF # 3	65	0.6	
Jai Balaji Industries, Durgapur	Coal DRI + hot metal + scrap	EAF # 1	60	0.5	0.5
Jayaswal Neco Industries, Raipur*	Coal DRI + hot metal + scrap	EAF # 1	40	0.4	0.4
Bhushan Steel, Dhenkanal*	Coal DRI + hot metal + scrap	EAF # 1	60	0.47	0.47

Note: MTPA = million tonnes per annum
Sources: 2012, *Green Rating of the Indian Iron and Steel Sector*, CSE, New Delhi, *Company websites

furnace (IF) route[7].

Out of the shortlisted 21 iron and steelmaking plants in the Green Rating Project (GRP), eight have adopted the use of EAFs. The unit capacities of furnaces differ widely across these eight plants (see Table 5.2.1: *EAF design capacity and installed annual capacity, 2009-10*).

There are 38 EAF-based steel plants operating in the country with an aggregate capacity of 17.99 MTPA[8]. GRP has covered eight plants with 14.92 MTPA (or 83 per cent) of the total EAF route crude steel capacity in India. Two plants, Jayaswal Neco, Raipur and Bhushan Steel, Dhenkanal did not participate in this rating exercise and hence their data has not been verified under GRP.

In the eight plants covered under GRP till 2009-10, the largest furnace is of 190 tonnes/heat capacity installed at Ispat Industries, Raigad and the smallest furnace has capacity of 40 tonnes/heat installed at Usha Martin, Jamshedpur.

The EAFs may be of AC (alternating current) or DC (direct current) type. AC furnaces require three electrodes and since electrodes are expensive, the cost of operation is higher. On the other hand, DC furnaces have advantages of using a single electrode. Electrode consumption can be reduced by up to 50 per cent in DC furnaces compared to a convectional three-phase AC furnace. Noise levels in the DC furnaces are also lower[9]. Lower maintenance costs are reported and refractory costs are less for the sidewalls but more for the furnace bottom in DC furnaces. However, the capital investment for the DC furnace is higher. Also, there is a limit to higher unit capacity in these furnaces[10].

CLEAN TECHNOLOGIES INSTALLATION STATUS

The following section discusses the major technological features affecting energy use and environmental performance of the EAFs. These features have been considered as major indicators for the assessment of EAF plants under GRP.

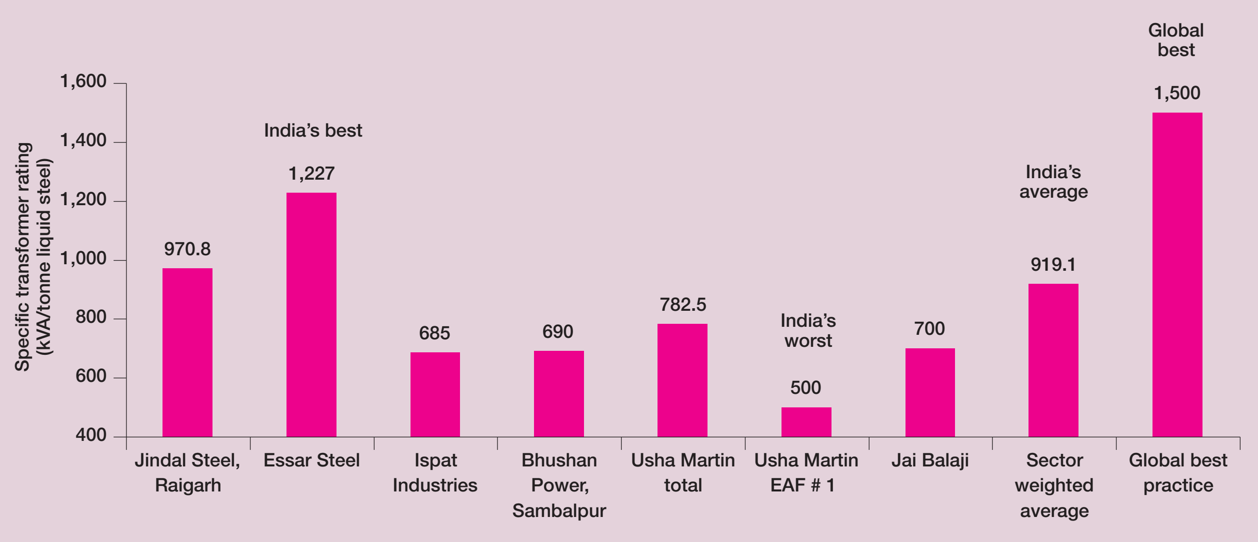
Specific transformer rating

The EAF transformers receive low current-high voltage power and converts this into high current-low voltage power for use in the EAF. The power ratings of these transformers are in the range of 10-300 megavolt ampere (MVA)[11]. The specific transformer rating is defined as the total apparent power supply in kilo volt ampere (kVA) 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 flexibility of using oxy-fuel burners helps in reduction of overall energy consumption[12].

Of the total 20 EAFs considered under GRP till 2009-10, data of specific transformer rating was available for 18 EAFs. The capacity sector weighted averaged transformer rating

Graph 5.2.1: COMPANY-WISE SPECIFIC TRANSFORMER RATING OF EAFS IN INDIA, 2009-10

Indian arc furnaces are yet to scale up to the ultra-high power configuration



Source: 2012, *Green Rating of the Indian Iron and Steel Sector*, CSE, New Delhi

was found at 919.1 kVA/tonne of crude steel in 2009-10. The highest transformer rating was at 1,227 kVA/tonne of crude steel in Essar Steel and the lowest was 500 kVA/tonne of crude steel at EAF#1 of Usha Martin (see Graph 5.2.1*: Company-wise specific transformer rating of EAFs in India, 2009-10*). The global best practice has been reported at 1,500 kVA/tonne of crude steel[13].

Foamy slag practice

The foamy slag layer is developed during the arcing process which helps in shielding the arc and molten steel liquid, thus minimising heat transfer losses. The electrode remains protected. Oxygen injected with granular coal or carbon produces carbon monoxide (CO). Entrapment of this gas forms bubbles which foams the slag.

Foamy slag increases the thermal efficiency of electric arc furnace steelmaking by 40-60 per cent. If a deep foamy slag is achieved, it is possible to increase the arc voltage considerably. This allows a greater rate of power input. Slag foaming is usually carried out once a flat bath is achieved.

The net energy savings (accounting for energy use for oxygen production) are estimated at 5-7 kWh/tonne crude steel. Installing the oxygen lances requires investment. However, through this practice, tap-to-tap time is reduced, increasing productivity and saving operating costs[14].

The 18 EAFs across the six participating plants under GRP were all operating with foamy slag practice.

Oxy-fuel burners

An oxy-fuel burner uses natural gas or oil, together with pure oxygen (or an air and oxygen mixture) to produce an extremely high flame temperature which is used to melt the solid charge between the electrodes and provide heat to cold spot. Oxy-fuel burners promote a uniform melting of the scrap and partially offset the effect of demand control on electricity supply. Usually, additional energy input by oxy-fuel burners and oxygen lancing results in the required total energy input.

In most modern ultra-high power furnaces, the primary function of burners is to provide heat to cold spots on the edges of the furnace to ensure uniform charge melting and to decrease the melting time necessary to reach a flat bath. While oxy-fuel burners increase the off-gas flow from the molten steel bath, they decrease the overall energy demand[15].

Out of total of 18 EAFs across six participating plants under GRP, only nine were found to be equipped with oxy-fuel burner technology. These nine furnaces were those of Ispat Industries, Usha Martin and Jindal Steel and Power Limited (JSPL).

Single slag practice vs double slag practice

In single slag practice in EAF, only phosphorus is removed during steelmaking. If sulphur is also to be removed in addition in the same EAF vessel, it is called double slag practice. Removing some sulphur from the EAF by increasing the amount of lime is not effective. It requires additional cycle time and is energy inefficient[16]. Rather, it is beneficial to remove sulphur in a separate furnace called ladle furnace.

All the plants participating under GRP have adopted single slag practice.

Coherent jet or shrouded jet lancing

The supersonic oxygen jet impinged on the charge material loses velocity quickly and is not able to travel deeper into the charge bath of the EAF vessel. Further, the oxygen jet mixes with ambient carbon monoxide, losing its ability for removing carbon. This delays the heating EAF cycle and hence requires more energy consumption.

For this reason, the 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[17]. This helps in reducing overall energy consumption significantly. It also helps in lower oxygen consumption.

Of the 20 EAFs considered under GRP till 2009-10, 13 were installed with coherent jet lancing system. These are spread across JSPL, Usha Martin, Ispat Industries and Essar Steel, Hazira.

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.

Bottom stirring system in EAF utilises additional gases such as argon or nitrogen for injecting through a direct or indirect contact plug from the bottom of the furnace. 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[18].

Of the 20 EAFs covered under GRP, only four EAFs of Ispat Industries were found to be equipped with the bottom tuyers for argon injection.

Charge pre-heater system

If the cold charge materials can be pre-heated prior to charging, it helps in lowering power consumption in the EAF. 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 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[19].

Scrap pre-heating is economical only when the recovered waste energy is utilised as the thermal energy source. Nearly 20 per cent of the EAF energy is released through waste offgas, representing 130 kWh/tonne of crude steel. Efficient utilisation of this energy is the key for scrap pre-heating. This 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[20].

Of the 20 EAFs covered under GRP, none have installed with the scrap pre-heating technology.

Recently the system of hot charging directly from gas reactors has emerged. The hot DRI can be transferred through a pneumatic or an insulated container transportation system. In India, Essar Steel, Hazira has adopted the latter technology of insulated vehicle for hot DRI charging into electric arc furnaces at 675°C. The plant states the measure saves 20 per cent of power in its EAFs.

In other plants such as JSPL Raigarh and Ispat Industries, Raigad the molten iron from blast furnace operation is supplied directly to the EAFs, thus significantly minimising power consumption required for iron melting.

DRI continuous charging

Continuous feeding of DRI is accomplished by conveying the materials from a storage silo to the top of the melt shop. From there it is fed by a series of bins and belts through a weighing system, down a chute or pipe and into the furnace proper through a hole in the roof. Generally, the hole is located on the half of the roof between the electrode(s) and the rear wall.

All the 18 EAFs across the six participating plants under GRP were found to have installed continuous DRI charging facilities.

Eccentric bottom tapping

In modern EAFs, the bottom has been made eccentric 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.

All the 18 EAFs examined by GRP were found to have installed the eccentric bottom tapping facility.

Post combustion system

During the oxygen lancing and slag foaming process, carbon monoxide (CO) gas is produced in large quantities in EAF. This gas must be combusted either in the furnace freeboard or in the 4th hole evacuation system conveying the off-gases from the furnace to the baghouse.

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.

Further studies have shown that by practising post combustion heat recovery, 35-60 per cent of the energy in the off-gas can be recovered. EAF operators are now moving toward adopting this practice and typical electric energy savings are about 4 kWh/Nm^3 of oxygen injected.

Of the total 20 EAFs covered under GRP, only 13 in five plants were equipped with the post-combustion system. It was found that the Ispat Industries plant did not have the post-combustion system for the EAFs. Rather, the plant had an air damper system in the off-gas evacuation duct, for dilution with fresh air. When the carbon monoxide concentration is measured at more than 7 per cent in the off-gas duct, the damper is fully opened to allow fresh air mixing for combustion and dilution.

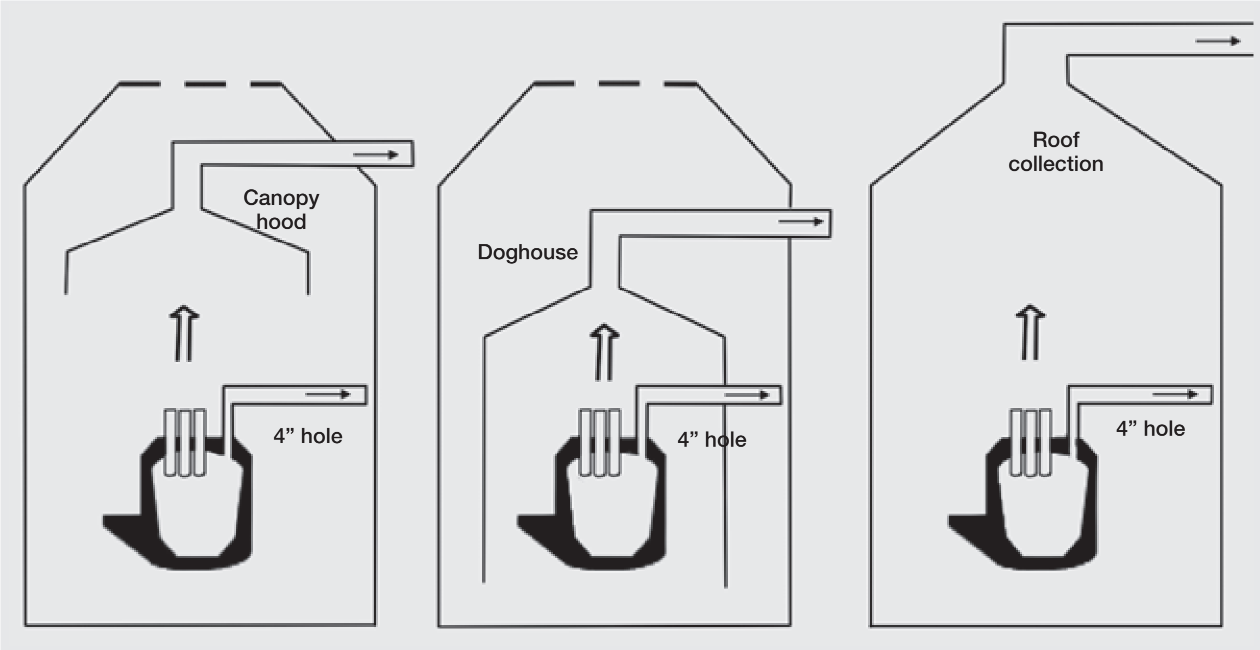
Doghouse and total building evacuation

Of the total EAF emissions, 95 per cent is primary off-gas emissions of which 85 per 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.

Dust emissions released during scrap handling, charging,

Figure 5.2.2: **OFF-GAS COLLECTION SYSTEM OPTIONS AT AC TYPE EAFS**

Modes of air pollution control in alternating current arc furnaces



Source: Anon 2012, 'Integrated Pollution Prevention and Control (IPPC) Best Available Techniques Reference Document, European Commission', p 433, http://eippcb.jrc.es/reference/BREF/IS_Adopted_03_2012.pdf, as viewed on March 30, 2012

tapping and from furnace openings can generate secondary emissions which can be captured using canopy hood, doghouse (enclosure) or roof (total building) collection system (see Figure 5.2.2*: Off-gas collection system options at AC type EAFs*). The evacuated dust-laden air is normally passed through a bag filter before release to the stack.

For complete primary collection, a plant should install the 2nd or 4th hole evacuation system. Further, for secondary emission collection, the plant can install canopy hood or doghouse. Nonetheless, a total building evacuation system is essential to ensure capture of all fugitive emissions from the area.

The doghouse (enclosure) system not only helps in controlling air emissions but also the high noise pollution, especially in the AC electric arcing process[21]. The total building evacuation system is, however, required for capturing not only EAF process emissions, but also emissions from raw material mixing, ladle furnace and post-treatment facilities.

In the eight EAF-based plants considered under GRP till 2009-10, off-gas collection configuration was available for the six participating plants. The typical configuration is 2nd or 4th hole collection as applicable, canopy hood and total building evacuation. However, in some plants, these collection equipments were found to be non-functional, leading to huge air emissions.

Thin slab casting

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[22].

Of the eight EAF-based plants covered under GRP till 2009-10, only one plant – Ispat Industries, Raigad – had thin slab casting facility.

ECO-EFFICIENCY

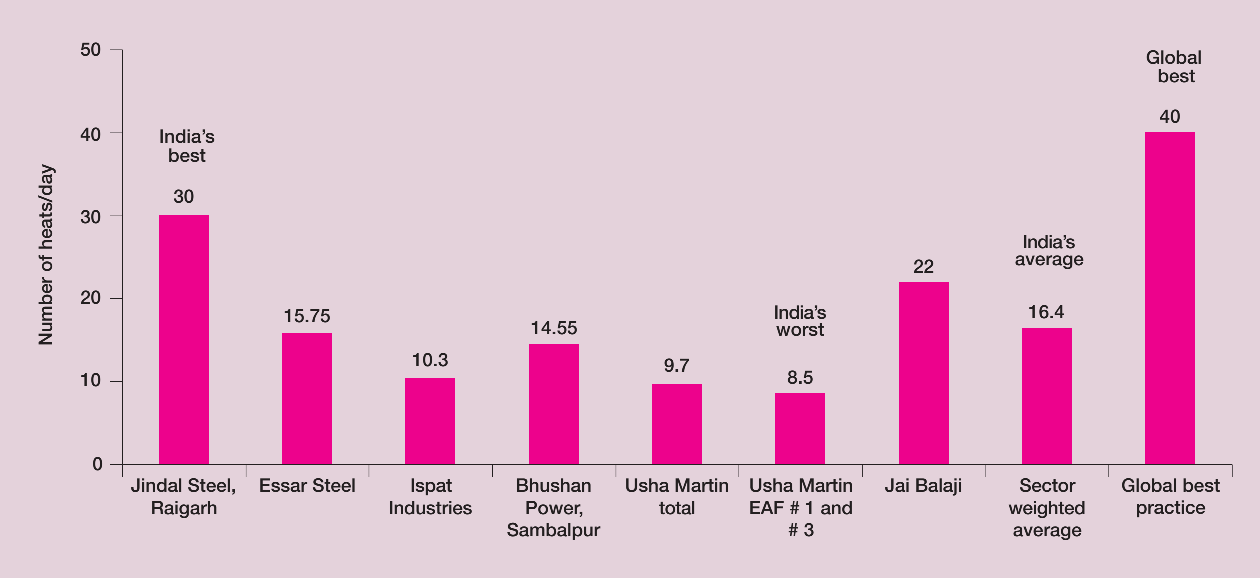
The EAF process capacity utilisation data for 2009-10 is available for seven plants, the exception being Bhushan Steel, Dhenkanal. The weighted average capacity utilisation of the sector was found to be 73.7 per cent in 2009-10. The highest capacity utilisation was 85 per cent in Bhushan Power and Steel, Sambalpur, while the lowest was 31 per cent at Usha Martin, Jamshedpur .

Productivity considering furnace volume

The productivity of an EAF is defined as tonne of liquid steel produced per day per unit hearth volume of the EAF. Higher productivity implies lower energy consumption per tonne of liquid steel produced.

Graph 5.2.2: **COMPANY-WISE HEATS PER DAY OF EAFS IN INDIA, 2009-10**

Indian arc furnaces are operating at very low levels of productivity, their average comparing poorly with the global best practice



Source: 2012, *Green Rating of the Indian Iron and Steel Sector*, CSE, New Delhi

Apart from the quality of charge mix, productivity also depends upon factors such as clean technology installation of continuous charging, coherent jet and hot DRI charging. High productivity per unit volume of furnace can be achieved by using the maximum available electrical power and chemical energy input (e.g. oxygen, gas, alloys).

Of the 20 EAFs considered under GRP till 2009-10, the productivity data was available for 18 across the six participating plants. The capacity weighted average productivity for the sector was found to be 100 tonne liquid steel/m^3 hearth volume/day. The individual plant that showed highest productivity was JSPL Raigarh at 176.5 tonne liquid steel/m^3 volume/day and the lowest was Usha Martin at 49.6 tonne liquid steel/m^3 volume/day.

Number of heats per day

This represents the amount of batch heating completed for steelmaking per day. The higher the heats per day, the higher will be the productivity and hence, lower the energy use[23].

Of the 20 EAFs considered under GRP till 2009-10, the number of heats/day data was available for 18 across the six participating plants. The capacity weighted average heats/day for the sector was found to be 16.4. The individual plant performance showed highest heats/day in JSPL Raigarh at 30 and the lowest at 9.7 in Usha Martin. EAF # 1 and # 3 at Usha Martin had the lowest 8.5 heats/day . The global best practice has been reported at 40 heats/day[24] (see Graph 5.2.2: *Company-wise heats per day of EAFs in India, 2009-10*).

Tap-to-tap time

Each operating cycle of EAF is called tap-to-tap time. 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 therefor, decrease tap-to-tap time.

Of the 20 EAFs considered under GRP till 2009-10, the number of tap-to-tap time data was available for 18 across the six participating plants. The capacity weighted average tap-to-tap time for the sector was found to be 68.6 minutes in 2009-10. The individual plant performance showed lowest tap-to-tap time in JSPL Raigarh at 45 minutes and the highest at 121 minutes in Usha Martin Jamshedpur. The poorest performance was at EAF # 1 of Usha Martin at 140 minutes (see Graph 5.2.3: *Company-wise tap-to-tap time of EAFs in India, 2009-10*). The global best practice has been reported at 36 minutes[25].

Slag generation rate

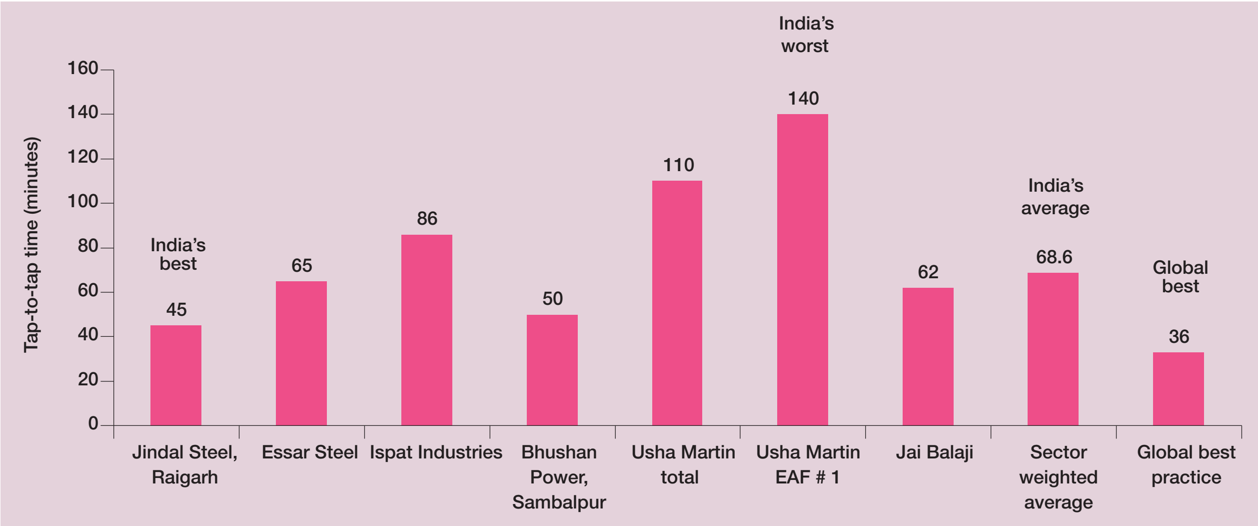
During melting and refining of steel from iron, the impurities are collected as slag. Quantity and quality of slag depends on the raw material input as well as desired quality of steel. Higher impurities in the charge mean higher slag generation.

The single oxidising slag practice is employed for removal of phosphorus impurity from bath. This practice is used generally for plain carbon, carbon and low alloy steelmaking. High basicity and ferrous oxide (FeO) content is prepared to remove the phosphorus followed by carbon (C) silicon (Si) and manganese (Mn). The generated oxidising slag may contain calcium oxide (CaO), silica (SiO_2), FeO, manganese oxide (MnO) and magnesium oxide (MgO), attaining black colour on cooling due to its high FeO content[26].

The highest slag generation rate among 18 EAFs across the six participating plants was found at 277 kg/tonne liquid steel in JSPL Raigarh; and the lowest was 140 kg/tonne of liquid steel at Jai Balaji, Durgapur. The capacity weighted average slag generation rate across the sector was 233.5 kg/tonne liquid steel against the global best practice, which is as low as 60 kg/tonne liquid steel[27] (see Graph 5.2.4: *Company-wise specific slag generation rate in EAFs in India, 2009-10*).

Graph 5.2.3: **COMPANY-WISE TAP-TO-TAP TIME OF EAFS IN INDIA, 2009-10**

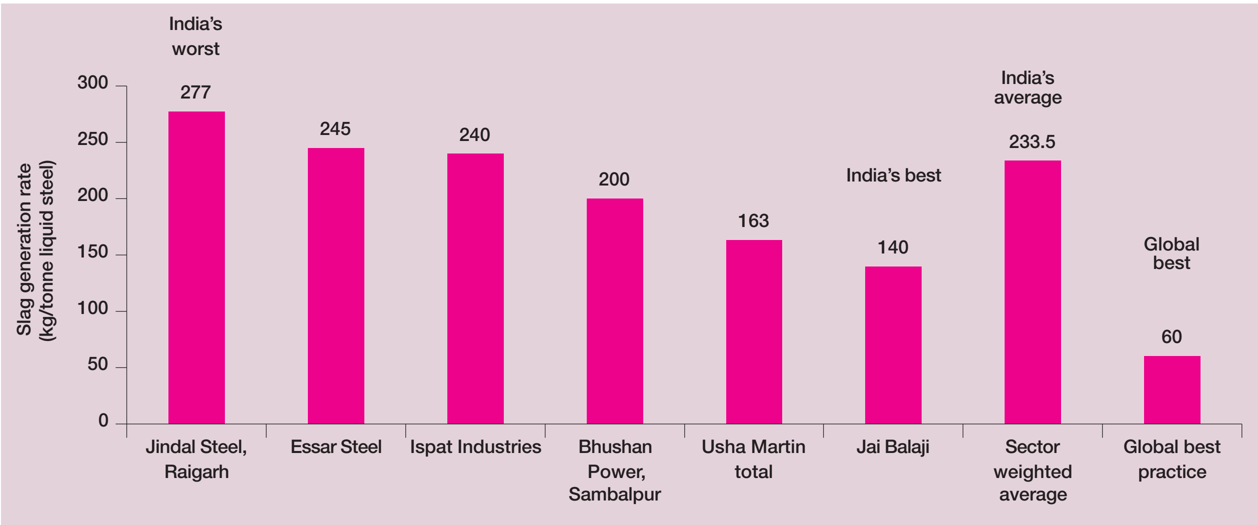
The average tap-to-tap time in India's EAFs is about two-third more than the global best



Source: 2012, *Green Rating of the Indian Iron and Steel Sector*, CSE, New Delhi

Graph 5.2.4: **COMPANY WISE SPECIFIC SLAG GENERATION RATE IN EAFS IN INDIA, 2009-10**

High slag generation indicates poor raw material quality. At an average, the slag generation rate is 233.5 kg/tonne liquid steel



Source: 2012, *Green Rating of the Indian Iron and Steel Sector*, CSE, New Delhi

AIR EMISSIONS

The air emissions from EAF operations mainly comprise of stack particulate matter (PM) emissions (including the secondary emissions from process and material handling) and fugitive emissions in the work zone area.

Stack particulate matter emissions

This involves fume extraction system through primary ducting where the major portion of hot waste gases arising due to arcing and removal of carbon are drawn through a duct from a forced draft fan and passed through a bag filter for dust collection before emitting to stack.

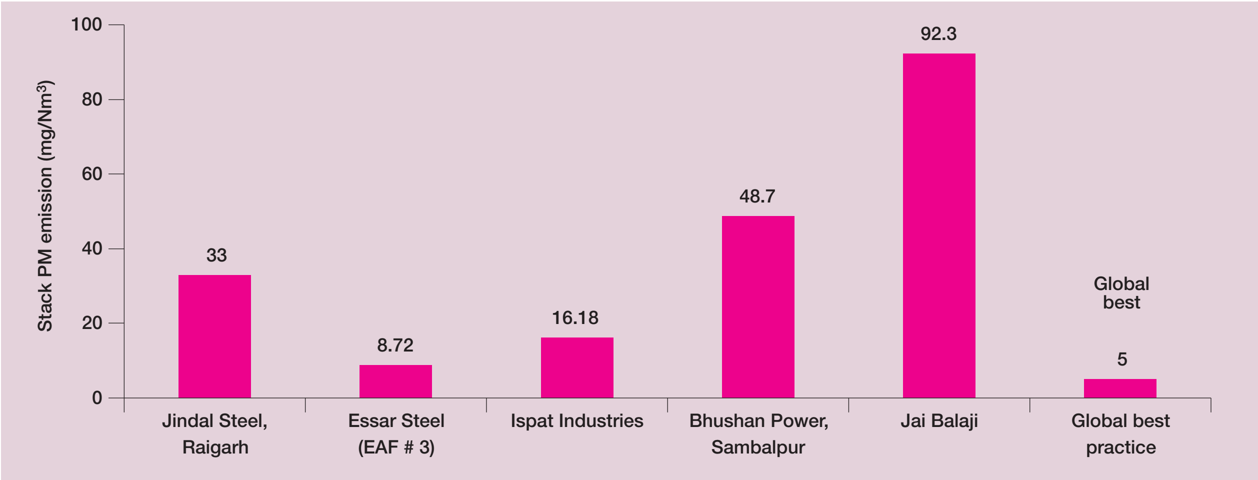
Primary emissions from EAF constitute around 95 per cent of the total emission from the EAF. These emissions are collected primarily by using the 4^{th} hole (in AC furnace) or the 2^{nd} hole (in DC furnace), canopy hood, doghouse or complete building evacuation system, or a combination of these.

The secondary ducting collects emissions which occur during charging of scraps, tapping, and gunning of walls. The fumes and dust are drawn by large canopy suction hoods located on the roof of the steel melting shop (SMS) floor and sent to the bag filter for dust collection before emitting to stack.

With the help of the off-gas collection system, dust is captured using bag filters. Generally, the treatment of different off-gas flows (i.e. primary and secondary emissions)

Graph 5.2.5: STACK PM EMISSIONS FROM EAF PLANTS IN INDIA, 2009-10

Air pollution control in Indian EAF is reasonably poor



Source: 2012, *Green Rating of the Indian Iron and Steel Sector*, CSE, New Delhi

is performed in the same device, mostly in bag filters. Only in a few cases are ESPs and wet scrubbers applied.

The national norms for stack particulate matter (PM) or dust emission from steelmaking operations is specified at 150 mg/Nm^3 as per GSR 742 (E) notification dated August 30, 1990 by the Union ministry of environment and forests (MoEF). However, some state pollution control boards have stipulated stricter norms for EAF stack PM emissions. Odisha has specified a norm of 100 mg/Nm^3, Gujarat at 80 mg/Nm^3 and Chhattisgarh at 50 mg/Nm^3.

Internationally, the corresponding norms have been specified at 5 mg/Nm^3 in Europe[28]. The World Bank-IFC guidelines specify stack PM emission levels of 50 mg/Nm^3 for all stacks including EAF in integrated steel mills.

Among the participating EAF plants under GRP, Usha Martin plant was observed to have huge secondary emissions from the EAF process and hence taken as non-complying. In the remaining plants, the highest stack (PM) emission norm from EAF unit was reported to be 92.3 mg/Nm^3 at Jai Balaji, Durgapur and the lowest at Essar Steel Gujarat at 8.7 mg/Nm^3 (see Graph 5.2.5*: Stack PM emissions from EAF plants in India, 2009-10*). However, as per the GRP survey,

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Inadequate roof dust capture system over the arc furnace unit at Bhushan Power and Steel, Sambalpur

found the inspection monitoring records of the Gujarat regulatory agency to be poor.

Red dust emission was observed by GRP surveyors from the roof of SMS units of the Usha Martin plant. A number of public complaints on poor ambient air quality have been filed by villagers of the nearby Jhurkhuli and Gamharia villages. The problem of the EAF dust emissions was noted as there was no effective canopy hood system for collecting secondary process emissions released during EAF steelmaking. Due to inaction by Jharkhand State Pollution Control Board (JSPCB), the Jharkhand High Court passed an order in April 2008 based on local community complaints, directing the board to take action on pollution. In this regard, JSPCB has issued a notice to Usha Martin dated February 24, 2010.

While the norms in India are for stack PM emissions alone, there is no proper regulation to ensure complete control of secondary emissions which are also a major source of dust emissions in EAF steel plants[29]. On the whole, Indian regulations need to address control of both primary and secondary emissions from EAF operations with instruction for installation of appropriate pollution control technologies.

Fugitive dust emissions in the work zone area

Across all the plants participating under GRP, fugitive emissions in the work zone area (defined as within 10 m from the source) was found high due to process fumes, raw material mixing and material handling. This affects the workers' health in the EAF area and also the overall housekeeping.

Almost all plants do not monitor or report on the work zone area fugitive emissions levels yet. A few plants compare the fugitive emission levels in the work zone against the prevailing Factories Act, 1948 generic standard of 10,000 μg/Nm^3. On the other hand, for coal-based DRI plants, the MoEF has stipulated work zone norms as 2,000 μg/Nm^3 through its notification 414(E) dated May 30, 2008. Further, CPCB has also proposed a guideline of 2,000 μg/Nm^3 in the work zone area of blast furnace and sinter plants.

There is a need to legally stipulate work zone fugitive emissions norms for the EAF plants area in India a standard level of 2,000 μg/Nm^3.

Toxic air pollutants

The other major air emissions from EAF off-gas, apart from particulate matter, include carbon monoxide, heavy metals including mercury, nitrogen oxides and sulphur dioxides, and volatile organic compounds (VOCs) such as chlorobenzenes, PCB, PAH and dioxins/furans. The bag filters can be added with adsorbents to control VOC emissions.

Zinc is the metal with the highest emission factors from EAF. Chromium and nickel emissions are generally higher in the manufacturing of stainless steel. Chromium can also occur in its hexavalent form which is recognised as carcinogenic on inhalation. Mercury emission is also significant depending on the scrap quality and quantity in use.

None of the plants participating in the rating was found to be monitoring toxic pollutants from EAF process. The MoEF is yet to provide the standards for the other pollutants from EAF operations.

WATER AND WASTEWATER

Water requirement in EAF process is mainly for furnace cooling, rapid quenching of off-gases, off-gas scrubbing, vacuum generation and for direct cooling in continuous or ingot

SANJEEV KUMAR KANCHAN / CSE

Heavy dust emissions from EAF units at Usha Martin, Jamshedpur

casting and slag cooling.

For cooling of furnace walls, water runs in a closed circuit and thereby the wastewater generation is insignificant. In the plants surveyed under GRP, water scrubbing is not used for EAF de-dusting, except for Ispat Industries, Raigad. The wastewater is sent to an effluent treatment plant and reused.

For slag cooling, generally, treated blow-down water is used. The housekeeping in these areas was found to be poor in most plants. Further, none of the plants ensure proper recycling of slag cooling water.

SOLID AND HAZARDOUS WASTES

EAF slag, effluent treatment plant sludge, fume extraction dusts, bag filter dusts and refractory matter are the solid wastes generated from the EAF steelmaking process.

The typical constituents of EAF slag reported in a plant is as follows[30]: SiO_2 – 20.3 per cent, Al_2O_3 – 7.4 per cent, CaO – 22.8 per cent and Fe_2O_3 – 42.78 per cent. EAF slag does not have pozzolanic (cement-making) property and has a high iron content. Generated slag from EAF and ladle furnace is mostly dumped in landfill areas within or outside plant premises. A small amount of metal recovery of iron from the EAF slag is done by the company itself or by third parties. EAF slag disposal is a common problem with the Indian steel industry.

- In Ispat Industries, Raigad, of all the generated EAF slag, 10 per cent is used in the sinter-making process as lime agent. The remaining is dumped within the premises.
- Essar Steel, Hazira has developed innovative ideas to use certain quantity of the EAF slag to make ceramic tiles, pavement blocks, parking bed area for heavy vehicles and boundary wall. However, the quantity or percentage reuse of EAF slag could not be verified independently.
- The JSPL Raigarh plant has been dumping EAF slag 5 km away in Parsada village. The local community has frequently raised serious concerns related to airborne dust and rainwater flowing from the slag dump site affecting nearby farmlands. The Chhattisgarh Environment Conservation Board has issued a notice to JSPL dated November 13, 2009 on this issue.
- In Usha Martin, Jamshedpur, the major environmental issue is the huge amount of EAF slag dumped around the premises, resulting in dust emissions and surface run-off pollution. Based on local community complaints, the JSPCB had issued a notice to the plant on September 15, 2009.
- With regard to Bhushan Power and Steel, Sambalpur, the Orissa State Pollution Control Board has said in an inspection report that EAF slag dumping in a corner of the plant is being done in a haphazard manner. The Board expressed its serious concern.

  Among the non-participating plants, in Bhushan Steel, Dhenkanal, it was noted that solid waste such as EAF slag is being dumped outside in a 26.5 acre area of land near Nimidha village, which was further proposed to be expanded to 115 acres. However, in December 2009 the district administration stopped the expansion of the dump site after protests from local villagers. Now, the dumping is done within the plant affecting the nearby village of Sibapur.
- In Jayaswal Neco, Raipur, the pollution regulator conveyed that EAF slag is dumped within the premises.

Overall, reuse of EAF slag is limited. Companies are dumping EAF slag outside the plant premises. This is because the plants do not plan for adequate land for solid waste disposal during the environmental clearance process. Buying huge tracts of land outside the steel plant premises for EAF slag disposal only creates intense pollution problems for the community around the dump site.

Generated fume extraction dusts and bag filter dusts were also found being dumped in landfills. However, in Ispat Industries, the EAF scrubber gas cleaning plant sludge was reported to be used along with EAF flue dust in the in-house sinter plant. Jai Balaji, Durgapur also reported reuse of generated flue dust through the in-house sinter plant.

NOISE AND THERMAL DOSE POLLUTION

Noise level in the EAF area is generally high due to the electric arcing operations. As per Factories Act, 1948, the operational work zone noise level in India should not exceed 90 db (A) for an eight-hour exposure. However, as per International Labour Organisation (ILO), the warning limit is 85 db (A). The noise level of AC type EAFs in India is found higher than the warning level, these EAFs are reported to have noise levels between 125 to 139 dB (A) due to high frequency arcing[31].

The workers in EAF usually wear ear plugs. Nonetheless, as workers and contract labourers are largely exposed to noise levels near EAF area, efforts need to be made to minimise exposure to warning limits. The doghouse system (complete enclosure) of air pollution control not only ensures control of dust emissions but also of noise pollution[32]. DC type furnaces also have lower noise levels compared to AC type furnaces.

Thermal dose pollution can affect EAF workers from exposure to high infrared radiation levels which can cause heat stress and is a serious occupational hazard[33]. However, no monitoring is being undertaken in Indian plants on thermal dose exposure from EAF operations.

RATING: ELECTRIC ARC FURNACE

KEY INDICATORS

- Method of handling, reuse and disposal of EAF slag
- Deviation from best practice of EAF stack PM emissions
- Deviation from best practice of measures taken for complete control of primary and secondary emissions
- Monitoring and conformity to work zone fugitive emission levels
- Initiative to measure and control dioxins/furans emissions
- Deviation from best practice of specific electricity consumption
- Deviation from best practice of noise levels in work zone area

Manufacturing unit	Scoring
Essar Steel, Hazira	
Jindal Steel and Power, Raigarh	
Ispat Industries, Raigad	
Jai Balaji, Durgapur	
Bhushan Power and Steel, Sambalpur	
Usha Martin, Jamshedpur	No leaves
Jayaswal Neco Industries, Raipur	No leaves
Bhushan Steel, Dhenkanal	No leaves

SCORING SCALE

Award category	Scores
5 Leaves	Above 75 %
4 Leaves	50-75 %
3 Leaves	35-49.9 %
2 Leaves	25-34.9 %
1 Leaf	15-24.9 %
No leaves	Less than 15 %