



Promoting Energy Efficiency and Renewable Energy in Selected MSME Clusters in India

A GEF-UNIDO-BEE Project



Best Operating Practices Indore Foundry Cluster

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This document has been developed after an extensive consultation with a number of experts and on the basis of BOP documents developed by expert energy auditing agencies engaged earlier under the project. The information contained in this document is indicative and is for information purposes only. BEE disclaim any liability for any kind of loss whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly, resulting from the publication, or reliance on this document.

Conceptualized by PMU, GEF-UNIDO-BEE Project



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FOREWORD

With its objective to reduce energy intensity of the Indian economy, Bureau of Energy Efficiency has partnered with United Nations Industrial Development Organization (UNIDO) to implement the Global Environment Facility (GEF) funded national project on "Promoting Energy Efficiency and Renewable Energy in Selected MSME Clusters in India".

I am pleased to share the handbook on "Best Operating Practices" for MSME units which has been published under the project. This handbook has been conceptualized as a single source of information and is an effort to provide summarized and lively presentation to enhance the knowledge on underlying issues in energy efficiency.

I trust that this book will be able to make wider reach in the clusters and will be greatly accepted by the engineers and managers as a ready reference for enhancing their knowledge and implementation of energy efficient operating practices.

I would like to record my appreciation for members of the Project Monitoring Unit – Shri Milind Deore (Energy Economist, BEE), Shri Niranjana Rao Devela (National Technology Coordinator, UNIDO) and Shri Ashish Sharma (Project Engineer, BEE) for their hard efforts and tireless commitments to bring out this publication.

I also compliment the efforts of all participating MSME units towards their endeavor in contributing to energy efficiency and making this project a big success.

New Delhi

(Abhay Bakre)

स्वहित एवं राष्ट्रहित में ऊर्जा बचाएँ Save Energy for Benefit of Self and Nation

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ABOUT THE DOCUMENT

As the MSME units are limited in their capacities and lack access to latest technological advancements in the field of energy efficiency, the GEF-UNIDO-BEE project is spread across 12 MSME clusters under 5 different sectors (Brass, Ceramic, Dairy, Foundry and Handtools) with an inclusive approach to promote energy efficient technologies and use of renewable energy.

Under the project, sample energy audits were conducted in each cluster, which helped to understand the basic pattern of energy consumption and possible energy conservation measures in the units within a cluster. As an outcome of the activity, Best Operating Practices (BOP) were identified for each cluster, the implementation of which are very effective, easy to implement and, economically viable to avoid improper use of energy and reduce the energy cost.

Through this handbook energy professionals in the units will be able to identify the underlying issues with the energy consumption and make quick reference for the best possible solutions.

Contents

FOREWORD.....	I
ABOUT THE DOCUMENT	II
CHAPTER 1: INTRODUCTION	1
1.1 BRIEF ABOUT THE PROJECT	1
1.2 BRIEF ABOUT THE CLUSTER AND PRODUCTION PROCESS	1
CHAPTER 2: BEST OPERATING PRACTICES - INDUCTION FURNACE.....	4
2.1 INTRODUCTION.....	4
2.2 OPERATING PRINCIPLE.....	4
2.3 TYPES OF INDUCTION FURNACE.....	4
2.4 BEST OPERATING PRACTICES FOR INDUCTION FURNACE.....	5
2.5 DO’S AND DON’TS IN INDUCTION MELTING FURNACE	9
CHAPTER 3: BEST OPERATING PRACTICES – CUPOLA FURNACE.....	10
3.1 INTRODUCTION.....	10
3.2 OPERATING PRINCIPLE.....	10
3.3 BEST OPERATING PRACTICES FOR CUPOLA FURNACE.....	11
3.4 DO’S AND DON’TS IN CUPOLA FURNACE OPERATIONS.....	16
3.5 PROBLEMS AND SOLUTIONS.....	17
CHAPTER 4: BEST OPERATING PRACTICES - COMPRESSED AIR SYSTEM	19
4.1 INTRODUCTION.....	19
4.2 BEST OPERATING PRACTICES FOR COMPRESSED AIR SYSTEM	19
4.3 DO’S AND DON’TS IN COMPRESSED AIR SYSTEM	24
CHAPTER 5: BEST OPERATING PRACTICES - MOTORS AND PUMPS	25
A. MOTOR.....	25
5.1 INTRODUCTION.....	25
5.2 TYPES OF MOTORS.....	26
5.3 BEST OPERATING PRACTICES FOR MOTORS.....	27
5.4 DO’S AND DON’TS IN MOTOR OPERATIONS	28
B. PUMPS	29
5.5 INTRODUCTION.....	29
5.6 EFFICIENT PUMPING SYSTEM OPERATION.....	29
5.7 BEST OPERATING PRACTICES FOR PUMPS.....	30
5.8 DO’S AND DON’TS IN PUMP OPERATION	31
CHAPTER 6: BEST OPERATING PRACTICES - REHEATING FURNACE.....	32
6.1 INTRODUCTION.....	32
6.2 OPERATING PRINCIPLE.....	32
6.3 TYPE OF RE-HEATING FURNACE.....	33
6.4 BEST OPERATING PRACTICES IN RE-HEATING FURNACE.....	33
6.5 DO’S & DON’TS IN RE-HEATING FURNACE OPERATIONS.....	38
CHAPTER 7: BEST OPERATING PRACTICES –LIGHTING	39
7.1. INTRODUCTION.....	39
7.2. FIXTURE SELECTION AND SIZING	39
7.3. LAYOUT.....	40
7.4. MAINTENANCE OF FIXTURES.....	40
7.5. CONTROL STRATEGIES:	41
7.6. EFFICIENCY IMPROVEMENT.....	42

CHAPTER 1: Introduction

1.1 Brief about the project

GEF-UNIDO-BEE project titled “Promoting energy efficiency and renewable energy in selected Micro Small and Medium Enterprises (MSME) clusters in India” is developing and promoting market environment for introducing energy efficiency and renewable energy in process applications in 12 selected energy-intensive MSME clusters in India which includes Indore Foundry cluster also. The overall motive of this project is to improve the productivity and competitiveness of units as well as to reduce carbon emissions and improve the local environment.

The ‘Indore Foundry Cluster’ located in Indore, Dewas, Ujjain and Pitampur (Madhya Pradesh) is one of the selected cluster under the project, wherein the units are being supported to adopt energy efficient and renewable energy technologies and practices. Institute of Indian Foundrymen (IIF), Indore Chapter is the cluster level project partner association which has collaborated to carry out the activities in the cluster.

1.2 Brief about the cluster and production process

Indore is one of the biggest industrial cluster belts of Madhya Pradesh. Nearly 70 foundry units are located in the cluster, however only few major units are registered with IIF, Indore Chapter. The key products manufactured by these units include Cast Iron (CI) castings, Spheroidal Graphite (SG) Iron castings, Investment casting and Sand castings. Most of these units have got local customer base which includes companies like Kirloskar Brothers, Jash Engineering, Avtech Ltd., Tata International, and BHEL Bhopal. The key sources of energy used in the cluster include electricity, kerosene oil, furnace oil and coke. Two types of production processes are mainly observed in the cluster, investment casting and sand casting.

1.2.1 Investment Casting Process

The scrap material to be poured in the shells is melted in electrical induction furnace. Scrap material is heated to around 1000 - 1100 °C after which molten metal composition is analyzed using spectrometer and accordingly, if required, correction is made to bring required composition of molten metal. The molten metal from induction furnace is poured in preheated shells and left for natural cooling. The castings are then processed through series of operations including fettling, grinding, and shot blasting. Finally, the finished metal products are passed through heat treatment to improve mechanical strength. Typical process of green sand casting is depicted in Figure 1.1.

1.2.2 Green Sand Casting

The simple process of casting involves pouring molten metal into moulds, with cores used to create hollow internal sections. After the metal has cooled sufficiently, the casting is separated from the mould and undergoes cleaning and finishing techniques as appropriate. Typical process of green sand casting is depicted in Figure 1.2. The main purpose of using core in casting and moulding processes is to produce internal cavities and re-entrant angles.

These cores are made of disposable material and are finally destroyed to get it out of the piece. The key steps followed in the core preparation process include core preparation, core dressing and core inspection. In moulding process, sand moulds are prepared to receive molten metal. This process usually involves: (i) preparing the consolidated sand mould around a pattern held within a supporting metal frame, (ii) removing the pattern to leave the mould cavity with cores. Moulding sand is used in the process received from knock out section after going through cooling and mixing operation. The sand received from knock out section is supplied to sand cooler through belt conveyors where it is cooled in a rotating drum and sent to hopper. From hopper, sand is sent to mixer to mix it with binding agents to attain the desired properties of the moulds and is finally sent for moulding operation using belt conveyers.

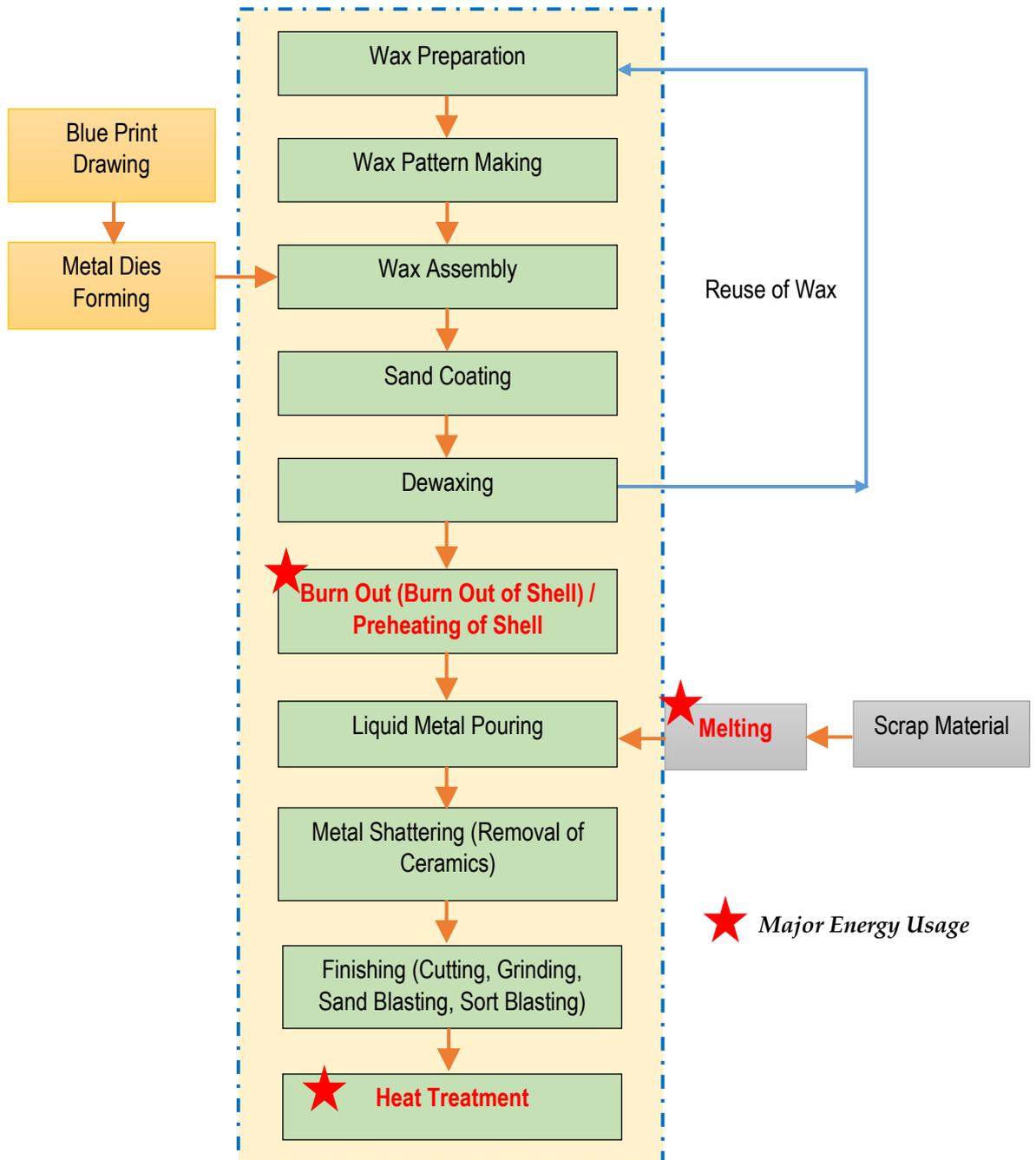


Figure 1.1: Process flow diagram for investment castings

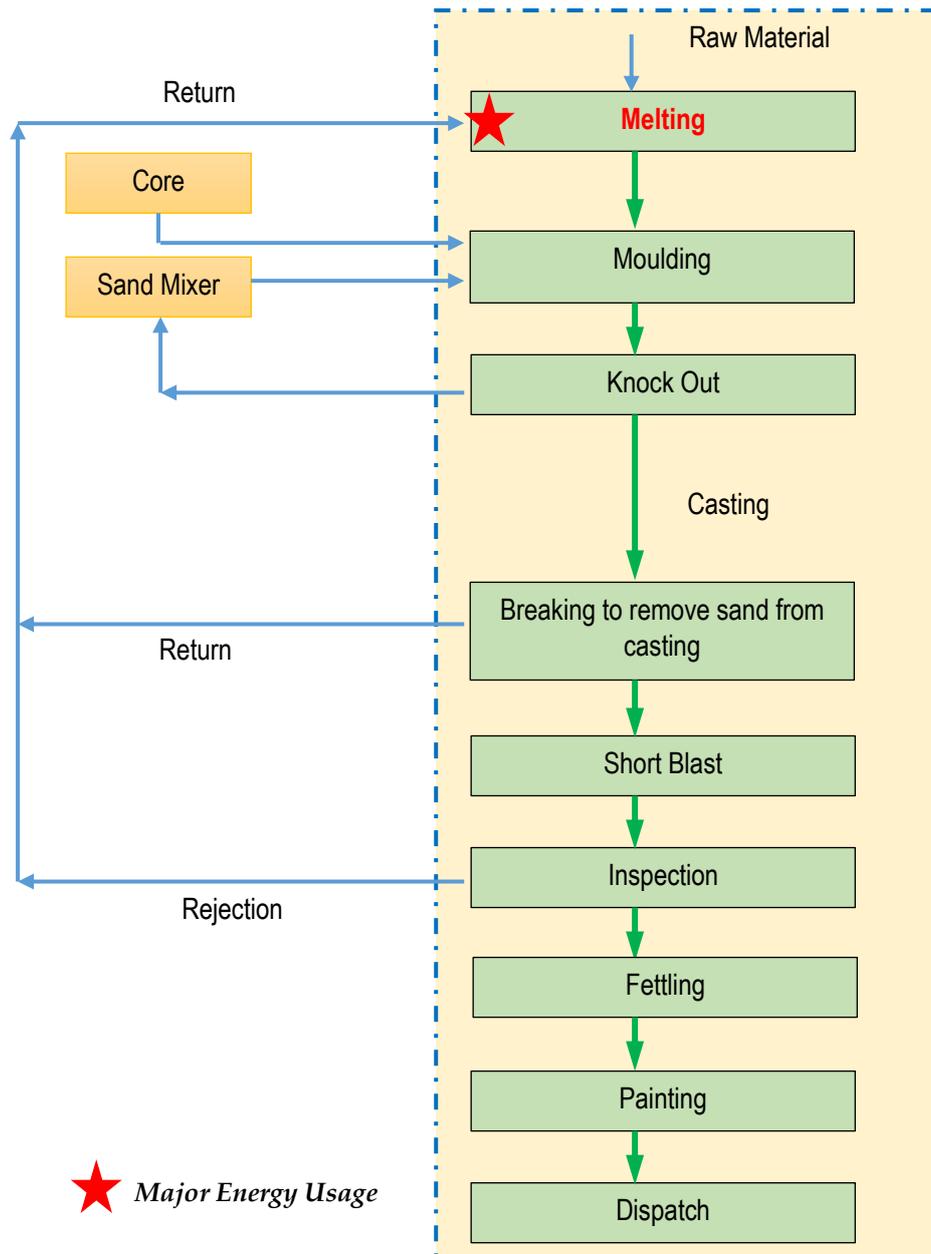


Figure 1.2: *Process flow diagram for green sand castings*

In parallel, scrap material is melted in electrical induction furnace or cupola furnace. The molten metal from furnace is poured into moulds using ladle and is left for natural cooling. Further, these moulds containing solid metal are broken and sand is separated from the casting. These castings are processed through series of operations including fettling, shot blast, grinding and painting and are finally dispatched after due inspection.

CHAPTER 2: Best Operating Practices - Induction Furnace

2.1 Introduction

An induction furnace is an electrical furnace in which the heat is applied by induction heating of metal. Induction furnace capacities range from less than one kilogram to one hundred tonnes. Induction furnaces are ideal for melting and alloying a wide variety of metals with minimum melt loss. Induction furnaces are used in most modern foundries as a cleaner method of melting metals than a reverberatory furnace or a cupola.



Figure 2.1: *Induction melting furnace*

2.2 Operating principle

An induction furnace consists of a nonconductive crucible holding the charge of metal to be melted, surrounded by a coil of copper wire. A powerful alternating current flows through the wire. The coil creates a rapidly reversing magnetic field that penetrates the metal. The magnetic field induces eddy currents, circular electric currents, inside the metal, by electromagnetic induction. The eddy currents, flowing through the electrical resistance of the bulk metal, heat it by Joule heating.

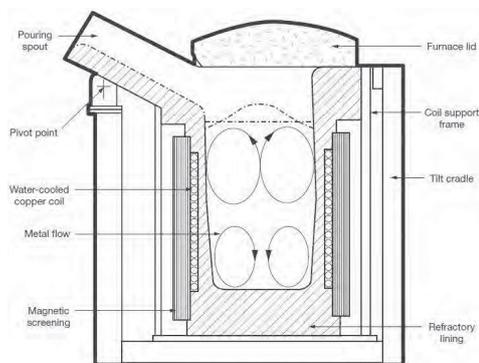


Figure 2.2: *Parts of induction furnace*

In ferromagnetic materials like iron, the material may also be heated by magnetic hysteresis, the reversal of the molecular magnetic dipoles in the metal. Once melted, the eddy currents cause vigorous stirring of the melt, assuring good mixing. An advantage of induction heating is that the heat is generated within the furnace's charge itself rather than applied by burning fuel or other external heat source.

2.3 Types of induction furnace

There are two main types of induction furnace: channel and coreless. The channel-type induction furnace consists of a refractory lined furnace body made of steel to which one or several channel-type inductors are flanged for heating the metal. Due to effects like thermal conductivity and buoyancy of the hot melt, in most cases the channel-type inductor is flanged at the bottom of the channel type furnace body. These furnaces are preferred for holding and casting of copper and copper alloys, as the copper is sensitive to oxygen pick-up from the air at a turbulent surface. Channel-type furnaces offer a smooth bath surface, but still provide a

sufficient turbulence inside the melt to mix it and ensure uniform chemical composition and temperature.

The coreless induction furnace has essentially replaced the crucible furnace, especially for melting of high melting point alloys. The coreless induction furnace is commonly used to melt all grades of steels and irons as well as many non-ferrous alloys. A modern coreless induction furnace can melt a tonne of iron and raise the temperature of the liquid metal to 1450°C using less than 600 kWh of electricity. Typically, Specific Energy Consumption (SEC) of coreless induction furnace varies from 500 to 800 kWh per tonne depending on type and grade of casting.

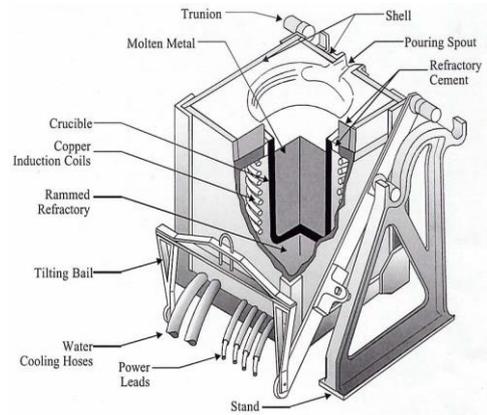


Figure 2.3: Coreless induction furnace

2.4 Best operating practices for induction furnace

Operating efficiency of an induction furnace involves preparation with right mix of raw material, charging of stock, melting, and pouring of mould.

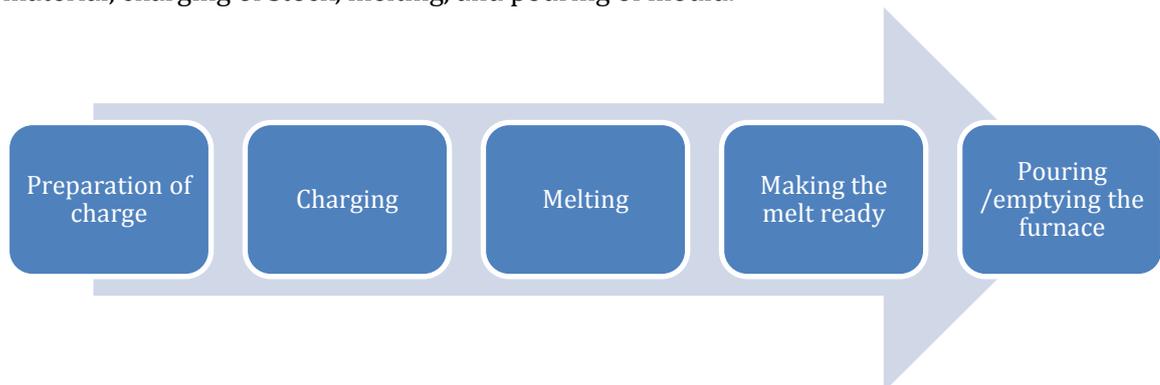


Figure 2.4: Induction furnace process

Best operating practices corresponding to different process involved in induction furnace has been described in sections below:

➤ BOP 1: Furnace lining preparation

Furnace lining plays an important role in overall performance of an induction furnace. In typical furnace, due consideration to the selection and maintenance of lining material is not given. The key areas for selection and maintenance of furnace lining are:

- ▶ Install linings as prescribed by the furnace manufacture to get optimum result for energy consumption.



Figure 2.5: Induction furnace working lining

- ▶ Selection of appropriate lining material, thickness and its sintering plays important role in energy saving.
- ▶ Thick lining reduces furnace crucible volume and hence the molten metal output; resulting high specific energy consumption.
- ▶ Thin lining, though it improves the power density, promotes heat loss from the side walls. Lining material with high thermal conductivity causes more heat loss.
- ▶ Lining material with long sintering cycle time consumes much energy for the first heat to get ready.
- ▶ Improper lining causes pre-mature failure.

➤ BOP 2: Preparation of raw material

Energy consumption pattern for induction furnace depends significantly on the nature and quality of scrap (raw material) charged into the furnace. Charging of scrap should be done only after proper segregation and preparation.

- ▶ Weigh and arrange the raw material on melt floor near to furnace before starting the melting.
- ▶ Charge must be free from sand, dirt and oil/grease. Rusty scrap not only takes more time to melt but also contains less metal per charging.
- ▶ The foundry return i.e. runner and risers must be turn blasted or shot blasted to remove the sand adhering to it. Typically runner and risers consists of 2 to 5 % sand by weight.
- ▶ Keep exact weight of alloys ready before charging, as alloys are very expensive. Proper handling will not only reduce wastage but also reduce time lost in alloying.
- ▶ The maximum size of single piece of metal/scrap should not be more than $\frac{1}{3}$ rd of diameter of furnace crucible.
- ▶ There should be no or less sharp edges, particularly in case of heavy and bulky scrap, as this may damage the refractory.

➤ BOP 3: Scrap charging

Subsequent to the preparation of raw material, next step involves charging of scrap into the furnace. Melting efficiency of an induction furnace depends predominantly of the charging process.

- ▶ Size of scrap is an important parameter to reduce energy consumption. The scrap charge should be as dense as possible. Lesser the air pocket between scrap pieces, more is the power density, higher the heat conductivity, faster melting with least energy consumption. Use small pieces of scrap, to the extent possible, to get optimum result.
- ▶ Scrap weighing in every heat to maintain charge mix proportion is required, for consistency in quality as well as energy consumption.
- ▶ Higher slag generation takes away more time for removal and decreases furnace utilization. Slag should be removed quickly.

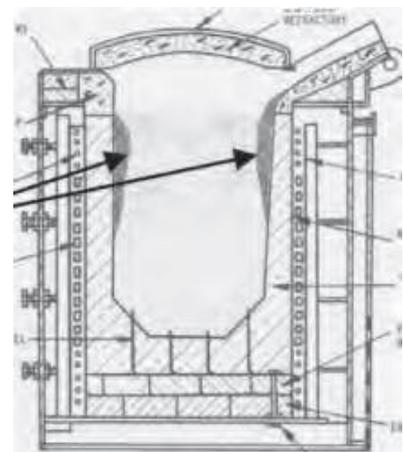


Figure 2.6: *Slag build-up near crucible neck*

- ▶ Scrap should be charged continuously as the melting proceeds as continuous charging helps in preheating the scrap.
- ▶ Avoid charging of furnace beyond the coil level, i.e. charging the furnace to its capacity.
- ▶ Proper charge sequence must be followed. Bigger size metal should be charged first, followed by smaller size and gaps must be filled by turnings and boring.
- ▶ Avoid introduction of wet or damp metal in melt, this may cause explosion.

➤ BOP 4: Power input

The power input provided for running an induction furnace during its melting operation has an important role on the overall energy consumption of the unit.

- ▶ Run furnace at maximum power since beginning. Maximum power input increases rate of melting and hence reduces cycle time of the heat.
- ▶ Power factor to be maintained near to one.
- ▶ Ensure no voltage drop from the source.

➤ BOP 5: De-slagging and sampling

Formation of slag in the furnace wall should be avoided as it leads to increase in energy consumption and decrease furnace life.

- ▶ Carry out de-slagging once the furnace is full with molten metal and has attained temperature of 1350 -1400 °C . Prior to it, slag removing tools should be brought near to the furnace and kept ready.
- ▶ Avoid slag deposition on lining by complete removal of slag. After de-slagging, sample should be taken and sent to chemical laboratory. Use of Carbon equivalent instrument gives faster estimation of bath composition hence shortens the heat time.

➤ BOP 6: Avoiding unnecessary superheating of bath

Determining the correct tap temperature plays a significant role in energy consumption. Unnecessary superheating of metal bath at times has detrimental impact on the furnace performance.

- ▶ Decide superheating temperature based on final pouring temperature of a component and temperature loss during transfer of metal to pouring zone. Avoid unnecessary superheating of metal.
- ▶ Measure and monitor metal bath temperature in every heat.



Figure 2.7: *Overflowing of induction furnace crucible*

➤ BOP 7: Maximize equipment utilization

Furnace should be utilized to its optimum level for better output. Operating practices for optimizing furnace efficiency are:

- ▶ Maintain short and optimum holding times for molten metal.
- ▶ Maintain short and optimum charging time in the furnace. Avoid manual charging to the extent possible as it can be a long, tedious and dangerous process. In addition, with manual charging, it is difficult to keep pace with full power melting and power has to be throttled back. Long charging time means low equipment utilization.
- ▶ Avoid overfilling of the furnace i.e. charging materials above the upper melt line.

- ▶ Never allow melting of bath when there are cold charge materials still to be added to the furnace. This increases the risk of wet or damp charge materials causing eruptions from the furnace when moisture comes in contact with the molten metal.

➤ **BOP 8: Maintaining buffer stock**

Due to product mix of light and heavy castings, situation arises when rate of melting is more than the rate of consumption. In such situation there are chances of metal held up in furnace causing wastage of energy.

- ▶ Use a holding furnace as buffer stock in between melting and pouring to avoid situation when rate of metal consumption is less than the rate of metal generation. Holding of metal also helps in consistency of metal chemistry and temperature through homogenization of metal with some variation coming from melting furnace.

➤ **BOP 9: Production scheduling**

Equipment efficiency can be optimized by a well-laid production schedule. Equalizing of loads between shifts plays an important role in reduction of energy consumption.

- ▶ Maintain appropriate production plan for equalizing the metal load in all shifts.
- ▶ Maintain production planning such that the rate of metal consumption is higher than the rate of metal generation.
- ▶ Optimize the peak output power of the melt power supply, saving money on demand charges.
- ▶ It is suggested to melt fewer days per week and more hours per day, if practical. This alternative will save on energy charges as less time will be spent on holding molten metal in the furnace at that temperature. It also will increase refractory life of the furnace.

➤ **BOP 10: Preventive maintenance**

Increasing equipment availability should be prioritized with an aim to reduce system breakdown and production downtime.

- ▶ Develop and maintain a well-defined Preventive Maintenance (PM) schedule with frequency for the furnace and all auxiliary equipment.
- ▶ Periodic infrared scans of all equipment to be done to eliminate hot spots in the furnace assembly, the power supply, interconnecting bus bar, water-cooled leads etc.
- ▶ It is suggested to have proper maintenance checks for the water-cooled leads. A furnace's water-cooled leads can produce unnecessary electrical losses if they are not properly maintained or configured. If they are old and have gone through many cycles of furnace tilting, there may be broken cables inside the leads that cannot be seen, but cause higher resistance in the lead and higher electrical losses. Leads should be tied together and polarized. Leads that are allowed to split apart from each other will have higher electrical losses than those that are bundled together properly.

➤ **BOP 11: Streamline temperature measurement and sampling**

Sampling and checks should be built in the system for adapting best operating practices.

- ▶ Temperature checks also can be time consuming and costly, particularly if the operator frequently undershoots or overshoots target temperatures and must make adjustments and take additional readings. Computerized melt control systems helps in getting the desired temperature.

- ▶ Another way to reduce energy consumption in the furnace is to pour at the coolest temperature that is practical and avoid temperature overshooting.

➔ **BOP 12: Manpower effectiveness**

Although a significant improvement can be achieved through increase in the equipment efficiency, manpower involvement and its effectiveness plays an important role in the overall efficiency of the system.

- ▶ Manpower plays very important role in melting operation. Due to comparatively hotter area of work, it might happen that the process is not followed sequentially and timely, which affects the output of the furnace adversely.
- ▶ Motivate manpower on a continuous basis to improve manpower effectiveness. Change of working area or rotation can help to achieve the best performance with maximum output.
- ▶ Training and re-training on energy saving techniques, getting maximum output from furnace is required.

2.5 Do’s and Don’ts in induction melting furnace

The Table 2.1 below summarizes the do’s and don’ts for efficient operation of induction furnace in a foundry unit:

Table 2.1: *Summary of operating tips in induction melting furnace*

Do’s	Don’ts
<ul style="list-style-type: none"> • Keep the size of charging material to about one-third of the furnace crucible size. 	<ul style="list-style-type: none"> • Don’t superheat the metal.
<ul style="list-style-type: none"> • Operate the furnace at full power and full capacity. Go for maximum compaction of material while charging. 	<ul style="list-style-type: none"> • Don’t hold the material in the furnace. It consumes power without increase in production.
<ul style="list-style-type: none"> • Keep the cycle time as short as possible by proper housekeeping 	<ul style="list-style-type: none"> • Don’t uncover the furnace unnecessarily.
<ul style="list-style-type: none"> • Maintain minimum holding periods for melt. Separate holding furnaces can sometimes be useful. 	<ul style="list-style-type: none"> • Avoid long tapping time and frequency to reduce radiation losses and to reduce operation at low power levels.
<ul style="list-style-type: none"> • Pre-heat ladle for energy saving. Well insulated ladles are also necessary. 	<ul style="list-style-type: none"> • Avoid long charging time and frequency

CHAPTER 3: Best Operating Practices – Cupola Furnace

3.1 Introduction

Cupola, which is the most commonly used melting furnace in the Indian foundries, is also the most energy intensive operation. It accounts for up to 50% of a foundry's total energy consumption and is a prime candidate to focus attention for improving end use energy efficiency in a foundry. The cupola can be made almost any practical size. The size of a cupola is expressed in diameters and can range from 1.5 to 13 feet (0.5 to 4.0 m). The overall shape is cylindrical and the equipment is arranged vertically, usually supported by four legs. The overall look is similar to a large smokestack.

3.2 Operating principle

Based on its principle, the cupola furnace is a shaft melting furnace, it is filled with fuel (coke), metal charge (pig iron, circulation material, scrap steel) and slag-forming additives (limestone) from the top. In the bottom part of the furnace, combustion air (blast) compacted by a blower is fed into the furnace shaft by nozzles. During this process, the counter flow principle is used to transfer heat from the combustion gases to the charge until it is melted. Thus, the required energy is generated in the cupola itself, i.e. without any transfer, and it is used at the site of generation. The quality of the fuel and the combustion process itself must be reproducible since all fluctuations have an impact on the melting process.

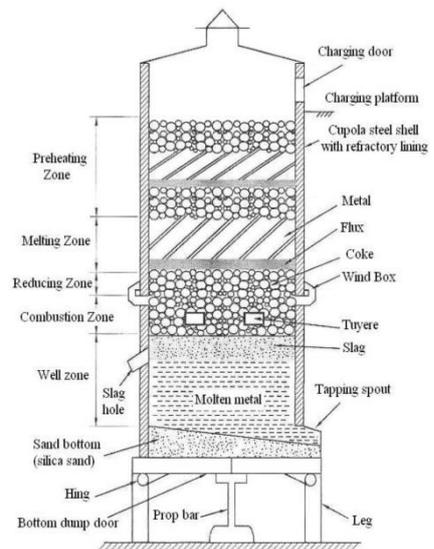


Figure 3.1: *Cupola furnace*

Preparing the hearth bottom with layers of coke is the first step in the operation cycle of a Cupola. Wood is used for initial ignition to start the coke burning. Subsequently, air is introduced through the ports in the sides called tuyeres. Once the coke bed is ignited and of the required height, alternate layers of metal, flux and coke are added until the level reaches the charging doors. The metal charge would typically consist of pig iron, scrap steel and domestic returns. The air reacts chemically with the carbonaceous fuel thus producing heat of combustion. Soon after the blast is turned on, molten metal collects on the hearth bottom where it eventually tapped out into a waiting ladle or receiver. As the metal is melted and fuel consumed, additional charges are added to maintain a level at the charging door and provide a continuous supply of molten iron. Then charging is stopped but the air blast is maintained until all of the metal is melted and tapped off. The air is then turned off and the bottom doors are opened allowing the residual charge material to be dumped.

Poorly designed cupolas lead to high consumption of coke resulting in increased input costs of melting. A divided blast cupola (DBC) reduces carbon monoxide (CO) formation by introducing a secondary air blast at the level of the reduction zone. Thus the DBC has two

rows of tuyeres with the upper row located at around 1m above lower row. Dividing the blast air has benefits in terms of energy savings. However, to realize the full benefits of energy efficiency, optimal design of the divided blast system is crucial. The coke consumption in the DBC is reduced by almost 35%. It increases tapping temperature by about 50 °C and the melting rate is also increased.

3.3 Best operating practices for cupola furnace

➤ BOP 1: Cupola base

The base of the cupola plays a significant role in proper functioning of the cupola and flow of hot metal from the cupola. Following points should be considered while making the base of the cupola:

- ▶ Ensure that the bottom sand is free from impurities, iron, etc., and that it has the proper moisture and clay content.
- ▶ The bottom should be dense, correctly rammed, heeled up around the wall and sloping towards the tap hole.

➤ BOP 2: Preparation of coke bed

The most important part in the successful operation of a cupola is the preparation of the coke bed. The initial height of the bed above the tuyeres and the degree to which it is burned before the charging commences are vital factors governing, to a large extent, the metal temperature and melting rates obtained during the early part of the melt. Following are main steps that needs to be followed:

- ▶ Prepare sand bed on the bottom of furnace and ram it properly to provide sufficient strength.
- ▶ Clean the vent holes on the damper plates.
- ▶ Place the required fire-wood on the sand bed. Large pieces of wood should be avoided as this may prevent subsequent installments of coke to consolidate easily. Be careful that sand bed is not damaged while placing fire-wood.
- ▶ Select and weigh the bed coke carefully every day
- ▶ Add 25% of the total bed coke on the fire wood.
- ▶ Place kindling wood or torches properly to ensure even lighting
- ▶ During the ignition of the bed, tuyere cover should be kept open
- ▶ Add second installment (i.e. 25%) of coke, when the ignition is found to be satisfactory.
- ▶ Similarly add on the third installment of coke.
- ▶ Close the tuyere covers and blow off air for few seconds from blower.
- ▶ Make sure that there is no hanging of coke in the cupola bed. Poke through the tuyeres, if required.
- ▶ With natural air, ignition time takes around 2 – 2 ½ hours. However to expedite ignition a small (portable) blower may be used. Normally this is necessary in rainy season when wood and coke contain more moisture.
- ▶ Add the last installment of bed coke and check the final bed coke height.



Figure 3.2: *Coke bed preparation*

- ▶ After coke is satisfactorily ignited, close the upper tuyere covers. Keep the lower tuyere covers open. Tap hole and slag hole should also be kept open. Fettle door also to be kept open. Place guards in front of tap hole and slag hole to arrest shooting spark and coke pieces causing injury to people.
- ▶ Start the blower and blow off the ash for ½ minute strictly. This exercise cleans the furnace as well helps coke consolidation.
- ▶ After blow-off, open the tuyere covers. Close the breast door securely. Keeping lower tuyeres (air flow) open blow for another 2 minutes to ignite the coke fully. Shut blower, open tuyeres.
- ▶ Measure the bed height with a calibrated rod/gauge. If needed, add green coke to bring the height to the required level.
- ▶ The remaining last split of coke (kept for bed) has to be put in before measuring the bed-height.
- ▶ Record all coke bed data.

➤ BOP 3: Charging

Once the charge bed is prepared, next step involves charging of feed into the furnace. The furnace feed composition and quality plays an important role in energy consumption in the furnace. Following steps should be followed:

- ▶ Add the limestone above the bed coke and start charging of cupola.
- ▶ Before start of metallic charges, flux has to be charged on the bed.
- ▶ The flux (lime stone in most case) size should be $\frac{3}{4}$ – 2 inch for small cupolas.
- ▶ Clean charge should be fed into the furnace
- ▶ The acid insoluble content in flux stone should not exceed 5% of its total weight
- ▶ The diagonal dimension of a single piece of metal should be less than $\frac{1}{3}$ rd of the hearth diameter to ensure that the cupola operates efficiently
- ▶ The weight of a single piece of metal should be limited to 1% of the hourly melting rate.
- ▶ Heavy (thick) sections of scrap should be avoided in first 5 charges.
- ▶ The quality of purchased scrap should meet the specifications of the product to be manufactured
- ▶ The charging sequence of the metal must be maintained
- ▶ When the stack is full, close the tuyere covers and start the blower. The stack should always be full with charge material during the operations.
- ▶ Once charging starts, it has to be continued till, (i) the cupola shaft is filled up with the charging material, (ii) the cupola is lit up, and (iii) the blower and tuyeres are switched on
- ▶ To achieve initial tap temperatures, use light scrap for filling up.



Figure 3.3: Ignition of coke bed



Figure 3.4: Charging of cupola

- ▶ The tuyeres should be kept clear from the slag deposition at all times.
- ▶ Ensure that the cupola is full before turning on the blast.

➤ BOP 4: Melting

Melting commences once charging of feed is complete and after ensuring the cupola is full.

Following steps should be followed for efficient melting:

- ▶ Establish the proper initial blast rate and maintain it right through to tap-out.
- ▶ Dry and thoroughly pre-heat all runners and ladles daily.
- ▶ Use only dry inoculants. If the alloy is wet, proper inoculation will not take place leading to pinholes or other defects.
- ▶ Black top gas suggests that the blower motor is blocked or greasy scraps have been used in the charge.
- ▶ If the stack discharge appears reddish, the reasons could be:
 - Oxidizing conditions on account of low bed or high blast
 - Excessive amount of rust in the charge material
 - Scaffolding or hanging of charge
- ▶ Strong flame and high temperature at the charge door indicates a high bed and excessive coke splits between charges, or low stack height in the cupola.
- ▶ A blue-pink flame moving up and down the walls and clinging to projections indicates good melting conditions.
- ▶ During melting, burn-back occurs above the tuyeres in the melting zone. The following factors contribute to burn-back:
 - Low temperature of the melting zone
 - High blast rate
 - Incorrect tuyere dimensions
 - Uneven charge distribution.
- ▶ The melting rate of a cupola using low ash (< 14%) should be about 10 tonnes/hr/m² and for cupola using high ash coke (> 30%) should be about 7 tonnes/hr/m². If the melting rate is lower, check the parameters of cupola blower.

➤ BOP 5: Cupola operation

Cupola operation plays a significant role in energy consumption and overall efficiency of the furnace. Some useful guidelines for efficient operation of a cupola are:

- ▶ Close tuyere covers, plug tap hole and slag hole. Allow some time for the feed material to absorb heat. This is called soaking time. Generally 10 minutes is sufficient.
- ▶ Switch on blower and note time.
- ▶ Look for droplets of molten metal through the tuyere peep-hole and note time. Droplets should be visible approximately after 7 – 10 minutes of starting the blower.
- ▶ After blow on, first tapping can be made approximately within 15 – 20 minutes. If the tap – hole gets jammed due to cold metal or any other reason, do not attempt to open it by hammer. Put some lighted cotton waste and charcoal at the tap-hole and apply oxygen with a lancing tube (M.S. pipe of 2 mm bore diameter) at regulated pressure.
- ▶ Oxygen cylinder (kept for lancing) must have a regulator fitted on. Pneumatic pipe used for this purpose must match (bore) with the lancing pipe. No leak should be there.
- ▶ The oxygen will melt the solidified metal at the tap-hole.

- ▶ In intermittent tapped cupolas, the slag hole should be opened after $\frac{2}{3}$ rd tapping.
- ▶ Note down slag conditions i.e. fluidity/viscous or fluid. Ideal colour should be bottle green.
- ▶ Constant vigil should be kept to ensure that at no time charge stack level falls. If due to any reason this happens; shut off the blower, open tuyere covers, fill up the stack, close tuyere covers and start blower.
- ▶ Maintain proper sequence of charging. Bridging or hanging inside the cupola should be taken care of immediately. Fall in stack level, bridging or hanging affects quality and chemistry of molten metal.
- ▶ Maintain a log-book recording every detail for every heat. Some of the important parameters (apart from the weight of each charge) that must be recorded in the sheet are bed height, weight of bed coke (this may vary with the bulk density), bed light-up time, time taken for coke ignition, time taken and number of charges to fill up the stack at the beginning, blower on time, any interruption during melting, its cause, end time of melt i.e. blower off, last tapping, drain out, bottom door opened and bed dropped. All timings must be meticulously recorded.

➤ BOP 6: Cupola blower

The blast rate and pressure have an important influence on cupola performance. Blower rating should be determined from manufacturers' recommendation and should be ideally 15%-20% more than the optimum blast rate, to account for air losses in the pipeline. Do not overblow the cupola.

- ▶ Blast Rate: A higher blast rate increases oxidation loss of iron and other elements like silicon and manganese. A lower blast air leads to lower metal temperature, slower melting and higher coke consumption.
- ▶ Blast Pressure: Proper blast pressure is required to penetrate the coke bed. Incorrect air penetration adversely affects the temperature, carbon pick-up and the melting rate of the cupola.



Figure 3.5: Cupola blower

➤ BOP 7: Maintaining stack height and well capacity

- ▶ Inadequate stack height leads to lower heat exchange and higher coke consumption. Consider increasing stack height of the cupola if the same is inadequate. A stack height between 16 ft to 22 ft (depending upon its diameter) is necessary for heat exchange.
- ▶ Do not increase well capacity more than what is desired. Every inch increase in the well depth reduces molten metal temperature by 4 °C. For intermittently tapped cupola, the well capacity should match the capacity of the ladle. For continuously tapped cupola, a minimum well depth, ideally of 300 mm is usually sufficient.

➤ BOP 8: Optimum refractory lining

- ▶ Use IS 8 grade fire bricks for lining the cupola. For double brick lined cupola, IS 6 grade bricks can be used in the rear side towards cupola shell. Do not use cracked and corner chipped bricks in the melting zone. Store the fire bricks in a shed to keep them dry.
- ▶ Fire clay should be soaked for at least 48 hours before use. This is required to develop its plasticity and adhesive quality required for joining bricks. Provide proper tools, such as hammer, trowel (or karni), mallet etc. to operators. Make diameter gauge for the tap-hole. Provide a lighting arrangement inside the cupola during repair. Bricks should be set 15-20 mm away from the Cupola shell. Pack this gap with dry foundry sand. Mortar applied on the bricks should not be of thick layer. It should be just enough so that the brick sets firmly on to the other. Excess spilled mortar to be wiped off. Excess or thick layer of mortar are weak points through which molten metal can penetrate to the shell causing hot spots on the shell. 20-25 mm thick layer of ganister over the newly lined bricks is advisable.
- ▶ Cupola must be properly lined/ repaired after each melt. Correct internal diameter (ID) needs to be maintained.
- ▶ Patching material can be used to repair the refractory lining if erosion/burn-back is less than 3 inch (75 mm).

➤ BOP 9: Tapping and slagging

The slag produces from an efficient cupola operation should have higher fluidity with bottle green color. If the slag does not have satisfactory properties, the following corrective steps can be taken:

- ▶ If the slag is black or dark in color, it indicates oxidation of metal due to excess air. Reduce air by operating the valve in wind pipe.
- ▶ If the color of slag is pale green, it indicates high basicity of the slag. Reduce lime stone or soda ash. Such a slag is extremely fluid and light in weight.
- ▶ If the color of slag is dark green, increase lime stone and soda ash. Such a slag is vicious, sticky and lumpy. It does not flow smoothly.
- ▶ If the flow of slag is not smooth, it indicates disorder and choking of bed coke. Bed coke should be made free by poking through tuyeres.



Figure 3.6: *Cupola Slag*

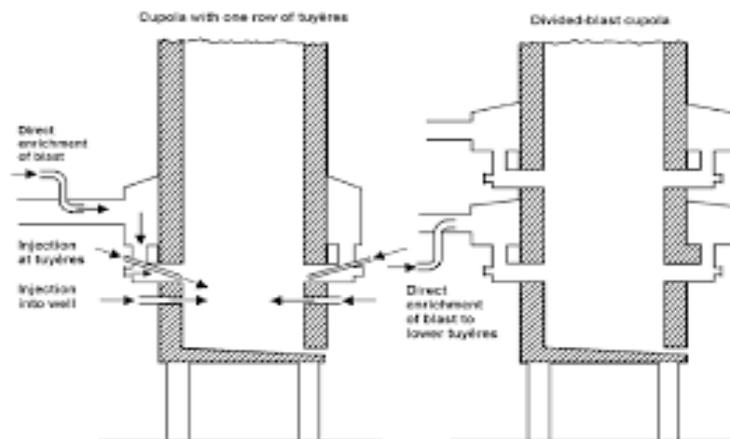
➤ BOP 10: Advanced technology

- ▶ With advances in melting practices, the conventional cupola has given way to the improved and more efficient Divided Blast Cupola (DBC). Table 3.1 below presents the advantages of a DBC over conventional cupolas.

Table 3.1: *Advantage of DBC over conventional cupola*

Saving in Coke	7 - 10%
Saving in Refractories	20%
Si and Mn loss	5% as compared to 15% in a conventional cupola
Carbon gain	20% better than conventional cupola.
Rise in metal temperature	30°C
Reduction in pollution	30%
Cupola operation	Operator friendly with no pocking of tuyeres required
Inclined tuyeres	Incline at 7.5° downwards to yield better performance in the combustion of coke

- ▶ Another advanced technology used in cupola operation is oxygen enrichment of the cupola. The enrichment quantity usually required is around 2 - 4% of the air blast. Following advantages are achieved over the conventional cupola operation.
 - Carbon pick-up is higher
 - Molten metal temperatures are higher by about 300 °C

Figure 3.7: *Conventional vis-a-vis divided blast cupola*

➤ BOP 11: Cupola shutdown procedure

- ▶ If the cupola has two levels of tuyeres – after the last charge, air from the top tuyere is to be reduced and air increased in the lower level. This can be done by use of blast control valves.
- ▶ Turn off the blower after tapping last ladle of molten metal.
- ▶ Open all the tuyere covers
- ▶ Remove props and open bottom drop door. There should not be any water collected in the drop area.
- ▶ Add on water on the drop material so as to recover the burnt coke for the next heat.

3.4 Do's and Don'ts in cupola furnace operations

The performance indicators which helps to predict the behavior of cupola furnace depends on the following factors:

- ▶ Flue Gas Analysis (O₂, CO and Temperature): Lower concentration of O₂ (<4%), CO (>1%) and temperature (>150-200 °C) indicates incomplete combustion

- ▶ Metal-Coke ratio: Higher the metal coke ratio (10:1 to 12:1), better is the combustion efficiency.
- ▶ Melting Cost: Lower melting cost (less than Rs 3/kg) indicates better combustion efficiency
- ▶ Fluidity of molten metal: High fluidity indicates better operation of cupola
- ▶ Color of slag: Bottle green color of slag indicates efficient cupola operation

The common do's and don'ts related to the operation of a cupola are summarized in table 3.2 below:

Table 3.2: *Summary of efficient operation of a cupola*

Do's	Don'ts
The bottom sand of the cupola should be free from iron particles and it should have proper moisture and clay content.	Do not hold the molten metal inside the cupola for longer period of time. It consumes energy as well as changes the metallurgical properties of melt
Measure the bed coke height with a calibrated gauge and add fresh coke to bring the height to the required level, if needed.	Blower should not be purchased from the local fabricators
Left over coke of the bed coke should be utilized in the next heat for its optimum utilization	Once charging starts, do not stop until the cupola shaft is filled with charging material
Pre heat all runners and ladles thoroughly	Charge size should not be large
The raw material should be stored under cover, organized in individual days	Do not charge very heavy raw material pieces (> 75 mm thick) in the cupola
Maximum weight of any single piece should be 1/10 th of the total weight of the charge	Large, heavy and sharp pieces of metal should not be used.
Instrumentation such as volume meter and manometer should be provided to optimize the blast volume and pressure	The cupola should not run immediately after the erection of new lining.

3.5 Problems and solutions

The common troubleshooting in the operation of cupola with suggested remedies is provided in the table 3.3 below:

Table 3.3: *Problems and solutions in operation of cupola*

SN	Problems	Causes	Remedies
1.	High CO concentration in flue gas (>1%)	<ul style="list-style-type: none"> • Less air supply • Heavy charge size • Small coke size used in bed coke preparation • Mixing of all charge materials in single bucket. 	<ul style="list-style-type: none"> • Optimize the blast volume and pressure • Charge size should vary according to the size of the furnace • All the charge materials should be fed separately
2.	High temperature of flue gas	<ul style="list-style-type: none"> • Lesser effective height. • Improper bed coke height • Lesser charge density. 	<ul style="list-style-type: none"> • Increase the effective height of cupola • Bed coke height should be as per design criteria • Avoid large size scrap especially CI pipes

SN	Problems	Causes	Remedies
3.	Low Metal Coke ratio	<ul style="list-style-type: none"> Unscientific design of cupola Utilization of poor quality of coke Improper blast volume and pressure 	<ul style="list-style-type: none"> Scientific design of cupola Utilization of good quality of coke Optimum blast volume and pressure
4.	Positive pressure at charging door	<ul style="list-style-type: none"> Unscientific design of cupola furnace 	<ul style="list-style-type: none"> Scientific design of cupola furnace
5.	Less life of refractory	<ul style="list-style-type: none"> High proportion of limestone in each charge Charging of sharp and large size material Improper lining thickness 	<ul style="list-style-type: none"> Addition of limestone depends upon the quality of charge materials Avoid sharp and large size charge materials Provide proper lining thickness
6.	Viscous Slag	<ul style="list-style-type: none"> Excess oxidation of iron 	<ul style="list-style-type: none"> Ensure that air blast is optimized to minimize oxidation
7.	Decreased tapping temperature and carbon pick up	<ul style="list-style-type: none"> High moisture content of coke High ash content of coke 	<ul style="list-style-type: none"> Ensure that coke ration and air blast are well adjusted Low ash content of coke to be used.

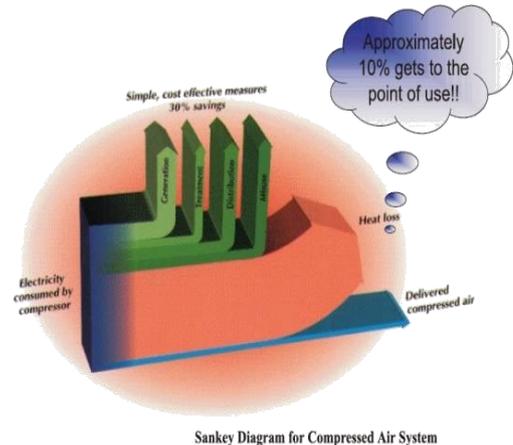
CHAPTER 4: Best Operating Practices - Compressed Air System

4.1 Introduction

Compressed air is a very useful and valuable utility, which must be managed to optimize overall system performance. In a foundry unit air compressors are used in the machine shop for pneumatic equipment and machine tools.

Air compression consumes a lot of energy. In a Compressor only 10 – 30% of input energy to the compressor reaches the point of end-use and the balance 90 – 70% of the input energy is wasted in the form of friction and heat loss.

Energy savings of up to 30% can be realized in a compressed air system by regular simple maintenance measures.



Sankey Diagram for Compressed Air System

Figure 4.1: *Sankey diagram of compressed air system*

4.2 Best operating practices for compressed air system

Some practices that will optimize air compression are listed below:

➤ BOP 1: Location of the compressor

The location of air compressors and the quality of air drawn by the compressors will have a significant influence on the amount of energy consumed. The following points should be taken into consideration while deciding the location of compressors or combined compressed air systems:

- ▶ Locate the compressor away from heat sources such as kilns, dryers and other items of equipment that radiate heat. The following table below shows the relative power savings that result from a decrease in intake air temperature.
- ▶ The compressor should be located such that it draws cool ambient air from outside because the temperature of the air inside the compressor room is high. While extending the air intake from the outside of the building, minimize excess pressure drop in the suction line by selecting a duct of large diameter with the smallest number of bends.
- ▶ The compressor should be placed where there is no particulate matter. Do not place the compressor near spray coating booths, sewing machines, the buffing section, etc.



Figure 4.2: *Compressed air system*

- ▶ Any moisture in the inlet air to the compressor will affect its performance adversely. The compressor should be placed away from equipment which may add moisture to the atmosphere, for example, rinsing lines, cooling towers, dryer exhaust, etc. If the compressed air is moist the components of the compressed air system will corrode. Also, the specific power consumption will increase.

➤ **BOP 2: Delivering air at the lowest practical pressure**

- ▶ Operating compressor at the minimum practical pressure at end uses, together with a corresponding reduction in compressor discharge pressure(s), will reduce the consumption of compressed air, the leakage rate, and the energy consumption.

➤ **BOP 3: Ensuring cool air intake**

- ▶ As a thumb rule, “Every 4^oC rise in inlet air temperature results in a higher energy consumption by 1% to achieve equivalent output”. Hence, cool air intake leads to a more efficient compression (see Table 4.1).

Table 4.1: *Effect of intake air temperature on power consumption*

Inlet Temperature (°C)	Relative Air Delivery (°C)	Power Saved (%)
10.0	102.0	+1.4
15.5	100.0	Nil
21.1	98.1	-1.3
26.6	96.3	-2.5
32.2	94.1	-4.0
37.7	92.8	-5.0
43.3	91.2	-5.8

- ▶ It is preferable to draw cool ambient air from outside, as the temperature of air inside the compressor room will be a few degrees higher than the ambient temperature. While extending air intake to the outside of building, care should be taken to minimize excess pressure drop in the suction line, by selecting a bigger diameter duct with minimum number of bends.

➤ **BOP 4: Ensuring dust free air intake**

- ▶ Dust in the suction air causes excessive wear of moving parts and results in malfunctioning of the valves due to abrasion. Suitable air filters should be provided at the suction side. Air filters should have high dust separation capacity, low-pressure drops and robust design to avoid frequent cleaning and replacement. See table 4.2 below for effect of pressure drop across air filter on power consumption.

Table 4.2: *Effect of pressure drop across inlet filter on power consumption*

Pressure drop across air filter (mm WC)	Increase in power consumption (%)
0	0
200	1.6
400	3.2
600	4.7
800	7.0

- ▶ Air filters should be selected based on the compressor type and installed as close to the compressor as possible. As a thumb rule “For every 250 mm WC pressure drop increase across at the suction path due to choked filters etc, the compressor power consumption increases by about 2 percent for the same output”
- ▶ Hence, it is advisable to clean inlet air filters at regular intervals to minimize pressure drops. Manometers or differential pressure gauges across filters may be provided for monitoring pressure drops so as to plan filter-cleaning schedules.

➤ **BOP 5: Use storage and automatic system controls to anticipate peak demands**

- ▶ Only the number of compressors required to meet the demand at any given time should be in operation and only one should be operated in a “trim” control mode. Automatic sequencing of compressors can optimize the selection of compressors for changing demand cycles

➤ **BOP 6: Identify leaks and repair them, beginning with the most significant**

It is common to find a leakage rate of 20 to 30 % in the compressed air system of an industrial plant. An aggressive and continuous program of leak detection and elimination can reduce consumption substantially.

- ▶ Avoid air leaks and associated energy losses.
- ▶ Conduct leakage tests regularly (once a month) to remove air leaks in the compressed air system.

Table 4.3 (a) below shows the loss in Free Air Delivery (FAD) through orifices of different sizes in a compressed air grid.

Table 4.3 (a): *Discharge of air (m³/min.) through orifice (Orifice constant CD = 1.0)*

Air Pressure (Bar)	Orifice size in mm						
	0.5	2	2	3	5	10	12.5
0.5	0.06	0.22	0.92	2.1	5.7	22.8	35.5
1.0	0.08	0.33	1.33	3.0	8.4	33.6	52.5
2.5	0.14	0.58	2.33	5.5	14.6	58.6	91.4
5.0	0.25	0.97	3.92	8.8	24.4	97.5	152.0
7.0	0.33	1.31	5.19	11.6	32.5	129.0	202.0

For leakage test in compressed air system, following table 4.3 (b) may be referred.

Table 4.3 (b): *Compressed air leakage trial format*

(DATE) / (DAY) : (dd/mm/yyyy) / (day)	
START TIME (hh:mm):	END TIME (hh:mm):
COMPRESSOR ID:	CAPACITY: CFM
PRESSURE SETING : Max - bar; Min - Bar	MOTOR: kW

S. NO.	ON TIME				OFF TIME			
	START TIME	END TIME	AMPERE	ON TIME (MINS)	START TIME	END TIME	AMPERE	OFF TIME (MINS)
(A)	(B)	(C)	(D)	(E) = (C) - (B)	(F)	(G)	(H)	(I) = (G) - (F)
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
		Average				Average		

Percentage Leakage Calculation:

Total Cycle Time = (E) + (I)

Percentage Leakage = { (E) X 100 } / { (E) + (I) }

Interpretation:

If percentage leakage is below 10% "Well Maintained System"

If percentage leakage is between 10 - 20% "Average Maintained System" - Requires leakage plugging

If percentage leakage is above 30% "Poorly Maintained System" - Requires immediate leakage plugging

NOTE :

1. Reading should be taken with ball valves at open position.

➤ **BOP 7: Make sure that compressed air is the best alternative for the application.**

- ▶ Although compressed air can be a very versatile utility, not all applications are best served by it. The cost of compressed air is often overlooked because of the convenience and ergonomic advantages it provides. Many of the productivity improvements in automated manufacturing processes have been achieved through the appropriate use of compressed air.
- ▶ Determine the minimum practical pressure required for the application and use a blower, rather than a compressor, if appropriate.

➤ **BOP 8: All parts of a process may not need air simultaneously.**

- ▶ Analyze the peak and average rates of flow to determine actual needs and whether local secondary storage may be advantageous

➤ **BOP 9: Turn off the compressed air supply at a process when it is not running.**

- ▶ Stopping the supply of compressed air to applications not in operation can reduce the consumption of compressed air. This can be accomplished very easily by means of a properly sized solenoid valve in the air supply to each application.

➤ **BOP 10: Determine the cost of compressed air for each machine or process.**

- ▶ Accurate measurements of air consumption and electrical power allow proper assessment and appreciation of the true cost of operation. This, in turn, can help in management and conservation of available resources.

➤ **BOP 11: Compressor lubrication**

- ▶ Use a synthetic lubricant if the compressor manufacturer permits it.
- ▶ Be sure lubricating oil temperature is neither too high (oil degradation and lowered viscosity) nor too low (condensation contamination).
- ▶ Change the oil filter regularly.
- ▶ Periodically inspect compressor intercoolers for proper functioning.

➤ **BOP 12: Minimize the pressure drop**

- ▶ Minimize the pressure drop in the line between the point of generation and the point of use. Excess pressure drop can result from the following:
 - ▶ Inadequate pipe size
 - ▶ Choked filter elements
 - ▶ Improperly sized couplings and hoses
 - ▶ All these lead to significant energy losses.

Table 4.4 below shows typical energy wastage on account of pressure drop created by smaller pipe

Table 4.4: *Typical energy wastage due to smaller pipe diameter for 170 m³/hr (100 cfm flow)*

Pipe Nominal Bore (mm)	Pressure drop (kg/ cm ²) per 100 meters of pipe length	Equivalent power losses (kW)
40	1.84	9.5
50	0.66	3.4
65	0.22	1.2
80	0.04	0.2
100	0.02	0.1

4.3 Do's and Don'ts in compressed air system

Table 4.5 below summarizes the general do's and don'ts for operation of compressor and compressed air system:

Table 4.5: *Summary of best operating practices for efficient operation of compressors in foundry units*

Do's	Don'ts
<ul style="list-style-type: none"> Try to locate the compressor suction pipe away from heat sources and moisture sources. 	<ul style="list-style-type: none"> Don't use valves to reduce the pressure in the compressed air grid because it wastes the energy that is consumed in building up the excess pressure. Compressed air pressure must be set at the point of generation.
<ul style="list-style-type: none"> Clean the air filters regularly for minimizing pressure drop. 	<ul style="list-style-type: none"> Don't leave compressed air leaks unattended. Conduct leakage test once in a month.
<ul style="list-style-type: none"> Use proper size of pipe for distribution of compressed air. 	<ul style="list-style-type: none"> Don't allow the compressors to run with loose or vibrating belts.
<ul style="list-style-type: none"> Segregate users of compressed air on the basis of the pressure they require for proper operation. 	<ul style="list-style-type: none"> Avoid over sizing - match the connected load.
<ul style="list-style-type: none"> Reduce air compressor discharge pressure to the lowest acceptable setting. (Reduction of 1 kg/cm² air pressure (8 kg/cm² to 7 kg/cm²) would result in 9% input power savings. This will also reduce compressed air leakage rates by 10%) 	<ul style="list-style-type: none"> Do not use back-up air compressor unless it is essential.
<ul style="list-style-type: none"> Minimize purges, leaks, excessive pressure drops, and condensation accumulation. 	<ul style="list-style-type: none"> Do not use refrigerated and heated air dryers when the air compressor is off.
<ul style="list-style-type: none"> Take air compressor intake air from the coolest (but not air conditioned) location. 	<ul style="list-style-type: none"> Do not use air/oil separators that are fouled.
<ul style="list-style-type: none"> Monitor pressure drops across suction and discharge filters and clean or replace filters promptly upon alarm. 	<ul style="list-style-type: none"> Do not use fouled heat exchanger

CHAPTER 5: Best Operating Practices - Motors and Pumps

A. Motor

5.1 Introduction

Electrical motors are the principal source of motive power in any foundry unit. Machine tools, auxiliary equipment and other utilities come equipped with one or more electric motors. A machine tool can have several electric motors other than the main spindle motor. These are used for allied operations. Motors are generally efficient, but their efficiency and performance depends on the motor load. Figure 5.1 shows the variation in efficiency and power factor vis-à-vis the total load, for a typical motor.

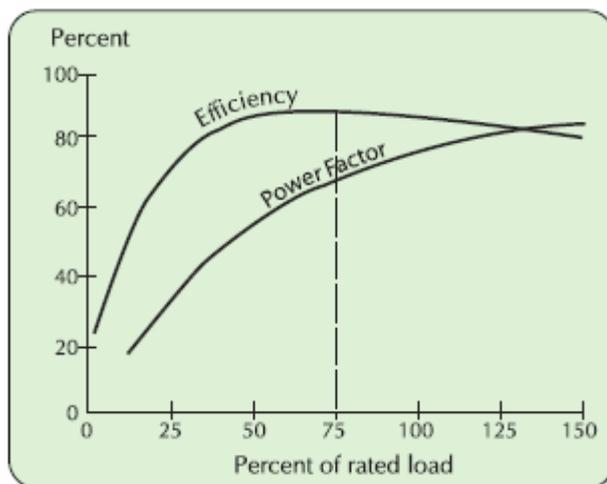


Figure 5.1: *Motor efficiency / Power factor vs. Load curve*

Since there are many different types of motors in a foundry unit, it is very important to maintain them and adopt proper operating practices. As they run for years, motors can become less efficient because of wear, breakdown of lubricants, and misalignment. Good motor-maintenance practice helps avoid or postpone these problems. A lack of maintenance can reduce a motor's energy efficiency and increase unplanned downtime. Scheduled maintenance is the best way to keep the motors operating efficiently and reliably.

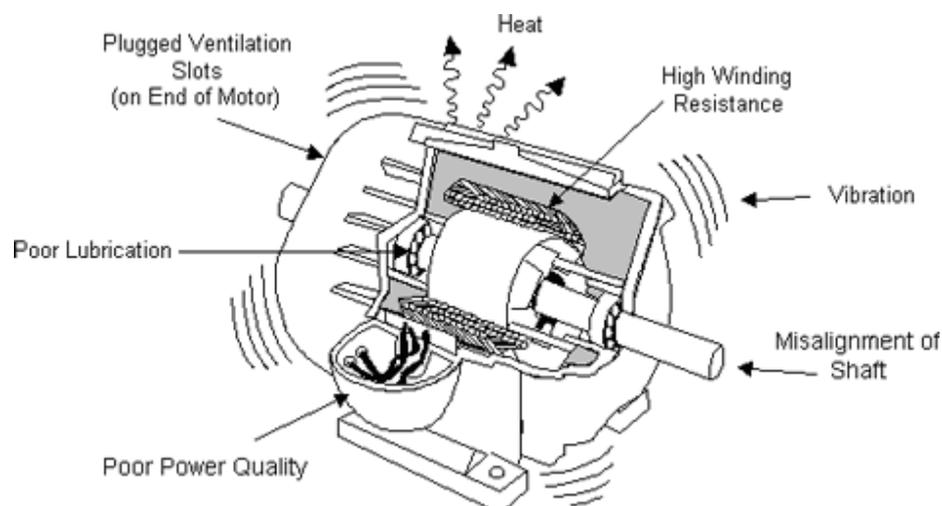


Figure 5.2: *Operational problems of a motor*

5.2 Types of motors

⇒ Induction motors

Induction motors are the most commonly used prime mover for various equipment in industrial applications. In induction motors, the induced magnetic field of the stator winding induces a current in the rotor. This induced rotor current produces a second magnetic field, which tries to oppose the stator magnetic field, and this causes the rotor to rotate. The 3-phase squirrel cage motor is the workhorse of industry; it is rugged and reliable, and is by far the most common motor type used in industry. These motors drive pumps, blowers and fans, compressors, conveyers and production lines. The 3-phase induction motor has three windings each connected to a separate phase of the power supply.

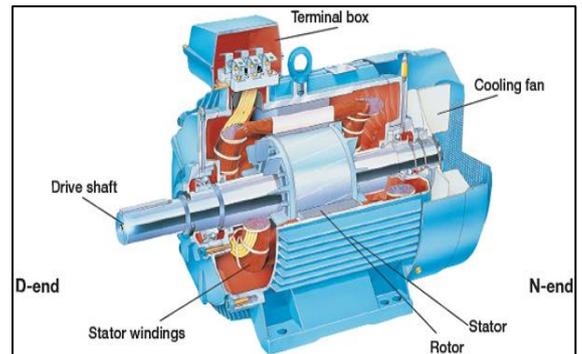


Figure 5.3: *Sectional view: Induction Motor*

⇒ Direct-Current motors

Direct-Current (DC) motors, as the name implies, use direct-unidirectional, current. Direct current motors are used in special applications - where high starting torque or smooth acceleration over a broad speed range is required.

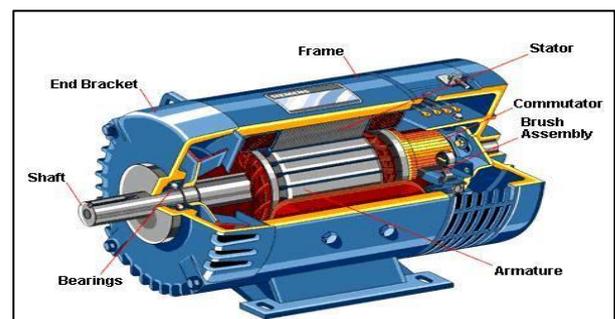


Figure 5.4: *Sectional view: DC Motor*

⇒ Synchronous motors

Synchronous Motor is called so because the speed of the rotor is same as the rotating magnetic field. It is basically a fixed speed motor because it has only one speed, which is synchronous speed and therefore no intermediate speed is there; or in other words it is in synchronism with the supply frequency. Alternating Current (AC) power is fed to the stator of the synchronous motor. The rotor is fed by DC from a separate source.

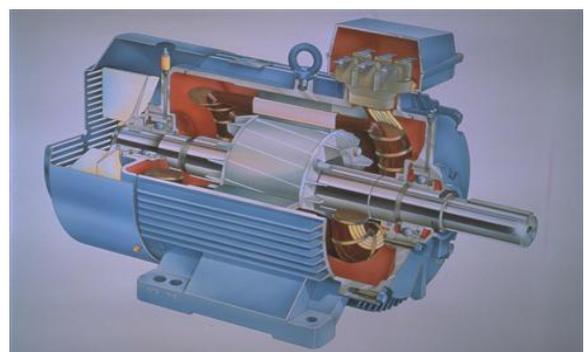


Figure 5.5: *Synchronous motor*

The rotor magnetic field locks onto the stator rotating magnetic field and rotates at the same speed. The speed of the rotor is a function of the supply frequency and the number of magnetic poles in the stator. While induction motors rotate with a slip, i.e., Revolutions Per Minute (rpm) is less than the synchronous speed; the synchronous motor rotate with no slip, i.e., the rpm is same as the synchronous speed governed by supply frequency and number of poles. The slip energy is provided by the D.C. excitation power.

5.3 Best operating practices for motors

⇒ BOP 1: Replace motors, rather than rewind, when appropriate

Motors are generally repaired more than once, with a typical loss of nearly 2 % in efficiency at each rewind. These motors are generally less efficient than their nominal ratings, and must be replaced appropriately. It is more common to rewind larger motors due to their high capital cost. But these motors usually operate at very high duty, and even a modest efficiency improvement may make it worthwhile to replace them with new, premium-efficiency motors rather than repair them.

⇒ BOP 2: Use appropriately sized motors for replacement

- ▶ Many motors are oversized for their applications, resulting in poor motor efficiency and excessive energy use. Always use motors sized according to the requirement of the load. It is good practice to operate motors between 75 -100 % of their full load rating because motors run most efficiently near their designed power rating.
- ▶ When replacing motors, always buy energy efficient motors instead of conventional motors. The cost of energy consumed by a conventional motor during its life is far greater than the incremental cost of the energy efficient motor.

⇒ BOP 3: Ensure voltage balance across motor terminals

A properly balanced voltage supply is essential for a motor to reach its rated performance. An unbalanced three-phase voltage affects a motor's current, speed, torque, and temperature rise. Equal loads on all three phases of electric service help in assuring a voltage balance while minimizing voltage losses. The options that can be exercised to minimize voltage unbalance include:

- ▶ Balancing any single phase loads equally among all the three phases
- ▶ Segregating any single phase loads which disturb the load balance and feed them from a separate line / transformer

⇒ BOP 4: Reducing under-loading

Probably the most common practice contributing to sub-optimal motor efficiency is that of under-loading. Under-loading results in lower efficiency and power factor, and higher-than-necessary first cost for the motor and related control equipment.

- ▶ Carefully evaluate the load that would determine the capacity of the motor to be selected.
- ▶ For motors, which consistently operate at loads below 40% of rated capacity, an inexpensive and effective measure might be to operate in star mode. A change from the standard delta operation to star operation involves re-configuring the wiring of the three phases of power input at the terminal box
- ▶ Motor operation in the star mode is possible only for applications where the torque-to-speed requirement is lower at reduced load.
- ▶ For applications with high initial torque and low running torque needs, Del-Star starters are also available in market, which help in load following derating of electric motors after initial start-up.

➤ BOP 5: Regular up-keep

Properly selected and installed motors can operate for many years with minimal maintenance. Nonetheless, regular care will extend their life and maximize their energy efficiency. A list of such practices and measures is presented below:

- ▶ Clean motor surfaces and ventilation openings periodically. Heavy accumulations of dust and lint will result in overheating and premature motor failure.
- ▶ Properly lubricate moving parts to avoid unnecessary wear. Be sure to apply appropriate types and quantities of lubricant. Applying too little or too much can harm motor components.
- ▶ Keep motor couplings properly aligned. Correct shaft alignment ensures smooth, efficient transmission of power from the motor to the load. Incorrect alignment puts strain on bearings and shafts, shortening their lives and reducing system efficiency.
- ▶ Check motor for over-heating and abnormal noises/sounds, sparking and ensure proper bedding of brushes.
- ▶ Tighten belts and pulleys to eliminate transmission losses.

➤ BOP 6: Install variable frequency drives

Motors frequently drive variable loads such as pumps, hydraulic systems and fans. In these applications, the motors' efficiency is often poor because they are operated at low loads. It is appropriate to use a Variable Frequency Drive (VFD) with the motor.



Figure 5.6: Use of VFDs

➤ BOP 7: Install capacitor banks

Induction motors are characterized by power factors less than unity, leading to lower overall efficiency (and higher overall operating cost) associated with a plant's electrical system.

- ▶ Install capacitor banks across motors with a high rating to reduce the distribution losses.
- ▶ Capacitors connected in parallel (shunted) with the motor are typically used to improve the power factor.
- ▶ The size of capacitor required for a particular motor depends upon the no-load reactive kVA (kVAR) drawn by the motor, which can be determined only from no-load testing of the motor. In general, the capacitor is selected to not exceed 90 % of the no-load kVAR of the motor. (Higher capacitors could result in over-voltages and motor burnouts).

5.4 Do's and Don'ts in motor operations

The common do's and don'ts with regard to operation of a motor have been summarized in table 5.1 below:

Table 5.1: *Summary of best operating practices for efficient operation of motors in foundry units*

Do's	Don'ts
<ul style="list-style-type: none"> • Properly sized to the load for optimum efficiency. 	<ul style="list-style-type: none"> • Avoid misalignment in motor
<ul style="list-style-type: none"> • Use energy-efficient motors where economical. 	<ul style="list-style-type: none"> • Avoid under-voltage and over-voltage conditions
<ul style="list-style-type: none"> • Use synchronous motors to improve power factor 	<ul style="list-style-type: none"> • Replace, rather than rewind, motors when appropriate
<ul style="list-style-type: none"> • Provide proper ventilation 	<ul style="list-style-type: none"> • Avoid slippage due to belt tension
<ul style="list-style-type: none"> • Demand efficiency restoration after motor rewinding. 	<ul style="list-style-type: none"> • Eliminate variable-pitch pulleys.
<ul style="list-style-type: none"> • Use flat belts as alternatives to v-belts. 	<ul style="list-style-type: none"> • Eliminate eddy current couplings.
<ul style="list-style-type: none"> • Balance the three-phase power supply. 	<ul style="list-style-type: none"> • Do not run motors when not in use.

B. Pumps

5.5 Introduction

Pumps used in foundry industries are centrifugal type. The main function of the pump is to convert energy of a prime mover into velocity or kinetic energy and then into pressure energy of a fluid that is being pumped. Improvements in efficiency of pumping systems can also:-

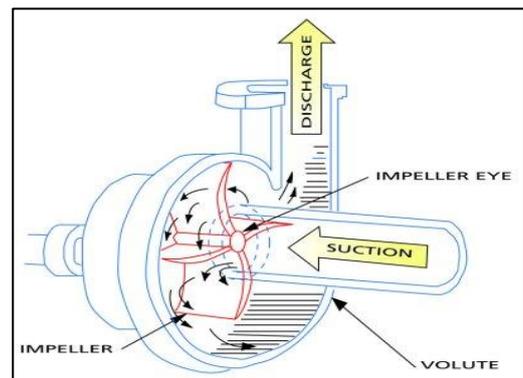
- ▶ Reduce energy costs
- ▶ Reduce maintenance requirements
- ▶ More closely match pumping system capacity to production requirements.

Figure 5.7: *Centrifugal Pump*

5.6 Efficient pumping system operation

To understand a pumping system, one must realize that all of its components are interdependent. When examining or designing a pump system, the process demands must first be established and most energy efficient solution introduced. For example, does the flow rate have to be regulated continuously or in steps? Can on-off batch pumping be used? What are the flow rates needed and how are they distributed in time?

The first step to achieve energy efficiency in pumping system is to target the end-use. A plant water balance would establish usage pattern and highlight areas where water consumption can be reduced or optimized. Good water conservation measures, alone, may eliminate the need for some pumps.

Figure 5.8: *Sectional view of a pump*

Once flow requirements are optimized, then the pumping system can be analysed for energy conservation opportunities. Basically this means matching the pump to requirements by

adopting proper flow control strategies. Common symptoms that indicate opportunities for energy efficiency in pumps are given in the table below:

Table 5.2: *Symptoms that indicate potential opportunity for energy savings*

Symptoms	Likely reason	Best solutions
Throttle valve-controlled systems	Oversized pump	Trim impeller, smaller impeller, variable speed drive, two speed drive, lower rpm
Bypass line (partially or completely) open	Oversized pump	Trim impeller, smaller impeller, variable speed drive, two speed drive, lower rpm
Multiple parallel pump system with the same number of pumps always operating	Pump use not monitored or controlled	Install controls
Constant pump operation in a batch environment	Wrong system design	On-off controls
High maintenance cost (seals, bearings)	Pump operated far away from BEP	Match pump capacity with system requirement

5.7 Best operating practices for pumps

➤ BOP 1: Location of pump

The location of pump plays a significant role in energy consumption pattern for pumping unit. Guidelines for efficient pumping system are:

- ▶ Ensure adequate Net Positive Suction Head (NPSH) at site of installation
- ▶ Operate pumps near best efficiency point.
- ▶ Avoid pumping head with a free-fall return (gravity);
- ▶ Reduce system resistance by pressure drop assessment and pipe size optimization

➤ BOP 2: Measurement and control

The pump efficiency can be determined by regular monitoring of key performance parameters like pressure, discharge flow etc.

- ▶ Ensure availability of basic instruments at pumps like pressure gauges, flow meters.
- ▶ Modify pumping system and pumps losses to minimize throttling.
- ▶ Repair seals and packing to minimize water loss by dripping.
- ▶ Balance the system to minimize flows and reduce pump power requirements.

➤ BOP 3: Use of variable speed drives

- ▶ Adapt to wide load variation with variable speed drives or sequenced control of multiple units.
- ▶ Stop running multiple pumps - add an auto-start for an on-line spare or add a booster pump in the problem area.
- ▶ Use booster pumps for small loads requiring higher pressures.

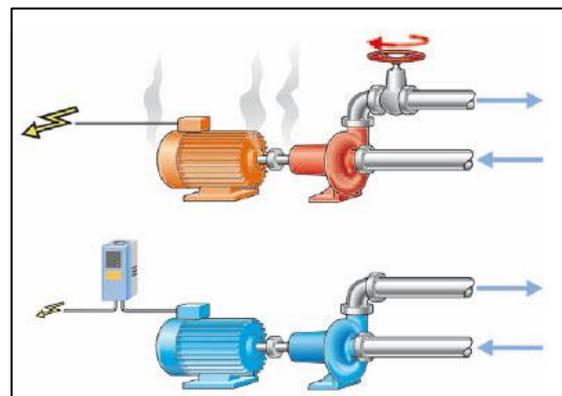


Figure 5.9: *Pictorial depiction of use of VFDs in Pumps*

➤ BOP 4: Pumping system design consideration

The efficiency of the pumps depends predominately by the design of the pumping system and selection of pumps of right capacity.

- ▶ Increase fluid temperature differentials to reduce pumping rates in case of heat exchangers.
- ▶ Conduct water balance to minimise water consumption
- ▶ Avoid cooling water re-circulation in DG sets, air compressors, refrigeration systems, cooling towers feed water pumps, condenser pumps and process pumps.
- ▶ In multiple pump operations, carefully combine the operation of pumps to avoid throttling
- ▶ Provide booster pump for few areas of higher head
- ▶ Replace old pumps by energy efficient pumps
- ▶ In the case of over designed pump, provide variable speed drive, or downsize / replace impeller or replace with correct sized pump for efficient operation.
- ▶ Optimise number of stages in multi-stage pump in case of head margins
- ▶ Reduce demand on Pumping System: Demand on pumping system can be reduced by:
 - ↳ Reducing consumption
 - ↳ Reducing leaks
 - ↳ Lowering pumping system flow rate
 - ↳ Lowering the operating pressure
 - ↳ Operating the system for a shorter period of time each day
 - ↳ Having the system off when not needed.

5.8 Do's and Don'ts in pump operation

The common dos and don'ts for efficient pumping operations are:

Table 5.3: *Summary of best operating practices for efficient operation of pumps in foundry units*

Do's	Don'ts
• Replace throttling valves with speed controls	• Do not use inefficient pumps
• Reduce speed for fixed load	• Avoid pumping head with a free return (gravity)
• Replace motor with a more efficient motors	• Avoid water loss by dripping
• Ensure adequate NPSH at site of installation	• Stop running multiple pumps - add an auto-start for an on-line spare or add a booster pump in the problem area.
• Provide metering of components (such as flows, kWh)	• Avoid inadequate NPSH
• Operate pumps near best efficiency point	• Do not run the system when not needed
• Use booster pumps for small loads requiring higher pressures	• Avoid over loading the pump system

CHAPTER 6: Best Operating Practices - Reheating Furnace

6.1 Introduction

The re-heating furnace is a type of industrial furnace used for heating of metal to its re-crystallization temperature (suitable for plastic deformation) at which metal can be rolled to required shape and size. A typical re-heating furnace uses solid, liquid or gaseous fuel to provide the required amount of thermal energy for the purpose of heating. Re-heating furnace varies in size from few kilograms to a hundred tones per hour (TPH) capacity.



Figure 6.1: *Re-heating furnace used in foundry units*

6.2 Operating principle

A re-heating furnace typically consists of a furnace chamber made of refractories and insulation. The heating process in a re-heating furnace is a continuous process where the steel stock is charged at the furnace entrance, heated in the furnace and discharge at the furnace exit. Heat is transferred to the steel stock during its traverse through the furnace mainly by means of convection and radiation from the burner gases and the furnace walls. The charging temperature of the steel stock may range from ambient temperature to 800°C. The target exit temperature of the steel stock is governed by the requirement of the process of rolling which is dependent on the rolling speed, stock dimension and steel composition. Steel quality aspects put constraints on temperature gradient and surface temperature.

The size of re-heating furnace is usually expressed as the capacity to supply the rolling mill with sufficiently hot steel from the cold stock and is expressed in tons per hour. The energy efficiency of re-heating furnace is usually defined as increase of steel stock heat content when heated from 10 °C to 1200 °C divided by the fuel energy (latent heat plus sensible heat) used for it. Many design features of the furnace affects the energy efficiency. These includes i) type of burners, ii) Furnace dimensions, iii) Number of furnace zones, iv) type of wall and roof insulation, v) skid design, and vi) preheating of fuel and combustion air in recuperators by the hot flue gases coming out from the furnace exit. An efficient

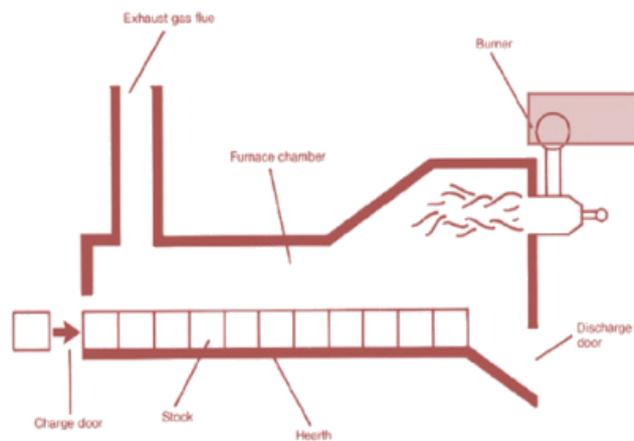


Figure 6.2: *Re-heating furnace block*

furnace is designed in such a way so that in a given time the steel stock, as per furnace capacity, is heated to a uniform temperature with the least possible fuel and labour.

6.3 Type of re-heating furnace

The re-heating furnace classification can be done in several ways. These are described below.

- ▶ Based on the method of heating, a re-heating furnace can be combustion type or electric type. The combustion type furnace can be oil fired or gas fired.
- ▶ Based on method of charging, a re-heating furnaces can be classified as batch type or continuous type. In batch furnaces the charged material remains in a fixed position on the hearth until heated to rolling temperature; while in continuous furnaces the charged material moves through the furnace and is heated to rolling temperature as it progresses through the furnace.
- ▶ Continuous furnaces can be further classified based on the movement of steel stock inside the furnace. Based on this classification the continuous type re-heating furnaces are pusher type, rotary hearth type, walking beam type, walking hearth type or roller hearth type.
- ▶ Based on heat recovery, the re-heating furnace can be either regenerative or recuperative.



Figure 6.3: *Re-heating furnace discharge door*

6.4 Best operating practices in re-heating furnace

➤ BOP 1: Efficient fuel preparation

Furnace efficiency depends significantly on the type of fuel being used, its chemistry and quality. Different types of fuels have different preparation criteria, which affects the overall efficiency of the furnace.

- ▶ For oil fired furnace, pre-heat the fuel feed to attain the required viscosity level. Viscosity is the most important characteristic in the storage and use of fuel oil. Viscosity influences the degree of pre-heat required for handling, storage and satisfactory atomization. If the oil is too viscous, it may become difficult to pump to light the burner as well as tough to operate which causes poor atomization. Therefore pre-heating is necessary for proper atomization as it may result in the formation of carbon deposits on the burner walls.
- ▶ For gas fired furnaces, maintain correct discharge pressure of gas at burner tip to avoid carbon deposits in furnace.
- ▶ For solid fuel, like pulverized coal, a number of parameters like fuel quality (gross CV), moisture content in fuel, ash content etc. determines the combustion efficiency. Select correct composition of coal to attain optimum combustion efficiency in the

furnace. Once, coal is received in the factory, maintain optimum coal fineness and consistency.

➤ BOP 2: Maintaining correct air-fuel ratios

In a re-heating furnace, if air fuel ratio is not properly maintained furnace efficiency decreases by 3-5%. High level of excess air in the flue gas results in excessive heat loss through flue gases, as well as cooling of the combustion chamber due to excess air. In a few cases it was observed that sometimes excess air present in re-heating furnace is less than excess air required for complete combustion. Both the cases lead to improper fuel combustion, which automatically leads to poor furnace efficiency. For optimum air-fuel ratio, following needs to be adopted:

- ▶ Determine the quantity of fuel required based on operational condition.
- ▶ Calculate corresponding amount of air required for stoichiometric combustion.
- ▶ Add percentage of excess air required for complete combustion.
- ▶ Determine optimum blower ratings based on manufacturer's recommendation.
- ▶ Air-fuel ratio to be monitored and controlled on a regular basis.
- ▶ Install automatic air-fuel ratio controller for better control.
- ▶ Periodically monitor oxygen percentage in flue gas. Optimum oxygen percentage needs to be maintained based on fuel type and composition.

➤ BOP 3: Selection and sizing of blower system

A proper capacity blower is necessary for combustion air to be delivered at correct pressure and in appropriate volume. Generally blowers are either locally fabricated without any proper design parameters or are under/over- sized without any consideration for correct air pressure.

- ▶ Select correct rating of blower as per manufacturers' recommendation
- ▶ Do not use locally fabricated blowers without any proper design parameters.
- ▶ Place blower near to the furnace to avoid transmission loss.
- ▶ Regular maintenance of blower impeller.

➤ BOP 4: Combustion air flow regulation by variable frequency drive

In a typical re-heating furnace, air flow is kept constant irrespective of temperature, draft and excess air in the re-heating furnace. It has been observed that due to inadequate supply of draft and excess air at times, the flames gushes out of the various openings of the re-heating furnace, making the furnace operation unsafe. Various manual mechanism viz, damper control, suction control, pulley change etc. are employed for controlling air flow in the furnace which do not provide proper checks & balances for the system.

- ▶ Air flow to be monitored regularly and controlled based on operational variations.
- ▶ Use variable frequency drives (VFDs) to regulate the air flow on continuous manner. VFD

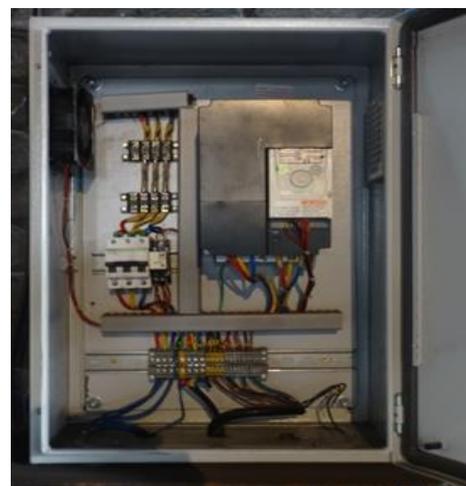


Figure 6.4: VFDs to regulate combustion air

reduces the speed of the fan for reduced air flow demand, and this speed reduction is achieved by altering the frequency of input power. Hence, power consumption of FD fans will be proportional to the air-flow being delivered to the re-heating furnace.

- ▶ The feedback for VFDs can be taken from an online oxygen analyser installed in the flue gas line.
- ▶ Along with stoichiometric air required for combustion, a certain amount of excess air needs to be supplied and this excess air varies based on the type of fuel used in the re-heating furnace. E.g. for oil fired furnaces, excess air should be limited to 10% with oxygen limited to 2%. An oxygen analyser is used to monitor the oxygen percentage in the flue gas, It is pertinent to mention here that a 10% reduction in excess air would result in 1% fuel saving.

➤ BOP 5: Waste heat recovery through recuperator

In most of the re-heating furnaces, a large amount of the heat supplied is wasted in the form of exhaust flue gases. These flue gases are at temperature ranging from 400 -700°C, which can be recovered to a certain extent and can be used for pre-heating of the combustion air.

- ▶ Pre-heat combustion air using waste heat from flue gas. As a thumb-rule, with every 20°C rise in the combustion pre-heat temperature leads to a fuel saving of 10%.
- ▶ Install recuperator of suitable design for pre-heating of combustion air. Efficiency of a recuperator depends on the material and surface area of heat exchange.
- ▶ Properly monitor waste heat temperature of flue gas and air pre-heat temperature on a regular basis.
- ▶ Frequently clean recuperator tubes for the soot or unburnt deposits. .



Figure 6.5: *Waste heat recovery system*

➤ BOP 6: Using optimum insulation and refractory for re-heating furnace

Around 5-8% of the total furnace losses accounts for wall and roof losses due to improper use of insulation and refractory. Furnace lining in a typical re-heating furnace are done with the locally available firebricks. The firebricks with low alumina content tend to get worn out in a short duration. Also, the insulation required for plugging heat loss through the furnace are usually done with locally available red bricks, which do not serve the purpose of insulation.

- ▶ Select optimum refractories and insulation based on manufacturers' recommendation.
- ▶ Maintain furnace skin temperature to < 60 °C.
- ▶ Minimise losses from openings such as pusher end, discharge door and inspection door.
- ▶ Use of ceramic fibre to be ensured for optimum thermal insulation.
- ▶ Furnace emissivity coating can be adopted for better thermal insulation.

- ▶ Refractory bricks of higher alumina backed by hot face & cold face insulation bricks and hysil blocks/ceramic fibre to be used in furnace side walls.
- ▶ High alumina bricks backed by hot face insulation and ceramic fibre blanket to be used in furnace roof.
- ▶ Minimum heat losses to be ensured after furnace shut-down.

➤ **BOP 7: Installation of temperature gauge in re-heating furnace**

It is important to maintain the correct furnace temperature regime for optimum furnace efficiency. In a typical furnace, the zonal chamber is usually 50 °C higher than the stock temperature. Over-heating of stock can lead to increased scale loss and melting of stock, whereas under-heating can lead to improper rolling condition.

- ▶ Maintain furnace zonal temperature regime to desired level.
- ▶ Install thermocouples in different zones of furnace (soaking, heating and pre-heating zone) with proper digital display.
- ▶ Furnace discharge temperature to be maintained at optimum level.
- ▶ Recommended reheating temperatures of different type of material in reheating furnace are presented in table below:



Figure 6.6: Thermocouples used in re-heating furnace

Table 6.1: Recommended reheating temperatures different materials

S.No.	Type of material	Temperature (°C)
1	Free cutting brass	700/750
2	Forging brass	700/750
3	Modify forging brass	600/650
4	High tensile brass	700/750
5	Lead free brass	800/850
6	IS319-II	800/850
7	DTP	800/850
8	SVF	800/850
9	CuZn40Pb2	800/850
10	C-3602	800/850
11	C-345	800/850

- ▶ Thermocouples to be selected based on temperature range to be monitored.
- ▶ It is recommended to install temperature gauges or thermocouples in re-heating furnaces for proper temperature control. This will lead to proper monitoring of the furnace temperature thereby leading to optimum furnace temperature control.

➤ BOP 8: Maintaining optimum heating regimes

The importance of temperature control in the furnace for fuel economy and reduction of burning losses are well established. Heating regimes is the temperatures at which the furnaces are required to be controlled. The fundamental principle that governs heating of billet/ingot in a re-heating furnace is that the metal should reach the desired level of temperature and within the permissible temperature gradient from top to bottom when it reaches the discharge point.

- ▶ Maintain correct temperature regimes in different zones of furnace as per manufacturers' recommendation
- ▶ Material to be properly soaked for proper processing.
- ▶ Automatic furnace temperature control system to be installed for proper monitoring and control of furnace temperature.

➤ BOP 9: Inadequate sizing of heating and pumping unit

In majority of the units it is commonly observed that heating and pumping systems are not designed properly. This is mainly due to lack of awareness about the standard oil temperature and pressure at the combustion stage and the benefits thereof.

- ▶ Pre-heat feed oil to the desired viscosity level.
- ▶ Use properly designed heating and pumping unit.
- ▶ Regular maintenance of feed oil pipe to be done.

➤ BOP 10: Replacement of conventional re-heating furnace with energy efficient re-heating furnace

Conventional re-heating furnace is of very primitive design; have poor preheating of charge, do not have waste heat recovery system and poor heat transfer efficiency between hot flue gasses & billets. It is recommended to replace the conventional re-heating furnace with energy efficient reheating furnace. The following parameters are to be kept in mind while designing a new energy efficient re-heating furnace:

- ▶ Complete combustion with minimum excess air.
- ▶ Proper heat distribution
- ▶ Operation at optimum furnace temperature
- ▶ Reducing heat losses through furnace openings
- ▶ Maintaining correct amount of furnace draft.
- ▶ Optimum hearth capacity utilization.
- ▶ Waste heat recovery from the flue gas.
- ▶ Minimum heat loss through refractory.
- ▶ Use of ceramic coatings
- ▶ Selecting right kind of refractory & insulation
- ▶ Control & Instrumentation of the furnace.

6.5 Do's & Don'ts in re-heating furnace operations

The table 6.2 below summarizes the do's and don'ts related to the operation of a reheating furnace in a foundry unit:

Table 6.2: *Summary of best operating practices for efficient operation of re-heating furnace*

Do's	Don'ts
<ul style="list-style-type: none"> Use proper refractories to keep skin wall temperature at <60 °C 	<ul style="list-style-type: none"> Do not keep furnace doors open unnecessarily
<ul style="list-style-type: none"> Maintain heating zone temperature at 10-50°C above soaking or discharge temperature 	<ul style="list-style-type: none"> Do not overheat the furnace
<ul style="list-style-type: none"> Recover maximum heat from the flue gases through suitable waste heat recovery systems. 	<ul style="list-style-type: none"> Avoid manual interference for control of furnace temperature, pressure and air-fuel ratio
<ul style="list-style-type: none"> Heat the furnace oil to about 90-100 °C to reduce the viscosity of the oil 	<ul style="list-style-type: none"> Do not run furnace in negative pressure to avoid ingress of cold air from openings
<ul style="list-style-type: none"> Maintain hearth productivity > 280kg/m²/hr 	<ul style="list-style-type: none"> Do not use locally fabricated blowers with no proper design parameters.
<ul style="list-style-type: none"> Insulate all hot air pipelines 	<ul style="list-style-type: none"> Do not use air over desired excess air level.
<ul style="list-style-type: none"> Use damper installed in the flue gas path for pressure control in the furnace. 	<ul style="list-style-type: none"> Do not use refractory of low alumina content.

CHAPTER 7: Best Operating Practices – Lighting

7.1. Introduction

Lighting system provides light for practical use and to make things visible and clear enough inside and outside factories. In industries/SMEs, lighting includes both day-lighting and artificial light source. Proper lighting fixture selection, layout and control not only enhance lighting effect but also reduce energy consumption by lighting fixtures.

Based on construction and operating characteristics, lights are basically categorized into 3 types: incandescent, florescent and high intensity discharge lamps (HID). Further, depending on the place of use, lights can be broadly classified for indoor and outdoor use.

7.1.1 Indoor lighting

- Most common types are incandescent lamp, fluorescent tube light (FTL), compact fluorescent lamp (CFL), high pressure mercury/sodium vapour lamp (HPMV/HPSV) and metal halide lamps. Now a days, light emitting diode lamp (LED) are also being used and gaining popularity; however brightness is an issue with LED as it may create glare and negative on user.
- Uniformity of illuminance is one of the important factors that must be considered during the initial planning stage and/or for modifying existing lighting scheme. Uniformity of illuminance is achieved by proper spacing between the centers of each luminaire/fixture of particular type, size and lux levels.

7.1.2 Outdoor lighting

- Commonly HID lamps are high pressure mercury/sodium vapour lamp (HPMV/HPSV), low pressure sodium vapour lamp (LPSV), halogen lamps and metal halide lamps.
- Recently light emitting diode lamp (LED) and magnetic induction lamps are gaining popularity due to long life and higher energy efficiency.

7.2. Fixture selection and sizing

7.2.1 Low-bay and High-bay light fixtures

- Low bay light fixture is typically used with ceiling heights 20' or less. High bay light fixtures are typically used for heights between 20' to 45'.
- Low bay light usually features some type of diffuser on the bottom of the light to spread the light in a manner reflective of the lower ceiling height. High bay lights typically have an aluminum reflector which allows a beam of light to reflect downwards to the floor area. Other types of high bay lights have a prismatic reflector which illuminates shelving, etc. from the floor to the ceiling.

- Irrespective of low bay or high bay lighting, metal halide type lighting allows users to illuminate large areas with very few lights, making it the energy savings choice for buildings of all sizes.

7.2.2 Flood-light Fixtures

- Flood-light fixtures with reflectors are used to illuminate a wide area like roads, car parking, playground etc.
- Parabolic aluminized reflector light fixtures are used when a substantial amount of flat lighting is required.

7.2.3 Luminaire efficiency

- The efficiency of a luminaire is the ratio of luminaire lumen output to the lamp lumen output. Mirror optics of a luminaire and louvers decides the luminaire efficiency along with the improved visual comfort and glare control.
- Lighting simulation tools can be used to choose which luminaire will suit best the required application by analyzing the lighting distribution and glare index.

7.3. Layout

- In order to design a luminaire layout that best meets the illuminance level and uniformity requirements of the job, two types of information are generally needed: average illuminance level and illuminance level at given point.
- Every luminaire/fixture will have recommended space to height ratio (SHR), it is better to choose luminaires with larger SHR, this can reduce the number of fittings and connected lighting load.
- Lighting layout at corners of room is undesirable hence lights layout at distance from all four corners is desirable in a room.

Table 7.1: *Recommended and average lux level in different areas of foundry*

Area	Recommended lux level	Average lux level in foundry
Corridors and walkway	40	5 – 20
Change rooms, storage	80	25 – 55
Mould and core preparation	160	45 – 85
Melting shop floor	240	105 – 165
Office work space	250	185 – 305
Laboratory	500	215 – 245
Inspection area	1500	255 – 365

7.4. Maintenance of fixtures

- Light levels decrease over time because of aging lamps and dirt on fixtures, lamps and room surfaces. Together, these factors can reduce illumination by 50 percent or more, while lights continue drawing full power.
- Regular maintenance is essential to ensure that facilities receive the desired quantity and quality of light, as well as energy efficiency, from their lighting systems. Periodic

maintenance can produce a range of benefits, including a brighter and cleaner workplace, a higher level of safety, and enhanced productivity.

- The basic maintenance includes cleaning of lamps and fixtures, cleaning and re-painting interiors and re-lamping. Keep light-reflecting surfaces and lenses clean in order to maintain designed light levels.
- Workers should take care not to touch the envelope of halogen bulbs because doing so leaves skin oils on the glass surface. As these bulbs heat and cool, the oils cause uneven stress, leading to glass cracking and shorter lamp life.
- Tips for cleaning fixtures:
 - Clean lighting fixtures whenever lamps are replaced. In areas where doors allow outside air or filtering is not adequate, clean at least twice a year.
 - Wipe plastic lenses with damp, not dry, cloth (a mild detergent may be needed). Small cell louver panels, including parabolic wedge louvers, should be removed and dipped in mild detergent solution, then air-dried.
 - Do not wipe luminaire or lamps while fixture is energized.
- Line voltage should be checked at the fixture and compared with the ballast rating to be sure it is within the prescribed limits, so as to prevent lamps premature failure due to flickering caused by voltage fluctuation, hence if voltage controllers/stabilizers are present then its maintenance should also be done periodically.
- Replacement of old conventional magnetic ballast with new electronic ballast also reduces maintenance part of ballast repairing.
- To avoid damage to ballasts, lamps are replaced when it ceases operation unexpectedly, failed to light up after turning it on.
- Lamps should be replaced when they reach 70%-80% of their rated life.
- Bulbs should be replaced not only when they break, but also on a schedule according to how the brightness of the lamp decays over time. Some bulbs lose over a third of their initial brightness over a few years.

7.5. Control strategies:

7.5.1 Localized Switching

Localized switching is preferred in large spaces. By using localized switching it is possible to turn off artificial lighting in specific areas, while still operating it in other areas where it is required, a situation which is impossible if the lighting for an entire space is controlled from a single switch.

7.5.2 Occupancy Sensors

Occupancy-linked control can be achieved using infra-red, acoustic, ultrasonic / microwave sensors, which detect either movement/noise in room spaces. These sensors switch-on lighting when occupancy is detected, and switch-off again when no occupancy movement is detected for a set time period. They are designed to override manual switches and to prevent a situation where lighting is left on in unoccupied spaces. With

this type of system it is important to incorporate a built-in time delay, since occupants often remain still or quiet for short periods and do not appreciate being plunged into darkness if not constantly moving around.

7.5.3 Photocells

These measure the amount of natural light available and suitable for both indoor and outdoor (Street lights) applications. When the available light falls below a specified level, a control unit switches the lights on (or adjusts a driver to provide more light).

Photocells can be programmed so that lights do not flip on and off on partially cloudy days.

7.5.4 Time based control

Timed-turnoff switches are the least expensive type of automatic lighting control. Electronic timer switch provides a choice of time intervals, which can be selected by adjusting knob located behind the faceplate. Most timer models allow occupants to turn off lights manually; some models allow occupants to keep on, overriding the timer. Timed-turnoff switches are available with a wide range of time spans. The choice of time span is a compromise. Shorter time spans waste less energy but increases the probability that the lights will turn off while someone is in the space.

7.5.5 Dimming technologies

It include common manual dimming switches as well as more sophisticated technology that automatically reduce light output according to the availability of daylight or other ambient light. While dimming of incandescent lamps is common, dimming of fluorescent fixtures can only be accomplished if they have ballasts designed especially for dimming applications.

7.5.6 Day lighting controls

It adjusts light output levels from fixtures in perimeter areas next to windows or under skylights in response to natural outdoor light entering the building. Day lighting controls are available in continuous dimming and stepped reduction models.

7.5.7 Automated lighting management systems

It provides centralized computer control of lighting systems.

7.6. Efficiency improvement

7.6.1 Use of daylights

Glass strips, running continuously across the breadth of the roof at regular intervals, can provide uniform lighting on industrial shop floors and storage bays, also maximum usage

of daylight should be done in industries/factories by using transparent/translucent roofing sheets so as to minimise usage of electrical lighting in daytime.

7.6.2 Lighting voltage transformer/controller

Higher and frequent voltage variation leads to increased energy consumption by lighting loads, lamp lumen depreciation and also reduces the life of lamps.

It is always recommended to maintain single phase voltage between 210 – 215 V exclusively for lighting circuit for better and optimum performance of luminaries.

It is recommended that the plant should install lighting transformers to separate the lighting load from other plant load and process load. In areas where lighting transformers may not be feasible, energy savers or voltage reduction devices may be installed in the outgoing circuit. This is likely to improve the power factor as well as increase the reliability of the lighting infrastructure.



LIGHTING VOLTAGE CONTROLLER

The reduction of voltage to these levels does not impair the ability of discharge lamps to strike, though an insignificant reduction in lumen output takes place. Usage of lower voltage leads to an increase in the operating power factor as well as the life of luminaries, which is confirmed by lower failure rates.

7.6.3 Occupancy sensors based control

In most of the offices and factories it is observed that the lighting in the most of the areas is ON during the non-use period as well.

To avoid the idle running of the lighting system, it is recommended to retrofit the occupancy sensors by identifying such areas to save energy.



OCCUPANCY SENSORS

7.6.4 Lighting dimmer control

Use of dimmer control in parking areas will reduce the substantial energy consumption as most of the time parking area is non-occupied space once shifts in the evening starts.



LIGHTING DIMMER CONTROL

7.6.5 Replacement of existing lights with energy efficient lighting

- Replace T12 (52 watts)/T8 (40 watts) with FTL T5 (30 watts) or LED tube light (20 watts)
- Replace CFLs with LED lamps with good lumens
- Replace of metal halide lamps of (250W) with magnetic induction flood lamp of (150 W)
- Replace of HPMV lamps of (400W) with high bay magnetic induction lamp of (250W)

Photographs of earlier discussed replacement options are provided below:

Existing



T12 and T8 FTL



CFL



Metal Halide flood lamp



High bay HPMV lamp

Replacement



T5 FTL



LED



Magnetic Induction Flood Lamp



High bay Magnetic induction lamp

Annexure 1

List of Experts / Suppliers - Indore Foundry Cluster

SN	Name of Expert	Name of Company & Address	Contact No.	Email ID	Website	Field of Expertise/Area of Supply
1	Bharat Tank	Electrotherm (India) Ltd. A-1, Skylark Apartment, Satellite Road, Satellite, Ahmedabad- 380015	Tel: +91-79- 26768844	ho@electrotherm.com	www.electrotherm.com	Induction furnace expert/supplier
2	Dinesh Dholakia	Inductotherm (India) Pvt. Ltd. Plot No. SM-6, Road No. 11, Sanand-2 Industrial Estate, BOL Village, Sanand, Ahmedabad 382170	Tel: +91- 2717- 621000, Mobile: 9376196153	ddholakia@inductotherm.com	www.inductotherm.com	Induction furnace expert/supplier
3	V.B. Mahindra	Encon Thermal Engineers Pvt Ltd. 297, Sector - 21 B, Faridabad - 121 001, Haryana (India)	Mobile: 9971499079, Tel: +91-129- 4041185, 4047847 4164829, 4164833	sales@encon.co.in	www.encon.co.in	Re-heating furnace expert / supplier
4	Er. S.K. Jain	Punjab State Council for Science & Technology (PSCST) MGSIPA Complex, Adjacent Sacred Heart School, Sector-26 Chandigarh	Mobile: 9878428505	stcouncilpb@gmail.com	www.pscst.gov.in	Cupola furnace expert
5	Vasant Panchal	Vitthal Enterprise 36-37,Gajanand Estate , Nargerwel Hanuman Road, Rakhial, Ahmedabad-380 023,	Mobile: 9825285536, 98253 46199	info@vitthalenterprise.com	www.vitthalenterprise.com	Cupola furnace expert/supplier
6	Navin Goyal	Essen Energy Technologies (P) Ltd. 109, DH, IDA Scheme 74 C, Indore-452010	Mobile: 9425056286, 9425056026, 9425057056	essenenergytech@gmail.com		Foundry expert
7	Dinesh Patidar	Shakti Pumps (I) Ltd. Plot No. 401, Sector - 3, Pithampur - 454774, Dhar (M.P.) India	Tel:+91- 7292- 410500	info@shaktipumps.com	www.shaktipumps.com	Pumps, Motors supplier
8	Bhavik Patel	Shah Enterprise 404, Meridian Tower, Nr. Apple Hospital, Udhna Darwaja, Surat-2	Mobile: 9825607102	shahgroupsurat@gmail.com	www.shahenterprise.in	Compressor, motors, pumps supplier
9	Kamlesh Bhavsir	Indo Air Compressors Plot No. 550, Main Road, Kathwada, GIDC, Ahmedabad - 382430	Mobile: 9824403616	tech@indoair.com	www.indoair.com/	Compressor, motors, pumps supplier

ABOUT PROJECT

With an aim to develop and promote a market environment for introducing energy efficiency and enhanced use of renewable energy technologies in process applications in the selected energy-intensive MSME clusters, Bureau of Energy Efficiency (BEE) in collaboration with United Nations Industrial Development Organization (UNIDO) is implementing a project titled “Promoting Energy Efficiency and Renewable Energy in Selected MSME cluster in India” funded by Global Environment Facility (GEF) and co-financed by Ministry of Micro, Small and Medium Enterprises (MOMSME) and Ministry of New and Renewable Energy (MNRE).

The project is being executed in 12 selected MSME clusters in 5 varied sectors (brass, ceramics, dairy, foundry and hand tools) identified as the most energy consuming sectors.

Project Component

- Increased capacity of suppliers of EE/RE product suppliers/ service providers/ finance providers.
- Increasing the level of end-use demand and implementation of EE and RE technologies and practices by MSMEs.
- Scaling up of the project to a national level.
- Strengthening policy, Institutional and decision making frameworks

Project Activities

- Conducting techno-economic studies at the unit and cluster level
- Assisting in information sharing
- Conducting training and awareness workshops to share experiences and knowledge on energy efficiency and renewable energy measures
- Assisting in detailed planning of the implementation of energy efficiency and renewable energy measures
- Providing initial financial assistance will be provided to “first movers” for a demonstration project
- Assisting in identifying financial resources for energy efficiency and renewable energy measures
- Training on best operating practices
- Capacity building of local service providers to provide energy efficiency and renewable energy services and products to the MSMEs
- Facilitation of “Energy Management Cells” at the cluster level

Project Beneficiaries

MSMEs shall be the key beneficiaries of this project as they shall receive technical, as well as, financial benefits from the implementation of energy efficient technologies.

With the increased use of energy efficiency and renewable energy, the capacity of energy efficiency and renewable energy product suppliers, service providers and finance providers will also increase.

For any further information and clarification related to project activities, please contact:

GEF-UNIDO-BEE Project Management Unit
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Details of GEF projects on energy efficiency being implemented by BEE can be found on www.indiasavesenergy.in