Comprehensive training material for technology providers Belgaum foundry cluster

GEF-UNIDO-BEE Project

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

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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

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, Kaizen in Induction furnace and Energy efficiency improvements in thermal applications. 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 Belgaum Foundry Cluster between February to April 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.

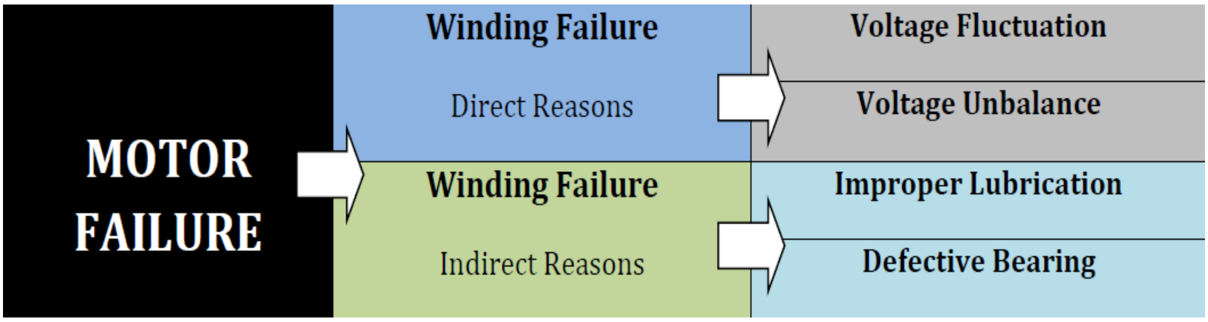
This comprehensive training material for Belgaum foundry cluster is targeted at 'technology providers' category. The material is structured in the following 4 modules.

Module 1	Good practices in motor rewinding
Module 2	Kaizen in Induction furnace
Module 3	Energy efficiency improvements in thermal applications
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

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

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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.

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

motor but is an important part of electrical safety. Best practices in 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.

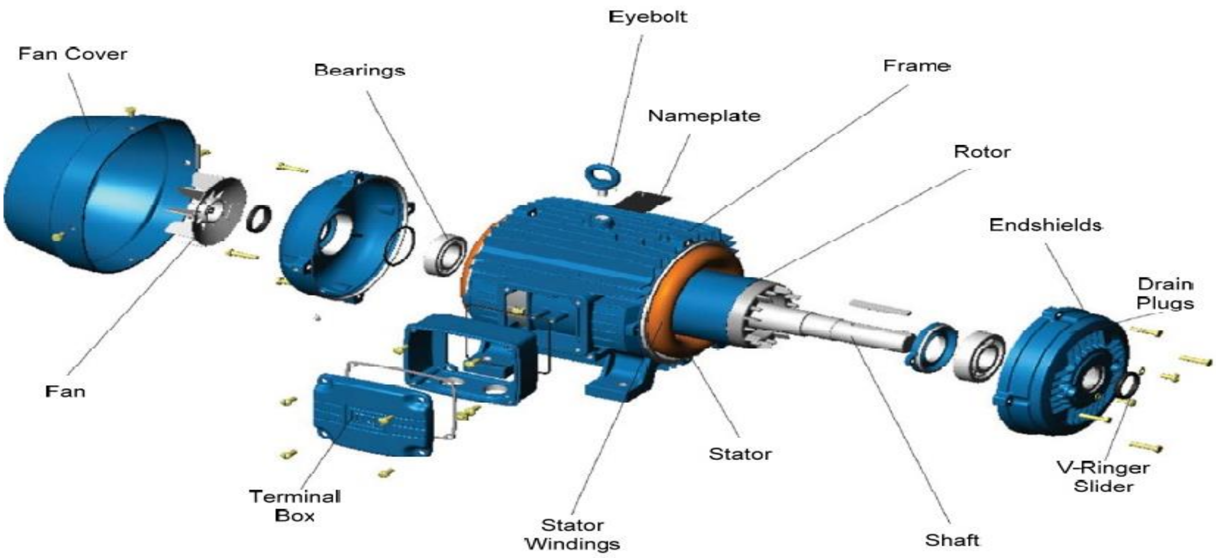
- **Copper Loss:** Stator copper loss is the largest loss (at full load) in most induction motors. The winding pattern may be changed during rewinding to simplify the process, and in doing so the repairer must consider the effect on flux density and resistance.
- These losses are reduced for example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

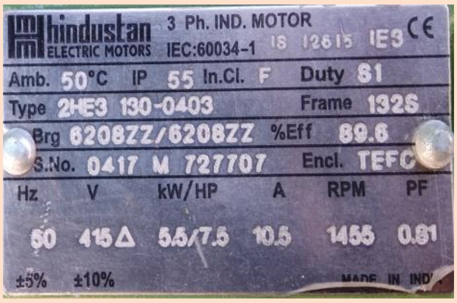
Most repair processes, if done improperly, can reduce motor efficiency. Conversely, doing them well will maintain and may even improve efficiency. It is also important to keep clear, concise written records throughout the repair process.

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
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. 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.)	Motor nameplate(s) data	• Keep record of all data on the nameplate. • Check whether motor is IE efficiency class (as per IS12615). 
	Results of external inspection	• 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.
	User/Customer input	• 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.
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	Terminal box position, layout and connections.	• 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

Recommended procedure	Key steps	Observations
in a suitable bin or tray that is labelled with the motor serial number or job card number.)		overheating (discoloration or brittleness). If it does, replace the leads. • 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.	• 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.	• 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).	• 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.	• 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.	• 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

Recommended procedure	Key steps	Observations
		replace rotors in horizontal motors is by using a rotor removal tool
	Internal inspection	• 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.	• 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	• 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	• 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	• Make sure the tests are conducted well within the manufacturer's recommended operating range for the tester being used. Carry out tests: - 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%: - Make sure the settings of the core loss tester have not been changed and repeat the test. - If the repeat test confirms the

Recommended procedure	Key steps	Observations
		increased loss, repair the core or consider replacing it.
	Removing old winding  	• 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 o Cut off one coil extension using a winding cut-off machine. o Burn out old insulation at appropriate temperature in a controlled-temperature burnout oven set to monitor core temperature. o Do not overheat the core. Remove the winding without damaging the core.
	Cleaning the stator core in preparation for rewinding 	• Key points–cleaning the stator core: o Careful scraping with a sharp knife. o High-pressure washing. o Blasting with a mildly abrasive material. o Brushing with medium/soft wire brush. • After cleaning the slots: o Reposition damaged teeth o 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).

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

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 I^2R losses to increase.

Recommended procedure	Key steps	Observations
Rewinding the motor	Copy (duplicate) rewinding	• 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 rewound motor: • Minimize the length of the coil extensions. • Increase the copper cross-sectional area in each coil. • Key points–copy rewinding o Check that old winding is manufacturer's original. o Use same winding configuration. o Keep coil extensions as short as practical. o Same (preferably less) length of overhang. o Use same coil pitch (or pitches). o Use same turns/coil. o Use same (preferably larger) copper cross-sectional area. o Use same or shorter mean length of turn (MLT). o Use same or lower winding resistance (temperature corrected).
	Minimize the length of the coil extensions	• It is important to keep the coil extensions as short as possible. • Attention to the following rules will prevent this: o Keep the coil extensions within the measured dimensions of the original winding. o Do not extend the slot insulation beyond the slot ends any more than is necessary to prevent strain on the slot cell. o 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.
	Changing to a two-layer lap winding	• 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.

Recommended procedure	Key steps	Observations
		• 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).
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 the coil extensions a final time, perform winding resistance, insulation resistance, phase balance and voltage withstand tests)	Winding resistance tests	• 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 (Ta) with the winding at room temperature. Correct both resistances to a convenient common reference temperature (normally 25°C) using the formula:  $R_x = \left(\frac{234.5 + 25}{234.5 + T_a}\right)$ x Measured resistance Where R_x = corrected winding resistance T_a = ambient air temperature • 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)
	Phase balance (or surge comparison) tests	• 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).
	Impregnation	• Impregnating the winding with varnish and subsequently air drying or baking this varnish until it is cured serves the

Recommended procedure	Key steps	Observations
		several purposes: ○ 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 I^2R 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 – Kaizen in induction furnace

3.1 Lean manufacturing

The lean approach is primarily based on finding and removing wasteful steps that do not add value to the end product. There's no need to reduce quality with lean manufacturing – the cuts are a result of finding better, more efficient ways of accomplishing the same tasks. Lean manufacturing is not only aimed at the elimination of waste in every area of production but also focuses on the activities which will help for good customer relations/satisfaction, production machine layout, waste reduction and factory management.

3.1.1 Objective

The objective of a lean approach to manufacturing is to maximize the value of the product to the customer while minimizing waste. Many companies in the manufacturing industry use lean manufacturing principles (LMP) to maximize their profit, minimize their cost of production, and eliminate waste. The goal of lean manufacturing is to incorporate less human effort, less inventory, less time to manufacture products, and less space and to become highly responsive to customer demand, while at the same time producing top quality products in the most efficient and economical manner. Lean principles can be applied to nearly anything from optimizing management to developing vertical and horizontal integration that help with optimizing the flow of products.

The lean manufacturing adopts a customer-value approach that focuses on the question "What is the customer willing to pay for?" Customers want value, and they'll pay only if needs are met. They should not pay for defects, or for the extra cost of having large inventories. In other words, customer should not be made to pay for a unit's waste. Waste is anything that doesn't add value to the end product.

Figure 3.1.1a: Objectives of Lean Manufacturing

Principles of Lean

Lean manufacturing is a series of applied processes and tools that eliminate waste from production. Improved efficiency, effectiveness, and even profitability are all byproducts of lean manufacturing. A unique feature about lean manufacturing is that it focuses more on perpetual improvement of products rather that the final output. By shifting the attention to the process in which the product is made, defaults are minimized, the right raw materials are used, people are properly organized and coordinated, and the costs of production are properly optimized. For the process to work effectively, the manufacturing industry should consider the following five principles that will help in implementing lean techniques:

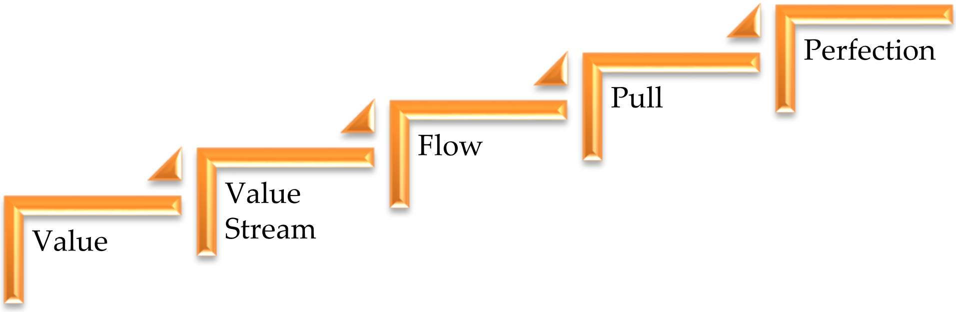


Figure 3.1.1b: Five Principles of lean

The lean management works through a number of concepts, a few of them are:

- Kaizen (continuous improvement)
- 5S and visual management
- Root cause analysis
- Value stream mapping (VSM)
- Poka-yoke (error proofing)
- Total productive maintenance (TPM)
- Just-in-time (JIT)

The focus of this module is on Kaizen for improving energy efficiency and productivity in melting area vis-à-vis. induction furnace.

3.1.2 Kaizen

The Japanese word kaizen simply means "change for better". It is a Japanese business philosophy of continuous improvement of working practices, personal efficiency. The content of Kaizen activities stipulated is as follows:

- 5S (3S) activities: Seiri (Sort; orderliness), Seiton (Set in order; neatness and tidiness), Seisou (Shine; cleanliness), Seiketsu (Standardize) and Shitsuke (Sustain)
- Adoption of suggestion system: Combined usage with petit suggestion system
- Small group activities: Visibility management of data and conditions that allow recognition of workplace problems as problems

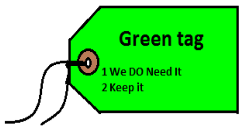
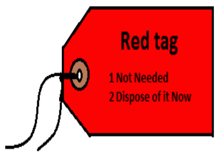
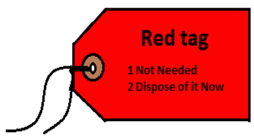
5S – Workplace Organization

5S is a technique originated from Japan and it was first developed by Hiroyuki Hirano in 1980s. The 5S philosophy focuses on simplification of the work environment, effective workplace organization, and reduction of waste while improving safety and quality. It allows the enhancement of efficiency and productivity. The 5S technique is a structured program to systematically achieve total organization cleanliness and standardization in the workplace. The benefit of 5S technique is improvement in productivity, quality, health and safety. Through 5S methodology, the management can create an environment where quality work is comfortable, clean and safe in the organization and it can ensure the compliance to standards and will further foster continuous improvement. The term "5S" is derived from five Japanese words Seiri (Sort), Seiton (Set in order), Seiso (Shine), Seiketsu (Standardize) and Shitsuke (Sustain).

Sorting – Separating the needed from the unneeded. Sorting activities aim to eliminate unneeded items from the work area and to perform an initial cleaning. Sorting clears the deck for the remaining activities. The steps of sorting are:

- Establish criteria for what is not needed. For example, if something hasn't been used for a year, it may be a candidate for disposal
- Identify the unneeded items and move to a holding area
- Dispose of the not needed items, either by transferring to a department that needs them, selling them, or discarding them
- Conduct an initial cleaning

Table 3.1.2a: Tagging criteria & recommended action

Priority	Frequency of use	Action Required	Tag
High	Daily	Store at the workplace, where it is needed and is easily assessable	
Medium	Once per week, once per month	Store together, near the workplace	 OR 
Low	Less than once per year	Throw away, or store away from the workplace	 OR 
No	Unusable items	Throw away	

Setting in Order – Once the initial sorting is completed, the natural sequence is to get the work area organized. After initial sorting the unit will be benefitted with approximately 20% of space saving. The disposable items should be tagged red. The setting in order of things will most efficiently be stored as required. Frequently-used items must be as close to where they are used as possible. The steps of simplifying are:

- Determine a location for each item based on frequency of use and proper safety zone (decreasing the likelihood of strain injuries, for example)
- Develop shadow boards and label items - a home for everything
- Determine how to replenish supplies
- Document layout, equipment, supplies and agreements for returning items

Shine – The third step in the 5S process initiates a work ethic of keeping everything clean and in order at all times. Examples of shine include wiping machinery, sweeping, tightening loose belts or bolts, cleaning gauges and indicators, tracking the source of leaks, overheating or undue noise, and organizing papers and books on office desks and shelves. Systematic cleaning provides a way to inspect, by doing a clean sweep around a work area. This means visually as well as with a broom or rags. The idea is make the job of doing daily cleaning and inspections easier. The steps of systematic cleaning are:

- Identify points to check for performance
- Determine acceptable performance
- Mark equipment and controls with visual indicators
- Conduct daily cleaning and visual checks

Standardize – The first three steps will slip unless standardized procedures, schedules and expectations are clearly identified and regularly measured. Standardizing assures that everyone knows what is expected. Since the workplace team establishes the standards, everyone should have had some involvement in establishing the 5S in their work area. Still, it is important to make these standards very clear. The steps in standardizing are:

- Establish a routine check sheet for each work area. The check sheet is like a pilot's pre-flight check list. It shows what the team should check during self-audits
- Establish a multi-level audit system where each level in the organization has a role to play. 5S system evolves and strengthens
- Establish and document standard methods across similar work areas
- Document any new standard methods for doing the work

Sustain – In order to sustain improvements made during deployment of the first 4S's, old inefficient habits will have to be removed. Changing the culture and instituting new habits will demand time and attention. It would not happen by itself. Sustaining is usually thought of as the toughest "S." However, the trick is to let the 5S system work, engage everyone in the work area during 5S activities and have a "tell at a glance" visual workplace to sustain easily. That is important, but not sufficient. A more systematic way to prevent backsliding and to foster continuous improvement is needed. The steps of sustaining are:

- Determine the 5S level of achievement - the overall grade
- Perform worker-led routine 5S checks using the 5S check list
- Address backsliding and new opportunities found during routine checks
- Conduct scheduled, routine checks by team leads or supervisors or by people from outside of the workgroup

Perform higher-level audits to evaluate how well the 5S system is working overall. For example, are there systemic issues with sustaining 5S? Often, the company's safety committee is an excellent body for conducting these audits.

5S Implementation Committees

The launch of 5S activities should involve a declaration by the Chairs of Implementation Committees in front of all employees. Activities should be carried out to follow a set schedule for implementation procedures. Each group should consult with the group leader to determine the theme for each month and activities should be carried out by the group based on this theme. Selection of activities and themes should be clarified and consideration given to linking to results in productivity enhancement, quality improvement, and ensuring safety.

Development of action plans

An example of a schedule for implementation procedures is shown below. The activity period of each item is decided based on discussion with implementation offices. Implementation offices should provide advice to groups that fall behind schedule or suggestion extensions of activity periods.

Table 3.1.2b: 5S implementation schedule/plan

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Prior preparation	→											
Clarification of policy, elaboration of 5S standard		→										
Seiri (Sort) and Seiton (Set in order) Red-tagging, signboard operation			→	→	→	→						
Seisou (Shine) Daily cleaning, cleaning check							→	→	→			
Seiketsu (Standardize)												
Shitsuke (Sustain)										→	→	
Summary of activity and standardization												

Defining and clarification of problems

Problems at factory sites are never-ending. In order to develop problem-solving activities in small group activities, the nature of problems must first be clarified. Problems are…

- "matters that require solutions"‖;
- "matters related to persons or their organisations that must be solved or improved"

In "Quality Control" problem-solving methods, the ―problem‖ is defined as the gap between the ideal situation and objectives and the present situation.

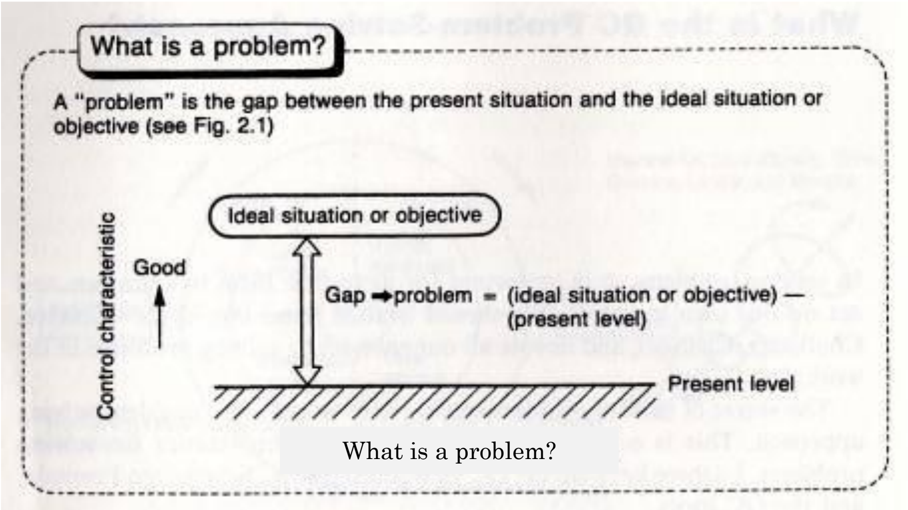


Figure 3.1.2a: What is a problem?

In "Quality Control" problem-solving methods, the ―problem‖ is defined as the gap between the ideal situation and objectives and the present situation. In order to improve workplace skills, difficult problems should be actively addressed.

Visualisation of operation data

Operational data serves as information for devising important improvements. Data becomes valuable only when understood by people. The key to understanding is converting data into formats perceptible to the human eye. Through conversion and management of all kinds of operational data on production sites into graphs, figures and tables, it is possible to ascertain abnormalities that occur on a daily basis at production sites.

In many cases, visualisation reveals problem points that were not evident in mere lists of numbers.

Different types of graphs are available for visualization of the measured data, a few of them are:

- Bar graph: To compare the size of numbers or amounts
- Line graph: To show changes in numbers and amounts
- Pie chart: To show breakdown of percentages
- Pareto chart: To analysis data with combination of bar and line graph

- Scatter plot: To display values of two variables

Sample of the above mentioned graphs/charts is shown in figure.

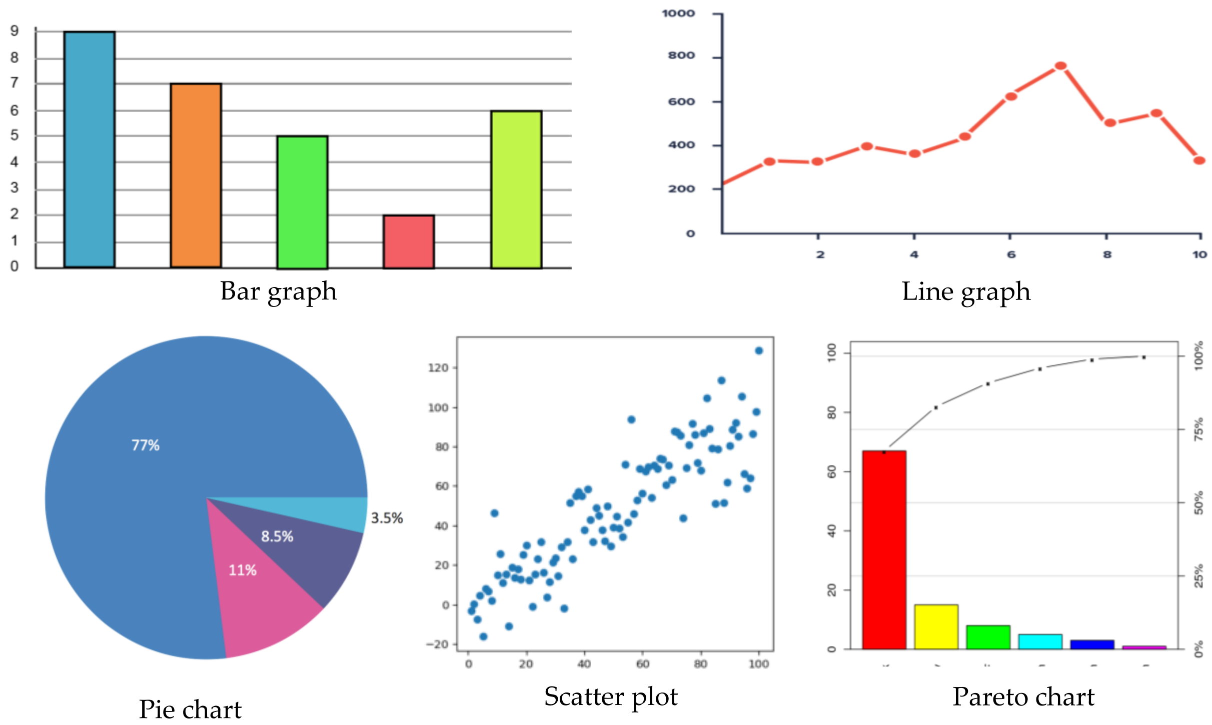


Figure 3.1.2b: Visualization of data

3.2 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.

3.2.1 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 salable 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.

3.2.2 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

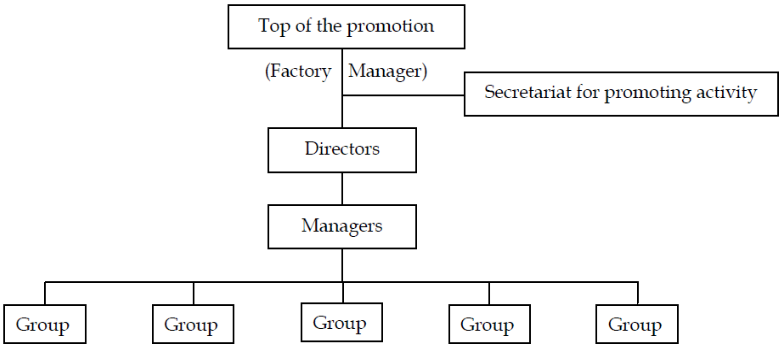


Figure 3.2.2: Implementation support group

3.2.3 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 3.2.3a, b & c.

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

Table 3.2.3a Data collection format – Part 1

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

Table 3.2.3b 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 3.2.3c 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										

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 3.2.3d: 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.

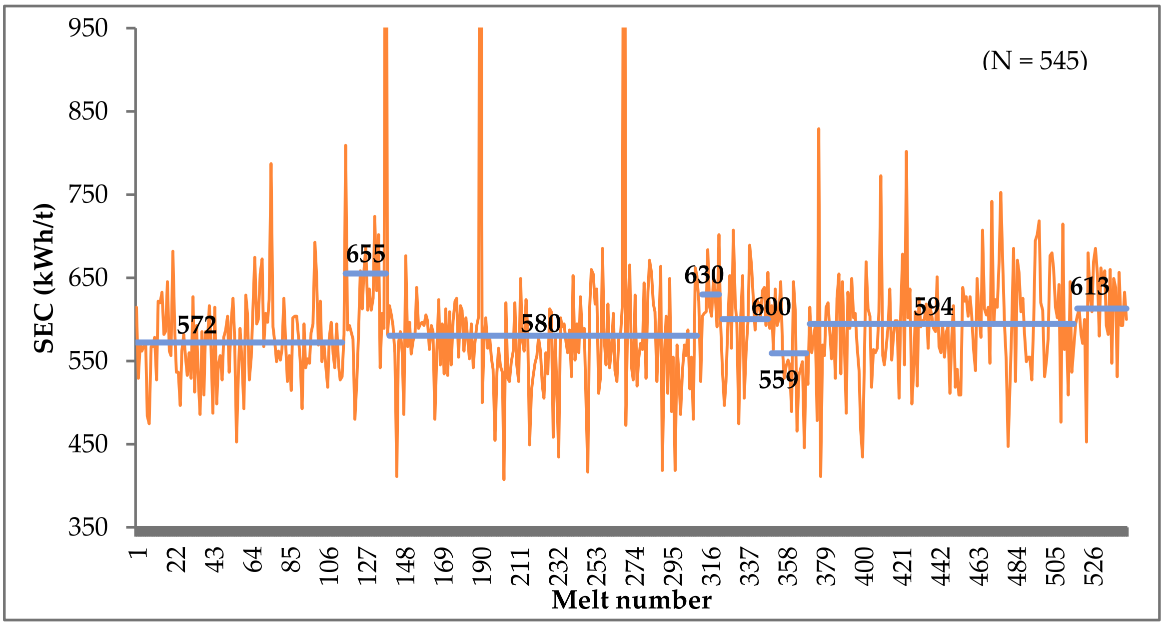


Figure 3.2.3e: Melt number vs. SEC

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.

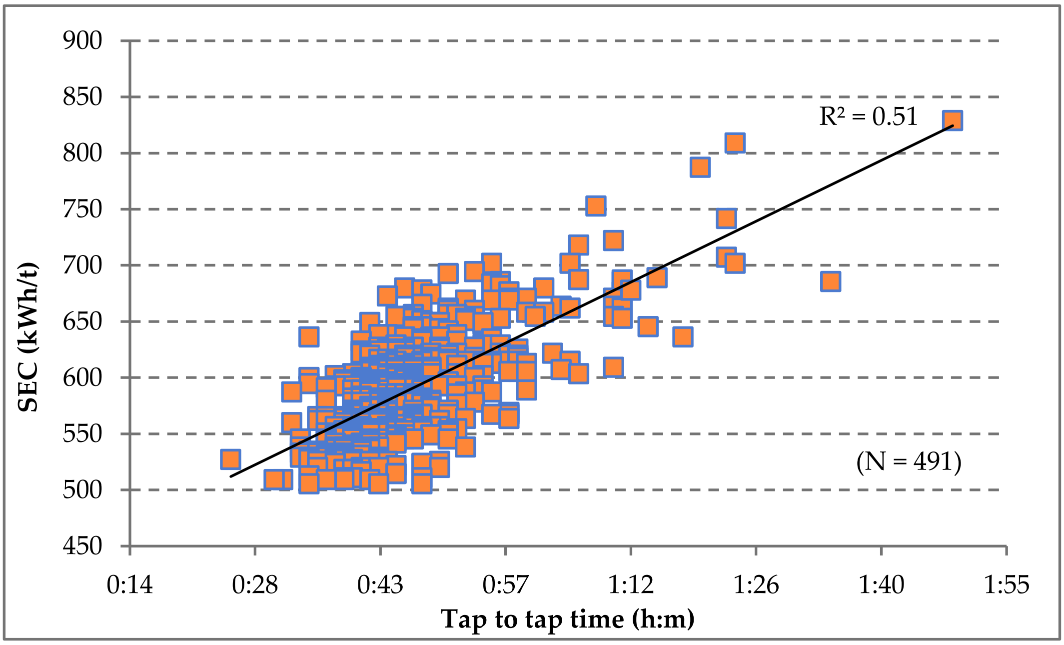


Figure 3.2.3f: Tap to tap time vs. SEC

Tapping temperature occurrence (Histogram)

A total of 528 heats were observed were 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.

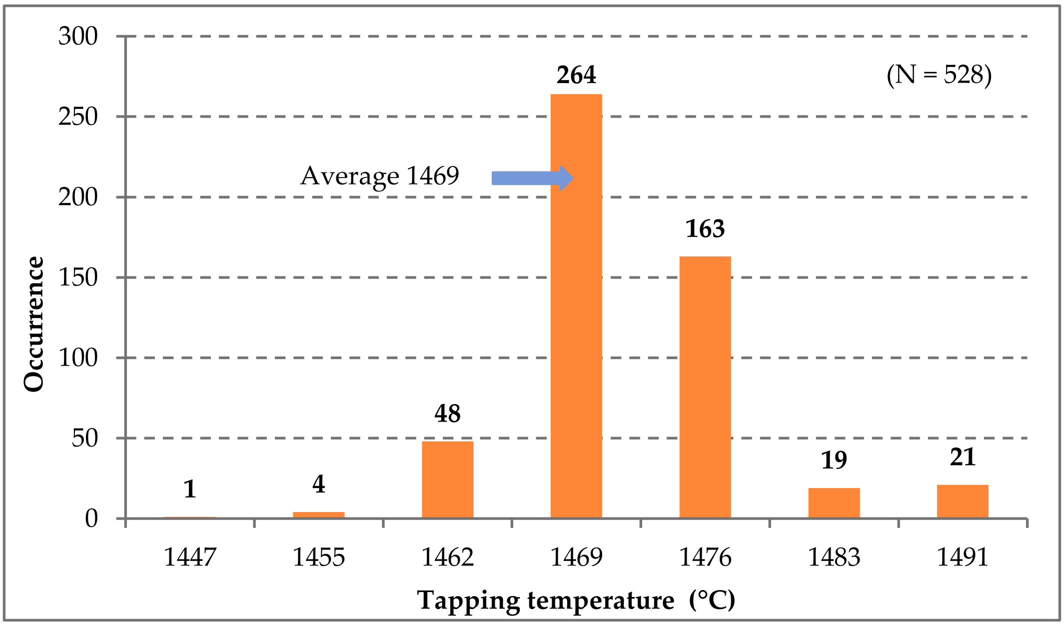


Figure 3.2.3g: Tapping temperature occurrence

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.

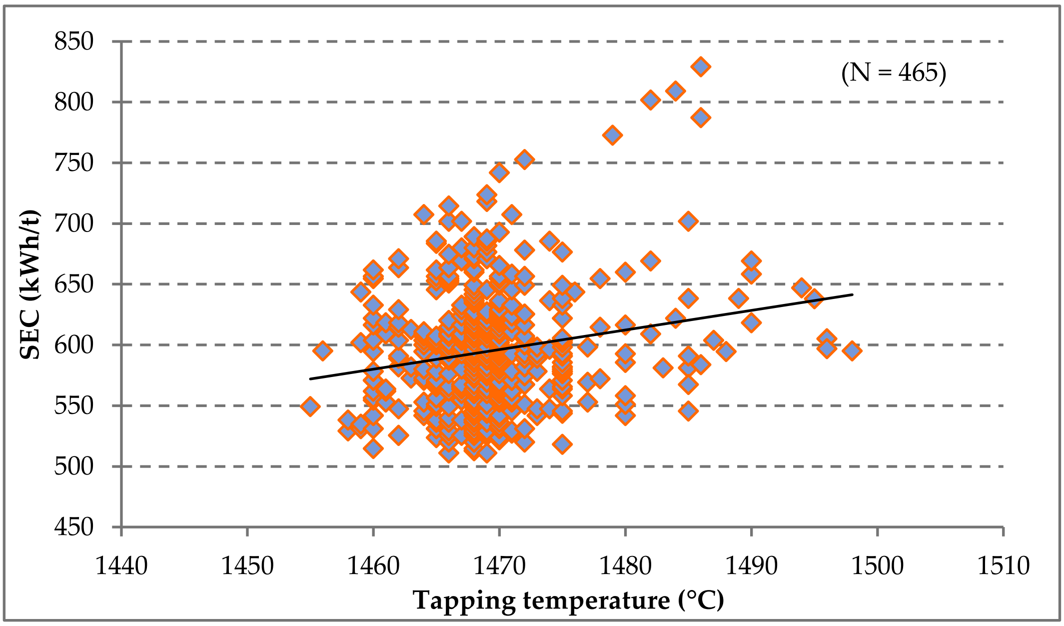


Figure 3.2.3h: Tapping temperature vs. SEC

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.

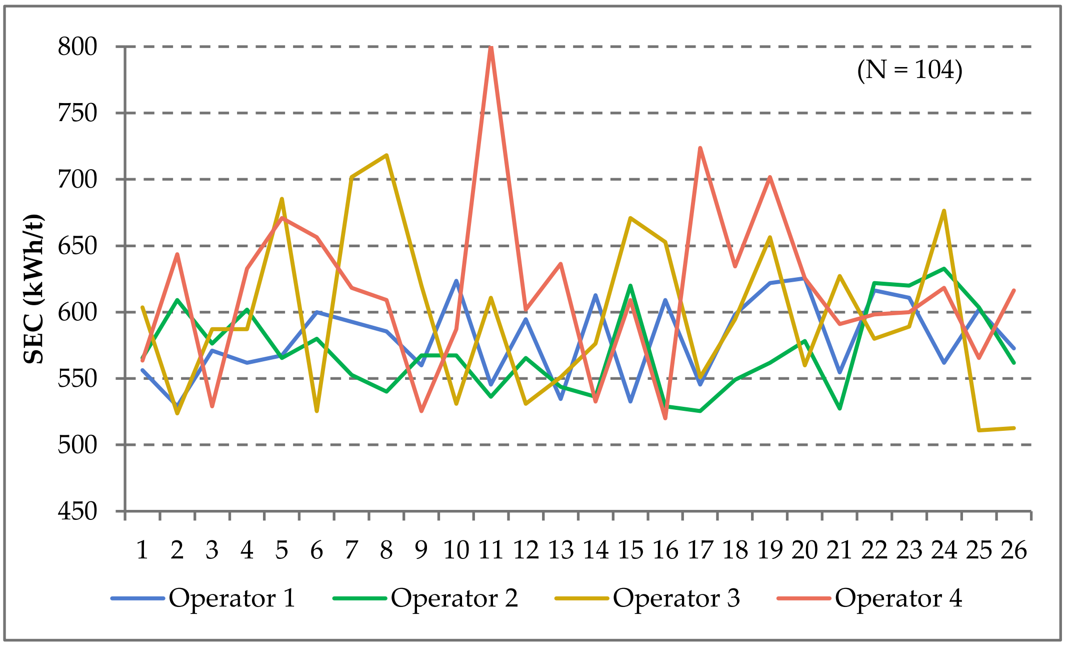


Figure 3.2.3i: Operator vs. SEC

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.

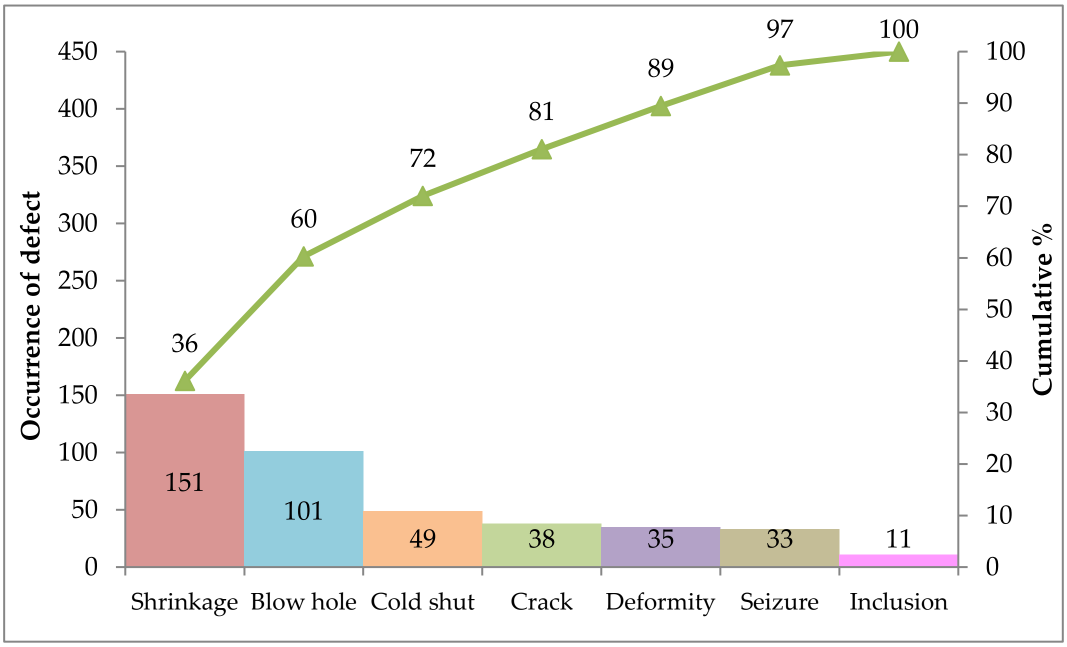


Figure 3.2.3j: Rejection analysis

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%.

3.2.4 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 3.2.4: 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 3.2.4.

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

Figure 3.4: Pictorial view of a few implementations

3.2.5 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.

List of references

Bureau of Energy Efficiency Guide Books – Furnace

Kaizen activity manual for Indian foundry units, Prepared by TERI

Best Operating Practices in foundry, prepared by TERI

TERI – Past studies on foundries

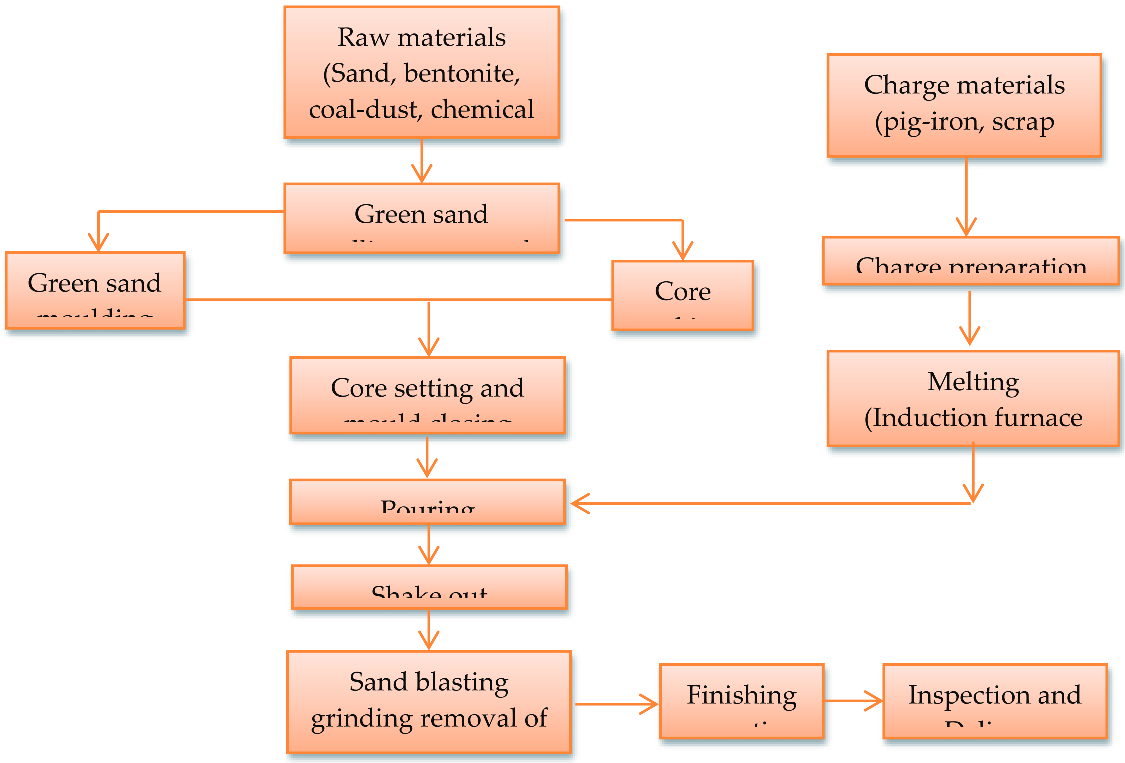
4.0 Module 3 – Energy efficiency improvements in thermal applications

4.1 Thermal applications in foundry

The primary process steps in conventional metal casting production method are preparation, melting, pouring and finishing. Of these, melting accounts for major energy consumption. In a foundry using induction furnace for melting, electricity accounts for about 85–95% of the total energy consumption of the unit. Induction furnace is the major electricity consuming equipment consuming about 70–85% of total electrical energy consumption. In foundry units wherein heat-treatment of castings is done, fuel (FO/NG/HSD/LPG) consumption accounts for about 15–25% of total energy consumption. In cupola-based units, coke typically accounts for 85–90% of the total energy consumption of the unit. Foundry industry is energy intensive and energy cost accounts for about 15–20% of total production cost.

4.1.1 Process description

The manufacturing process followed in a typical foundry unit is shown in figure below. The melting of raw material is either done using electricity in an induction furnace or coke in a cupola (conventional or divided blast type). The typical size of induction furnace varies from 75kW/100 kg to 1250 kW/5000 kg. The capacity of cupola is generally indicated by its shaft size. Majority of the cupola falls in the size range of 24 inch to 40 inch. A brief description of the required processes is given below.



Manufacturing process of a typical foundry unit

Preparation of sand

Fresh sand is thoroughly mixed with suitable binders like bentonite, water, and other ingredients and additives in intensive mixers to prepare green sand, which is the most commonly used to prepare moulds for the castings. Sand mixing is undertaken using either semi or fully automatic equipment.

Preparation of mould

In casting, the primary piece of equipment is the mould, which contains several components. The mould is divided into two halves - the cope (upper half) and the drag (bottom half), which meet along a parting line. Both mould halves are contained inside a box, called a flask, which itself is divided along this parting line. The mould cavity is formed by packing sand around the pattern (which is a replica of the external shape of the casting) in each half of the flask. The sand can be packed by hand, but machines that use pressure or impact ensure even packing of the sand. There are four unique types of sand moulds as described below.

- *Greensand mould* - Greensand molds use a mixture of sand, water, and a clay or binder. Typical composition of the mixture is 90% sand, 3% water, and 7% clay or binder. Greensand molds are the least expensive and most widely used.
- *Skin-dried mould* - A skin-dried mold begins like a greensand mold, but additional bonding materials are added and the cavity surface is dried by a torch or heating lamp to increase mold strength. Doing so also improves the dimensional accuracy and surface finish, but will lower the collapsibility. Dry skin molds are more expensive and require more time, thus lowering the production rate.
- *Dry sand mould* - In a dry sand mold, sometimes called a cold box mold, the sand is mixed only with an organic binder. The mold is strengthened by baking it in an oven. The resulting mold has high dimensional accuracy, but is expensive and results in a lower production rate.
- *No-bake mould* - The sand in a no-bake mold is mixed with a liquid resin and hardens at room temperature

Melting

Metal scrap, pig iron and other alloys are loaded in the furnace (either electric based or thermal based) for melting. The ratio of different raw materials depends on properties required for final castings. A typical cast iron casting has raw material in the following proportion: metal scrap, boring, pig iron, and others. The raw material mix is melted either in a cupola furnace (conventional/ divided blast) or induction furnace. The typical temperature requirement for cast iron is about 1400°C, for steel castings about 1650°C, and for aluminium casting 750°C. Once the melting is completed, the molten metal is poured into sand moulds using ladles which are operated either manually or using semi/automatic pouring system and allowed to cool down and harden.

Shot blasting and finishing

The melt poured inside the mould takes the shape of the mould. The casting is removed, shot blasted and cleaned with the help of either wheel-blasting or air-blasting. In wheel-blasting abrasive energy is generated by a set of turbine wheel and electric motor but in air-blasting, the blast media is pneumatically accelerated by compressed air and projected by nozzles onto the component. For special applications a media-water mix can be used, this is called wet blasting.

4.1.2 Thermal heating applications

Thermal energy has the largest share in the consumption of foundry production processes. Melting process accounts for maximum thermal energy consumption followed by heat treatment, sand drying, core drying and ladle preheating process. Foundries use gaseous or liquid fuels for heating applications other than melting. Details of equipment used for heating applications are mentioned below;

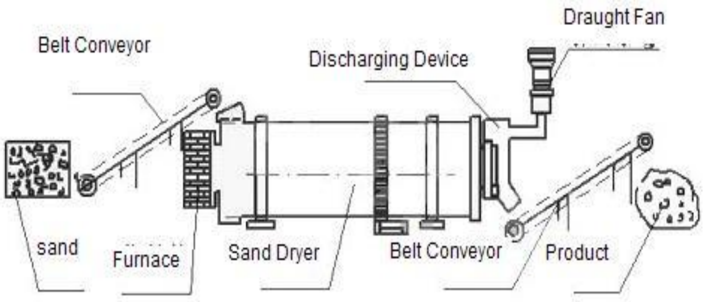
Sand dryer

Drying is a highly energy-intensive process, accounting for 10–20% of total industrial energy use. The main reason for this is the need to supply the latent heat of evaporation to remove the water or other solvent. Dryers can be classified based on mode of operation such as batch or continuous. In case of batch dryer the material is loaded in the drying equipment and drying proceeds for a given period of time, whereas, in case of continuous mode the material is continuously added to the dryer and dried material continuously removed. Drying processes can also be categorized according to type of heating system i.e. conduction, convection, radiation is another way of categorizing the drying process.

In foundries continuous type of dryers are used for sand drying applications where heat is supplied by direct contact with hot air at atmospheric pressure, and the water vaporized is removed by the air flowing.

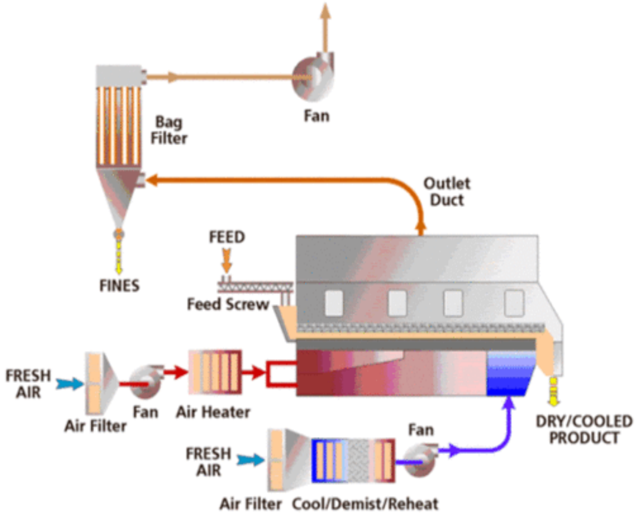
Rotary Dryer

The rotary drier is basically a cylinder, inclined slightly to the horizontal, which may be rotated, or the shell may be stationary, and an agitator inside may revolve slowly. In either case, the wet material is fed in at the upper end, and the rotation, or agitation, advances the material progressively to the lower end, where it is discharged. In direct-heat revolving rotary driers, hot air or a mixture of flue gases and air travels through the cylinder. The feed rate, the speed of rotation or agitation, the volume of heated air or gases, and their temperature are so regulated that the solid is dried just before discharge. The feed rate, the speed of rotation or agitation, the volume of heated air or gases, and their temperature are so regulated that the solid is dried just before discharge.



Rotary drum dryer

Fluidised Bed Dryer



Fluidised bed dryer

Fluidized bed dryer consist of a steel shell of cylindrical or rectangular cross section. A grid is provided in the column over which the wet material is rests. In this type of dryer, the drying gas/blower air is passed through the bed of solids at a velocity sufficient to keep the bed in a fluidized state. Mixing and heat transfer are very rapid in this type of dryers. If fine particles are present, either from the feed or from particle breakage in the fluidized bed, there may be considerable solid carryover with the exit gas and bag filters are needed for fines recovery. The main advantage of this type of dryer are: rapid and uniform heat transfer, short drying time, good control of the drying conditions.

Ladle preheater

Ladle preheater

Ladles are used to carry molten steel from the melting furnace to the ladle refining station or to the casting operation. These ladles must be preheated to minimize thermal shock and damage to the refractory lining and to reduce temperature drop in the ladle. Ladles preheaters available in the market are of fuel fired both gaseous and liquid and electrically heated. Ladle Preheater is generally used for removing the moisture from the ladle to avoid formation of gas / reaction in the liquid metal.

The transport ladles lined with refractory material are heated to a target temperature in the empty state. For this purpose a geometrically adjusted and insulated cap is placed on the ladle. Inside the cap, the integrated burner transmits the heat first onto a radiating body made of high temperature resistant steel that is adjusted to the internal contour of the ladle, which in turn transfers the energy as infrared radiation to the lining of the ladle.

In some systems the lid is lowered onto the vertical ladle, in others the ladle is tilted horizontally and brought up against the fixed face of the ladle heater. The sealing system can be either a ceramic fiber seal or an air curtain that eliminates cold air induction at the ladle mouth.

Core baking oven

Core making is an important branch in any foundry and the choice of core making depends on various factors. To name them are depending on type of metal to be cast, depending on the size of casting, choice based on complexity involved in a casting process, depending on the requirement of quality in final product, depends on equipment used for production and energy source. There are six most common technologies involved in core making as below;

- Oil as the sand binder
- Green sand
- Hotbox
- Cold-box
- No-bakes
- Shell process

When each of the above technology is ranked based on the consumption of energy per unit of product, ranking from greatest to lowest amount the order is oil as the sand binder being the highest followed by green sand, hotbox, cold-box, no-bakes and shell process being lowest usage of energy in ranking.

The oil as the sand binder as well as the green sand technology uses high energy because it needs high temperatures for the process of curing and refractory coating and pasting has to be carried out on cores. The hotbox technology gives output as solid cores and needs hot curing for the process of binder setting. The technology of cold-box is carried out with the usage of heated sand and amine gas mixture. No-bakes technology operates at accurately controlled setting. The least usage of energy is by shell process technology in which no coating is necessary.

The complete core making procedure consists of the following eight steps:

1. Mixing of Core Sand
2. Ramming of Core Sand
3. Venting of Core
4. Reinforcing of Core
5. Baking of Core
6. Cleaning and Finishing of Core
7. Sizing of Cores

8. Joining of Cores

For baking operation, the cores are placed on the baking plates and put into the baking furnace. During baking, moisture is driven out at 100°C. On further increasing the temperature of about 200-270°C, some chemical changes also occur in the core oil and binders which strengthens the core sand. The baking period of about 1 to 3 hours are quite common in some cases it may vary in a higher cycle time.

The proper baking of the core is essential and judged by the brown colour. An under-baking core will generate a large amount of gases, which produces blow holes in the casting, while over-baking will burn the binders completely and may collapse too soon and break before solidification of casting. Oil fired ovens, gas fired ovens, dielectric bakers or radiant bakers are used for this purpose. Ovens in the foundry can be classified as batch ovens and continuous ovens based on type of operation. Also these ovens are available with fuel fired burner or electrically heated.

Core baking oven

Heat treatment furnace

Heat treatment is a method of controlled heating and cooling of metals to alter their mechanical and physical properties without changing the product shape. The technique involves the use of heating or chilling, usually to extreme temperatures, to attain a desired result, such as - hardening or softening of a metal. Some of the common techniques of heat treatment include annealing, case hardening, precipitation strengthening, tempering and quenching.

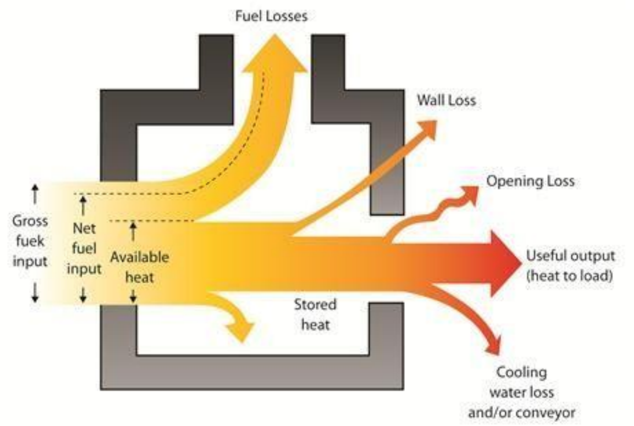
Heat treatment activities are carried out according to specific requirements regarding heat treatment for a given type of material. The entire heat treatment process is controlled using furnace thermocouples and contact thermocouples which are periodically checked for temperature distribution. The primary source of energy used for heating material in heat treatment furnaces is fossil fuel in most cases or electricity. In case of fossil fuel, furnace is equipped with burner and air blower for combustion.

Heat-treating furnaces can be grouped into two main categories: batch and continuous. The fundamental difference between these two styles is not in their materials of construction, although there are some differences due to inherent design requirements. Instead, the key difference lies in how workloads are positioned in the units and how they interact with the atmosphere within the furnaces.

Heat treatment furnace

4.1.3 Losses in thermal system

Thermal efficiency of heating equipment, such as furnaces, ovens, heaters, & kilns is the ratio of heat delivered to the material and heat supplied to the heating equipment. The purpose of heating process is to introduce a certain amount of thermal energy into a product being heated, raising it to a certain temperature to prepare it for additional processing or change its properties.



Heat Losses in thermal system

The thermal energy supplied to the heating equipment results in energy losses in different areas and different forms of the equipment. For most of the heating equipment, a large amount of the heat supplied is wasted in the form of exhaust gases. These thermal losses include:

1. Heat storage in the structure
2. Surface heat/wall losses
3. Heat transported out by load conveyors, fixtures, trays etc.
4. Radiation losses from opening, hot exposed part etc.
5. Heat carried by cold air infiltration
6. Heat carried by excess air used in the burners with flue gases

Storage Heat Losses

First, the metal structure and insulation of the heating equipment must be heated so their interior surfaces are about the same temperature as the product they contain. This stored heat is held in the structure until the equipment shuts down, then it leaks out into the surrounding area. The more frequently the equipment is cycled from cold to hot and back to cold again, the more frequently this stored heat must be replaced. Fuel is consumed with no useful output.

Surface Heat losses

Additional heat losses take place while the equipment is in operation. Wall or transmission losses are caused by the conduction of heat through the walls, roof, and floor of the heating device. Once that heat reaches the outer skin of the equipment and radiates to the surrounding area or is carried away by air currents, it must be replaced by an equal amount taken from the combustion gases. This process continues as long as the equipment is at an elevated temperature.

Material handling losses

Many units use equipment to convey the work into and out of the heating chamber, and this can also lead to heat losses. Conveyor belts or product trays that enter the heating chamber cold and leave it at higher temperatures drain energy from the combustion gases. In car bottom furnaces, the hot car structure gives off heat to the room each time it rolls out of the furnace to load or remove work. This lost energy must be replaced when the car is returned to the furnace.

Cooling Media Losses

Water or air cooling protects rolls, bearings, and doors in hot equipment environments, but at the cost of lost energy. These components and their cooling media (water, air, etc.) become the conduit for additional heat losses from the equipment. Maintaining an adequate flow of cooling media is essential, but it might be possible to insulate the furnace and load from some of these losses.

Radiation (Opening) Losses

Equipment operating at temperatures above 540 °C might have significant radiation losses. Hot surfaces radiate energy to nearby colder surfaces, and the rate of heat transfer increases with the fourth power of the surface's absolute temperature. Anywhere or anytime there is an opening in the furnace enclosure, heat is lost by radiation, often at a rapid rate.

Flue gas losses

Flue-gas loss, also known as stack loss is made up of the heat that cannot be removed from the combustion gases inside the equipment. The reason is heat flows from the higher temperature source to the lower temperature heat receiver.

Cold air infiltration

Excess air does not necessarily enter the equipment as part of the combustion air supply. It can also infiltrate from the surrounding room if there is a negative pressure in the equipment. Because of the draft effect of hot equipment stacks, negative pressures are fairly common, and cold air slips past leaky door seals, cracks and other openings in the equipment. Every time the door is opened, considerable amount of heat is lost. Economy in fuel can be achieved if the total heat that can be passed on to the stock is as large as possible.

4.2 Energy Conservation Opportunities

Industrial process heating consumes a significant amount of energy in foundry industries. While the efficiency of many industrial heating systems such as furnaces, ovens, and kilns have been improved over time, there are still significant opportunities remaining for improving the efficiency of these systems.

4.2.1 Optimum excess air

To obtain complete combustion of fuel with the minimum amount of air, it is necessary to control air infiltration, maintain pressure of combustion air, fuel quality, and excess air monitoring. Higher excess air will reduce flame temperature, equipment temperature and heating rate. On the other hand, if the excess air is less, then un-burnt components in flue gases will increase and would be carried away in the flue gases through stack.

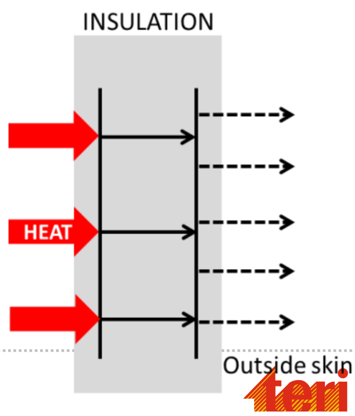
The optimization of combustion air is the most attractive and economical measure for energy conservation. The impact of this measure is higher when the temperature of equipment is high. Air to fuel ratio is the value that is given by dividing the actual air amount by the theoretical combustion air amount, and it represents the extent of excess of air.

4.2.2 Temperature control

It is important to operate the equipment at optimum temperature as required. Operating at too high temperatures than optimum causes heat loss, excessive oxidation, de-carbonization as well as over-stressing of the refractories. These controls are normally left to operator judgment, which is not desirable. To avoid human error, automated controls should be provided.

4.2.3 Reduction in surface heat losses

About 30–40% of the fuel input to the equipment generally goes to make up for heat losses in intermittent or continuous operating equipment. The appropriate choice of refractory and insulation materials goes a long way in achieving fairly high fuel savings in industrial furnaces.



Surface losses

Heat losses can be reduced by increasing the wall thickness, or through the application of insulating bricks. Outside wall temperatures and heat losses of a composite wall of a certain thickness of firebrick and insulation brick are much lower, due to lesser conductivity of insulating brick as compared to a refractory brick of similar thickness. In the actual operation in most of the small furnaces the operating periods alternate with the idle periods. During the off period, the heat stored in the refractories during the on period is gradually dissipated, mainly through radiation and convection from the cold face.

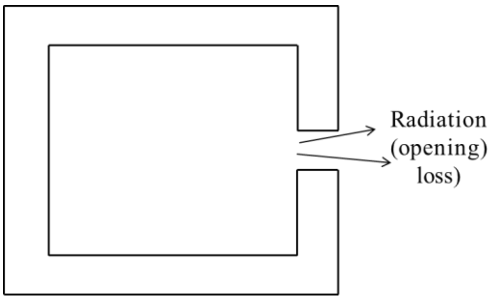
Ceramic fiber is a low thermal mass refractory used in the hot face of the equipment and fastened to the refractory walls. Due to its low thermal mass the storage losses are minimized. This results in faster heating up of furnace and also faster cooling.

Ceramic coatings in heating chamber promote rapid and efficient transfer of heat, uniform heating and extended life of refractories. The emissivity of conventional refractories decreases with increase in temperature whereas for ceramic coatings it increases. This outstanding property has been exploited for use in hot face insulation.

Ceramic coatings are high emissivity coatings which when applied has a long life at temperatures up to 1350°C. The coatings fall into two general categories-those used for coating metal substrates, and those used for coating refractory substrates. The coatings allow the substrate to maintain its designed metallurgical properties and mechanical strength.

4.2.4 Reduction in heat loss through openings

Heat loss through openings consists of the heat loss by direct radiation through openings and the heat loss caused by combustion gas that leaks through openings. If the heating chamber pressure is slightly higher than outside air pressure during its operation, the combustion gas inside may blow off through openings and heat is lost with that. But damage is more, if outside air intrudes into the heating chamber, making temperature distribution uneven and oxidizing billets. This heat loss is about 1% of the total quantity of heat generated in the equipment, if heating chamber pressure is controlled properly.



Opening losses

In addition to the proper control on furnace pressure, it is important to keep the openings as small as possible and to seal them in order to prevent the release of high temperature gas and intrusion of outside air through openings such as the charging inlet, extracting outlet and peephole on furnace walls or the ceiling.

5.2.5 Reduction in stored heat losses

The product being heated in many furnaces and ovens must be carried or supported by conveyors, fixtures, trays, etc. This material must be heated to the same temperature as the product and will exit the furnace carrying that heat away with it. Reducing the heat lost through fixtures requires a reduction in the heat capacity (mass times mean specific heat) of these systems and materials.

Instead of the classical steel and cast iron trays used in the past, nowadays charging racks made of CFC are the first choice in very many cases. Their high stability and extreme distortion resistance are decisive advantages that come into play especially in automated processes. Their low density and weight not only facilitate handling, but also ensure an exceptional energy balance as compared to trays made of steel or cast iron. Although its heat-absorbing capacity is 2.5 times higher, CFC has a clearly better energy balance because of its low density and high thermal stability.

Description		Steel 1.4818 (example)	CFC
Density	-	7.9 kg/dm³	~ 1.6 kg/dm³
Flexural strength (at 1000° C)	-	~ 10 MPa	~ 230 MPa
Spec. thermal cap. (at 1000° C)	-	0.7 kJ/kg K	1.8 kJ/kg K
Energy for heating 1 dm3 from 20° C to 1000° C	$Q = m \times Cp \times \Delta t$	5400 kJ 100%	2800 kJ 50%
Energy with same stability	$Q = \sigma_{CFC} / \sigma_{Stahl} \times m \times cp \times \Delta t$	-16000 kJ 100%	2800 kJ < 20%

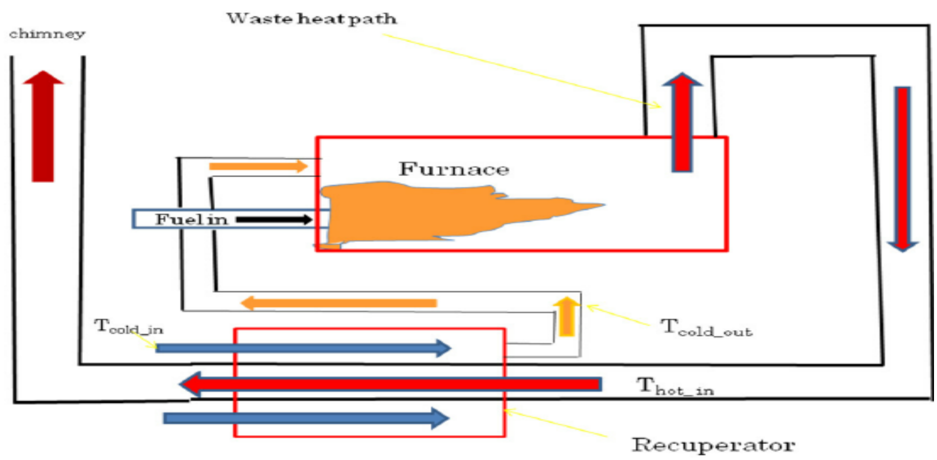
4.2.6 Waste heat recovery

In any industrial heating equipment the products of combustion leave the heating chamber at a temperature higher than the stock temperature. Sensible heat losses in the flue gases, while leaving the chimney, carry 35 to 55 per cent of the heat input to the equipment. The higher the quantum of excess air and flue gas temperature, the higher would be the waste heat availability. Waste heat recovery should be considered after all other energy conservation measures have been taken. Minimizing the generation of waste heat should be the primary objective. The sensible heat in flue gases can be generally recovered by the following methods.

- **Charge (stock) preheating:** When raw materials are preheated by exhaust gases before being placed in a heating furnace, the amount of fuel necessary to heat them in the furnace is reduced. Since raw materials are usually at room temperature, they can be heated sufficiently using high-temperature gas to reduce fuel consumption rate.

- **Preheating of combustion air:** For a long time, the preheating of combustion air using heat from exhaust gas was not used except for large boilers, metal-heating furnaces and high-temperature kilns. This method is now being employed in compact industrial heating systems as well. The energy contained in the exhaust gases can be recycled by using it to pre-heat the combustion air. A variety of equipment is available; external recuperators are common, but other techniques are now available such as self-recuperative burners.

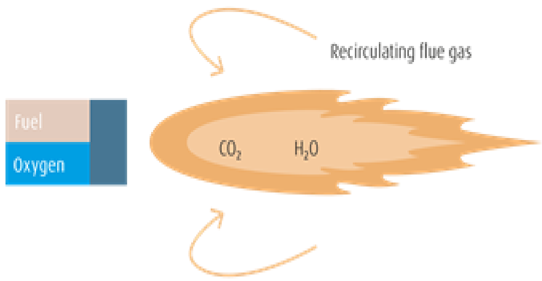
- **Utilizing Waste Heat as a Heat Source for Other Processes:** The temperature of heating-equipment exhaust gas can be as high as 400–600 °C, even after heat has been recovered from it. If the exhaust gas heat is suitable for equipment in terms of heat quantity, temperature range, operation time etc., the fuel consumption can be greatly reduced. In one case, exhaust gas from a quenching furnace was used as a heat source in a tempering furnace so as to obviate the need to use fuel for the tempering furnace itself.



Recuperator/Air pre-heater

4.2.7 Oxyfuel burners for ladle preheating system

The ladle of the caster needs to be preheated, usually using gas burners. Fuel consumption for preheating the ladle containing liquid steel is estimated at 0.02 GJ/t-steel. Heat losses can occur through lack of lids and through radiation. The losses can be reduced by installing temperature controls, installing hoods, by improved ladle management to reduce preheating need, and through the use of recuperative burners and oxyfuel burners.



Oxyfuel combustion

The efficiency of the ladle preheating can be improved by using an efficient burner, properly scheduling the heating times and reducing heating durations, monitoring temperatures, installing hoods to reduce radiative losses, and by using recuperative and oxyfuel burners.

The principle of flameless oxyfuel:

- During combustion, flue gases are mixed into the combustion reaction zone to dilute the reactants. This distributes the combustion process, delays the release of heat and lowers the peak flame temperatures – all of which reduce NOx emissions without compromising efficiency.
- Mixing flue gases into the flame also disperses energy throughout the entire vessel, ensuring faster, more uniform heating. The dispersed flame contains the same amount of energy but distributes it much more effectively throughout the vessel.

4.2.8 Biomass gasifier

Biomass gasification, or producing gas from biomass, involves burning biomass under restricted air supply for the generation of producer gas. Producer gas can also be burnt directly in open air, much like Liquid Petroleum Gas (LPG), and therefore can be used for industrial heating applications including ladle preheating, sand dryers, core ovens and heat treatment.

Biomass gasifier needs uniform-sized and dry fuel for smooth and trouble-free operation. Most gasifier systems are designed either for woody biomass (or dense briquettes made from loose biomass) or for loose pulverized biomass. Biomass gasifiers are more appropriate

Biomass Gasifier

for small-scale industries, where presently diesel or furnace oil based combustion systems are in use.

4.3 Case Studies

4.3.1 Supplying optimum excess air for complete combustion

The unit has installed natural gas (NG) fired furnace of capacity 250 kg per hour. The efficiency of this furnace found to be very low based on the operating parameters measured during the detailed study. It was observed during study that due to insufficient level of excess air, there was large amount of CO formation causing incomplete combustion hence total heat available in fuel is not utilised fully.

The unit implemented the measure to replace the existing lower capacity combustion air blower with optimum capacity blower, which supplied and maintain optimum amount of excess air required for complete combustion of fuel. The specific energy consumption with implementation of the recommended ECM came down from 240 SCM to 215 SCM of natural gas per tonne.

The annual energy saving was 11,668.3 SCM of natural gas equivalent to cost saving of Rs. 4.90 lakh per year. The investment required was Rs. 0.41 lakh towards installation of new blower with simple payback period of 2 months.

4.3.2 Improvement of surface insulation

The unit has installed a natural gas (NG) fired hardening furnace of capacity 300 kg per hour. During cold start up, the temperature of the furnace needs to be raised up to 830°C and once the temperature reaches to the set value, the products are loaded into the furnace. The cold start-up after weekly off took about 1.98 hours to attain the set temperature. The higher surface temperatures found at door side and longitudinal sides. Application of the veneering modules (ceramic fibre insulation) inside the surface was done to avoid the surface heat losses due to high temperatures. Application of modules reduced surface heat losses with reduction in residual heat stored during the non-firing time, resulting in reduction in cold start-up time. The estimated reduction is cold start-up time by applying the veneering is about 0.84 hour (i.e 50 minutes).

The annual energy saving was 12,581 SCM of NG per year equivalent to a monetary saving of Rs 5.29 lakh. The investment required was Rs. 1.02 lakh with payback period of less than 3 months.

Ceramic fibre insulation

4.3.3 Installation of recuperator

The unit has installed a natural gas (NG) fired batch type heat treatment furnace of capacity 700 kg per batch which caters to annual production of 866 tonnes. Previously temperature of air at the inlet of burner is at room temperature i.e. around 35°C.

It was recommended to install the recuperator to reduce the overall energy consumption of the furnace. Due to recuperator the combustion air from blower gets heated up to temperature of 180°C, before supplying the burner, which improved the efficiency of furnace with reduction in specific energy consumption with reduction in heating cost.

The annual energy saving was 3,131 SCM of natural gas per year equivalent to a monetary saving of Rs 1.31 lakh per year. The investment required was Rs. 3.12 lakh with payback period of 2.4 years.

4.3.4 Installation of door to avoid radiation losses

The unit has installed a natural gas (NG) fired furnaces of capacity 200 kg per hour. There was no door at loading side of this furnace, which was leading to higher radiation heat loss from inside the furnace and thereby reducing the efficiency of the furnace. The total radiation heat loss in this furnace was estimated to be 2,51,962 kCal per day.

It was recommended to install a door to the furnace from loading side to avoid the radiation heat loss due to high operating temperature. Implementation of this recommendation prevented heat loss during 60% of time when operator is not loading the material inside the furnace resulting in significant reduction in energy consumption.

The annual energy saving was 2,775 SCM of natural gas per year equivalent to a monetary saving of Rs 1.16 lakh. The investment required was Rs. 0.09 lakh with payback period of 1 month.

Radiation losses thorugh door opening

4.3.5 Biomass gasifier

Unit manufactures aluminium strips, which are used for frames. In the process, Aluminium billets are heated at around 750ºC temperature and then drawn in the form of rectangular strips. This unit was using diesel fired furnace to meet the heating requirements and were consuming around 120 liters of diesel per day (24 hours operation). A gasifier of 20 kg/hr capacity has been designed to meet the energy requirement of the furnace.

This gasifier was commissioned in January 2009 and since then it is operating 24 hours a day and 6 days a week. The comparative cost-benefit analysis of the gasifier system is given in the table below:

Comparative cost-benefit analysis of gasifier system

Assumptions	
Price of diesel	Rs. 35 per kg
Price of processed biomass	Rs. 3.5 per kg
Plant Operating hours / day	24
Energy consumption in conventional system (Diesel based)	
Hourly diesel consumption	5 kg

Daily diesel consumption	120 kg
Total cost of the diesel	Rs. 4200 / day
Present Energy Consumption Gasifier based	
Hourly biomass consumption	20 kg
Daily biomass consumptions	480 kg
Total cost of the biomass	Rs. 1680 / day
Cost Saving	Rs. 2520 / day
Capital Cost	Rs. 1 lakhs
Operating Cost	Rs. 1 lakhs annually
Simple Payback	80 days (2 – 3 months)

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%.

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

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 valve 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

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

where P0, P1, . . . Pn equals the cash flows in periods 1, 2, . . . n, respectively; and IRR equals the project's internal rate of return.

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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 12thPlan 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 apprised 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 5.4. It is understood that the DPRs will be structured keeping in view their acceptability to financial institutions/ banks.

Table 5.4: 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