

Comprehensive training material for technology providers Indore foundry cluster

GEF-UNIDO-BEE Project

Promoting Energy Efficiency and Renewable Energy in selected MSME clusters in India

Prepared for:



Bureau of Energy Efficiency

©Bureau of Energy Efficiency, 2018

This document has been originally prepared by TERI as a part of 'Capacity Building of LSPs' activity under the GEF-UNIDO-BEE project 'Promoting Energy Efficiency and Renewable Energy in selected MSME clusters in India'.

Suggested Format for Citation

This document may be reproduced in whole or in part and in any form for educational and non-profit purposes without special permission, provided acknowledgement of the source is made. BEE and TERI would appreciate receiving a copy of any publication that uses this document as a source. A suggested format for citation may be as below:

GEF-UNIDO-BEE Project, Bureau of Energy Efficiency, 2018

“Capacity Building of Local Service Providers”

For more information

GEF-UNIDO-BEE PMU

Bureau of Energy Efficiency

4th Floor, Sewa Bhawan, Sector-1,

R.K. Puram, New Delhi-110066

Email: gubpmu@beenet.in

pmc@teri.res.in

Website: www.beeindia.gov.in

www.teriin.org

Disclaimer

This document is an output of an exercise undertaken by TERI under the GEF-UNIDO-BEE project's initiative for the benefit of MSME units and is primarily intended to assist the decision making by the management of the intended unit for

the proposed technology. While every effort has been made to avoid any mistakes or omissions, GEF, UNIDO, BEE or TERI would not be in any way liable to any person or unit or other entity by reason of any mistake/omission in the document or any decision made upon relying on this document

Contents

About this manual

1.0	Introduction.....	1
1.1	Background	1
2.0	Module 1 - Good practices in motor rewinding	3
2.1	Reasons of motor failure.....	3
2.2	Overview of possible motor Losses	4
2.3	Best practices in motor rewinding	5
	List of references	14
3.0	Module 2 - Energy conservation_(with focus on melting).....	15
3.1	Best operating practices in induction furnace	15
3.2	Replacement and retrofit options in induction furnace.....	19
3.3	Case study - A foundry in Kolhapur	22
4.0	Module 3 - Pollution control system	33
4.1	Foundry process.....	33
4.2	Present environmental standards	34
4.3	Measurements	35
4.4	PCS design vis-a-vis standards	35
4.5	Commonly used PCS.....	37
4.6	Technologies used in different foundry clusters.....	40
4.7	Legal framework.....	45
4.8	Solutions/action plan	46
	References	50
5.0	Module 4 - Financing schemes and DPR preparation for EE projects.....	51
5.1	Introduction.....	51
5.2	Major financial schemes for MSMEs in India.....	54
5.3	Various credit lines and bank schemes for financing of EE	56
5.4	Preparation of detailed project report (DPR)	57
5.5	Step by step approach for loan application.....	59

About this manual

This manual provides, in a direct and simple manner, guidance on improving energy efficiency for local service providers (LSPs) in the 'technology providers' category.

The aim is to build their capacities and equip them with the necessary knowledge and skills and to provide background information and tips regards energy efficiency (EE)/renewable energy (RE) options in important foundry operation viz. Good practices in motor rewinding & electrical maintenance, Energy Conservation (with focus on melting) and Pollution Control System. A separate module on Financing schemes and DPR preparation for EE projects has been added to build the capacities of LSPs on preparation of bankable DPRs.

The manual is designed to complement the knowledge shared with the participants through a series of four one day training/capacity building programs undertaken by TERI in Indore Foundry Cluster between February to May 2018 under the GEF-UNIDO-BEE Project "Capacity Building of Local Service Providers".

1.0 Introduction

1.1 Background

The overall aim of the GEF-UNIDO-BEE project is to develop and promote a market environment for introducing energy efficiency and enhancing the use of renewable energy technologies in process applications in selected energy-intensive MSME clusters in India. This would help in improving the productivity and competitiveness of the MSME units, as well as in reducing the overall carbon emissions and improving the local environment.

The following three foundry clusters are targeted under the assignment - Coimbatore, Belgaum and Indore.

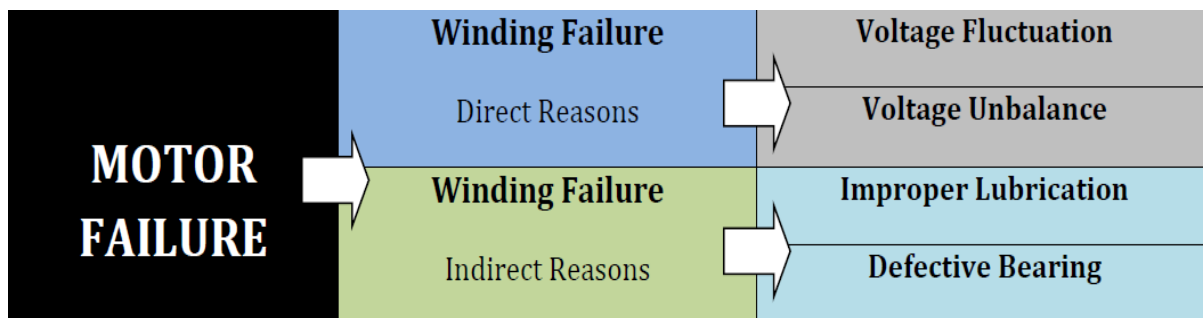
This comprehensive training material for Indore foundry cluster is targeted at 'technology providers' category. The material is structured in the following 4 modules.

Module 1	Good practices in motor rewinding & electrical maintenance
Module 2	Energy Conservation (with focus on melting)
Module 3	Pollution Control System
Module 4	Financing schemes and DPR preparation for EE projects

2.0 Module 1 - Good practices in motor rewinding

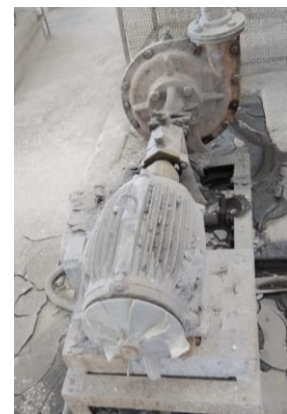
2.1 Reasons of motor failure

Electric motors fail for a variety of reasons. Certain components of motors degrade with time and operating stress. Electrical insulation weakens over time with exposure to voltage unbalance, over and under-voltage, voltage disturbances, and temperature. Contacts between moving surfaces cause wear. Wear is affected by dirt, moisture, and corrosive fumes and is greatly accelerated when lubricant is misapplied, becomes overheated or contaminated, or is not replaced at regular intervals. When any components are degraded beyond the point of economical repair, the motor's economic life is ended. The major cause of motor failure is shown in figure.



Power quality is one of the major issues leading to motor failure. Fluctuating/low voltage from the supply side (in LT industries) and voltage imbalance (due to major concentration of single phase loads) at the motor side are identified as the major reasons of on motor failure. This seems to be the cause of winding failure because of high winding temperature resulted by high current and subsequent insulation failure. Apart from the above, O&M practices like improper lubrication or/and defective bearing (selection and installation) also play role in winding failure. This is because of high inrush current in order to overcome the friction loss. It is highly felt that awareness creation must be done among the practicing engineers on how to reduce the chances of voltage imbalance at the motor end and frictional loss in motor bearings.

Poor housekeeping and cleanliness of workplace are also other reasons contributing to failure of the motor during operation in ceramic industries. The housekeeping activities like proper maintenance of motor inventories spare parts, cleanliness of name plates/motor body surface, proper ventilation and cabling, cleanliness of MCC panels and motor junction box are very important for healthy running of the motor. Apart from this quality of earthing are important areas which should not be ignored at the unit end. A poor earthing may not necessarily result in failure of the motor but is an important part of electrical safety. Best practices in



Highest efficiency motors use thin laminations of high quality steel, coated with a microfilm of varnish and these were found to exhibit no increased loss over the test range of 350 – 400°C

No load losses, stator copper losses are caused by heating from the current flow through the stator winding. Techniques for reducing these losses include optimizing the stator slot design. Rotor losses are caused by rotor currents and iron losses.

Replacement bearing & lubricants should be to the original specification and repairers should be aware that high efficiency motors use newer & sophisticated bearings.

housekeeping will certainly improve the motor health further in MSMEs cluster.

2.2 Overview of possible motor Losses

The loss in efficiency on rewinding depends on the techniques, processes and skill used to perform the rewind. Based on largely on a handful of studies of mostly smaller motors (up to 30 hp or 22.5 kW), they often assert that efficiency drops 1-5% when a motor is rewound-even more with repeated rewinds. It is usually between 1 and 2%.



In general, there are three factors affecting the efficiency of rewound motors

- ↪ **Increase in Iron Losses:** An increase in the iron losses can be caused
- ↪ **Mechanical stress in the core** will increase the hysteresis loss, as might happen if the core is fitted into a new frame with an undersized bore. The practice of hammering stator teeth back into place after stripping will result in increased hysteresis locally as a result of the residual stress. Eddy current loss will increase if the insulation between adjacent laminations is damaged, for example by burring together by filing or by accidental impact.
- ↪ **Thermal damage to the core:** thermal damage to the oxide or varnish insulation between the laminations is normally regarded as the usual cause of increased iron loss following a rewind. New work in which the increased loss after rewind under carefully controlled conditions for a number of motors was measured has shown that for conventional steels the temperature should not exceed 380°C. Losses increase very rapidly at higher temperatures.
- ↪ Most motors are designed to run with flux densities in the stator and rotor core just over the knee of the magnetisation curve. If the winding characteristics

are changed after rewind, for example if the numbers of turns are reduced, the flux density and hence the loss will increase.



Copper Loss: Stator copper loss is the largest loss (at full load) in most induction motors. The winding pattern may be changed during rewinding to simplify the process, and in doing so the repairer must consider the effect on flux density and resistance.

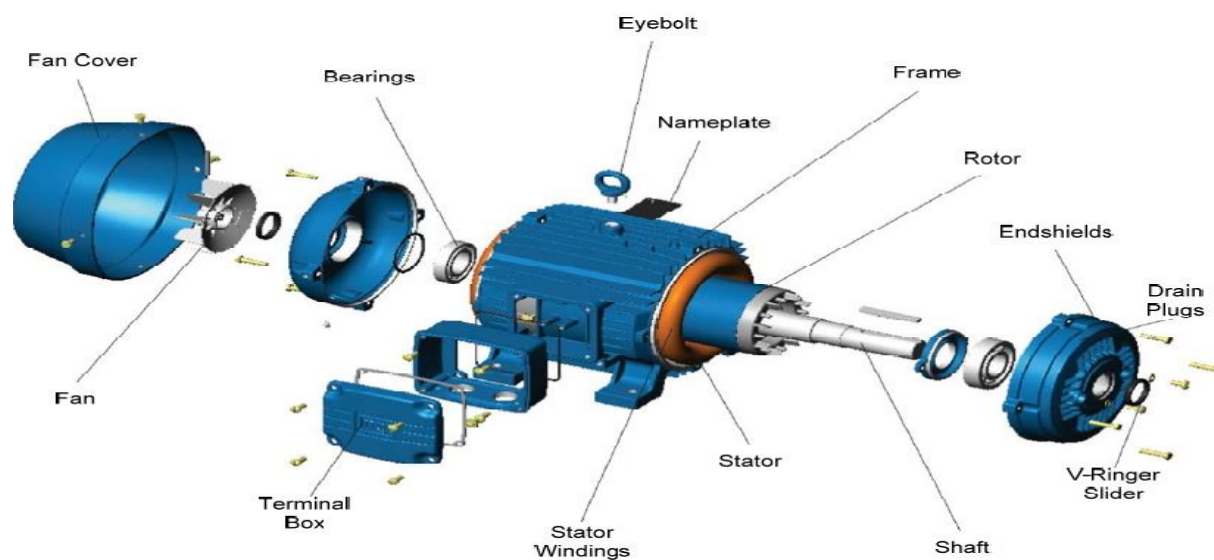
↳ These losses are reduced for example by increasing the size of the conductive bars and end rings to produce lower resistance. Stray load losses are the result of leakage fluxes induced by load currents. These can be decreased by improving slot geometry of rewound motors.

↳ **Mechanical Considerations:** The concentricity of rotor and stator is very important. It is common practice **to metal spray shafts or bearing housings** which have been damaged in service. This is acceptable only if special care is taken to preserve concentricity – errors which result in a minimum to **maximum gap ratio greater than 1:1.25** will adversely affect efficiency.

2.3 Best practices in motor rewinding

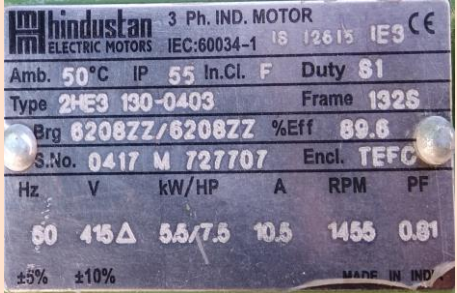
Most repair processes, if done improperly, can reduce motor efficiency. Conversely, doing them well will maintain and may even improve efficiency. It is also important to keep clear, concise written records throughout the repair process.

The following sections provide good practice procedures for each stage of the repair process, beginning with the preliminary inspection and dismantling the motors. The key recommended steps and standard/good practices is given in table below




STEPS OF REPAIR PROCESSES


- Preliminary inspection
- Dismantling the motor
- Removing old winding
- Cleaning the core
- Rewinding the motor
- Reassembling the motor

Recommended procedure	Key steps	Observations
<p>Preliminary inspection (The preliminary inspection forms an important part of the complete motor repair record and may yield vital clues about the cause of failure.)</p> <p>Sometimes it is obvious from its outward appearance that the returned motor is not repairable and that a new one must be supplied. More often, however, the motor must be dismantled before this decision can be made.)</p>	<p>Motor nameplate(s) data</p>	<ul style="list-style-type: none"> • Keep record of all data on the nameplate. • Check whether motor is IE efficiency class (as per IS12615). 
	<p>Results of external inspection</p>	<ul style="list-style-type: none"> • General condition–old/new, dirty/clean, etc. • Cooling air ducts clear/ obstructed – may have caused overheating. • Shaft discolored (brown /blue) – sign of rotor overheating or bearing seizure. • Parts missing, damaged or previously replaced/ repaired - e.g., seals, stator cooling ribs, fan, fan cover, terminal box, etc.
	<p>User/Customer input</p>	<ul style="list-style-type: none"> • Customers may be able to provide: • Operating environment – temperature, vibration, etc. • Type of driven equipment. • How many hours/day motor runs. • Approximate motor load. • How often it is started. • type of starter used • Rewinding history • How long the motor has operated since new (or since last rewind). • Unusual events–e.g., power outage, lightning strike, water damage, problem with driven equipment, etc.
<p>Dismantling the motor (It is essential to dismantle the motor carefully and to keep adequate records to ensure that if the motor is repaired it can be reassembled correctly. Place all parts that are not to be repaired in a suitable bin or</p>	<p>Terminal box position, layout and connections.</p>	<ul style="list-style-type: none"> • Record markings on both winding leads and terminals. • Record positions of any links between terminals (make sketch). • Check that insulation on winding leads immediately adjacent to terminals does not show any signs of overheating (discoloration or

Recommended procedure	Key steps	Observations
tray that is labeled with the motor serial number or job card number.)		brittleness). If it does, replace the leads. <ul style="list-style-type: none"> • Confirm that all terminals are firmly crimped or brazed to winding leads. • Record size & type of lead wire. • Record lug size and style.
	Orientation of end brackets and bearing caps.	<ul style="list-style-type: none"> • End brackets and bearing caps should be installed in exactly the same positions as originally fitted. • Mark all end brackets and stator frames at both ends of the motor (punch marking components with a center punch) before dismantling the motor
	Bearing sizes, types and clearances.	<ul style="list-style-type: none"> • Bearing enclosure • Fit and tolerance • Precision class • Internal clearance • Load application • Type of lubricant
	Axial position of rotor relative to stator (drive end - DE or opposite drive end - ODE).	<ul style="list-style-type: none"> • Rotor should be centered axially within the stator core. • If it is displaced axially, centering forces will exert pressure on the bearings. • If it is displaced beyond the end of the stator core, magnetizing current will increase. • Note position of axial thrust washer when dismantling the motor (i.e., DE or ODE).
	Orientation of shaft with respect to the main terminal box.	<ul style="list-style-type: none"> • Document the mounting position of the shaft in relation to the leads (F1 or F2). • There many ways to do this. Some repairers describe this as “leads left facing shaft” or “shaft right facing leads.”
	Careful rotor removal to prevent damage to air gap surfaces or winding.	<ul style="list-style-type: none"> • Rotor presents a considerable overhung load when one end bracket has been removed. • Allowing it to scrape along the stator bore during rotor removal can damage the air gap surfaces of both stator and rotor and increase losses. Winding damage can also result. • An effective way to remove and replace rotors in horizontal motors

Recommended procedure	Key steps	Observations
		is by using a rotor removal tool
	Internal inspection	<ul style="list-style-type: none"> • Water or dirt ingress. • Condition of stator and rotor cores–damage or overheating. • Condition of winding–discoloration, type of failure.
	Mechanical damage to components or signs of misuse.	<ul style="list-style-type: none"> • Damage to fan or fan cover • Damaged or blocked cooling ducts/channels/ribs • Shaft discoloration adjacent to either bearing (overload or misalignment)
	Motors with contamination	<ul style="list-style-type: none"> • If the exterior is packed full of contaminants, address maintenance procedures or consider a different enclosure. • If the winding is packed full of contaminants, the enclosure may not be suitable for the operating environment.
Removing the old winding and cleaning the core (Although removal of old winding and cleaning core are necessarily carried out sequentially, recording the winding details is a coordinated activity carried out both before and during winding removal. Likewise, core loss testing is carried out at fixed points throughout the process.)	Recording the winding details on appropriate data cards or sheets	<ul style="list-style-type: none"> • Winding configuration (lap, concentric, single, two or three layers, etc.) • Number of slots & poles • Number of phases • Number, size & marking of leads • Turns/coil • Grouping • Coil pitch & Connections • Coil extension/overhang–connection end • Coil extension–non-connection end • Number and size of wires in each coil
	Core loss testing	<ul style="list-style-type: none"> • Make sure the tests are conducted well within the manufacturer’s recommended operating range for the tester being used. Carry out tests: <ul style="list-style-type: none"> - Before burnout - After the core has been cleaned prior to rewinding. • Remember that figures obtained are comparative, not actual losses. • If the core loss increases by more than 20%: <ul style="list-style-type: none"> - Make sure the settings of the core loss tester have not been changed and repeat the test.

Recommended procedure	Key steps	Observations
		<p>- If the repeat test confirms the increased loss, repair the core or consider replacing it.</p>
	<p>Removing old winding</p> 	<ul style="list-style-type: none"> • Step 1–Cut off one coil extension (usually opposite connection end): Cut off coil extension of the winding as close to stator core as possible without damaging the stator core. • Step 2–Remove the old stator winding: Varnish and insulation must be broken down before windings to be removed. • To be with a controlled temperature burnout oven. Coils must be heated sufficiently to burn out old insulation from windings without damaging interlaminar insulation. • It is important to set the oven temperature to monitor the temperature of the stator core. (See figure). • Key points–removing the old windings <ul style="list-style-type: none"> ○ Cut off one coil extension using a winding cut-off machine. ○ Burn out old insulation at appropriate temperature in a controlled-temperature burnout oven set to monitor core temperature. ○ Do not overheat the core. Remove the winding without damaging the core.
	<p>Cleaning the stator core in preparation for rewinding</p>	<ul style="list-style-type: none"> • Key points–cleaning the stator core: <ul style="list-style-type: none"> ○ Careful scraping with a sharp

Recommended procedure	Key steps	Observations
		<p>knife.</p> <ul style="list-style-type: none">○ High-pressure washing.○ Blasting with a mildly abrasive material.○ Brushing with medium/soft wire brush.● After cleaning the slots:<ul style="list-style-type: none">○ Reposition damaged teeth○ Repair minor damage to air gap surfaces● Replace or reinsulate and rebuild cores if major damage has occurred

After performing the inspection and removal the winding, if choosing the replacement of winding the repairer has two options:

- Copy (duplicate) the winding already in the motor (provided it is the manufacturer’s original).
- Choose a different style of winding that will perform as well as or better than the original.

At this stage, the repairers have opportunity to redesign the motors to make them more energy efficient. Most of the time, however, the best way to maintain motor efficiency is to duplicate the original winding, while increasing the copper cross sectional area as much as possible and keeping the end turns as short as possible (certainly no longer than those of the original winding).

Though, that in some designs, the coil extension is critical for heat dissipation. If it is too short, the temperature of the winding may rise, causing I²R losses to increase.

When production volume justifies the cost, motor manufacturers use automatic coil winding and inserting machinery to produce motors with concentric coil groups. Repairers often find lap windings much quicker and easier to install.

This section therefore sets out the basic rules (in terms of maintaining efficiency) for just two types of rewind:

- A “copy” (or duplicate) rewind
- Changing the original concentric winding to a conventional lap winding

Recommended procedure	Key steps	Observations
Rewinding the motor	Copy (duplicate) rewinding	<ul style="list-style-type: none"> • If the details of old winding have been recorded, and provided that it is the manufacturer’s original winding, the core can now be prepared for rewinding. • Even though the coil pitch (or pitches), turns/coil and the connections will be the same as those of the original winding, two changes could be made that will help to maintain or even slightly improve the efficiency of the re-wound motor: <ul style="list-style-type: none"> • Minimize the length of the coil extensions. • Increase the copper cross-sectional area in each coil. • Key points–copy rewinding <ul style="list-style-type: none"> ○ Check that old winding is manufacturer’s original. ○ Use same winding configuration. ○ Keep coil extensions as short as practical. ○ Same (preferably less) length of overhang. ○ Use same coil pitch (or pitches). ○ Use same turns/coil. ○ Use same (preferably larger) copper cross-sectional area. ○ Use same or shorter mean length of turn (MLT).

Recommended procedure	Key steps	Observations
		<ul style="list-style-type: none"> ○ Use same or lower winding resistance (temperature corrected).
	<p>Minimize the length of the coil extensions</p>	<ul style="list-style-type: none"> • It is important to keep the coil extensions as short as possible. • Attention to the following rules will prevent this: <ul style="list-style-type: none"> ○ Keep the coil extensions within the measured dimensions of the original winding. ○ Do not extend the slot insulation beyond the slot ends any more than is necessary to prevent strain on the slot cell. ○ Do not extend the straight portions of the coil sides any farther than is necessary to clear the slot insulation. • Reducing the length of the coil extension will reduce the amount of copper in the winding and reduce losses.
	<p>Changing to a two-layer lap winding</p>	<ul style="list-style-type: none"> • Repairers often prefer to use lap windings because all coils are the same. This is acceptable if the new winding has the same flux/pole as the original. • Single-layer lap windings are sometimes used for small to medium-sized motors, because the coils are easier to insert and no separators are required. This allows more room for copper. • Double-layer windings distribute flux through the core better than single-layer windings. Replacing a double-layer winding with a single-layer winding will certainly reduce motor efficiency, so it is not recommended. • Lap windings should be appropriately short-pitched (i.e., the coil pitch must be less than the pole pitch unless the winding has only one coil per group).
<p>Completing the winding (After fully inserting the winding, connect the coils and leads to match the original connections exactly (if a copy or duplicate rewind) or appropriately for the replacement lap winding. Use connection leads that are as large as practical and mark all of them correctly. Brace the coil extension either as the manufacturer's original winding or better (i.e., more rigid). After checking</p>	<p>Winding resistance tests</p>	<ul style="list-style-type: none"> • Measure resistance of first coil group wound and compare it with the calculated resistance. If possible, measure the resistance of a coil group from the original winding for comparison. • Measure the ambient air temperature (T_a) with the winding at room temperature. Correct both resistances to a convenient common reference temperature (normally 25°C) using the formula:

Recommended procedure	Key steps	Observations
<p>the coil extensions a final time, perform winding resistance, insulation resistance, phase balance and voltage withstand tests)</p>		<div data-bbox="772 237 1362 546" data-label="Image"> </div> <div data-bbox="948 584 1305 640" data-label="Equation-Block"> $R_x = \left(\frac{234.5 + 25}{234.5 + T_a} \right) \times \text{Measured resistance}$ </div> <div data-bbox="895 645 1230 734" data-label="Text"> <p>Where R_x = corrected winding resistance T_a = ambient air temperature</p> </div> <ul data-bbox="715 745 1461 976" style="list-style-type: none"> • The corrected value of resistance of the new coil group must be equal to or lower than that of the original coil group. • When the stator is fully wound, measure and record the resistance of each phase (or between leads) as well as the ambient temperature. Resistance of each should be equal within 5% (See figure)
	<p>Phase balance (or surge comparison) tests</p>	<ul data-bbox="715 987 1461 1261" style="list-style-type: none"> • Perform on completed winding before impregnation. • Test compares decay rate of identical voltage pulses applied simultaneously for 2 winding phases. • Trace pattern indicates phases identical (okay–identical traces) or different (fault–traces do not match). • Trace pattern gives guidance to type of fault (see equipment manufacturer’s guide).
	<p>Impregnation</p>	<ul data-bbox="715 1272 1461 1657" style="list-style-type: none"> • Impregnating the winding with varnish and subsequently air drying or baking this varnish until it is cured serves the several purposes: <ul data-bbox="743 1391 1461 1585" style="list-style-type: none"> ○ It provides a mechanical bond between conductors. ○ It increases the dielectric rating of the insulation. ○ It protects the winding from moisture and contamination. ○ It fills the air spaces between conductors (particularly in the slots). • Lower winding temperature = lower resistance = lower I²R losses

List of references

International Copper Association India (Effect of Repair/Rewinding On Motor Efficiency © 2003, Electrical Apparatus Service Association, Inc.)

3.0 Module 2 – Energy conservation

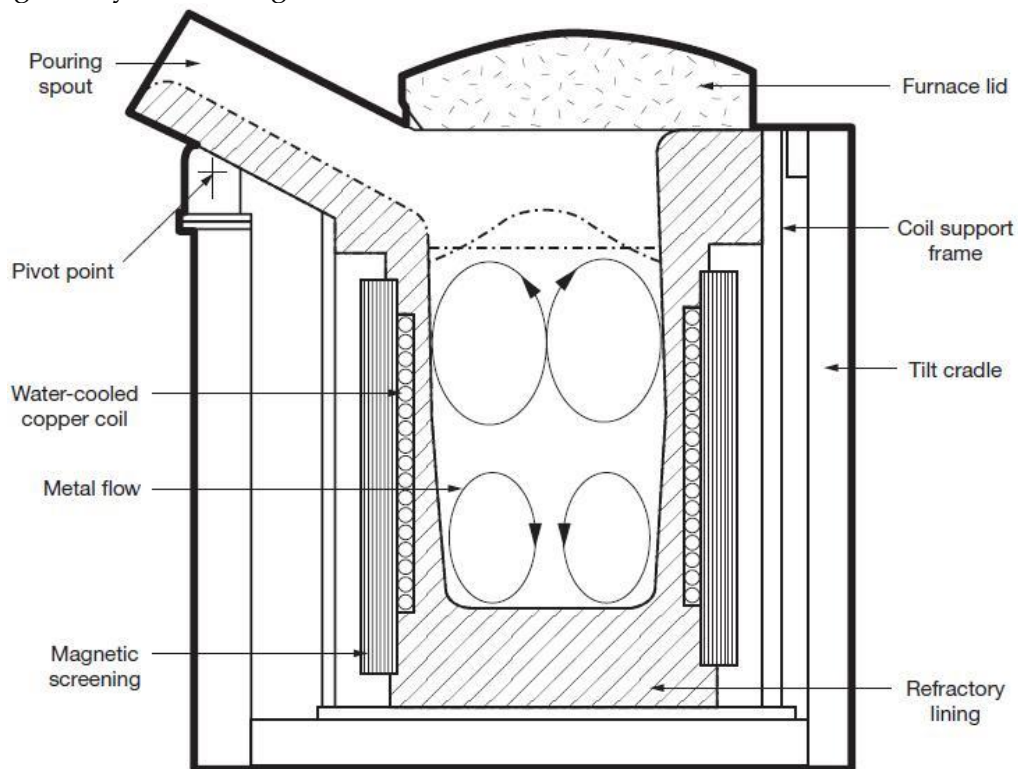
(with focus on melting)

3.1 Best operating practices in induction furnace

3.1.1 Introduction and working principle

The electric induction furnace is a type of melting furnace that uses electric currents to melt metal. The principle of induction melting is that a high voltage electrical source from a primary coil induces a low voltage, high current in the metal or secondary coil. Induction heating is simply a method of transferring heat energy. Two laws that govern induction heating are: *Electromagnetic induction and The joule effect*.

The high frequency induction furnaces use the heat produced by eddy currents generated by a high frequency alternating field. The inductor is usually made of copper in order to limit the electric losses. The inductor is in almost all cases internally water-cooled. The furnace consists of a crucible made of a suitable refractory material surrounded by a water cooled copper coil. In this furnace type, the charge is melted by heat generated from an electric arc. The coil carries the high frequency current of 500 to 2000 Hz. The alternating magnetic field produced by the high frequency current induces powerful eddy currents in the charge resulting in very fast heating.



Typical arrangement of coreless induction furnace

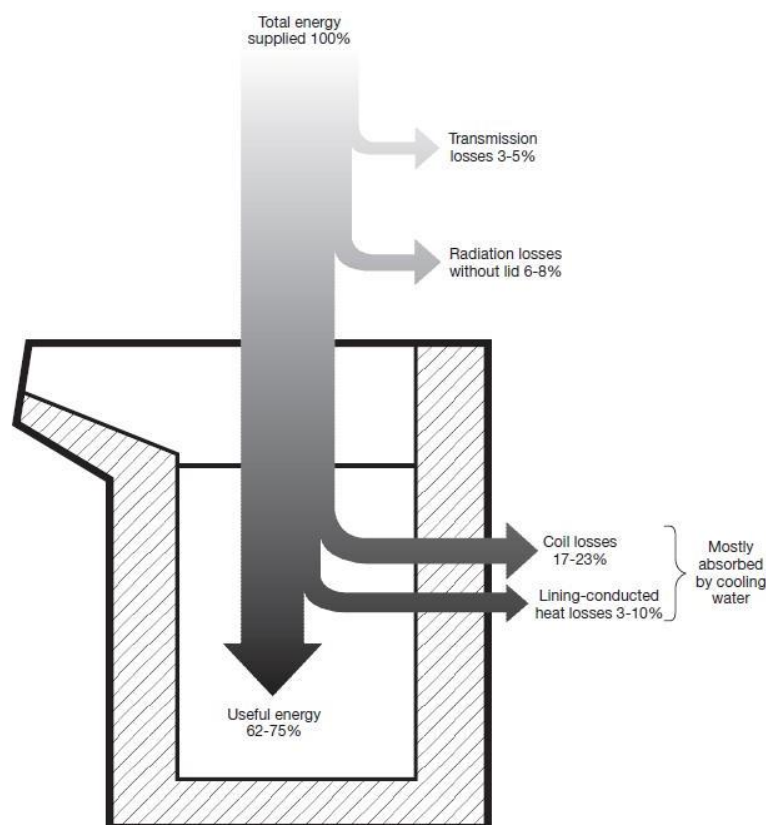
Source: BCIRA *Efficient Melting in coreless induction furnace*

There are two main types of induction furnace: *Coreless and Channel*. The coreless induction furnace has essentially replaced the crucible furnace, especially for melting of high melting point alloys. The coreless induction furnace is commonly used to melt all grades of steels and irons as well as many non-ferrous alloys.

A modern coreless induction furnace can melt a tonne of iron and raise the temperature of the liquid metal to 1450 °C using less than 600 kWh of electricity. Typically, specific energy consumption of coreless induction furnace varies from 500 to 800 kWh per tonne depending on type and grade of casting. The overall efficiency of induction furnace depends on many factors, such as: scrap charging system, furnace design, furnace cover, harmonics control, multiple-output power supply and refractory.

3.1.2 Losses in induction furnace

Electrical energy required for heating one tone of iron to 1500 °C is 396 kWh. In furnace numerous losses takes place which increases the specific energy consumption to above 500 kWh. The losses are: thermal furnace losses, furnace coil losses, capacitor bank losses, convertor losses and losses on main side transformer. The losses are represented in figure below.



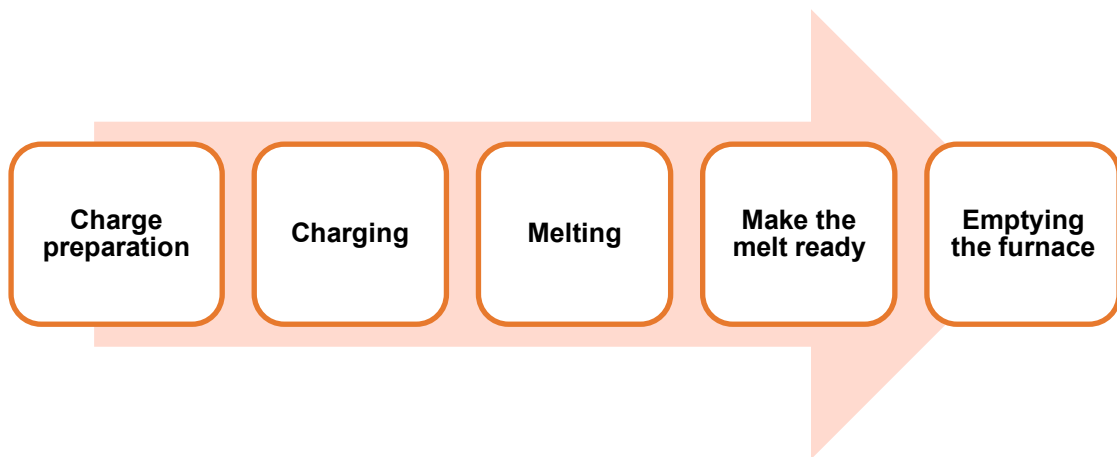
Sankey diagram of energy loss in coreless induction furnace

Source: BCIRA *Efficient Melting in coreless induction furnace*

In a typical induction furnace the energy loss in equipment is between 100 to 130 kWh per tonne. The furnace efficiency is around 65 to 75%. With new development in energy efficient coils, new refractory material, reduction of converter losses and reduction in transformer losses the state of art furnace equipment energy loss is reduced to 60 to 90 kWh per tonne. The new furnaces have efficiency 81 to 87%.

3.1.3 Best operating practices

Efficient operation of coreless induction furnace depends primarily on implementation of good/best operating practices. The steps involved in operation of induction furnace are shown in figure below. Best operating practices under each of stages are elaborated in following section.



Steps of operation of induction furnace

Source: ABP Induction - High energy efficient melt-shop design and operation

Charge preparation and Charging

- The raw material must be weighed and arranged on melt floor near to furnace before starting the melting. E.g. for 500 kg crucible weigh and keep 500 kg raw material ready.
- Charge must be free from sand, dirt and oil/grease. Rusty scrap not only takes more time to melt but also contains less metal per charging. Use of clean, dry and dense charge material can result in saving of 10 kWh per tonne.
- The maximum size of single piece of metal/scrap should not be more than 1/3rd. of diameter of furnace crucible. It avoids problem of bridging.
- Furnace should not be charged beyond the coil level, i.e. charging the furnace to its capacity. It should be noted that as furnace lining wears out the charging may slighting increase.
- Proper charge sequence must be followed. Bigger size metal first followed by smaller size and gaps must be filled by turnings and boring.

- The foundry return i.e. runner and risers must be tum blasted or shot blasted to remove the sand adhering to it. Typically runner and risers consists of 3 to 5 % sand by weight.
- Process controll through melt processor leads to less interruptions. Typically reduce interruptions by 2 to 4 minutes.
- Limit the use of baled steel scrap and loose borings.
- Use of charge driers and pre-heaters to remove moisture and pre-heat the charge.

Melting and making melt ready

- Follow the melt process and run the furnace with full power.
- Use lid mechanism for furnace crucible, radiation heat loss accounts for 4 – 5 % input energy. E.g. 500 kg crucible melting at 1450 °C with no lid cover leads to radiation heat loss of up to 25 kWh per tonne.
- Avoid build-up of slag on furnace walls.
- Proper tools must be used for de-slagging. Use tools with flat head instead of rod or bar for de-slagging; it is more effective and takes very less time.
- Spectro-testing lab must be located near to melt shop to avoid waiting time for chemical analysis.
- Avoid un-necessary super-heating of metal. Superheating my 50 °C can increase furnace specific energy consumption by 25 kWh per tonne.

Emptying the furnace

- Optimization of the ladle size to minimize the heat losses and empty the furnace in the shortest time.
- Optimization of the ladle transportation.
- Plan melting according to moulding. Metal should never wait for mould rather mould should be ready before metal.
- Use of ladle pre-heater. Proper positioning of burner is important to get uniform heating.
- Quantity of liquid metal returned to furnace must be as low as possible.
- Glass-wool or ceramic-wool cover for pouring ladle.
- Minimize plant breakdown by implementing a planned maintenance schedule.

Furnace lining

- Select the correct lining material.
- Do not increase lining thickness at bottom or sidewalls. Increase in lining means reducing capacity of furnace.
- Do not allow furnace to cool very slow. Forced air cooling helps in developing cracks of lower depth, this helps in faster cold start cycle. Cold start cycle time should be ideally not more than 120% of normal cycle time.

- Do not remove worn-out lining without witnessing. Measure left over thickness of lining, erosion up to 50% is SAFE.
- Coil cement should be smooth, in straight line and having thickness of 3 to 5 mm.
- While performing lining ensure that each layer is not more than 50mm. Compaction is better with smaller layer.
- Consider use of pre-formed linings.
- Monitor lining performance.

Energy monitoring and data analysis

- Separate energy meter for furnace must be installed.
- Monitor energy consumption on heat by heat basis. Analyse them in correlation with production data to arrive at specific energy consumption of furnace on daily basis.
- Any peak or valley in data must be studied and investigated.
- Energy monitoring the first step for achieving energy saving.

Others

- Effective raw material storage is important for optimum performance of the furnace equipment.
- Coil cooling and panel cooling water's temperature and flow rate must be monitored regularly.
- The panel must be checked on weekly basis and cleaning must be done on monthly basis.
- Check the condition of fins in cooling tower, do cleaning of fins on monthly basis.

3.2 Replacement and retrofit options in induction furnace

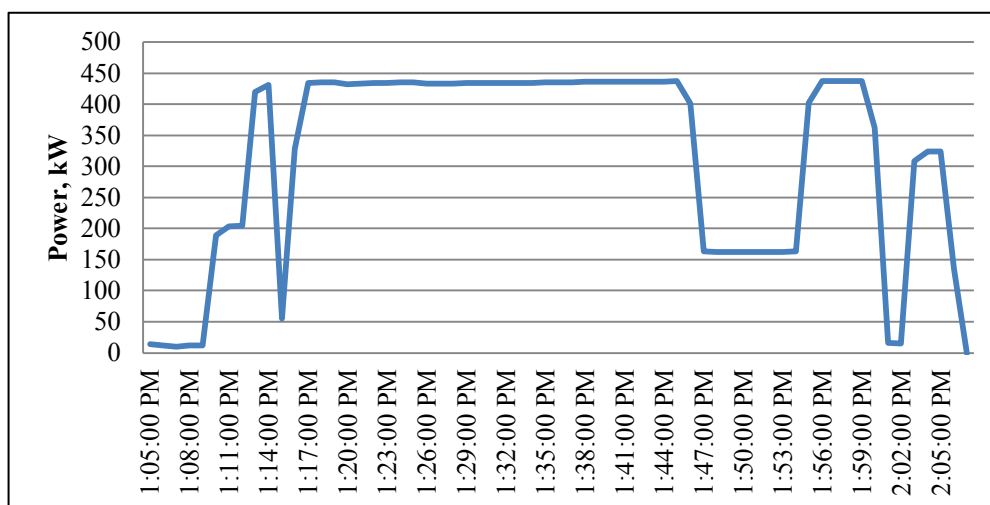
Melting is the heart of the foundry industry. A number of options are available for melting but induction furnace is by far the most famous and used furnace for melting.

3.2.1 Performance assessment of induction furnace

The performance of induction furnace is represented by its specific energy consumption (SEC). The SEC of induction furnace is defined as the energy consumed by tonne of liquid metal. Energy consumption in melting could be noted from a dedicated energy meter installed in induction furnace panel and the charged metal could be weighed using an electronic balance and maintain a log sheet to record the weight of metal during actual operation of the induction furnace.

$$SEC = \frac{\text{Total energy consumption (kWh)}}{\text{Liquid metal production (tonne)}}$$

The deviations of efficiency or SEC levels from design values indicate the scope for energy saving potential. The assessment of induction furnace power curves helps understand where the delays in production are actually coming from, a sample power curve of induction furnace is presented in figure below.



Power curve of a sample batch of melting in induction furnace

The starting of power curve indicates start of the heat, during initial charging the power is OFF. The furnace takes some time to stabilize to an average power level. Towards the end of heat a dip in power level shows sampling for chemistry, the second dip is for temperature measurement followed by ending of heat.

The energy conservation measures (ECM) in induction furnace can be categorized into selection & sizing and best operating practices. The parameters under selection and sizing of induction furnace affecting energy performance are as follows:

- Crucible size
 - Melt rate handling capacity
 - Moulding capacity
 - Number of crucibles in operation
- Panel capacity and type
 - Technology adopted: SCR or IGBT
 - Power density of furnace i.e. kW/kg
- Cooling water circuit
 - Pump selection: flow rate and head design
 - Type and size of sizing

The improvements in energy performance in melting can be categorized based on the investment required as follows: complete replacement of technology, retrofits and best operating practices.

3.2.2 Replacement of in-efficient induction furnace

Traditionally induction furnace uses a silicon controller rectifier (SCR) which is a 6-pulse operation with a maximum power factor at full load of about 0.95. The average energy consumption of a SCR based induction furnace in a typical small scale foundry producing cast iron is 650 kWh per tonne of liquid metal.

Insulated Gate Bipolar Transistor technology, or IGBT, is considered to be the most effective and efficient induction melting technology. IGBT technology is fairly new, with its first generation devices coming in the 1980s and early 1990s. The technology is now in its third generation which also happens to be its best generation given its speed and power. Compared to older methods, such as a traditional furnace, an induction furnace utilizing IGBT technology is not only more efficient, but is also easier to operate. Such ease of use means more time can be spent on metal melting rather than ensuring the furnace is operating correctly. Another cost-effective feature is the fact that IGBT technology coupled with the induction furnace allows for loss prevention. Some of the advantages of IGBT induction furnace are as follows:

- Higher power factor (0.95-0.98)
- Noise reduction
- Better efficiency
- Low switching losses
- Better control and
- Simpler yet stable operation

3.2.3 Retrofits in induction furnace

Lid mechanism for induction furnace

The loss of heat through radiation and convection from opening of induction furnace crucible is about 3%. Typically foundries do not have a practice of covering the opening.



Different options for lid mechanism for induction furnace

Low cost automation in raw material charging

Charging of raw material is one of the most important steps in induction furnace operation. Majority of small scale foundry relies on manual labour for charging. Typically the charging of raw material takes up about 50-60% of total duration of the batch, leading to lower production efficiency and higher energy consumption.

3.3 Case study – A foundry in Kolhapur

With focus on improving productivity and enhancing energy efficiency in melting section of the foundry a Kaizen implementation activity was planned. The following section presents findings from application of Kaizen, 5S and small group activities in a MSME foundry.

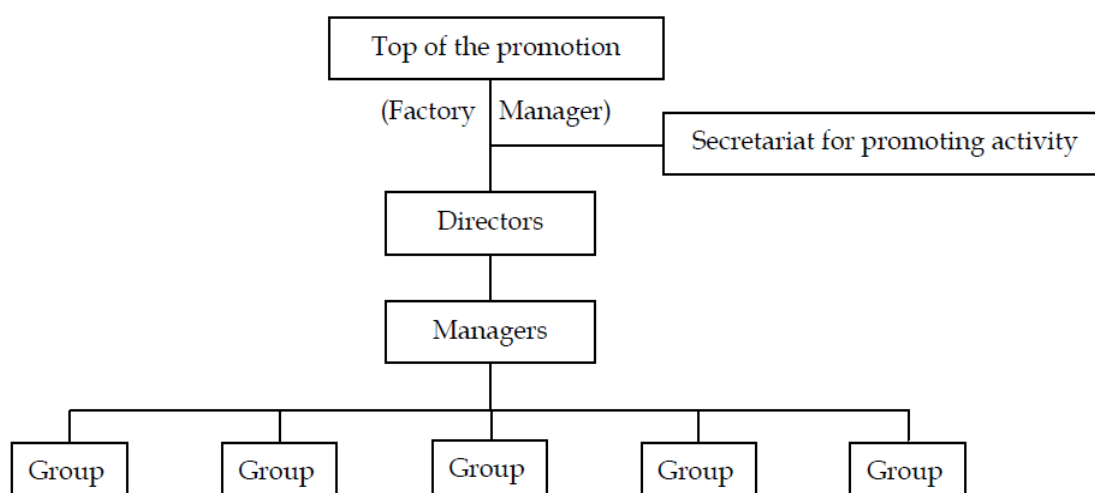
3.3.1 Background about the unit

A medium scale foundry in western region (Kolhapur) established in the 1990s with an annual production of 1,450 tonne of saleable casting (FY 2014-15). The foundry produces grey cast iron castings for end-use sectors including but not limited to automobile, air compressors, tractor, railway and textile. The melting operation in the foundry was done using induction furnace. It was equipped with a 500 kg induction furnace powered by 550 kW SCR based power pack.

3.3.2 Kaizen implementation methodology

The implementation of Kaizen was carried out by the foundry team with support from external experts. The implementation of the Kaizen was as follows:

- Formation of implementation support group
- Formation of small groups
- Formulating criteria and means of evaluation of the activities
- Data collection, analysis and visualization
- Identification of problem statements
- Looking for solutions with help of “small group activity”
- Validation and implementation of suggested solution
- Post implementation verification by data collation



Implementation support group

3.3.3 Data collection, visualization and analysis

Data collection

A number data pertaining to melting operation in induction furnace were collected. A standard format was prepared in agreement with the foundry and data was collected on heat-wise basis for months. The present case study data of 545 heats of FG220 grade casting is presented. A sample format of data collection sheet is shown in table 3.3.3a, b & c.

Table 3.3.3a Data collection format – Part 1

Melt No.	Date	Operator Name	Material Grade	Charging Weight (kg)					Supplementary Material (kg)		Total kg
				Pig iron	Steel Scrap	C.I Scrap Boring	Domestic Scrap (RR)	Heel Metal	Innoculant	Graphite Agent	
1											
2											
3											

Table 3.3.3b Data collection format – Part 2

Time & Power Meter Readings										Total Time (min)	Total Power (kWh)	Total Power (kWh/t)	
Material charging start		Material charging End		C.E. Meter Check		Tapping Temp.	Tapping start		Tapping End				
Time	Power	Time	Power	Time	Power		Time	Power	Time	Power			

Table 3.3.3c Data collection format – Part 3

Melt No.	Material Grade	Time & Power Meter Readings				Total Time (min)	Total Power (kWh/t)	Standard Chemical Composition (%)						
		Tapping Temp.						C	Si	Mn	P	S	C.E	
1														
2														
3														

During the first phase of Kaizen, data was collected for a number of batches. The foundry produced following grades FG220, FG260, FG300 and FG350. The data collected during Kaizen pertaining to most common grade i.e. FG220 was analysed and is presented in following section. Important parameters are defined as follows:

1. Melt no. : The heat number of the batch
2. SEC : Specific energy consumption i.e. electrical energy consumed per tonne of raw material input (UNIT: kWh/t)
3. TTT : tap to tap time for one batch i.e. from start of raw material charging to end of liquid metal tapping (UNIT: minutes)
4. TT : Tapping temperature of liquid metal (UNIT: °C)
5. Operator : The person who operates the induction furnace

Visualization and analysis of data

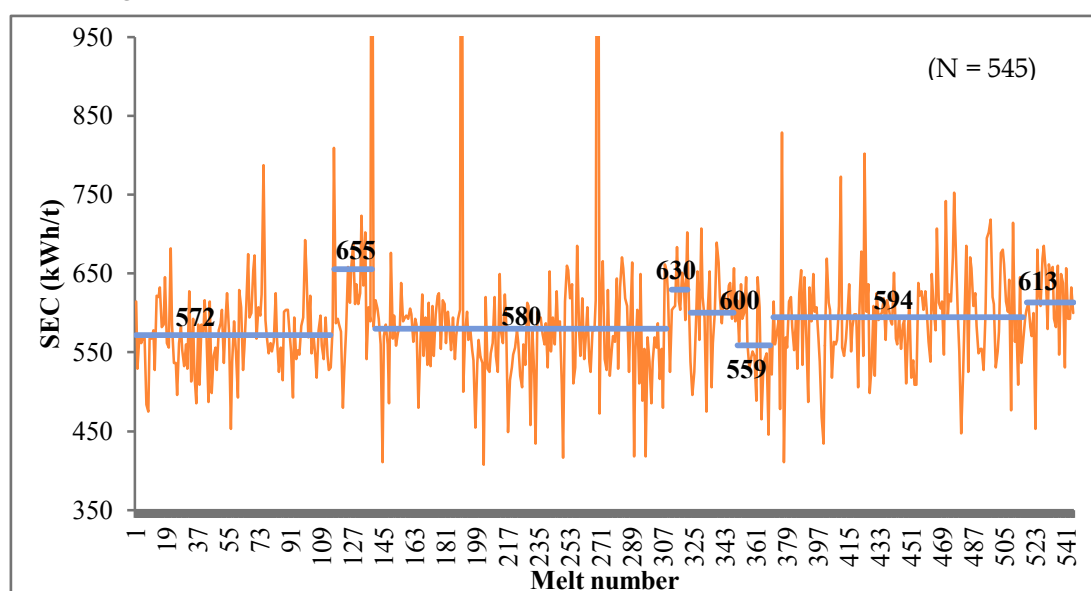
A number data visualization tools were utilized to analyse the date collected. The following analysis was conducted to improve understanding of the induction furnace operation:

Table 3.3.3d: Data analysis vs. visualization tool

S. No.	Data analysis	Visualization tool
1	Melt no. vs. SEC	Line graph
2	TTT vs. SEC	Scatter plot
3	TT occurrence	Histogram
4	TT vs. SEC	Scatter plot
5	SEC vs. Operator	Line graph
6	Rejection vs. Occurrence	Pareto chart

Melt no. vs. SEC (Line graph)

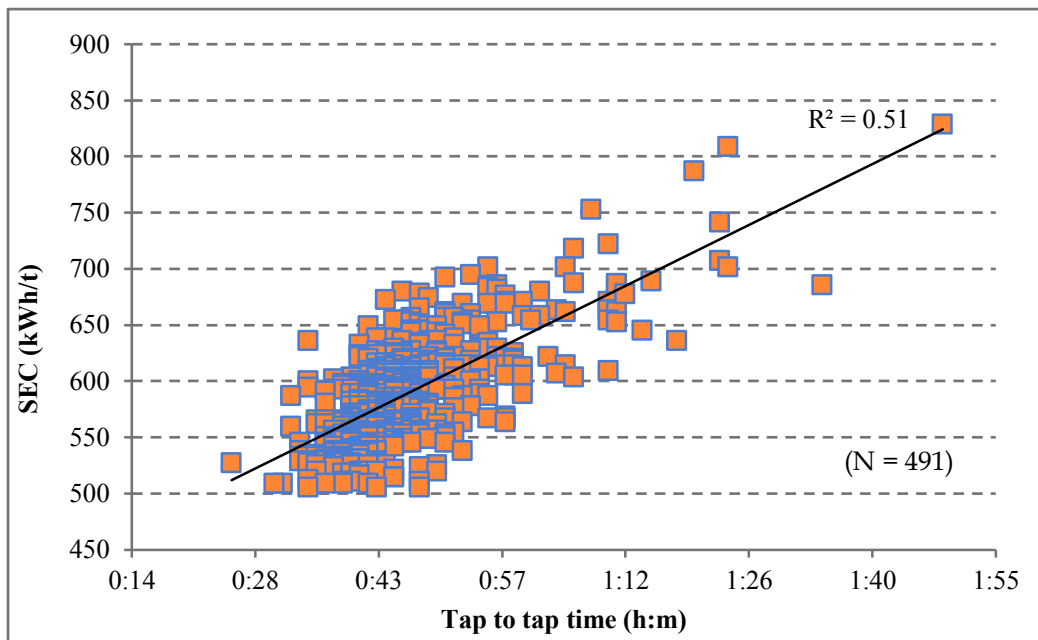
A total of 545 heats of FG220 grade melting were recorded. A line graph was plotted for SEC vs. melt number. Local averages were highlighted to show the variation in SEC over time. The local averages of SEC varied from 655 to 559 kWh per tonne.



Melt number vs. SEC

TTT vs. SEC (Scatter plot)

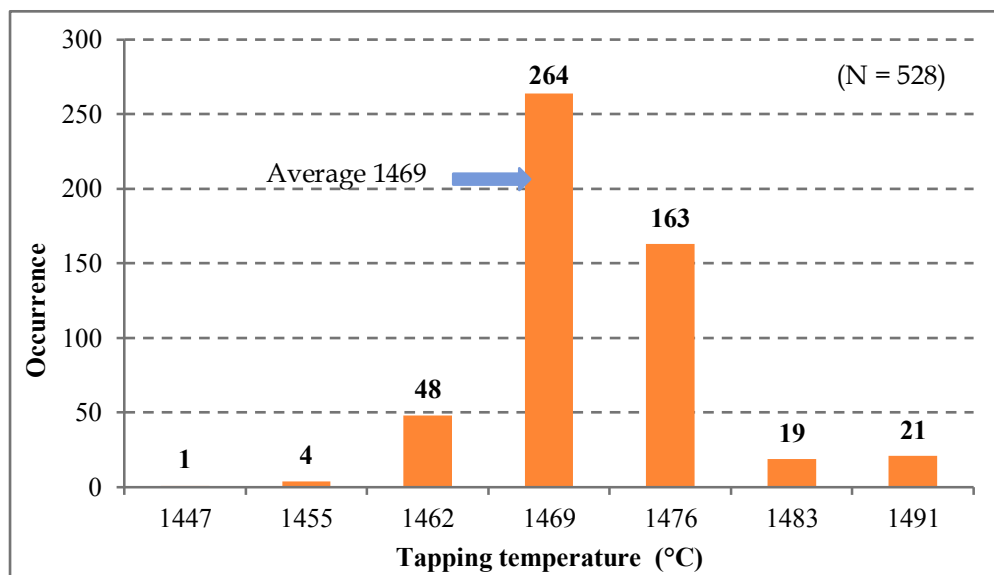
The tap-to-tap time of the heat varied depending on a number of parameters such as raw material availability, rate of charging, readiness of moulds, and delay in chemistry adjustment. A scatter was plotted for tap-to-tap time vs. the specific energy consumption. The cold start heat were omitted from this analysis, a total of 491 heats were represented.



Tap to tap time vs. SEC

Tapping temperature occurrence (Histogram)

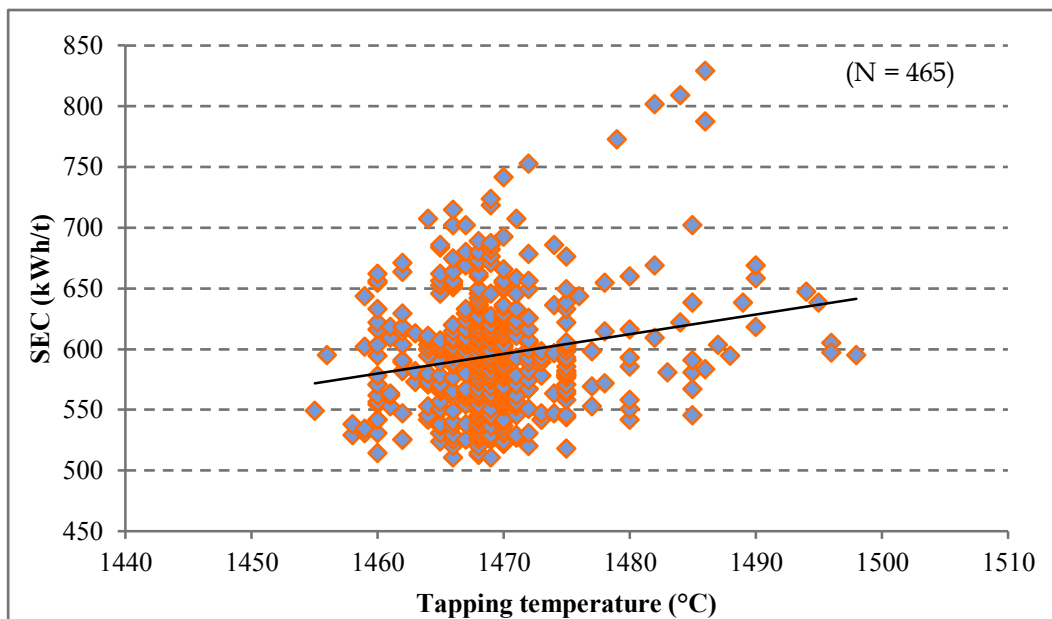
A total of 528 heats were observed where tapping temperatures data was available. The range of tapping temperature was from 1442 to 1527 °C, with a median at 1469 °C. The data was evenly balanced as the mean and the median were same. The frequency of occurrence of tapping temperature in range of one standard deviation from mean is expected to contain 90% of heats. But for the foundry it was 84% meaning a scope of improvement of tighter control of tapping temperature.



Tapping temperature occurrence

Tapping temperature vs. SEC (Scatter plot)

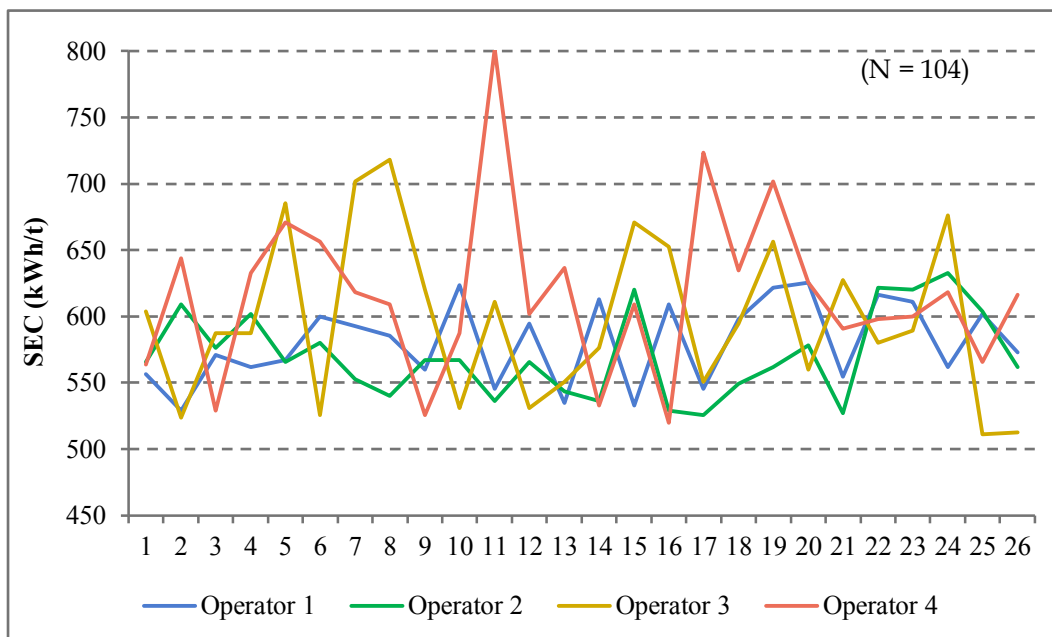
The tapping temperature required for FG220 grade was in range of 1465 – 1475 °C. The SEC of the furnace is believed to have strong correlation with tapping temperature. A scatter plot for 465 heats for tapping temperature and specific energy consumption is shown in figure.



Tapping temperature vs. SEC

SEC vs. operator (Line graph)

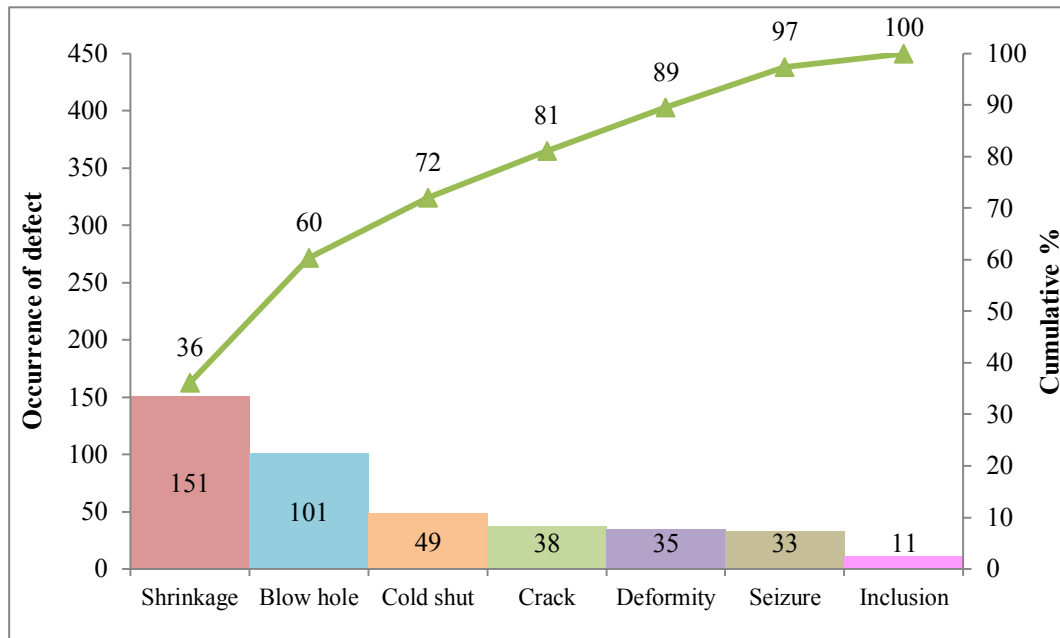
The plant had employed a total of four operators. They took different shifts. Two operators i.e. Operator 1 and Operator 2 were experienced and it reflected in their operation, their respective SEC for a sample of 26 heats was 588 and 584 kWh per tonne. The other two operators were young and new to induction furnace operation hence had slightly higher SEC of 606 and 616 kWh per tonne respectively.



Operator vs. SEC

Rejection occurrence (Pareto chart)

The rejections during the Kaizen period were recorded and categorised based on the reasons. A number of reasons were observed which on discussion with the small group led to identification of seven major types of defects/rejections. A Pareto chart was plotted for analysing the defects and to prioritize which cause has to be targeted first.



Rejection analysis

The following observations were drawn based on visualization and analysis of collected data for induction furnace for melting:

- The average specific energy consumption for the 545 heats was 588 kWh per tonne. But when looked at local averages it was observed that there are instances (few heats/days) when the local average SEC is as high as 655 kWh per tonne.
- A scatter between SEC and tap to tap time shows a correlation of 0.51. In two standard deviation range about 83% of the heat fell i.e. tap to tap time in range of 37 to 59 minutes.
- The tapping temperature was looked into for variations; it was observed that only about 84% of the heats have their tapping temperature in range of one standard deviation i.e. 1462 to 1477 °C.
- The specific energy consumption had a direct positive correlation with the tapping temperature i.e. with rise in tapping temperature the specific energy consumption of the induction furnace also increased
- Observations were drawn on four operators. It was observed that the more experienced and trained operators had better specific energy consumption (584 kWh per tonne). The two fresh operators with relatively scarce experience and training had a higher specific energy consumption 606 and 616 kWh per tonne respectively.

- Seven major types of defects were identified in the foundry, a Pareto analysis showed that shrinkage was the major culprit and was responsible for about 36% of total rejections in the foundry, followed by blow holes at 24%.

3.3.4 Activities for implementation

According to the analysis of the operation status, it is found that there are large variation range of the time and the power consumption rate of the 'Tap to Tap' at each melting, specific energy consumption and also the gaps of results among the furnaces of each unit. The draft proposals of matters which the expert thinks necessity of starting the Kaizen activities for power consumption reduction of high-frequency furnace immediately are summarized below with priority. Proposal of activities proposed for implementation by various small groups are as follows:

Table 3.3.4: Proposal of activities

Category	Draft Proposal of Theme of Activities	Priority
Operation of high frequency induction furnace	Creation of the check standard list based on the past troubles	△
	Creation of the prior checking standard for oil pressure and water system	△
Maintenance of high power factor operation	Prior-operation check of the installation state of magnetic shield board	◎
	Connection situations, and cleaning situation of bus bar, etc.	◎
Heat radiation from furnace body	Heat radiation from cooling coil (amount of cooling water)	○
	Heat radiation from an outer wall (furnace building plan, consideration of insulation)	△
Shortening of materials charging (input) time	Form (shape) of input materials, proper charging amount	◎
	Mixing of different materials (Prevention from adhesion of slag, sand, refractory, etc.)	◎
Melting operation	Prevention from overheat of molten metal in operation	◎
	Consideration of heat radiation prevention cap from molten metal surface	◎
	Creation of operation melting work standard	◎
Management of the ladle preheat	Enhancement of back (rear) insulation	○
	Consideration of ladle cap	△
Creation of production plan and accomplish	Reduction of residual hot water, reduction of waiting time of mould	△

Priority: ◎ Taking immediate action is recommended,
○ Taking an action not immediately but sometime after is recommended,

△ *Taking an action carefully and thoroughly*

The foundry implemented the draft proposals based on the priority level. A pictorial view of some of the implemented measures is shown in figure below.



Installation of induction furnace energy monitoring system



Lid mechanism for induction furnace crucible



Proper sizing of pump and improving energy efficiency



Removal of obstruction to cooling tower air intake and FRP blades

Pictorial view of a few implementations

3.3.5 Results

The first phase of Kaizen was dedicated to monitoring, visualization and analysis of data. The phase two of the Kaizen was focussed on getting proposals from small groups, validating them and prioritising proposal for implementation. In third phase proposals were implemented and in final phase measurements were conducted to verify the results.

The specific energy consumption came down from 588 to 559 kWh per tonne. The rejection level came down from 418 pieces per month to 335 pieces per month.

References

1. British Cast Iron Research Association, Good Practice Guide Series
2. Inductotherm, The Induction Foundry Safety Fundamentals, 2008
3. Vivek R Gandhewar, et. al., Induction Furnace – A Review, 2006
4. ABP Induction - High energy efficient melt-shop design and operation, 2013
5. Shyam Kulkarni, Induction furnace – Efficient ways of operating

6. Kaizen activity manual, IGES and TERI, 2013

4.0 Module 3 – Pollution control system

4.1 Foundry process

The foundries generate significant amount of particulates and volatile organic compounds (VOCs) during the production process. These pollutants cause enormous damage to the environment and health of plants and animals over prolonged exposure. While particulate emissions lead to respiratory and other diseases in human and animals, it reduces the rate of photosynthesis in plants by depositing on the leaves of the plants. Besides, dust deposition causes soiling of the buildings and damage to building fabrics. The finer the particles are, higher is the extent of damage, as finer particles can penetrate into the deepest part of the lungs where gases are exchanged with the blood stream.

VOC causes formation of ozone at ground level. Ozone, an aggressive ground level pollutant, is formed by reaction between VOCs and nitrogen oxides in the presence of sunlight, includes respiratory distress and also damages crops and building materials, besides causing odor nuisance. Amines used to catalyze phenolic urethane cores are mainly responsible for generation of VOCs. Breakdown products from the casting of moulds with phenol-based chemical binders have also implicated in some cases. Table presents various emissions from different processes of the foundry.

Table 4.1: Emissions from different processes of the foundry

Process	Particulate emissions	Volatile organic compound emissions
Patternmaking	Wood dust, resin dust	Solvents from paints and adhesives
Mould and core making	Sand dusts (silica, zircon or chromite)	Phenol, formaldehyde, furfuryl alcohol, toluene, benzene, isocyanates, esters, amines, methyl formate, etc.*
Investment shelling	Shell material dusts	Solvents (where used)
Mould coating and burn-off	Soot	Isopropyl alcohol
Melting	Metal dust and fume, dirt from scrap, dusts from metal treatments, fluxing and refractories Cupolas only : coke dust	Organic compounds from the burn-off of oil, grease, paints and plastic contaminants, if present
Casting and knock-out of sand moulds	Silica dust, resin dust, metal fume	Phenol, cresols, xylenols, anilines, naphthalene, aromatics, formaldehyde, toluene, benzene, xylene, butadiene, acrolein, etc.*
Shotblasting and fettling	Silica dust, metal dust	N/A
Casting painting	Paint particles	Solvents, e.g. xylene

* The actual compounds emitted vary according to the chemical binder system used. Not all substances shown will be emitted from all mould and coremaking processes.

4.2 Present environmental standards

Existing emission standards for foundries prescribed by Central Pollution Control Board (CPCB) are given in table 5.2a below.

Table 4.2a: Existing emission standards for foundries prescribed by CPCB

Type	Pollutant	Concentration (mg/Nm ³)
i. Cupola capacity (melting rate) :		
less than 3 Mt/hr	Particulate matter	450
3 Mt and above	Particulate matter	150
ii. Arc furnaces capacity : all sizes	Particulate matter	150
iii. Induction furnaces capacity :		
all sizes	Particulate matter	150

Note:

1. It is essential that stack is constructed over the cupola beyond the charging door and the emissions are directed through the stack which should be at least six times the dia of cupola.
2. In respect of arc furnaces and induction furnaces provision has to be made for collecting the fumes before discharging the emissions through stack.

Source: EPA Notification, G.S.R. 742 (E), dt. 30 th August, 1990

Emission standard for SO₂ from cupola furnace is prescribed to be 300 mg/Nm³ at 12% CO₂ correction as referred in MOEF notification dated 2nd April, 1996, New Delhi. To achieve the standard, foundries may intake scrubber, followed by a stack of height six times the diameter of cupola beyond charging door. In case due to some technical reasons, installation of scrubber is not possible, the value of SO₂ to the ambient air has to be effected through the stack height. The rule to be called the Environmental (Protection) Act, 1996.

Standards in other countries

Emission standards for hot and cold blast cupola prescribed by EPA, UK are given in table 5.2b below. The existing standard promulgated only for particulate matter but no standards for gaseous pollutants.

Table 4.2b: Emission standard for foundry prescribed by EPA, UK

Type	Pollutant	Concentration (mg/Nm ³)
New cupola (Oct,1991): Hot and cold blast	Particulate matter	100
New cupola (April,1997):		20

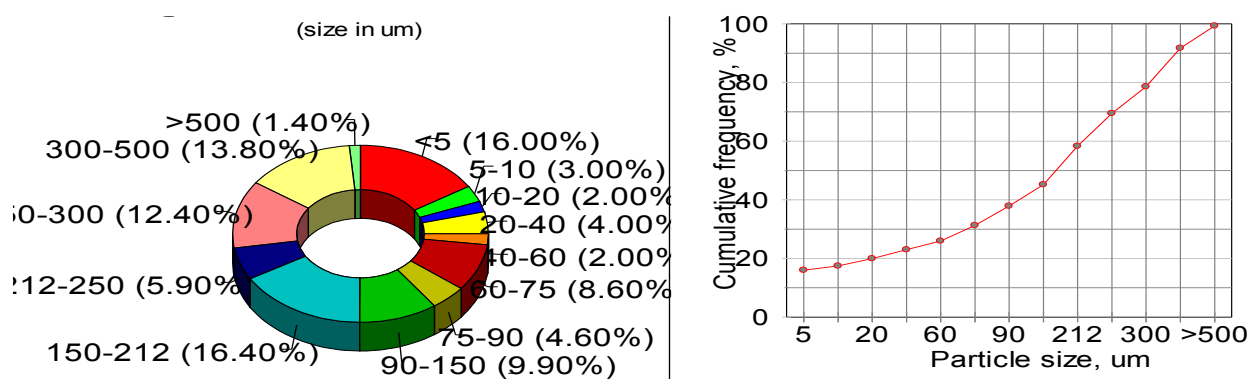
Type	Pollutant	Concentration (mg/Nm ³)
Hot and cold blast		
Existing hot blast cupola (1991)	Particulate matter	115
Existing hot blast cupola (1997)		100
Existing cold blast cupola Capacity : less than 4 tonne/hr 4 tonne/hr and more (1991) 4 tonne/hr and more (1997)	Particulate matter	No standard 115 100

4.3 Measurements

Typical emission levels from cupola are presented in table 4.3. The particle size distribution of the flue gas analysed by centrifugal dust classifier are given in figure below.

Table 4.3: Emission measurements at two units

Unit	Location	Particulate matter emission, g/Nm ³
Foundry 1	Below scrubber, charging door open	1.17
	Below scrubber, charging door open	2.20
	Below scrubber, charging door closed	5.66
	Above scrubber, charging door open	0.56
	Above scrubber, charging door open	2.44
Foundry 2	Sampling port, charging door open	1.38
	Sampling port, charging door closed	2.77
	Sampling port, charging door open	3.94



The particle size distribution of the flue gas analysed by centrifugal dust classifier

4.4 PCS design vis-a-vis standards

The emissions from cupola consist mainly of particulate matter, sulphur dioxide, oxides of nitrogen and carbon monoxide. The emission level of particulate matter depends on a number of variables such as the size and design of cupola, size and composition of raw

materials, specifically the ash content of coke, volume and velocity of the air blast, blast temperature, melting practice. etc. Sulphur dioxide mainly arises out of the sulphur in the coke. Approximately, 50% of sulphur in coke is usually absorbed in the metal and slag, and the rest gets discharged as sulphur dioxide through the stack along with the exhaust gases. Nitrogen oxide is emitted due to the intense combustion conditions prevailing near the tuyers. There is high presence of carbon monoxide in the exhaust gases which is to be expected considering the design of a cupola to ensure that the melt is not exposed to oxidising atmosphere which will adversely affect the melt quality.

Depending upon the sizes of the particulates and their distribution in the exhaust gas and presence of gaseous pollutants, a controlling device or combination of device may be selected for use. The different pollution control options for cupola furnace are given in Table 4.4.

Initial separators namely settling chamber, baffle chamber etc. can remove upto 90% of the higher size particles but overall collection efficiency would be of the order of 30 - 40%. Centrifugal separators namely cyclone, multiple cyclone can remove effectively upto 90% of the particles more than 10 μm size and with overall collection efficiency of 70%. The low energy scrubber like spray tower, centrifugal wet cyclone is very effective to remove the particle size greater than 5 μm with the overall efficiency of 90%. These units have an added advantage of removing gaseous pollutants like NO_x , SO_2 . Installation of a well-designed after burner above the charging door will reduce CO emissions by 80-90% and raise flue gas heat content.

Table 4.4: Various pollution control options for cupola foundries

Equipment	Minimum particle size, microns	Overall collection efficiency, %
Dry Inertial Collection		
Settling Chamber	> 50	< 50
Baffle Chamber	> 50	< 50
Cyclone	> 10	< 85
Multiple Cyclone	> 5	< 95
Impingement	> 10	< 90
Wet Scrubber		
Centrifugal	> 5	< 90
Impingement	> 5	< 95
Packed bed	> 5	< 90
Jet	0.5 - 5	< 90
Venturi	> 0.5	< 99
Fabric Filter	> 0.2	< 99
Electrostatic Precipitators	> 2	< 99

4.5 Commonly used PCS

Cyclone

- Not effective for controlling finer size particles ($< 10 \mu\text{m}$)
- Very difficult to meet emission standard of $450 \text{ mg}/\text{m}^3$ when ash content in coke fluctuates so widely between 20 to 40 %
- Dry process does not control SO_2 emission

Wet arrester or cap

- Can capture a large amount of dust particles and also dissolve a part of SO_2 emitted
- Water is recycled if proper provision for settling can be provided
- Suitable for meeting $450 \text{ mg}/\text{m}^3$ standard but not for $150 \text{ mg}/\text{m}^3$ prescribed for cupola above 3 Mt/hr
- Not effective for particles less than $5 \mu\text{m}$

Multicyclone

- Pressure loss of around 150mm Hg across collector
- Induced draft fan is needed
- Not effective for $150 \text{ mg}/\text{m}^3$ prescribed for cupola above 3 Mt/hr
- Cannot control sulphur dioxide emissions

Venturi Scrubber

- Highly efficient for meeting stringent PCB norms of both SPM and SO_2
- Pressure loss of around 1000mm Hg
- Hence, induced draft fan is required
- Particles upto $0.5 \mu\text{m}$ can be collected with an efficiency of 99%
- Suitable for cupola of all sizes

Fabric Filter

- Most efficient type suited for cupola furnace
- Needs fan for cooling of exhaust gas
- Can remove $0.2 \mu\text{m}$ size particles with 99% efficiency
- Costly but cannot remove SO_2

More details of these PCS are given below:-

Cyclone

The major drawback of cyclone is that it is not effective for controlling the finer size (<10 μm) particulate matter whereas overall control efficiency can be achieved upto maximum 85% which is considered as low. It is very difficult to meet the emission standard of 450 mg/m^3 by cyclone particularly when ash content in coke fluctuates so widely between 20 to 40%. So there would be always uncertainty to meet the prescribed CPCB standard by dry cyclone. Moreover, emission standard for SO_2 for cupola furnace has also been prescribed by CPCB which is not possible to control by dry cyclone.

Wet arrester or cap

Wet arrester can capture a large amount of dust particles and also dissolve a part of sulphur dioxide emitted. Water is sluiced back into settling tank and can be recycled by providing a proper provision for settling. It may be suitable for meeting 450 mg/m^3 standard but difficult to achieve the standard of 150 mg/m^3 prescribed for cupola capacity of above 3 t/hr. Its overall efficiency is of the order of 90%. It is not very effective for particulate matter less than 5 μm size. Coke containing higher percentage of finer particulate (say for instance more than 20% of size below less than 5 μm) may lead to problems of meeting even 450 mg/m^3 emission standard.

Multicyclone

Induced draught fan is needed. Moderate pressure loss (app. 150 mm Hg) across the collector and hence more energy consuming than simple wet arrester. This is sensitive to particle size changes. It can meet the emission standard of 450 mg/m^3 with greater degree of certainty as its overall efficiency goes upto 95%. Since it is not effective for less than 5 μm size particulate, it is difficult to meet the standard of 150 mg/m^3 prescribed for above 3 t/hr capacity cupola. This cannot control sulphur dioxide emission.

Venturi scrubber

Highly efficient for meeting the stringent standard of SPM and SO_2 . Fan is required to overcome the high pressure loss (as high as 1000 mm Hg). With the development of high energy venturi type collector, it can collect sub-micron particulates, fumes and smoke (upto 0.5 micron) with high efficiency of 99%. In general, high efficiency collection of fine particles require increased energy inputs, which will be reflected in higher collection pressure loss. It can meet the emission standard of 150 mg/m^3 prescribed for above 3 t/hr capacity cupola with certainty.

Fabric filter

This is one of the most efficient type of particulate collector for cupola emission control. More energy intensive, needs cooling of exhaust gas (<140 C) before entering the bag filter. It can even remove the finer particulates upto 0.2 μm with 99% efficiency. It is used for even more stringent standards. It is very costly pollution control device but it cannot remove SO_2 in the flue gas.

Table 5.5: Comparison of Collection Methods

Method	Ability to give invisible emission	Typical weight of Dust	Cost Index	Power Index	Water Pollution	Comment
Simple Wet Collector	No	4	1	1	Yes	Simple, Cheap. Remove 50-60% dust
Multicyclones	No	2	5	10	No	Simplest of Power collectors. Meets some regulations
Medium/low intensity scrubber	No	0.4-2	5	12	Yes	Some designs can be updated to high efficiency
High intensity scrubber	Yes	0.4 or less	8	49	Yes	Simplest collector capable of cleaning gases to invisibility. Cheapest of high efficiency units but uses most power
Wet Electrostatic precipitator	Yes	0.4 or less	15	10	Yes	Complex. Sensitive to gas conditions. Potential explosion hazard
Dry Electrostatic Precipitator	Yes	0.4 or less	15	10	No	Complex. Sensitive to gas conditions. Potential explosion Hazard.
Fabric Filter	Yes	0.02	12	15	No	Needs good maintenance. Collected dust may need treatment to prevent dust nuisance.

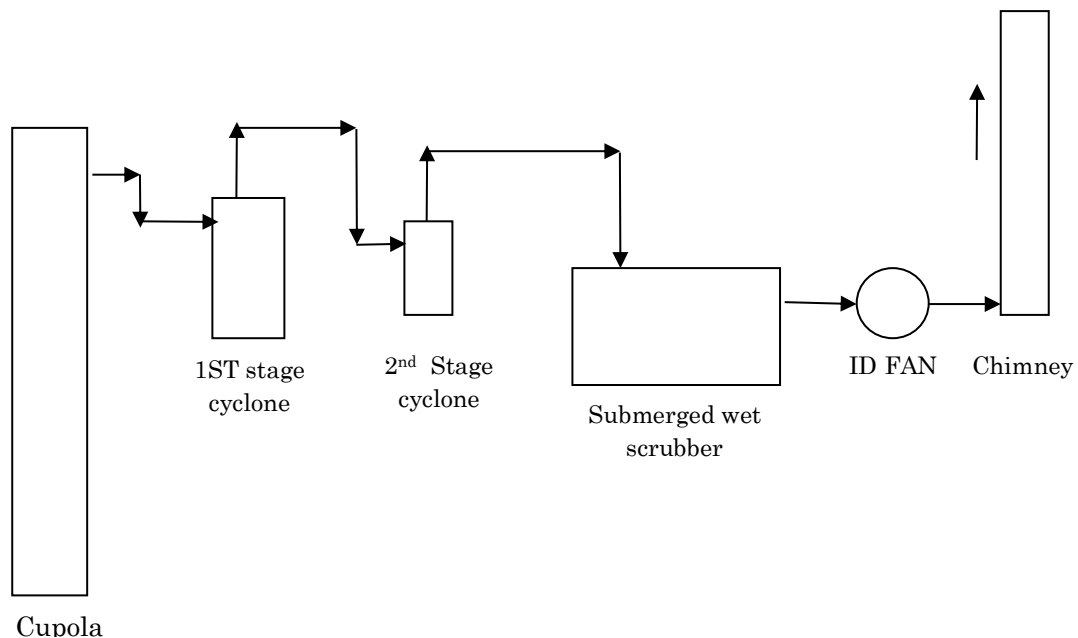
It is clear from the above discussion that venturi scrubber and bag filter can meet the standard of 150 mg/Nm³ prescribed for particulate matter with greater degree of certainty. Bag filter cannot remove SO₂ whereas, venturi scrubber is very effective for controlling SO₂ emission. Multi cyclone can meet the emission standard of 450 mg/Nm³ prescribed for particulate matter with certainty. It cannot control SO₂ emission. Wet cap can be suitable for meeting 450 mg/Nm³ standard but presence of higher percentage of finer particulates might be difficult for meeting the said standard with certainty. Many units have installed dry cyclone after intervention of Supreme Court in Howrah cluster. A very clear direction needs to come from PCB towards installation of pollution control system for different capacity cupola.

4.6 Technologies used in different foundry clusters

4.6.1 Pollution control system used in Howrah foundry cluster

The Howrah Foundry Association (HFA) and The Industry-Institute Partnership Cell (IIPC) at Jadavpur University devised a low-cost pollution control device using conventional dry cyclone and a new type of wet scrubber, a patented item, in tandem for the treatment of the stack emission.

The existing cyclone's collector efficiency was assessed before the new design and was rated satisfactory. However, the residual SPM had a high percentage of medium and small particles. A high efficiency cyclone has therefore been incorporated after the existing one for arresting medium-size particles and a submerged wet scrubber separator (figure.4.6.1), based on a new technology, was designed for arresting smaller ones. The flue gases would



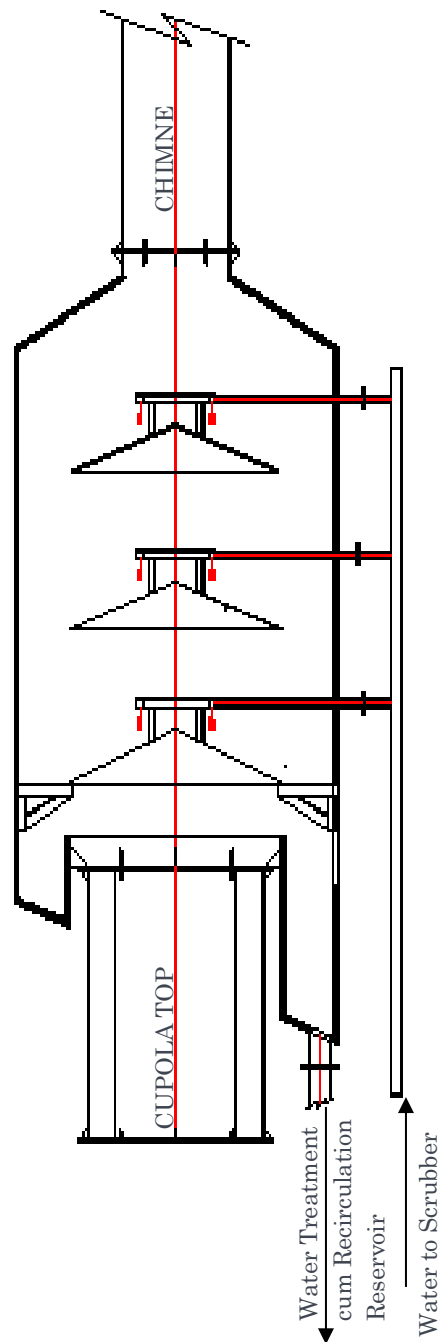
pass through the devices in series before release to the atmosphere.

Figure. 4.6.1: The schematic flow diagram of the flue gas path through the control devices

4.6.2 Cupola wet cap (3-stage scrubber)

The 3-stage scrubber called Cupola Wet Cap is positioned just above the Cupola top shell and just before the Chimney (figure 4.6.2). scrubber apparatus is provided for recovering or removing entrained particulate matter from gases comprising a settling basin, a wet scrubber mounted over the settling basin, the scrubber having a tower free of a bottom wall so as to be completely open at the bottom to said settling basin and open at the top to exhaust and open adjacent to its bottom to a source of said gases. Liquid spray means are mounted in the tower for spraying liquid counter current into contact with the gases rising in the tower to remove the particulate matter by gravity directly to the settling basin. The tower has an outer shell and an elastic liner. Means are provided for introducing a

pressurized medium between the liner and the shell to distort the liner to loosen accumulated matter therefrom for discharge by gravity directly to the basin. The elastic liner is porous to permit discharge of at least some of the pressurized medium through the liner to aid in removal of the accumulated matter from the liner. The liquid spray means also includes a plurality of circular conduits located adjacent to the inner surface of the liner, the conduits containing apertures for discharging spray liquid into the gases and also tangentially along the surface of the liner to aid in removal of the accumulated matter from



the liner.

Figure 4.6.2: Cupola wet cap

4.6.3 Twin cyclone separator

This is a type of multi-cyclone separator with two cyclones placed parallel to one another (figure 4.6.3). Collection of dust in a cyclone separator is the outcome of action of inertial (centrifugal) forces upon dust particles. The primary roles of cyclone separators are the collection of coarse dust particles. This equipment is also used for control high concentration and it has long life. The dust particles are separated due to the whirling action and vortex formation and are collected in the hopper. There is a pressure loss of around 150 μ mm Hg across the pollution control system. Hence induced draft fan is needed. It is not effective for prescribed standards of cupola above 3 Mt/hr. It also cannot control sulphur dioxide emissions.

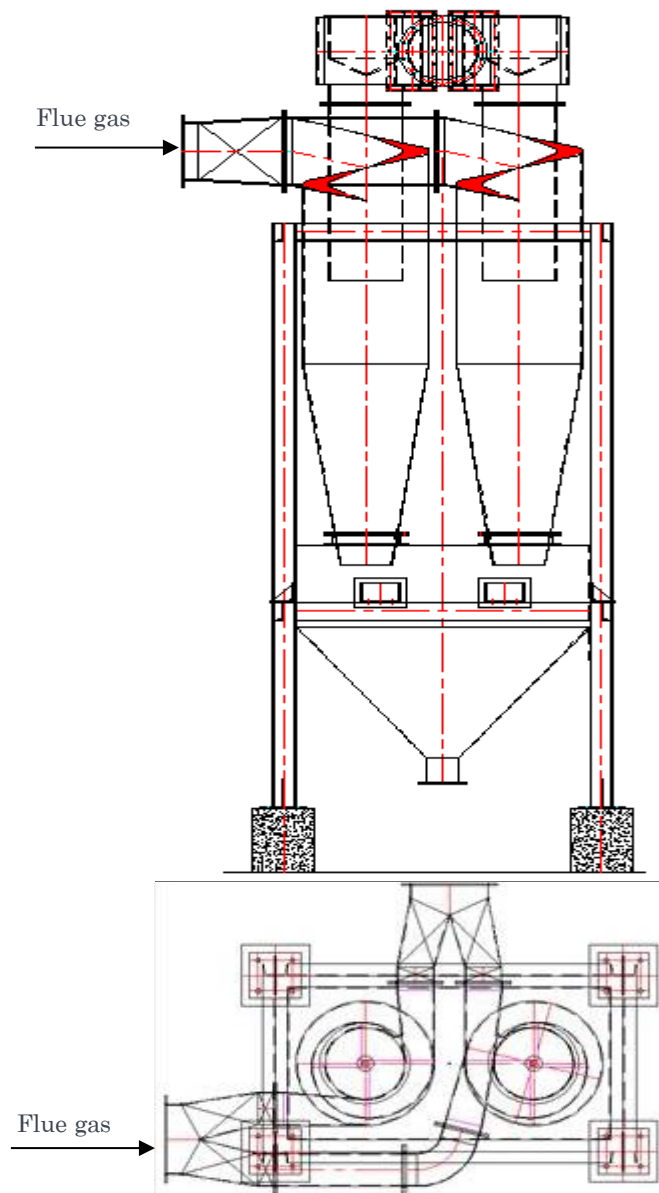


Figure 4.6.3: Twin cyclone separator

4.6.4 Pollution control system used in Punjab foundry cluster

The Air Pollution Control & Energy Conservation Cell of The Punjab State Council for Science & Technology (PSCST), Chandigarh has developed and commissioned cross current scrubbing technology (figure 5.6.4) for controlling particulate emissions from cupolas with molten capacity more than 3T/hr. The flue gas from the cupola is passed on to the deflector held at the top. There is a stream of cool water re-circulated from a tank. The cool water comes in contact with the flue gas from the deflector. Water and the entrapped dust particles are collected at the bottom and treated.

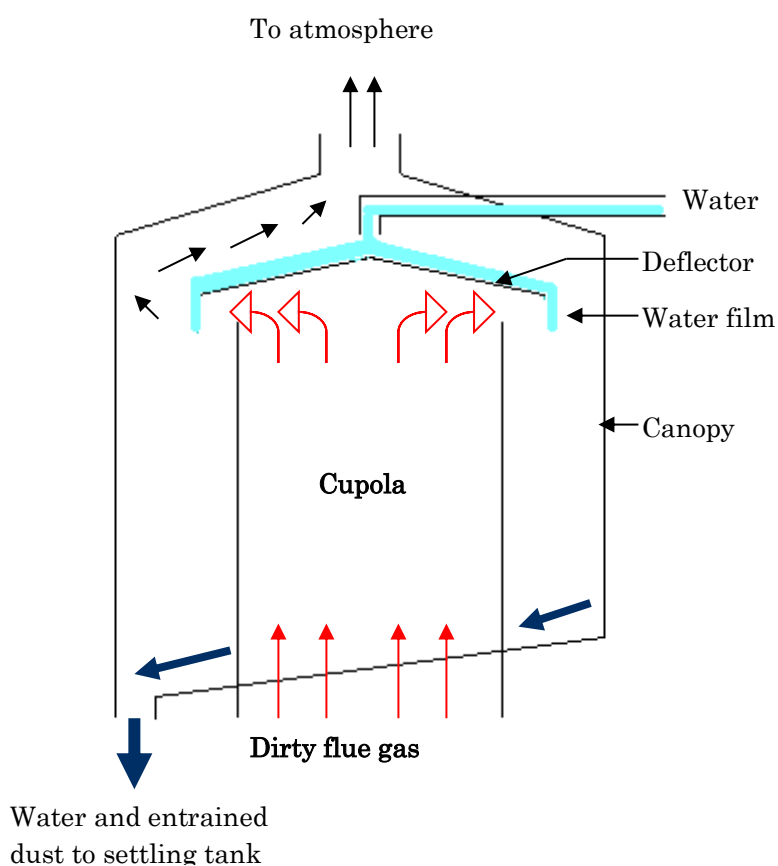


Figure 4.6.4: Cross current scrubber technology

4.6.5 TERI venturi scrubber design

The analysis by TERI reveals that cupola stack gases contain a significant percentage of fine particulates. The most effective pollution control device to bring down these particulate emissions to below 150 mg/Nm³ is the venturi scrubber (Figure 5.6.6a). Figure 5.6.6b shows a schematic of the venturi scrubber system. Salient features of the venturi scrubber design are listed below.

Hot gas from the cupola is sucked into the venturi through an ID (Induced Draft) fan. Water is injected into the Venturi throat. Water mixes with the hot, high-velocity gas, it mixes with the gas to form a very fine, fast-moving 'mist'. The mist then passes through a 'dewatering cyclone'; which removes the water droplets along with particles adhering to them. The remaining gas, now dry and cleaned of almost all particle matter, is allowed to escape through the chimney.

- Variable venturi throat to clean the gas by binding the particles to water droplets
- Optimum gas velocity at the throat, liquid/gas ratio, and throat geometry for maximum efficiency
- Dewatering cyclone after the venturi to retain water droplets in the gas stream
- ID (induced draft) fan to ensure sufficient pressure drop
- Stainless steel construction to prevent corrosion
- Closed-circuit recirculation to minimize water requirement
- Lime dosing to maintain the pH of the recirculating water
- Explosion-proof doors and gas-tight construction

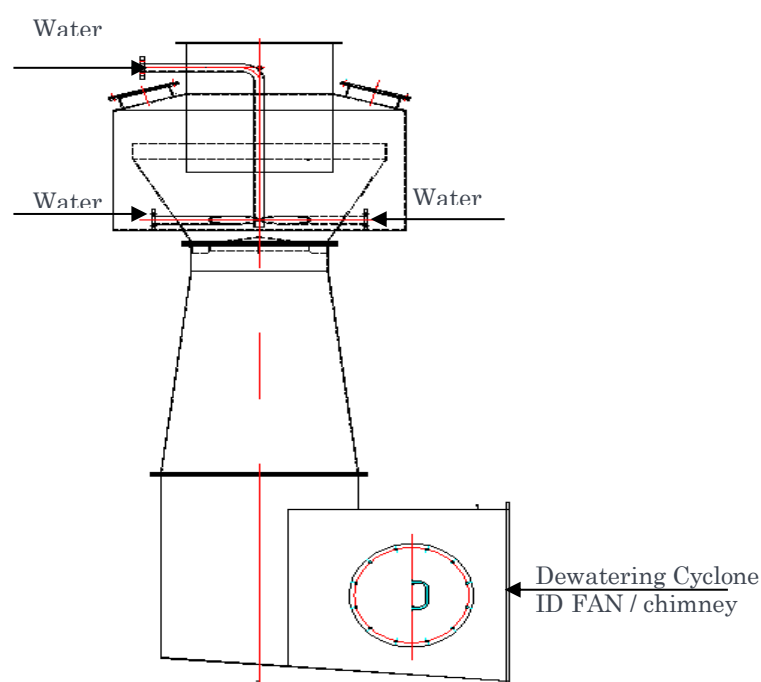


Figure 4.6.5a: TERI venturi scrubber design

TERI installed a venturi scrubber system at Bharat Engineering Works, Howrah – the site where the DBC was first demonstrated. Analysis revealed that the system reduced SPM emissions to a mere 50 mg/Nm³; well below the most stringent emission norm of 150 mg/Nm³. Figure 4.6.6c shows a comparison of particulate emission levels of (a) cupola without PCS (2000 mg/Nm³); (b) with commonly used PCS (500 mg/Nm³); and (c) with demonstration venturi scrubber (50 mg/Nm³).

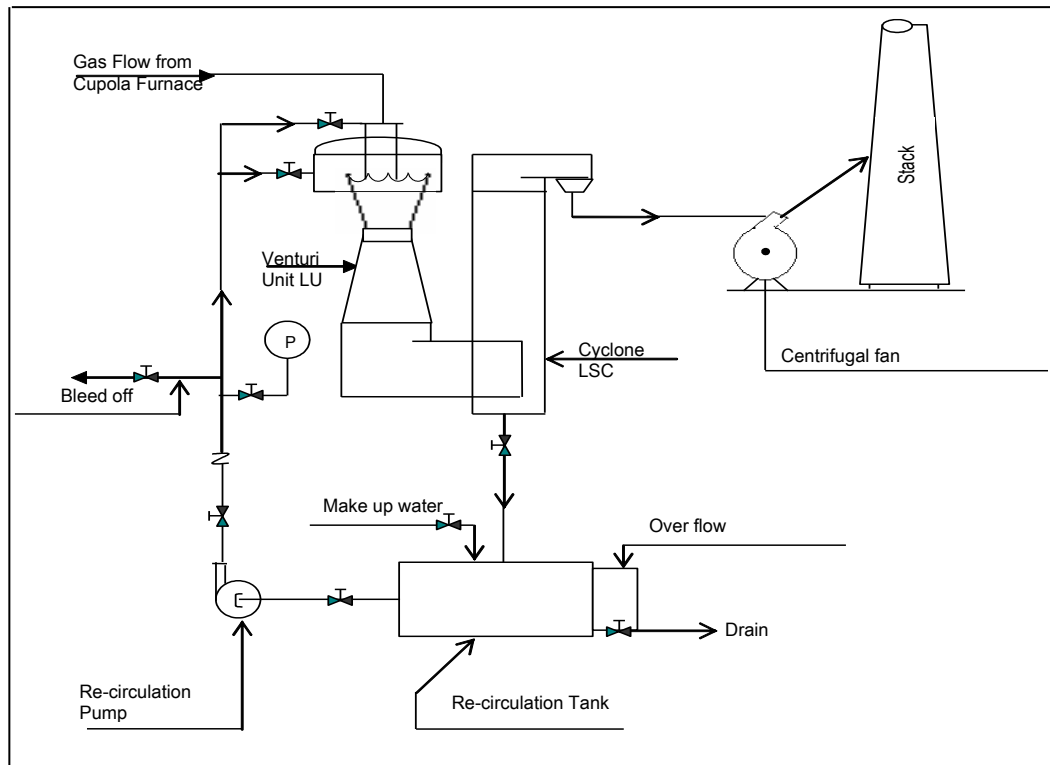


Figure 4.6.5b: Schematic of the venturi scrubber system

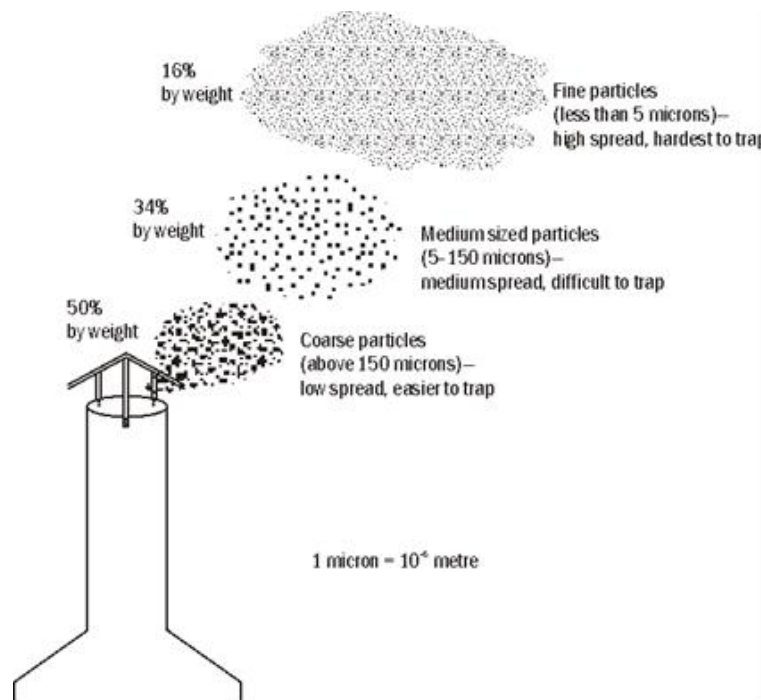


Figure 4.6.5c: Comparison of particulate emission levels

4.7 Legal framework

Central Pollution Control Board has responsibility to lay down standards for a stream or well and for air quality, planning and execution of nationwide programmes for the

prevention, control or abatement of water and air pollution, and ensure compliance with the provisions of Environment (Protection) Act, 1986. State pollution control boards has responsibility to ensure compliance with the provisions of the relevant Acts, lay down or modify effluent and emission standards and ensure legal action against defaulters.

Where it is apprehended by the Board that emission of any air pollutant, in excess of the standards laid down by the State Board under clause (g) of section 17, is likely to occur by reason of any person operating an industrial plant or otherwise in any air pollution control area, the Board may make an application to a court, not inferior to that of a Metropolitan Magistrate or a Judicial Magistrate of the first class for restraining such person from emitting such air pollutant. On receipt of the application, the court may make such order as it deems fit. Where under section (2), the court makes an order restraining any person from discharging or causing or permitting to be discharged the emission of any air pollutant, it may, in that order, I) direct such person to desist from taking such action as is likely to cause emission, ii) authorize the Board to implement the direction in such manner as may be specified by the court.

Any person aggrieved by an order made by the State Board under the act may, within thirty day from the date on which the order is communicated to him, prefer an appeal to Appellate Authority as the State Government may think fit to constitute: provided that the Appellate Authority may entertain the appeal after the expiry of the said period of thirty days if such authority is satisfied that the appellant was prevented by sufficient cause from the filing the appeal in time.

(Note: Appellant authority means an Appellate Authority constituted by the Central Government under sub-section (l) of section 31 of the act. Appellant means any person aggrieved by and appealing against an order made by the Board).

The Appellant Authority shall consist of a single person or three persons as the State Government may think fit to appoint. The form and manner in which an appeal may be preferred under sub section (l), the fees payable for such appeal and the procedure to be followed by the Appellate Authority shall be such as may be prescribed. On receipt of an appeal, the Appellant Authority shall, after giving an appellant and State Board an opportunity of being heard, dispose of the appeal as expeditiously as possible. No court shall take cognizance of any offence under this Act except on a complaint made by: I) the Central Government or any authority or officer authorized in this behalf by that Government, or ii) any person who has given notice of not less than sixty days in the manner prescribed, of the alleged offence and of his intention to make complaint, to the Central Government or the authority or officer authorized as aforesaid.

4.8 Solutions/action plan

One of the major reasons for general reluctance to foundries to adopt pollution control is the high pollution control costs. Since pollution control costs do not increase at the same rate as

plant output the additional cost per ton of castings due to installation of pollution device for a small foundry is be very high. This calls for some policy changes, so that small foundries are self-motivated to adopt pollution control.

Some of the possible measures to help adoption of pollution control systems in foundry industry could be:

a) Institutional development of foundry associations

Technical and financial help should be given to foundry associations so that they are geared to conduct environmental measurements, design pollution control equipment, and provide all technical advice in matters of design, fabrication, procurement and installation, so that individual foundries do not have to experiment with different designs.

b) Concessions in sales tax on pollution control equipment

To reduce the cost of pollution control equipment, sales tax exemption on materials and equipment's required for pollution control device could be granted.

c) Facility of loans on easy terms

To partially meet the financing of expensive pollution control devices, an environment service company exclusively for small scale foundry could be established. This has been discussed in more detail below in financing of PCS.

Policy Issues

Acceptable accuracy for emission value

Since foundries have to meet the emission standards prescribed for particulate matter and sulphur dioxide by CPCB, it is extremely important to carry out the systematic and accurate measurement of flue gases emanating from the stack. Since sampling has to be carried out iso-kinetically (velocity of flue gas would be the same as suction velocity of the measuring instrument), erroneous measurement of velocity or not maintaining the accurate velocity during isokinetic sampling might lead to erroneous emission value. Therefore, it is rational to have some minimum acceptable accuracy level for described method of measurement. The British Standard describes a method for measuring, with an accuracy of +25% under defined conditions, the concentration of particulate matter including grit and dust in the gases and total mass of these solids carried in unit time by gases passing through a flue or discharging from the chimney. The other alternative would be the measurement of emission level directly using instrument based on light extinction principle. The laser light source has become popular due to its compact beam size, good stability and high intensity with specific wave length.

Velocity and temperature measurement of flue gas

Since different instruments are used for measuring the velocity and temperature, it needs to have the acceptable accuracy of the measurement. Velocity is an important parameter as it has to be set iso-kinetically to carry out the emission measurement. If there is some error in velocity measurement, it bound to have some effect on measured emission value. Things are more critical for measurement of low velocity flue gas.

As per BS standard, the gas velocity at any sampling point shall be positive and the pitot-static difference shall not be less than 5 Pa. This is the lowest pressure difference that can practically be measured under field conditions and is equivalent to a gas velocity of about 3 m/s at 200 C. If the ratio of the highest to lowest pitot-static readings exceeds 9:1 or if the ratio of highest to lowest gas velocities exceeds 3:1, another sampling position shall be sought. A gas flow rate measuring device capable of determining the rate of flow of the gas sample with an accuracy of $\pm 5\%$. A temperature measuring device capable of measuring the temperature of the flue gases with an accuracy of $\pm 5\%$ C.

At each sampling point repeat the readings of gas velocity and temperature as soon as sampling points has been completed. If the sum of the pitot static readings differ by more than $\pm 10\%$ (or the sum of the gas velocity readings by more than $\pm 5\%$) from the original readings, the test result shall not be regarded as having the required accuracy (BS standard).

Maximum stack height

CPCB recommends that the stack is constructed over the cupola beyond the charging door and emission is directed through the stack which should be atleast 6 times the diameter of the cupola. WBPCB has suggested the chimney height of 15 m for hard coke fired hot/room/core stove and raise the height of the cupola stack to 6 times the cupola diameter from charging door. For cupola capacity of above 3 t/hr, fumes collected from the top of the cupola should pass through heat exchanger and packed bed wet scrubber or bag filter by using suction fan and finally discharge through stack height of 15 m from ground level. From the dispersion equation it was found that the stack height of 15 m would be sufficient for keeping the particulate concentration level below 200 mg/m³ as prescribed by CPCB for residential area contributed by single foundry. It was calculated by using the dispersion equation under various stability conditions that to keep the sulphur dioxide level within 80 mg/m³ as prescribed for residential area by CPCB, it is preferred to have stack height of 20 m.

The height of the chimneys from process and arrestment plant should be assessed on the basis of estimated ground level concentration of the emitted residual pollutants. The chimney height so obtained should be adjusted to take into account local meteorological data, local topography, nearby emission and the influence of plant structure. The assessment should take into account the relevant air quality standards and criteria that apply for the emitted pollutants. The minimum chimney height should be 6 m above the roof ridge height of any building within the distance of 5 times the uncorrected chimney height and in no circumstances should be less than 20 m above ground level (EPA 1990, Part I, UK).

Sharing of PCS

Multi cyclone/wet cap can meet the standard of 450 mg/m³ whereas venturi scrubber/bag filter can meet the standard of 150 mg/m³ as prescribed for cupola with greater degree of certainty. Since all these pollution control systems are very costly, it may be difficult for single unit to install the system. It is very important to have some policy where a group of

foundries situated adjacent might be allowed to share their pollution control system. The stack height would be adjusted accordingly based on number of units are using the system and the maximum ground level concentration.

Measurement condition

There are no clear guidelines about the suitable conditions of measurement either by CPCB or SPCB. The different options available are during charging time, operating time and blow-down period. Measurement during blow-down period would not be truly representative since duration is much shorter in comparison to total melting campaign. The extremely high temperature of the top gas during blow-down which might ruin the PCS. Besides, the unstable conditions during blow-down making it impossible to make isokinetic measurement. There needs to have a clear direction whether the charging door would remain open or close during measurement. The suitable measurement time would be during operation.

Measurement time

It is always preferable to have online monitoring system which would facilitate obtaining emission level continuously over the duration of operation. Since it is very costly instrument, normally non continuous monitoring is followed for measurement of foundry flue gas in India. Therefore, it is important to prescribe the measurement time as representative for the operation duration and the frequency of measurement.

Measurement port/stand

In no conditions, there should be any negative pressure at the point of sampling port. It may prove to be dangerous for person carrying out sampling or workers around because of outlet of CO.

Particle size analysis

Particle size distribution of the flue gases is the most important guiding factor for selection of pollution control devices. It is the recognised fact that the correct determination of particle size distribution of the stack flue gases is the difficult task. Normally U shaped thimble or other glass fibre filter papers are used during sampling of stack particulate emission. Different particulate size analyzer namely centrifugal dust classifier, image analyzer, laser based malvern master particle sizer, etc. are commonly used for determination of particle size distribution. Since finer particulates get deposited on the filter paper, due to having fibre on filter paper, it is very difficult to remove particulates from filter paper which would lead to erroneous results. Image analyzer would be better choice for particle size analysis of flue gas in comparison to other analyzer.

Financing of PCS

There is a general reluctance of foundries to borrow money from financial institutions and banks. Lack of professional manpower, proper accounting practices and tedious documentation required, inhibit foundry owners in approaching banks for loan. To partially

meet the financing of expensive pollution control devices, an environment service company exclusively for small scale foundry could be established. The company could be set-up with initial financial assistance from foundry associations, bilateral or multilateral organisations. The bottlenecks for borrowing money could be eliminated by making loan disbursement easier and providing guidance through the foundry associations.

References

1. Environmental Law Institute (ELI), 1999. From Policy to Action: Strengthening the implementation of Environmental Law in India. Edited by ELI, Washington DC, October 1999
2. S. Dutta, P.K. Datta, S.Ghosal, A.Ghosh and S.K. Sanyal ; Low Cost Pollution Control Devices for Continuous Cupolas
3. T.K. Ray, An overview of Air Pollution Control Technology in Foundry
4. TERI, From 1994 to 2001, Consolidated SDC Foundry Project Reports
5. The Punjab State Council For Science & Technology (PSCST) <http://www.pscst.com>, The Air Pollution Control & Energy Conservation Cell of PSCST, Chandigarh
6. TERI, Towards Cleaner Technologies: A process story in Small-scale foundries
7. Pal P and Bhattacharjee S. 2000, Energy Efficiency and pollution reduction in cupola route foundry, Indian Foundry Journal 46(11): 33-37
8. TERI, India: Cleaner technologies in the small-scale foundry industry (action research and pre-dissemination)- consolidated report for the period January 2002 to December 2004 [Submitted to Swiss Agency for Development and Cooperation (SDC)]
9. www.indianfoundry.com

5.0 Module 4 – Financing schemes and DPR preparation for EE projects

5.1 Introduction

Energy efficiency projects may be identified by either internal expert or hired external agency through day to day performance monitoring and analysis of observed data. The identified projects are to be screened for technical and financial viability before deciding to implement any project demanding higher capital investment. It is essential to justify capital investment in any energy efficiency project through financial appraisal. The standard financial analysis tools can reveal status of various indicators such as IRR (internal rate of return), NPV (net present value), projected cash flow and its sensitivity to various changing scenarios, average payback period, etc., which will indicate overall post tax return from investment as well as the viability of the project

All these tools are quite reliable, depending on the accuracy of evaluation of the cash inflow and outflow, estimation of the discount rate (cost of capital), and prediction of the possible rate of increase of the energy price. Within these limitations, the most precise method is the 'present value criterion', which compares the present value of all-future after-tax cash inflow and outflow over specified period of time to the present value of the cost of investment. The different financial tools for assessment of the investments are summarized below.

5.1.1 Average rate of return (ARR)

It is a basic tool for financial analysis based on the projected future annual cash savings from the project, which is considered to be same. It provides a preliminary guide to investment decisions and indicates whether further analysis is required using more accurate tools. The estimation of ARR is described with the following example.

Example: Plant invested Rs 950,000 to replace existing compressor with alternative system to improve energy performance. The estimated year wise saving in energy cost for a period of five years are Rs 65,000 in the first year, Rs 71,000 in the second year, Rs 69,000 in the third year, Rs 70,000 in the fourth year, and Rs 72,000 in the fifth year. The total cumulative energy savings in five years is Rs 347,000. Dividing this number by the 5 years, we get Rs 69,400 as an average annual energy savings. Now to obtain ARR, divide Rs 69,400 by the initial capital investment of Rs 950,000, which is equal to 7.3%.

$$ARR (\%) = \frac{\text{average annual cash saving} \times 100}{\text{capital employed}}$$

Guideline- Invest in a project with higher ARR

5.1.2 Return on investment (ROI)

ROI is a profitability measure based on the cost of capital invested and evaluates the performance of a business or efficiency of an investment. The ROI of an investment can be calculated using following relation.

$$ROI (\%) = \frac{(Gain\ from\ investment - Cost\ of\ investment) \times 100}{Capital\ employed}$$

The 'gain from investment' refers to energy savings accrued from implementing an EE technology. The financial gain is to be estimated based upon the discounted value of the energy savings over the life time of the project. Return on investment is a very popular measure because of its versatility and simplicity. The project is considered to be financially viable if ROI from an investment is positive.

Discounted value of energy savings

Discounted value is an analysis based on time value for money (considering money is relative - A Rupee is worth more today than it is worth in the future). So the energy savings over the years have to be discounted to obtain their present value.

Guideline: Invest in a project with higher ROI

5.1.3 Simple payback period (SPP)

SPP is the time period required to recover the initial capital investment amount through net annual energy savings or cash flow return (annual benefits- annual expenses). It is calculated as the investment cost divided by the net annual energy saving.

$$Simple\ payback\ period\ (SPP\ in\ years) = \frac{Cost\ of\ project}{Net\ annual\ monetary\ savings}$$

Unlike the ROI method, the payback criterion has some limitations as it does not take into consideration the discount rate, the change in energy prices, or the lifetime of the investment project. It has one advantage over ROI in respect of precise indication of the annual benefit, namely the cash flow instead of profits. However, both suffer from the difficulty in justifying the threshold value beyond which no project should be considered. In practice, investment projects with a payback period of three years or less are considered viable as they normally have a positive net present value. Thus the payback period is often used as a "filter", calculating NPV when the payback period is over three years and accepting the project when it is less. The advantages of SPP are as follows.

- It is a simple calculation and easy to use by semi-skilled shop floor personnel
- It favours projects with substantial cash flow in initial years but rejects projects that generates substantial cash flow in later years instead of earlier

The limitations of SPP tool are:

- It fails to account for the time value of money
- It ignores potential cash flow beyond the payback period
- It only indicates time period to recover capital investment but ignores profitability

Guideline: Invest in a project with small SPP

5.1.4 Net Present Value (NPV)

The net present value (NPV) is the present value of the entire cash flow considering both out flow and inflow (energy savings) from a project under analysis in entire project life cycle, including any residual or salvage value of the equipment on disposal/ completion life cycle. In simple terms, the difference between the present value of energy savings (inflows) and the present value of cash outflows is NPV.

It is calculated using a given discount rate, also known as the hurdle rate and is usually equal to the incremental cost of capital. NPV is very useful analysis that enables the plant management to take an informed decision about whether to accept or reject a particular project. Project could be accepted if its NPV is more than zero, which indicates the investment would add value to the firm. In case of zero NPV, project could still be accepted if it has some strategic value for the firm. However, the project with negative NPV would subtract value from the firm and hence, should be rejected. The future energy savings are converted to present value using following formulae.

$$PV = \frac{FV}{(1 + i)^n}$$

Where,

FV – future value of energy savings

i - interest or discount rate or hurdle value

n - number of years under analysis

The NPV is then calculated by subtracting the initial cost of investment from the total PV of future energy saving from entire life cycle:

NPV = total PV- Initial cost of investment

NPV indicates the return that the management can expect from the project at various discount rates. It can also be used to compare various EE projects with similar discount rates and risks, as well as compare them against a benchmark rate. The advantages of NPP are given below.

- It consider the time value of money
- It consider entire cash flow stream during project life cycle including salvage value

Guideline:

NPV > 0 : Should be accepted

NPV = 0 : Should be accepted if the project has some strategic value

NPV < 0 : Should not be accepted

5.1.5 Internal rate of return (IRR)

IRR also referred as 'economic rate of return' is the highest discounted rate, which makes the present value of the energy savings / inflows (including residual or salvage value of the equipment from its life cycle) equal to the initial capital cost of the investment or equipment. In other terms, internal rate of return is the discount rate that makes the net present value equal ZERO. It is also the rate, which makes benefits to cost ratio ONE. A project is considered viable, if its IRR is greater than the returns (interest rate) offered by the bank/financial institution on investments/deposits made with them.

The formula for IRR is

$$0 = \frac{P_0 + P_1}{(1 + IRR)} + \frac{P_2}{(1 + IRR)^2} + \frac{P_3}{(1 + IRR)^3} + \dots + \frac{P_n}{(1 + IRR)^n}$$

where P_0, P_1, \dots, P_n equals the cash flows in periods 1, 2, . . . n, respectively; and IRR equals the project's internal rate of return.

As such, IRR can be used to rank several prospective projects a firm is considering. Assuming all other factors are equal among the various EE projects, the EE project with the highest IRR would probably be considered the best and undertaken first.

Guideline: Invest in a project with high IRR

5.2 Major financial schemes for MSMEs in India

The Government of India and respective State governments have announced various policies and schemes from time to time to address emerging issues and develop the MSME sector.

Most of the programmes & schemes for the development of the MSME sector are being implemented by Ministry of MSME through its field level organizations – state level MSME Development Institutes (MSME-DI) and National Small Industries Corporation Limited (NSIC).

Some of the important initiatives by the Government of India for development of the MSME sector as well as promotion of new technologies and energy efficiency are mentioned below.

- National Manufacturing Competitiveness Programme (NMCP)
- Credit Linked Capital Subsidy Scheme (CLCSS)
- Credit Guarantee Trust for MSEs ISO 9000 and ISO 14001 Certification Reimbursement Scheme
- Financial Assistance for using Global Standard (GS1) in Barcoding
- Sustainable Finance Scheme

- Subsidies/schemes for undertaking energy audits by various state governments such as Maharashtra, Gujarat etc.

5.2.1 National Manufacturing Competitiveness Programme (NMCP)

The programme was launched by the Ministry of MSME (MoMSME) to support SMEs to improve their competitiveness both in national and international trade market. It offers a bundle of 10 sub schemes that are listed below:

1. Lean Manufacturing Competitiveness Scheme
2. Enabling manufacturing sector to be competitive through Quality Management/Standards/Quality Technology Tools (QMS/QTT)
3. Promotion of ICT (Information and Communication Technology) in MSME sector
4. Technology and Quality Upgradation Support to MSMEs (TEQUP)
5. Marketing Assistance and Technology Upgradation Scheme
6. Marketing Support/ Assistance to SMEs (Bar Code)
7. Design clinic scheme for design expertise to MSME sector
8. Setting up of Mini Tool Rooms
9. National campaign for building awareness on Intellectual Property Rights (IPR)
10. Support for Entrepreneurial and Managerial Development of SMEs through Incubators

The relevant scheme for supporting EE project is TEQUP Scheme, which is summarized below.

The MoMSME launched the scheme TEQUP scheme during May 2010. The scheme under NMCP is focused specifically on improving energy efficiency in the MSME sector. It provides support for technical assistance for energy audits, preparation of DPRs and also offers significant capital subsidy to MSME units willing to adopt energy efficient technologies through a cluster approach. In addition, support is also offered to MSMEs in acquiring international and national Product Quality Certification. The scheme also provides MSMEs an opportunity to trade carbon credits through Carbon Credit Aggregation (CCA) centers. The TEQUP scheme is currently in operation, and the government has proposed to continue the scheme during the 12th Plan with enhanced budgetary support.

5.2.2 CLCSS Scheme

The CLCSS. One of the oldest schemes of MoMSME, it aims at facilitating technology up-gradation in the MSME sector. It provides for 15% capital subsidy (limited to maximum Rs.15 lakhs) to eligible micro and small units for adoption of proven technologies approved under the scheme. At present there are over 1500 technologies under 51 sub-sectors that are eligible for subsidy under the scheme. Till March 2014, 28,287 units had availed subsidy of INR 1620 crores under the scheme.

5.2.3 Credit Guarantee Scheme

The Credit Guarantee Fund Scheme for Micro and Small Enterprises (CGTMSE) was launched by MoMSME and SIDBI. It aims to make available collateral-free credit to the MSEs to enable them to easily adopt new technologies. Both the existing and the new enterprises are eligible to be covered under the scheme. Under the scheme, collateral free loans up to 1 crores can be provided to micro and small scale units. Additionally, in the event of a failure of the MSME unit which availed collateral free credit facilities to discharge its liabilities to the lender, the Guarantee Trust would guarantee the loss incurred by the lender up to 75 / 80/ 85 per cent of the credit facility.

5.2.4 Scheme for Common facilities Center (CFC) in industrial cluster

A group of at least 25 registered SME foundry units (formed as Special Purpose Vehicle-SPV) within a cluster can avail financial support under this scheme to establish CFC relevant to the industrial process being followed in the cluster., e.g. CFC for sand reclamation in any foundry cluster. The brief details of the scheme are mentioned below.

Operating authority - The office of Development Commissioner, MoMSME

Eligibility criteria – SPV comprising at least 25 registered located in the cluster

Financial support - 70 % by Central Government and balance 30 % by SPV /State government for project value up to Rs 15 Crores.

The cluster members can apply through the State government or its autonomous body for DSR (Diagnostic Study Report) for which a grant of up to Rs 2.5 Lakhs is available. The report must be submitted within 3 months to DC MSME which will justify the creation of CFC. On acceptance of the DSR by DCMSME, a DPR is to be submitted for which a funding of Rs 5 Lakhs is available. The DPR, which needs to be appraised by SIDBI establishes the tech-economic viability of the project .On acceptance of the DPR the financial grant to set up the CFC is released to the SPV through the state government.

5.3 Various credit lines and bank schemes for financing of EE

There are several special lines of credit under which loans are provided to MSMEs at reduced rate of interest for adoption of clean and energy efficient technologies. SIDBI is the nodal agency for management and implementation of these lines of credit. More details related to existing credit lines and its scope of services is available with SIDBI. Some of these schemes are mentioned below.

- JICA – SIDBI financing scheme
- KfW – SIDBI financing scheme
- AfD – SIDBI financing scheme
- Sustainable Finance Scheme (SFS)

5.4 Preparation of detailed project report (DPR)

The guidelines to prepare DPRs for seeking loans from banks for the capital expenditures for implementing viable energy efficiency project are provided below.

Detailed financial analysis of the moderate to large investments is required as much for the promoter, as it is for the banker. The promoter is interested to see if the true return on the investment over the project life is comparable to returns on other sources of investment, such as a fixed deposit in a bank, while the banker needs to be convinced on the financial viability of the investment made through the loan. In general, each DPR on EE project is to be structured to include the company profile, energy baseline assessment, technology assessment, financial assessment and sustainability assessment.

The company profile of the unit will include assessment of its past financial reports (balance sheet, profit and loss account), registration details, compliance with pollution control board norms, as well as, details of products, production capacities, customers, and marketing and selling arrangements.

Similarly, the energy baseline assessment will include current energy bill, cost of energy as a percentage of total manufacturing cost, and overall and section-wise specific energy consumption levels.

Technology assessment will include the details of the design of equipment/ technology along with the calculation of energy savings. The design details of the technology for EE project will include detailed engineering drawing for the most commonly prevalent operational scale, required civil and structural work, system modification, and included instrumentation and various line diagrams. A list of vendors (technology providers/ equipment suppliers) will be provided along with quotations for major bought-out equipment. Examples of similar interventions as proposed in other industries within India or abroad with the benefits will also be provided. The estimated lead time for implementation of the new technology, or enhancement of the existing technology will be provided.

The financial assessment will contain details of investment required for each EE measure and means of financing for the proposed measures. Financial projects such as cost-benefit analysis for each of the proposed measure and for the unit as a whole including IRR and cash flow will be provided.

The sustainability assessment will include environmental and social sustainability assessments like Green House Gas (GHG) reduction (over the estimated lifetime in terms of certified emission reductions or CERs), reduction in conventional pollutants; air (sulphur dioxide, particulates etc.), water and solid waste, productivity enhancements and social impacts on the workforce.

A typical outline of the content page of a DPR is provided in table 4.1. It is understood that the DPRs will be structured keeping in view their acceptability to financial institutions/banks.

Table 4.1: Typical contents page of DPR

Executive Summary	
1.0	Introduction
1.1	Brief introduction about cluster/ unit
1.2	Energy performance in existing situation
1.3	Proposed EE intervention
1.3.1	Description of existing technology/ equipment
1.3.2	Energy audit methodology
1.3.3	Performance analysis of the existing technology
1.4	Barrier analysis in adoption of proposed EE intervention
2.0	Implementation methodology
2.1	Approach of modification
2.2	Description of modified system/ equipment
2.3	Availability of equipment
2.4	Source of equipment
2.5	Terms and conditions in sales of equipment
2.6	Process down time during implementation
2.7	Life cycle assessment and risks analysis
2.8	Suitability of unit for implementation of proposed technology
3.0	Benefits from proposed EE intervention
3.1	Technical benefit
3.2	Monetary benefits
3.3	Social benefits
3.4	Environmental benefits
3.5	Examples of similar interventions
4.0	Project Financial Statements
4.1	Cost of project and means of finance
4.2	Financial projections of the unit
4.2.1	Projected financial summary of the unit
4.2.2	Projected operating statement of the unit
4.2.3	Projected balance sheet of the unit
4.2.4	Projected cash flow statement of the unit
4.2.5	Projected fund flow statement of the unit
4.2.6	Projections of current assets and current liabilities of the unit
4.2.7	Debt Service Coverage Ratio
4.2.8	Debt Equity Ratio
4.2.9	Other major financial ratio calculations
4.2.10	Maximum permissible bank finance for working capital as per Nayak Committee
4.2.11	Working capital requirements
4.2.12	Assumptions for financial calculations
4.2.13	Marketing & Selling arrangement

4.2.14	Risk analysis and mitigation
4.2.15	Conclusion
Typical Appendices	
	Process flow diagram
	Baseline energy performance
	Schematic diagram of the modified system
	Technical specification and information brochure of equipment
	Details of fabricators/ suppliers
	Budgetary quotation for the proposed equipment
	Cash flow and financial analysis
List of used abbreviations	

5.5 Step by step approach for loan application

Energy efficiency projects are normally supported by banks and financial institutions under the broad umbrella of various government schemes and credit lines. These schemes and credit lines are formulated with specific eligibility criteria to promote special thematic issues for improving overall business sustainability of the target sector.

Loan application for EE projects is to be developed using standard format of individual scheme guidelines or credit line requirements. It is advisable for the concerned MSME unit to obtain the standard template of loan application from the prospective banking institute, which is going to evaluate loan application before granting financial support. The following activities are required to be undertaken for developing loan application to seek financial support from bank towards implementation of EE projects by the unit.

- Establish baseline performance through detailed study
- Identify implementable energy conservation measures (ECMs) including alternative energy efficient (EE) technologies wherever applicable
- Prepare preliminary cost-benefit analysis
- Identify suitable technology suppliers who can also provide regular maintenance
- Obtain techno commercial quotations
- Negotiate price and finalize suppliers
- Estimate miscellaneous costs for implementation of ECMs
- Estimate project cost and means of finance
- Undertake the financial projections of the unit
- Identify eligible financing scheme and credit line for financial support
- Discuss the EE project with the prospective financial institution (FI)
- Develop detailed project report as per the guidelines provided and format of the scheme that includes baseline monitoring and verification (M&V) protocol
- Submit the DPR to the FI for review
- Follow up with the FI and provide clarification if any
- Obtain loan approval and complete necessary contract with concerned FI

- Implement the project that includes commissioning, trial runs and troubleshooting required if any
- Undertake post implementation M & V protocol
- Submit status report to FI as per the agreement