National Program

on

Promoting Energy Efficiency and Renewable Energy in MSME Clusters in India

Indore Foundry Cluster

Detailed Energy Audit Report
Mallika Alloy Cast Pvt. Ltd.

Submitted to

Submitted by

InsPIRE Network for Environment

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Contents

List of Tables

List of Figures

Abbreviations

APFC	Automatic Power Factor Controller
BEE	Bureau of Energy Efficiency
CO	Carbon Mono-oxide
CO_2	Carbon Di-oxide
GEF	Global Environment Facility
HP	Horse Power
kcal	Kilo Calories
kg	Kilogram
kVA	Kilo Volt Ampere
kW	Kilo Watts
kWe	Kilo Watts Electrical
MDI	Maximum Demand Indicator
MDC	Maximum Demand Controller
MS	Mild Steel
MSME	Ministry of Micro Small and Medium Enterprises
PF	Power Factor
ppm	Parts per Million
SEB	State Electricity Board
SEC	Specific Energy Consumption
SME	Small and Medium Enterprise
SS	Stainless Steel
TOD	Time of Day
UNIDO	United Nation's Industrial Development Organization
VFD	Variable Frequency Drive

About the Project

The project promoting "Energy Efficiency and Renewable Energy in Selected MSME clusters in India" supported by Global Environment Facility (GEF), United Nations Industrial Development Organization (UNIDO), and Bureau of Energy Efficiency (BEE) aims to bring down the energy consumption in Indore Foundry cluster located in Indore (Madhya Pradesh) by supporting them to adopt Energy Efficient and Renewable Energy practices. There are more than 70 Small and Medium Enterprise (SME) foundry units operating in the various industrial pockets of the district. InsPIRE Network for Environment, New Delhi has been appointed as the executing agency to carry out the activities in the cluster.

The activities to be conducted under the proposed energy efficiency study in Indore Foundry Cluster include following:

- Conducting Pre-activity Workshop
- Comprehensive energy audit in 6 Foundry units
- Discussion with 3 cluster experts and 2 equipment suppliers to develop best operation practice document
- Development of Best Operating Practices Manual for top 5 technologies
- Identification of monitoring parameters and measuring instruments
- Conducting 3 post energy audit technical workshops for knowledge dissemination

As part of the activities conducted under the energy efficiency study in Indore Foundry cluster, detailed energy audits in 6 Foundry units in Indore was conducted in the month of June'2015.

Executive Summary

Name of SME unit : M/s Mallika Alloy Cast Pvt. Ltd.

Location of the SME unit : Plot no. 571-573, Sector No. 3, Pithampur, Dhar, Madhya Pradesh

Based on the measurements carried out and data collected during field visit in the month of June'2015 and analysis of the data, process wise scope for energy efficiency improvement are identified and relevant recommendations are made. The proposed energy saving measures along with the annual savings, investment required and the simple payback period is given the table 1 below:

Table 1: *Cost Economic Analysis*

SN	Energy Efficient Measures	Annual Savings (In Rs)	Estimated Investment (In Rs)	Simple Payback Period (Year)
1	Switching off the main grid power supply to transformer during non-operation of Induction furnace	18,000	Nil	Immediate
2	Modification of preheating furnace design	2,263,200	700,000	0.3
3	Installation of Air Fuel Controller	334,440	125,000	0.4
4	Installation of Air pre-heater in reheating furnace	1,051,792	100,000	0.1
5	Insulation of existing dewaxing unit	96,000	40,000	0.4
6	Installation of steam based dewaxing unit	574,012	1,500,000	2.6

- **Electrical Panels:**

The unit has installed two separate transformers of 210 and 200 kVA rating. 200 kVA transformer is used to directly supply electricity to the induction furnace, whereas, 210 kVA transformer is used to cater electricity requirements of other loads of the unit. It was observed that even having separate distribution transformer (200 kVA) supplying the induction furnace, the transformer is not disconnected from the grid main supply when the induction furnace is not in operation. This results in energy loss of around 200 electrical units per month in the distribution transformer. It is suggested to switch off main grid power supply to the transformer when induction furnace is not in operation. This would result in energy saving of around 200 units per month.

- **Shell Preheating Furnace:**

The kerosene oil based shell preheating furnace being used in the unit was measured to have low efficiency in the range of 6~8%. Based on the information collected, it is suggested to re-design the furnace to obtain fuel saving of around 43% without compromising the present production. Other suggestions made include plugging of fuel and blower leakages, arrangement for air preheating, maintenance of proper air to fuel ratio etc.

- **Wax Preparation:**

Currently, wax is heated to a temperature of 120^{0}C in the oil heating tank which is on the higher side as the melting temperature of wax is around 62~65^{0}C, so it is suggested to reduce the melting temperature from 120^{0}C to 80^{0}C. This will lead to saving in both, the additional energy used to melt and wax material loss. The appropriate heating of wax (at round 80^{0}C) will reduce wax evaporation loss.

- **Induction Furnace:**

Induction furnace is the most energy intensive equipment being used in the unit. There were many deficiencies observed in the current operation practice including no data logging, scrap loading above coil level etc. Based on the observations and measurements detailed recommendations were made and implemented in the units which resulted into the reduction of Specific Energy Consumption (SEC) from 671 kWh per ton to 652 kWh per ton, around 3% reduction in SEC. On the cooling circuit for induction furnace, it is suggested to use a fan to cool the hot crucible for few hours and reduce the running of motor / pump to reduce the operation of motors / pump.

- **Dewaxing Unit:**

Prevailing arrangement for dewaxing in the unit incorporates a kerosene fired burner to remove the wax from the sand moulds, dewaxing is carried out in a tank having melted wax at a temperature of around 200^{0}C. However, there was no energy saving measures being adopted in the dewaxing unit. Therefore, suggestions made to improve efficiency of dewaxing unit include proper insulation of the heating tank, replacement with steam based dewaxing technology.

- **Compressor:**

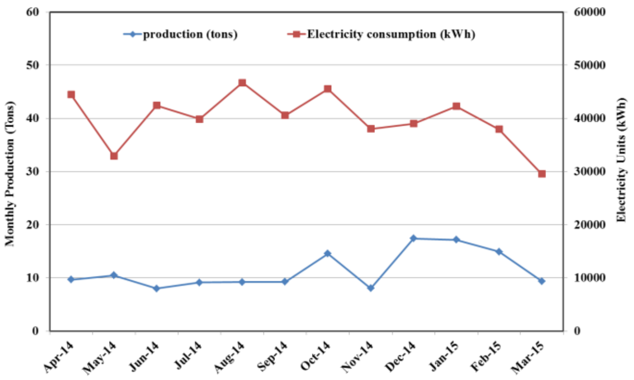
The unit has installed air compressor to use compressed air for sand coating, fettling, induction furnace and sand blasting section. Based on the information collected, it is strongly recommended to carry out leakage trail fortnightly to assess the leakage level and necessary actions to be taken if any. Further, suggestion regarding relocation of one reservoir nearer to sand blasting section is made to avoid sudden jerks and to operate smoothly.

Introduction

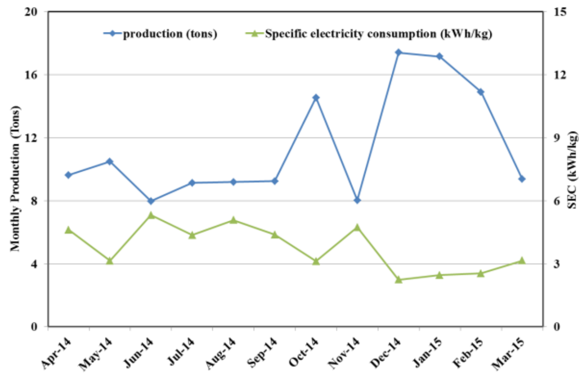
1.1 ABOUT THE UNIT

Mallika Alloy Cast Pvt. Ltd. is engaged in manufacturing of different types of investment casting and sand casting and was established in 2008. Most of the castings produced in the unit are used for captive consumption and also supplied to key customers include Kirloskar, high tech metal forming and companies located in Faridabad.

The monthly production of the unit lies in the range of 10 to 17 tons. The unit uses electricity supply from State Electricity Boards (SEBs) for various process and utility applications in premises and kerosene for reheating furnace, wax formation and dewaxing process. Figure 1.1 depicts monthly electricity consumption vis-à-vis total monthly production of the unit for last one year. Unit has installed Variable Frequency Drive (VFD), Maximum Demand Controller (MDC) and Automatic Power Factor Controller (APFC) to reduce energy expenditure.



(a) Monthly variation of production and electricity consumption



(b) Monthly variation of production and specific electricity consumption

Figure 1.1: *Electricity consumption and production details*

Inference: It can be observed from the above figures that the monthly energy consumption is directly proportional to the production for a month. However, specific energy consumption is inversely proportional to the production. Lower the productivity of the plant, higher is the specific electricity consumption. This implies that lower productivity means lower utilization of the equipment thus leading to higher downtime and high specific energy consumption.

However, as observed in Fig a and b above, anomalies in direct relationship between production and electricity consumption can be observed in certain months like June 2014 and May 2014. For the month of June 2014, the unit has a low production and a high energy consumption and reverse in the month of May 2014, wherein the unit has a high production with low energy consumption. These anomalies can be related to reasons such as lower productivity due to low demand, idle running of machines, higher rate of rejections, lower utilization and high peak hour operations.

Major electricity consumption is required by electrical induction furnace for scrap melting operation. Unit has installed two oil based preheating furnace for carrying out shell baking and heat treatment of products.

Unit uses kerosene for dewaxing and shell pre-heating operations. The monthly kerosene consumption is around 5,250 liters. According to the assessment of the energy consumption data collected, the specific thermal energy consumption and specific electrical energy consumption is 0.46 Liters per kg and 4 kWh per kg of product respectively. The total specific energy consumption (in kCal) is 7,154 kCal per kg of product. Details of annual electrical and thermal energy consumption and specific energy consumption details in Mallika Alloy Cast Pvt. Ltd. are presented in Table 1.1 below:

Table 1.1: ***Details of M/s Mallika Alloy Cast Pvt. Ltd.***

SN	Parameter	Value	Unit
1	Name and address of unit	Mallika Alloy Cast Pvt. Ltd., Plot no. 571-573, Sector no. 3, Pithampur, Dhar, Madhya Pradesh	
2	Contact person	Mr. Manish Neema, Contact (M): 9770287443	
3	Manufacturing product	Investment casting and sand casting	
4	Monthly Production	11.4 tons	
	Energy utilization		
6	Average monthly electrical energy consumption	39,939	kWh/ month
7	Average monthly thermal (Kerosene) energy consumption	5,250	Liters/ month
		47.20	MCal/month
8	Average specific thermal energy consumption	0.46	Liter /kg of product
9	Specific electrical energy consumption	3.50	kWh/kg of product
10	Specific energy consumption	7,154	kCal/kg of product
11	Electrical energy cost	27	Rs/kg of product
12	Thermal energy cost	18	Rs/kg of product
13	Total energy cost	45	Rs/kg of product

Note:

Specific gross calorific value of Kerosene is considered as 8991 kCal / liters

Thermal equivalent for one unit of electricity is 860 kCal/kWh.

The unit operates for 25 days a month (1 shift of 8 effective hours per day).

Cost of Kerosene = Rs. 40 per liters (the purchase price provided by the unit)

Cost of Electricity = Rs. 7.58 per unit (average cost calculated from electricity bills of last four months)

Figure 1.2 provides annual energy mix for both electrical and thermal energy on cost as well as kCal basis. It can be observed share of thermal energy is very high as compared to electrical energy mainly due to presence of preheating furnace and dewaxing using thermal energy.

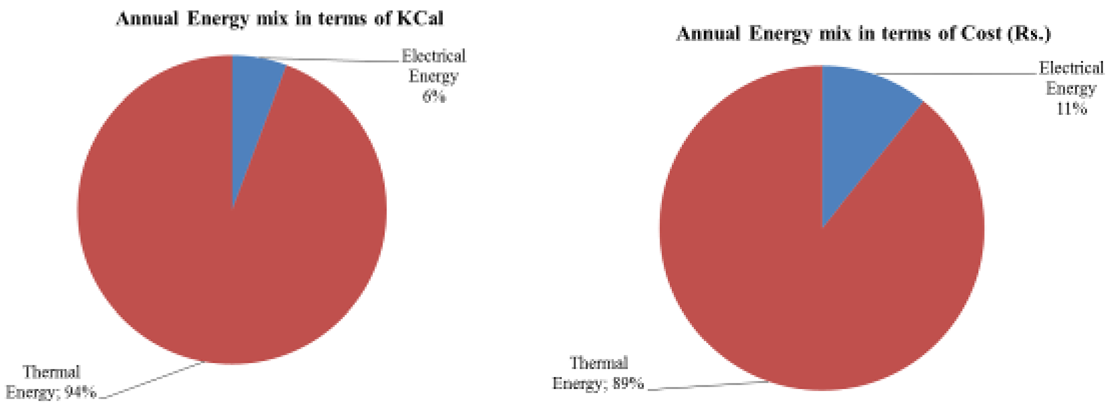


Figure 1.2: ***Annual energy mix of the unit in terms of kCal and Rupees.***

1.2 ENERGY AUDIT METHODOLOGY

The primary objective of the energy audit was to study prevailing energy consumption pattern and to identify scope for energy efficiency improvement through technical intervention as well as inclusion of best operation practices. Figure 1.2 depicts the flow chart of activities being adopted for detailed energy audit study.

The activities for the current project started with organization of a pre-activity workshop attended by local unit owners, representatives from UNIDO. During the workshop, project objectives along with support required from the units were also discussed. After this workshop, six units for further consideration of energy audit studies were selected by the local association.

After selection of units, preliminary information relating to the energy consumption by the units was collected in a structured questionnaire. The intent of this preliminary data collection was mainly to get preliminary details about the units to make the energy audit process more effective. A copy of the same questionnaire is attached as ***Annexure 1***. Thereafter, field visit to selected industries was carried on a mutually decided dates. During energy audits, detailed data related to specific fuel consumption, various losses, operation practices being followed at the units were measured and collected. Further the gathered data is analyzed to assess prevailing energy consumption of each unit. Further, based on the observation as well as data analysis recommendations related to energy conservation opportunities are also made. List of measuring instruments used during detailed energy audit are summarized in Table 1.2.

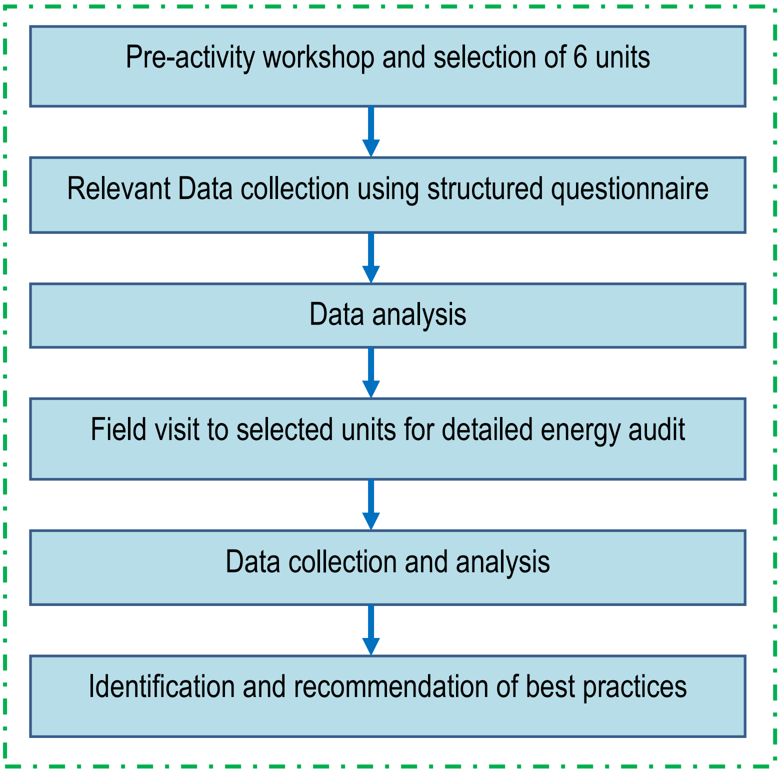


Figure 1.3: ***Flowchart depicting sequence of activities followed for carrying out detailed energy audit***

Table 1.2: ***List of instruments used during energy audit***

SN	Name of Instrument	Make / Model
1	Three Phase Power Quality Analyzer	Fluke/434/UNI
2	Single Phase Power Quality Analyzer	Fluke/43B
3	Ultra Sonic Water Flow Meter	GE Panametrics/PT878
4	Rotating Vane Anemometer	Prova Ltd., Taiwan/AVM -05
5	Lux Meter	Metravi/1332
6	Portable Non-contact Infrared Thermometer	Raytek, USA/ST 80
7	Flue Gas Analyzer	Kan May, KM 900

Present Process, Observations and Proposed Technology

2.1 PRODUCTION PROCESS OF PLANT

The process of investment casting is suitable for casting a wide range of shapes and contours in small size parts, especially those that are made of hard to machine materials. The process produces excellent surface finish for casting. In this process, mould is made in a single piece without any parting lines. Firstly, accurate dimensioned metal pattern are made after making several size adjustment which takes place in the process.

The following figure shows the typical process being followed at Mallika Alloy Cast Pvt. Ltd. for manufacturing of precision investment castings. The detailed description of each step along with the type of energy input and details related to critical parameters are provided in subsequent paragraphs.

▶ Blue Print Drawing:

The first stage of investment casting method is designing parts and drawing blue prints of the products that require no defects, light weight and rationality.

▶ Metal Dies Farming:

In this process metal dies are made after taking into account expansion rate between hot and cold temperature of the metal. Further these dies are used for wax pattern making.

▶ Wax Preparation:

In this process wax along with other required composition is heated in rotating drum under controlled heating to melt it in liquid form. This heating of wax is achieved by using a thermic oil heater equipped with automatic On/Off sensor. The cut-off temperature set for wax melting is 120^{0}C which is higher than the required temperature of 80^{0}C. However, it helps in removal of impurities from the top. The unit has installed two thermic oil heaters among them one is used as backup.

This process requires electrical energy to heat the wax using a thermic oil heater of capacity 1.5 kWe. The measuring parameter to be observed in this process is temperature as heating beyond required temperature would result into loss of electrical energy. Thermocouples are being used to observe process temperature and automatic controller is provided which switches electrical supply on and off based on the set values (in these case its “temperature”).

▶ Wax Pattern Making:

The molted wax from the heating tank is shifted to one bigger tank equipped with stirrer to avoid molten wax from getting solidify. Further this molten wax is sent to pneumatic cylinder press through which molted wax is injected into metal die to make one piece heat disposable pattern. These dies may range from a single cavity or automated multi cavity tool depending upon the production quantities and complexities of the part. This heat disposable pattern is required for each casting.

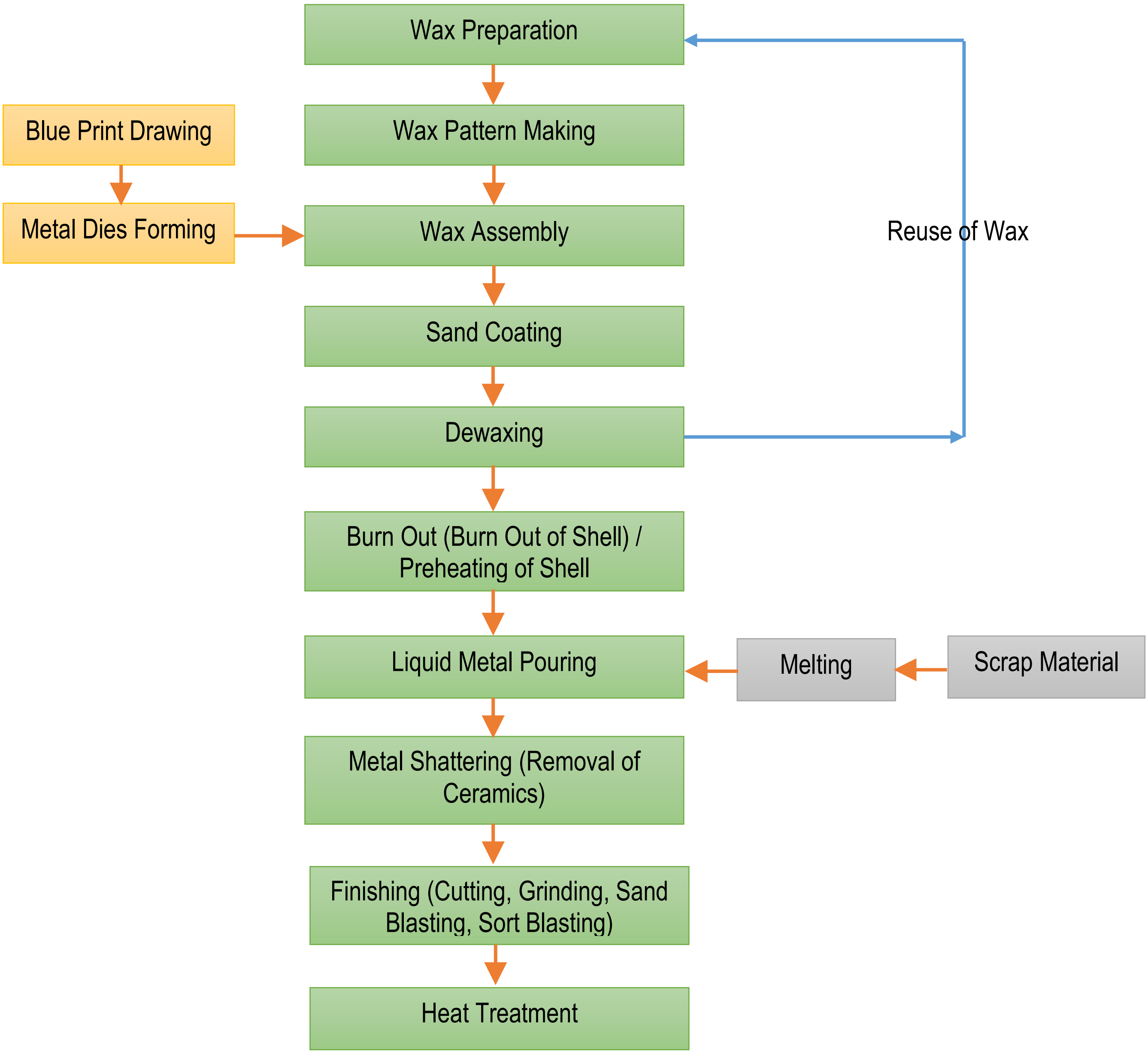


Figure 2.1: ***Process flow diagram***

Unit has got total of 9 automatic moulding presses. However, depending upon the production requirement they operate lesser number of automatic moulding presses. After injecting molten wax into dies operators observe the solidification time of molten wax in the display and remove the heat disposable pattern from die. This wax pattern is then cleaned to ensure smooth surface.

- **Wax Assembly:**

In this process, wax patterns are welded to sprue post. A sprue post may hold anywhere from one to several patterns in one assembly to form a tree kind of structure. It also acts as riser for during metal pouring.

- **Sand Coating:**

This process involves dipping of wax assembly into ceramic slurry, draining it and then coating it with fine ceramic sand. After drying, this process is repeated with progressively coarser grades of ceramic material, until a self-supporting shell has been formed. The wax assembly is initially coated with zirconium sand which can withstand higher temperature of around 2,000^{0}C. After each round of coating, the wax assembly piece is left for drying, the drying time depends on the climatic season.

This process requires electrical energy for operating stirrer in the mixing tank and blower in the sand coating. The capacities of these machines are provided in table 2.1. All the stirrers are operated round the clock to keep slurry in evenly liquid condition.

In this process, drying of the sand coated on the wax pattern is critical as it vary with the climatic season. So the unit has installed humidifiers to control atmosphere humidity and temperature inside the drying room. Further, fans are also used to speed up the drying process. After final stage of sand coating, the pattern is left over to minimum 24 hours for drying.

- **Dewaxing:**

The sand coated patterns are de-waxed to remove the wax pattern and create cavity in which molten metal is to be poured. For this dewaxing, sand coated pattern is soaked in the solution of heated molten wax filled in a tank. The tank is heated using a kerosene fired burner to maintain a temperature of 200^{0}C. Although, wax melting can be achieved at a temperature of 60 to 80^{0}C, the molten wax is maintained at a temperature of 200^{0}C to facilitate faster melting of wax from sand core. This is done to avoid crack development in sand core mould due to slow heating.

In the process, kerosene fired burned is operated for 2 hours to attend temperature of 200^{0}C of molten wax in the tank. After that fuel supply is controlled to keep the temperature in the range of 180^{0}C to 200^{0}C. In the process, sand coated mould is soaked for 4 to 5 minutes to melt and remove the wax from it.

- **Preheating Furnace (Shell Baking Furnace):**

De-waxed mould is then baked in the preheating furnace to burn out any residues. This is basically a heat treatment process in which de-waxed moulds are heated close to the pouring temperature (around 1050^{0}C). This process enhances the physical strength, permeability of the shell and to avoid thermal shock while pouring hot molten metal. This preheating is achieved using kerosene oil-fired furnace. The detailed description of this is further provided in the subsequent section of the report. Normally, the preheating of moulds is achieved within 45 minutes.

- **Metal Melting:**

In this process, scrap material is melted using an electrical induction furnace. The raw material in the form of various types of scraps are put in the induction furnace, however, the quantity and type of scraps put in the furnace are by the judgement of the furnace operators. Scrap material is heated to around 1600⁰C after which composition of the molten metal is analyzed using a spectrometer and accordingly, if required, correction is made to bring required composition of molten metal. Final melting temperature may change depending upon the composition of scrap. Normally, the time required for melting operation is between 60 to 80 minutes.

The process requires electrical energy input for induction furnace as well as for pumps and motors being used in the cooling circuit of induction furnace. The critical parameters to be observed in this process are composition of the molten metal as well as its temperature.

- **Metal Pouring:**

In this step, molten metal from induction furnace is poured in the preheated moulds from preheating furnace. Both moulds preheating and metal melting operations are synchronized so that by the time scrap is melted; preheating of the sand coated moulds is also complete. Molten metal from crucible is poured into sand moulds using laddle. To avoid sudden cooling of material, laddle is also preheated in the preheating furnace. After pouring molten material it is allowed to cool and solidify inside the sand moulds.

- **Metal Shattering:**

In this step, the mould containing solid metal is broken to remove ceramic sand coating and get the product. This process is achieved using a pneumatic cylinder machine in which compressed air is used to break the moulds. The time required for breaking one mould is around 5 minutes.

- **Finishing Operation:**

This process includes cutting, grinding, sand blasting, and shot blasting operations. In the cutting operation, products are cut from the sprue post using either electrode or oxyacetylene cutter. For Stainless Steel (SS) material electrode cutting is used, whereas, for Mild Steel (MS) material oxyacetylene cutting technology is used. This process requires electrical energy for machine operation. The duration of the cutting for each product may vary from 5 to 15 minutes depending upon the shape and size of the piece.

Grinding of the metal parts is carried out to remove residues from the surface of the products. The units uses motor grinder, hand grinder and belt rolls for grinding operation depending upon the shape and size of the product to be grinded.

Further to remove the sand coating from interior parts sand blasting is carried out. In this process, compressed air at higher pressure is sprayed over the metal component to remove residue sand. Finally, depending upon the final finish requirement, metal products are also subjected to sort blasting in which small sorts of 0.8 mm are thrown over the metal at high velocity. This process results into good surface finish of the metal.

- **Heat Treatment:**

The finished metal products are subjected to heat treatment for improving mechanical strength of the product. This heat treatment is achieved using oil based furnace. Based on the characteristics of the end material required, time and temperature of heat treatment is decided. After initial heating in the furnace, product is quenched in water. The hot water generated from this tank is again circulated through cooling tower to cool it down. Therefore, this process requires electrical energy to operate blower and pumps and thermal energy is required in the form of oil for furnace operation.

Pictorial Representation of Production Process

Figure 2.2: ***Wax melting in thermic oil heaters***

Figure 2.3: ***Wax pattern making using pneumatic cylinder press***

Figure 2.4: ***Different wax patterns***

Figure 2.5: ***Wax pattern after assembly***

Figure 2.6: ***Stirrer tank containing ceramic slurry and sand coating equipment***

Figure 2.7: ***Drying of patterns after sand coating***

Figure 2.8: ***Oil fired tank for dewaxing from sand coated moulds***

Figure 2.9: ***Sand coated moulds after dewaxing***

Figure 2.10: ***Melting of scrap material in Induction furnace***

Figure 2.11: ***Pouring of molten material from crucible to Laddle***

Figure 2.12: Pr*eheating of sand coated moulds in oil fired preheated furnace*

Figure 2.13: ***Sand coated moulds just after molten metal pouring***

Figure 2.14: ***Removal of ceramic using pneumatic cylinder machine***

Figure 2.15: ***Product after removal of ceramics***

Figure 2.16: ***Removal of ceramics from holes***

Figure 2.17: ***Grinding of product***

Figure 2.18: ***Sand blasting for removal of residue of ceramics from final products***

2.2 PRESENT TECHNOLOGIES ADOPTED

The list of energy consuming installation in the unit and used for foundry process are as follows:

Table 2.1: ***Process wise energy consumption information***

SN	Process	Number	Energy Source	Rated consumption	Daily operation in hours	Days per month	Capacity
1	Wax preparation machine	2	Electricity (Thermic Oil heater)	1.5 kWe	14 hrs	25	Around 100 kgs Quantity of wax to be melted is decided based on per day production target
2	Pneumatic cylinder press	9	Compressed air	2 Tons	Average 5 runs per day for 8 hrs	25	Depends on per day production
3	Sand Coating	3 Sand stirrer, 4 Sand raining	Electricity for stirrer and sand raining	3 Stirrer (6 HP) 3 Blower (Total 11 HP)	Stirrer – 24 hrs, Blower – 1 to 2.5 hrs	25	Depends on per day production
4	Dewaxing	1	Thermal, (Kerosene) Electrical (Blower)	0.5 HP	8	25	Depends on per day production
5	Shell Preheating	1	Electricity (Blower) Thermal, (Kerosene)	Blower (3 HP), Burner size 2A (Wesman make)	10	25	Depends on the quantity of the material to be melted
6	Induction Furnace	1	Electricity	Induction Furnace (175 kW), Cooling motor/pumps (10 HP)	10 hrs (furnace) 14 hrs (cooling motor/pumps)	25	350 kg per melt
7	Shattering	1	Compressed air	Not known	4 hrs	25	
8	Cutting & Grinding	3	Electricity	7.5 HP Motor grinder, 1 HP Belt Roll	Cutting m/c (4hrs) Motor Grinder (1 hrs) Belt roll (3 hrs)	25	
9	Sand Blasting	1	Compressed air	Not known	4 hrs	25	
10	Shot Blasting	1	Electricity	10 HP, 1 HP for turning	2.5 hrs	25	

S N	Process	Number	Energy Source	Rated consumption	Daily operation in hours	Days per month	Capacity
11	Heat Treatment	1	Electricity (Blower) Thermal, (Kerosene)	3 HP	4 hrs	4	800 ~ 1000 kg per heat

^A shift is equal to 8 effective hours of working / operation.

2.3 DETAILED ENERGY AUDIT

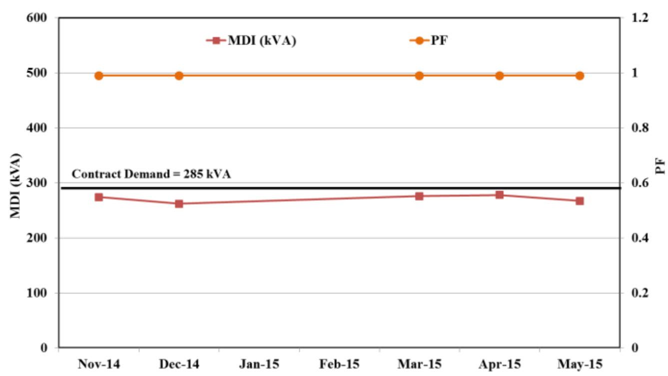
During the field visit to the unit detailed measurement of the following equipment were carried out. Following sections provides present observations and recommendations for each equipment to improve energy efficiency.

2.3.1 Electrical Panels:

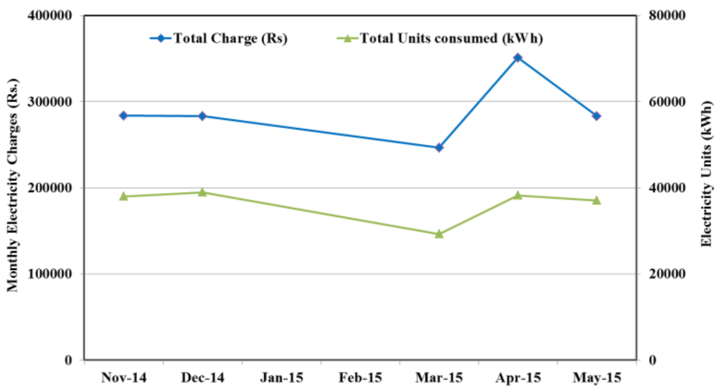
► Present System:

The unit has got connected load of 285 kW. The unit has installed two separate transformers of 210 and 200 kVA. One transformer (200 kVA) is used to directly supply electricity to the induction furnace, whereas, other one (210 kVA) is used to cater electricity requirements of other loads in the unit. The unit has installed automatic power factor controller. Unit has installed separate energy meter to record power consumption for induction furnace.

Apart from regular consumption tariff, the SEB has time of day (TOD) tariff – a rebate of 7.5% is provided for operations between 10 pm to 6 am and a penalty of 15% is levied for electricity usage between 6 pm to 10 pm. Figure 2.19 provides the monthly variation of electricity consumption, Maximum Demand Indicator (MDI) and power factor for the unit. It is observed, the total monthly maximum demand of the unit is close to its contract demand value of 285 kVA. Further, Unit has installed automatic power factor controller because of which the PF of the unit is observed to be higher.



Monthly Variation of MDI and PF



Monthly Variation of Electricity Consumption

Figure 2.19: ***Monthly variation of selected electrical parameters***

Figure 2.20: ***Pictorial depiction of transformers and electrical panels***

▶ Observations:

During field visit to the unit, it was found that the induction furnace is operated twice or thrice a week for around 8 ~ 10 hours per day. The low capacity utilization around 21% (30 hours of operation in 144 available hours per week) of the induction furnace is due to low production schedule and lower order size. It was observed that even having separate distribution transformer (200 kVA) supplying the induction furnace the transformer is not disconnected from the grid main supply when the induction furnace is not in operation. This results in energy loss as fixed (or no load) loss incurred in the distribution transformer. For a 200 kVA oil filled transformer, no loss or fixed load losses are around 400 watts. In the unit, transformer is ideal for around 114 hours per week (79% ideal time) resulting into loss of around 200 electrical units per month.

▶ Recommendations:

It is suggested to switch off main grid power supply to the transformer when induction furnace is not in operation. This would result in energy saving of around 200 units per month (refer Table 2.2). Considering per unit cost of Rs. 7.5, this measures would provide annual benefit of around Rs. 18,000.

Table 2.2: ***Cost Economic Analysis***

SN	Energy Efficient Measure	Estimated Energy savings (kWh/Year)	Annual Savings (In Rs)	Estimated Investment (In Rs)	Simple Payback Period (Year)
1	Switching off the main grid power supply to transformer during non-operation of Induction furnace	2,400	18,000	Nil	Immediate

2.3.2 Shell Preheating Furnace:

- **Present System:**

The unit has installed oil fired preheating furnace to bake the moulds at temperature of around 1085^{0}C. The furnace has got two burners on each side. Fuel is supplied through nozzles from an overhead tank and air for combustion is supplied using motor driven blower which supply air to both burners. During combustion, temperature inside the furnace is measured using two thermocouples, located close to both the burners. Material is placed and removed from the furnace through a drop gate type front discharge door of the furnace. Based on the information provided by furnace suppliers, the fuel consumption per burner should be 10.5 liters per hour. However, the fuel consumption as informed by the unit owner from his past experience was around 13.5 liters per hour per burner. The details of the furnace specifications and the schematic drawing are given in Table 2.3 and Figure 2.21.

Table 2.3: *Furnace specifications*

Shell Preheating Furnace Dimensions	1.2 m x 1.2 m x 1 .2 m
Burner model / make	2 Wesman (2A type)
Fuel type input	Kerosene
Fuel tank dimension	2 ft x 2 ft x 3 ft
Fuel flow	Gravity
Blower motor rating	5 HP
Fuel consumption	13.5 liters per burner per hour
Hours of operation per day	10

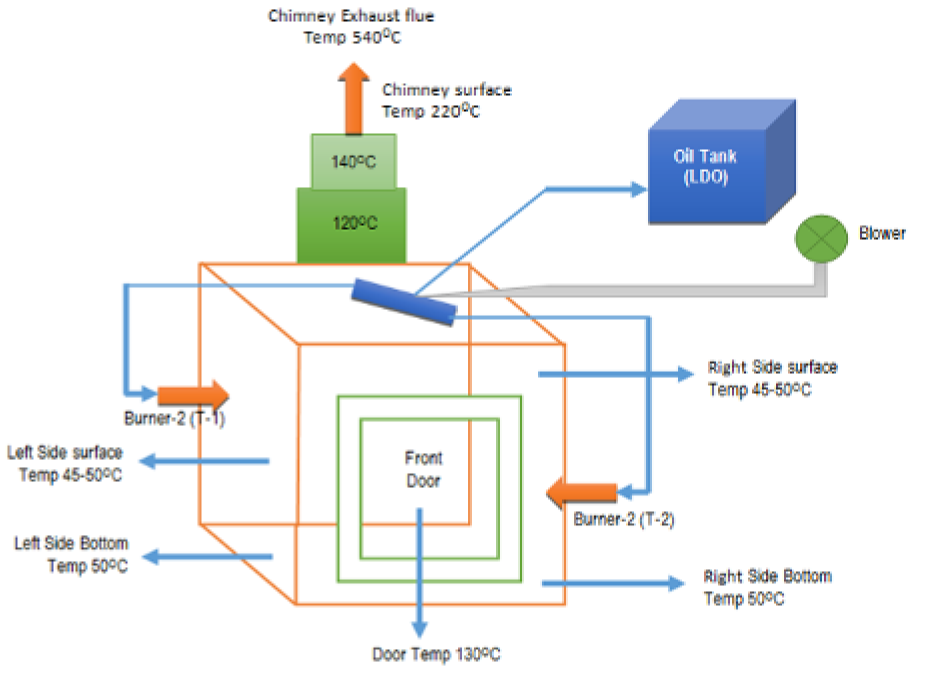


Figure 2.21: *Schematic diagram of the shell preheating furnace*

During field visit to the unit, detailed measurement of furnace performance assessment was carried out. Data related to fuel consumption, blower loading, furnace loading, time of operation, furnace temperature, exhaust measurement (flue gas composition &

temperature) was measured. All these data related to one preheating was measured and collected. Figure 2.22 provides information related to furnace operation vis-à-vis time required for completion. Based on the measurement and field visit, following observations are made.

- Average time required to preheat one charge (shells) is around 45 minutes at steady state conditions and it take 1.5 hours to cold start the furnace.
- Efforts are given to synchronize both preheating of shells moulds is competed in preheating furnace and molten metal from induction furnace is ready for pouring.
- Furnace is heated to reach a temperature of 1080^{0}C after which fuel supply is controlled to hold the temperature at this level (refer Figure 2.20)
- It was found that the furnace temperature was controlled by increase or decrease (open or close of fuel valve) of fuel supply. The open/close of fuel valve was governed by the judgement of the operator by seeing the flame length and colour.
- Two thermocouples were used to measure furnace inside temperature. However, there was no clear marking as to which temperature belong to which thermocouple.
- Kerosene fuel was observed to leak from three fuel supply points.
- Blower was leaking as three nuts were found missing, due to which low suction was observed at the mouth of the blower input air.
- It was observed that air supplied by blower is divided in two air paths supplied to each burner. There is no mechanism to control air supply at each burner.
- Furnace temperature is increased or decreased by controlling the fuel supply without changing the combustion air being supplied by blower, which would affect the air fuel supply ratio.
- Furnace capacity was found to be much more than the required capacity. The preheating furnace capacity should be decided based on the amount of molten material available per charge.
- Left and right side surface temperature of the furnace were found to be in the range of 45 to 50^{0}C indicating use of good quality of refractory.
- Furnace exhaust flue gas temperature was found to be around 540^{0}C which was discharged in atmosphere through a chimney.
- Performance measurement of blower motor revealed a loading of 52% and power factor of 0.65. Both the blower motor loading and the power factor were found to be on the lower side.
- The composition of exhaust flue gas was found to have 10.3% of O_2 content indicating around 90% of the excess air supply. This high excess air supply lowers the furnace efficiency as useful fuel energy is wasted to heat the extra amount of air.
- Specific fuel consumption (kerosene) was found to be 19 liters per hour per burner, which is very high compared to the design consumption of 10.5 liters per hour per burner suggested by the burner supplier. The reasons for this higher consumption are oil leakage being observed from three fuel supply points, excess air supply, and low furnace loading.
- The operational efficiency of the preheating furnace was found to be very low and in the range of 6 to 8 % only. The detailed efficiency calculation is attached as ***Annexure 6.***

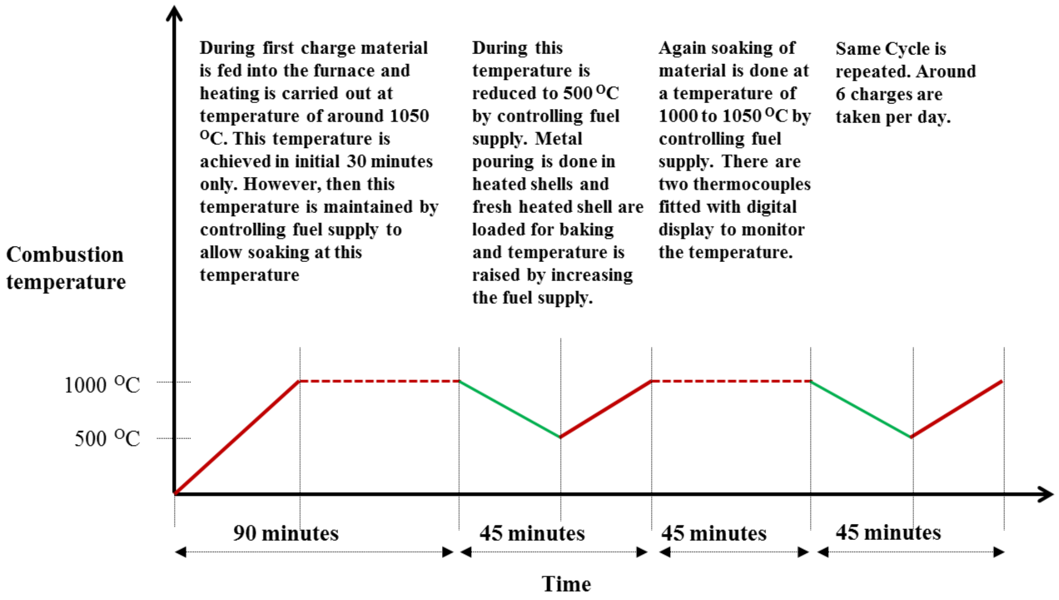


Figure 2.22: *Depiction of shell preheating process in preheating furnace*

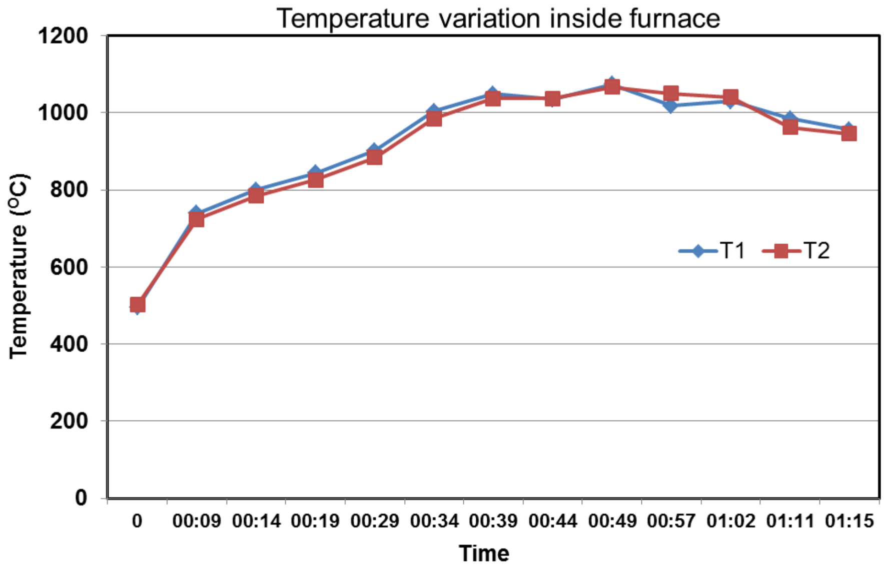


Figure 2.23: *Temperature variation inside preheating furnace*

Table 2.4: *Measurements performed on Blower Motor*

Current (Amps)				Voltage (Volts)	Actual Power (kW)	PF Factor	Rated Motor HP (kW)	Loading (%)
R	Y	B	Average					
4.25	4.05	4.06	4.12	413	1.92	0.65	5 (3.73)	51.36

Table 2.5: *Flue Gas Analyzer Measurement Reading*

Exhaust Temp (°C)	CO_2%	O_2%	CO (ppm)
540	6	10.3	35

Figure 2.24: ***Pictorial depiction of shell preheating furnace, temperature indicator, and exhaust line***

- **Recommendations:**

1. **Re-design the furnace:** During trial measurement, it is found that shell preheating furnace capacity is 1.92 times more than Induction furnace capacity. Therefore, it is proposed to reduce the preheating furnace capacity to half the present size and use one burner instead of two burners to fire the furnace. This re-design would result into fuel saving of around 43%. Mathematical calculations of the estimated fuel saving through re-design of furnace are given in ***Annexure 2***.

2. **Plug fuel and blower leakages:** It is suggested to avoid any leakage in blower as well as fuel line as it adversely affects the efficiency of furnace.

3. **Maintain Air-fuel ratio**: It becomes difficult to maintain air fuel ratio manually, it is suggested to install automatic air-fuel ratio to have complete combustion and enhance the furnace efficiency.

4. **Arrangement for air pre-heating:** The temperature of flue gas was measured to be around 540^{0}C which is being discharged to the atmosphere. It is suggested to use air preheater to pre-heat the air being used for combustion using the waste exhaust heat to improve overall efficiency of the furnace.

The cost economic analysis of the above suggested measures are compiled in Table 2.6. It can be observed that all the measures suggested towards energy efficiency improvements of furnaces have good payback period of less than 6 months.

Table 2.6: *Cost Economic Analysis – Preheating Furnace*

SN	Energy Efficient Measure	Estimated Fuel savings (Liters/year)	Annual Savings (In Rs)	Estimated Investment (In Rs)	Simple Payback Period (Year)
1	Modification of preheating furnace design	56,580	2,263,200	700,000	0.3
2	Installation of Air Fuel controller	8,361	334,440	125,000	0.4
3	Installation of Air pre-heater in preheating furnace	26,295	1,051,793	100,000	0.1

2.3.3 Wax Preparation:

▶ Present System:

In this process, wax along with other required composition is heated in rotating drum under controlled heating to melt it in liquid form. This heating of wax is achieved by using a thermic oil heater equipped with automatic temperature On/Off sensor. The cut-off temperature set for wax melting is 120^{0}C which is higher than the required temperature of 62 to 65^{0}C. However, it helps in removal of impurities from the top.

▶ Observations:

In the current arrangement, electrical supply to electric heater is automatically switched off once temperature of 120^{0}C is attained. However, tank is not insulated from sides and also remained open from the top resulting into heat loss in the atmosphere. Due to the higher temperature (around 120^{0}C) the wax is evaporated leading to loss is wax.

▶ Suggestions:

The unit has installed two thermic oil heaters of capacity of 1.5 kWe each, with one as backup. It is suggested to cover the tank from the top as well as along the sides with insulation to avoid heat loss. The set temperature of 120^{0}C is on the higher side as the melting temperature of wax is around 62 to 65^{0}C, so it is suggested to reduce the temperature from 120^{0}C to 80^{0}C. This will lead to saving in both terms electrical energy and materials (wax), to avoid overheat the wax to reduce the wax evaporation loss.

2.3.4 Induction Furnace:

- **Present System:**

Unit has installed electrical furnace supplied by Inductotherm (India) Pvt. Ltd. The induction furnace is 175 kW with crucible capacity of 300 kgs. Using this, scrap is melted at a temperature of around 1600^{0}C. Unit has also installed one standby crucible of same capacity. During energy audit, detailed study pertaining to performance assessment of induction furnace was carried out. In the operation, crucible is filled with the scrap material and heating is done by switching on the power supply. The required temperature is typically attained in 60 to 80 minutes except for the cold start for which more time is required. Once the metal is melted and properly mixed, its composition is checked using spectrometer and based on the results, if required necessary correction is made. Temperature of the molten metal is used using a dip stick pyrometer. Once melting of the scrap in crucible is achieved, small amount of silica is added to the molten metal which absorbs the slags present in scrap material and brings it on the top. This slag is removed from the top of the molten metal after that the molten metal is ready for pouring. Based on the production schedule, average four charges are taken per day.

Table 2.7: ***Furnace specifications***

Model/Make	Inductotherm India Pvt. Ltd
Energy Input	Electricity, 175 kW
Crucible Capacity	300 kg

Figure 2.25: ***Induction furnace along with crucibles***

Figure 2.26: ***Separate panel for electricity supply to induction furnace, Electrical panel of induction furnace***

To avoid over heating of the coils used in induction furnace, cooled water is continuously circulated through coils. The schematic of the water circuit for the same is shown in Figure 2.26. Water in this cooling circuit operates even after closing of furnace operation to remove the residual heat from the crucible.

▶ Observations:

During field visit to the unit, detailed performance study of induction furnace was carried out for three charges. The observations made are summarized in Table 2.8. It is observed that first charge being a cold start, took more time for melting operation. The specific energy consumption for all the three charges is shown in Figure 2.27.

Table 2.8: ***Summary of performance study***

EE Trial No.	Total Metal (kg)	Furnace Start Time (hh:mm)	Furnace End Time (hh:mm)	Total Melt Time (hh:mm)	Tapping temp (⁰C)	Initial kWh reading	Final kWh reading	Total kWh consumed	SEC (kWh/ ton)	Remarks
1	316	10:28	12:35	02:07	1613	326772	327059	287	908	Cold start after 18 hours of shut down
2	316	12:44	14:15	01:31	1625	327087	327299	212	671	Induction furnace was overloaded (or overfilled)
3	290	14:24	15:45	01:21	1635	327327	327516	189	652	Furnace was appropriately loaded

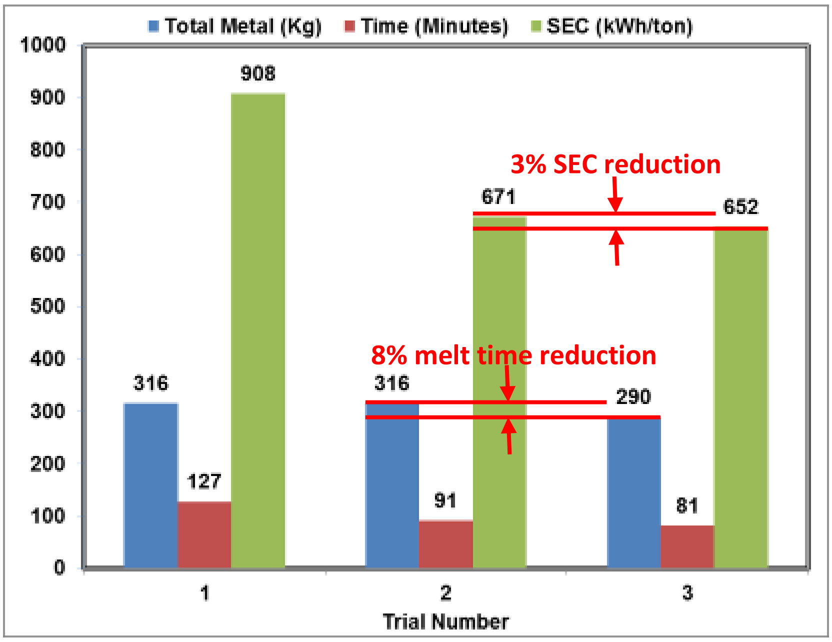


Figure 2.27: *Specific energy consumption of Induction furnace*

EE Trail No 1: Cold start after 18 hours of shut down
EE Trail No 2: Induction furnace was overloaded (or over filled above the induction coil)
EE Trail No 3: Furnace was appropriately loaded

In addition following observations were made;

- Scarp material used for melting was not measured and charged.
- Loading of furnace was based on judgement of the operator and often loading was more than the furnace capacity. The overfilling of material above the induction coil is practice of the furnace operator to enhance the production.
- Tapping temperature was 1615^{0}C maximum. On both the trials, the tapping temperature was exceeded by 10 and 20^{0}C respectively.
- Comparison between EE trail No. 2 (overloading of furnace) and 3 (rightly loaded furnace) was been demonstrated
- Scrape material was weighed and charged into the induction furnace during EE trial No. 3
- Meting time taken during EE trail No. 3 was reduced by 10 minutes (nearly 8%).
- SEC during EE trail No. 3 was reduced by 19 kWh per tons (around 3% saving).
- Both these reduction, melting time and SEC, are shown in figure 2.27.

Recommendations:

- Best Practice #1 (Material Log Book): Maintain log records of type and quantity of scrap material being used and electricity consumed for every charge (See ***Annexure 3***).
- Best Practice #2 (Furnace Loading & Operation): Level of molten metal should not exceed the level of induction furnace coil (See ***Annexure 4***).
- As far as possible, no overheating of material beyond the required temperature should be carried out as it directly consumes energy.

- Holding of furnace should be avoided by proper planning of moulds / shells in advance
- Heel metal should be avoided.
- During pouring and molten metal composition measurement, power supply to the induction furnace should be reduced to around 25% of the full capacity.

Figure 2.28: ***Coils of induction furnace around the crucible***

Figure 2.29: ***Pouring of molten metal to laddle***

Figure 2.30: ***Molten metal in the crucible***

2.3.5 Cooling Circuit for Induction Furnace:

▶ Present Arrangement:

In the present arrangement, heat of the water coming from coil is exchanged with cold water coming from heat exchanger using a plate heat exchanger. In addition, unit has also installed an overhead tank from which water is circulated through coils for cooling when the induction furnace is not in operation. This also serves cooling in case of power outage during operation. In order to avoid any damage, maximum temperature limits for the water flowing in the coil has been set beyond which system automatically shuts off.

▶ Observations:

During field visit, measurement related to motor loading for different motors being used in the cooling circuit was carried out. The results are summarized in Table 2.9. Both the pump was found to have loading in the range of 75 to 80%. Overall Power Factor (PF) for both the pumps was around 0.61. However, it was found that in one phase the power factor was found to be very low (around 0.09), which may be due to internal motor winding damage, this may be studied and rectified separately.

Table 2.9: ***Measurements of Loading of Cooling Water Motors / Pumps***

Pump Details	Current (Amps)				Voltage (Volts)	PF	Actual Power (kW)	Rated Motor (HP)	Loading (%)	Remarks
	R	Y	B	Average						
Pump for circulating water through coil	6.40	6.20	6.70	6.43	415	0.61^	2.82	5	75.62	Very low PF in one phase
Cooling tower pump	4.10	4.00	4.30	4.13	414	0.62#	1.84	3	82.11	Very low PF in one phase
Cooling tower fan motor	3.00	1.00	3.00	2.33	415	0.54	0.91	2	60.70	overall low PF

Note: ^ the PF recorded in 3 phases were, 0.83, 0.92 and 0.09. In one phase the PF was observed very low (0.09)

the PF recorded in 3 phases were, 0.78, 0.95 and 0.14. In one phase the PF was observed very low (0.14)

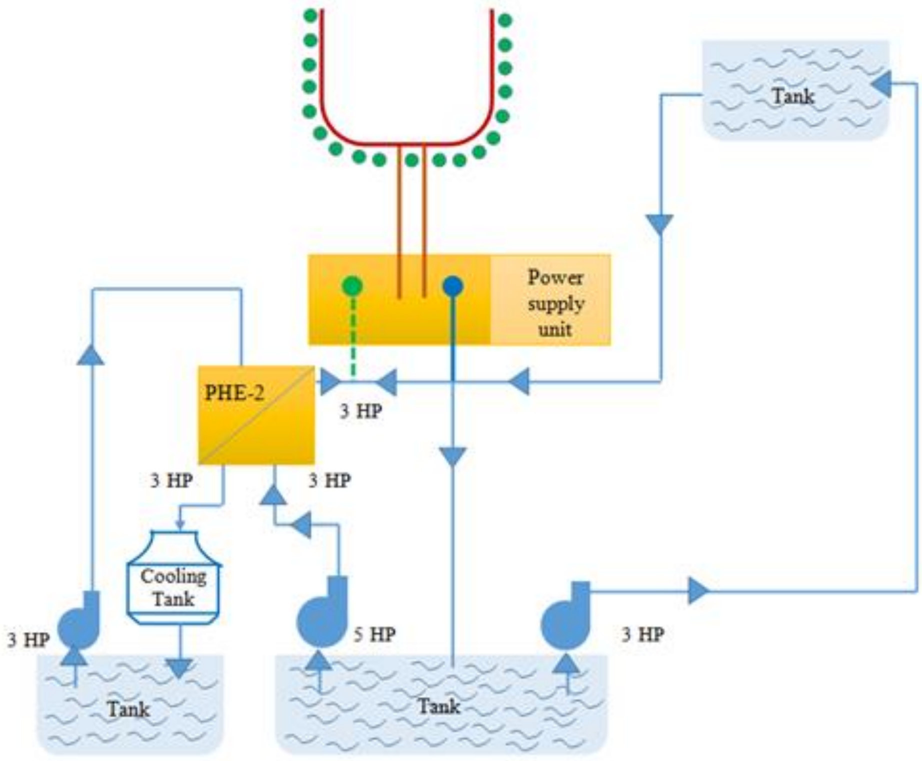


Figure 2.31: ***Flow diagram of cooling water circuit***

Figure 2.32: ***Pumps and plate type heat exchanger being used in the cooling circuit***

- **Recommendations:**

Presently, after the induction furnace operation is stopped the cooling water motor / pump is kept operating for around 5~6 hours to cool the coil and panel. In order to reduce the operation of motors / pump, it was suggested to use a fan to cool the hot crucible for few hours and reduce the running of motor / pump. This initiate would save electrical energy used in motor / coil.

2.3.6 Dewaxing Unit:

- **Present System:**

In order to remove the wax from the sand moulds, dewaxing is carried out in a tank having melted wax at a temperature of around 200^{0}C. Unit has installed small kerosene fired burner along with a small blower motor as shown in Figure 2.33. In this process, sand coated mould is soaked in the melted wax at 200^{0}C for five minutes after which the wax from the moulds gets removed. Further, this melted wax is recycled to the first process. During start of the operation the temperature of 200^{0}C is attained after 2 hours of firing. After this fuel supply is controlled to maintain the tank temperature at 180 to 200^{0}C.

Figure 2.33: ***Prevailing dewaxing arrangement***

Observations:

- The melted wax is maintained at 200^{0}C temperature which is higher than the melting temperature of wax. However, this is done to achieve fast rate of melting without developing any cracks in the sand moulds.
- Unit has earlier installed oil based and electrical heaters to dewax. However, there were cracks observed on the sand moulds due to slow rate of heating and the wax was not completed removed leading to wax loss.
- Significant amount is heat generated is wasted from all the sides of the wax tank as the tank is not insulted.
- Based on the discussion, it came out that around 7% of the wax is lost in the dewaxing process. This is significant monetary loss.
- Present method of dewaxing causes pollution in the proximity.
- Approximate, 40 litres of kerosene is consumed during 8 hours of operation per day.
- Some amount of wax remains in the inner sides of moulds which is removed during the shell preheating furnace. Wax is lost as it gets burned in high temperature of the shell preheating furnace.

Recommendations:

- It is suggested to make brick insulation from all side of the tank to reduce heat loss.
- It is suggested to put an insulated removable cover on the top to avoid heat loss from the top. This will stop wax evaporation loss.
- Prevailing conventional dewaxing technology may be replaced by steam based dewaxing technology. This would not only reduce heat loss but also would be more environment friendly
- By installing steam based dewaxing systems, wax evaporation loss would be arrested.

For improving energy efficiency of prevailing dewaxing operation, it is suggested to reduce heat losses of the heating tank by using proper insulation. This measure is very simple to implement and has good payback period of less than 6 months.

Another energy saving option would be to switch over to steam based dewaxing. This would not only save energy input but would also result into lesser wastage of wax material (around 5% reductions in burning loss). Further, this replacement would also be environmental friendly as the residue wax resting on the interior of sand moulds results in release of harmful emission during its heating in shell preheating furnace. Further, emission resulting from firing of kerosene would also be avoided.

Table 2.10: *Cost Economic Analysis - Dewaxing*

SN	Energy Efficient Measure	Annual Savings (In Rs)	Estimated Investment (In Rs)	Simple Payback Period (Year)
1	Insulation of existing dewaxing unit	96,000	40,000	0.4
2	Installation of steam based dewaxing unit	574,012	1,500,000	2.6

2.3.7 Compressor:

▶ Present System:

The unit has installed air compressor to meet compressed air demand in the unit. The specifications of the compressor are provided in Table 2.11. The compressed air is mainly used for sand coating, fettling, induction furnace and sand blasting section. The unit has installed two receiver capacities of 1,000 and 2,000 liters respectively totaling to 3,000 liters from which compressed air is supplied using overhead and underground air pipe lines. The schematic of compressor network observed in the unit is shown in Figure 2.34.

Table 2.11: ***Specifications of compressor***

Model/Make	Atlas Capco Compressor (GA 30 AP)
Year of manufacture	2009
Capacity (liters/second)	96
Power requirement (kW)	30
Tank storage capacity (liters)	3,000
Upper pressure settings (bar)	7
Lower pressure settings (bar)	6

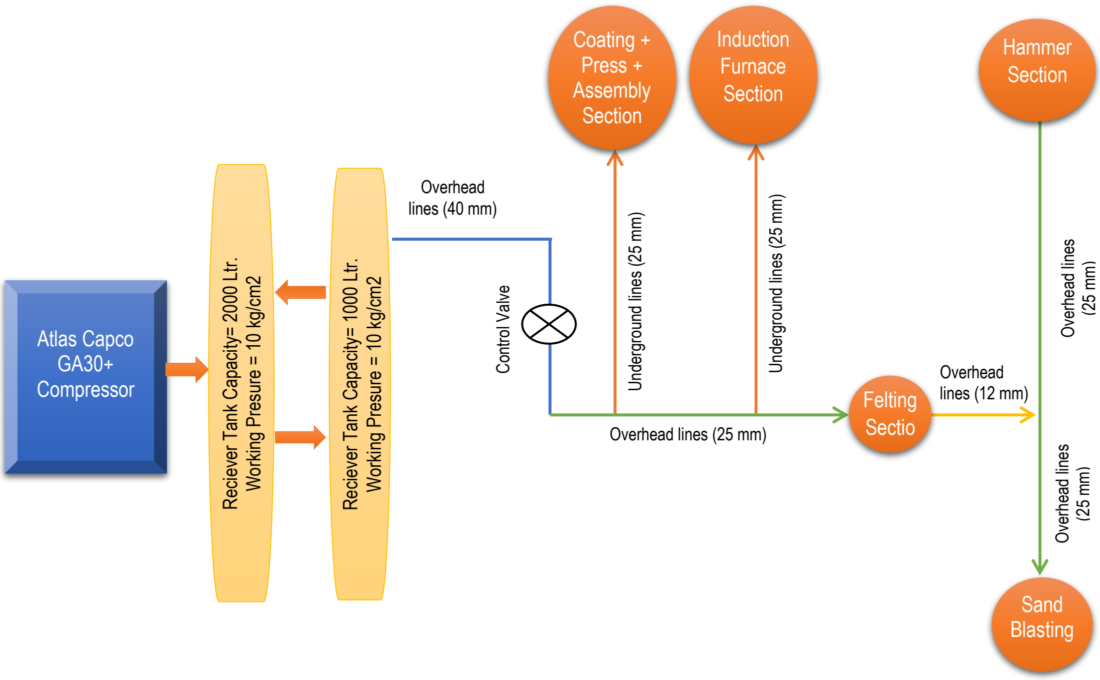


Figure 2.34: ***Single line diagram of compressor system***

▶ Observations:

During field visit to the unit, measurement of electrical parameters was carried out to estimate percentage loading of compressor. These observations are summarized in Table 2.12. Compressor leakage test could not be performed as the unit was in operation. Based on the measured data, it is observed that compressor motor is overloaded during loading i.e. when compressor motor is ON. During unloading when compressor motor is OFF, the loading is found to be 27%.

During visit, it was also found that reservoir of 1,000 liters has been added separately to increase storage capacity. However, this is located close to the point of generation of compressed air rather than close to consumption point.

Table 2.12: ***Measurements performed on the compres***sor

Loading Condition	Current (Amps)				Voltage (Volts)	PF	Actual Power (kW)	Rated Motor HP (kW)	Loading (%)
	R	Y	B	Average					
Unload	18	21	20	19.67	416	0.56	7.94	40 (29.84)	26.59
Load	55	57	56	56.00	416	0.93	37.52	40 (29.84)	125.75

- **Recommendations:**
- Best Practice #3 (Compressor Leakage Test): It is strongly recommended to carry out leakage trail fortnightly to assess the leakage level and necessary actions to be taken if any (See ***Annexure 5***).
- Use of compressed air is higher at sand blasting section, but both the reservoirs are located far from this section. It is recommended to relocate one reservoir at a nearer place from sand blasting section to avoid sudden jerks and to operate smoothly.

2.3.8 Exploring Opportunity for Renewable Energy Usage

During field visit, opportunities of using renewable energy applications were explored. Based on the process requirement observed in the unit, possibility of using solar thermal technology for dewaxing operation was explored. However, due to non-availability of area, this option was ruled out. Further, unit owner also rejected the idea of using renewable energy due to lesser anticipated savings against the cost and operational complexity associated with renewable energy interventions.

Annexure 1:

Questionnaire*

Energy Audit – Questionnaire Form

Promoting Energy Efficiency and Renewable Energy in MSME Clusters in India – Indore Foundry Cluster"

Name of the MSME unit:	Malka Alloy Cast Pvt Ltd.
Address:	Plot No. 571-573. Sector no. 3. Pithampur Dist Dhar
Ph. No:	9770287443.
Name of the respondent	Manish Neema
Designation:	Director

1. **Year of Establishment:** 2008
2. **Type of Products: a)** Investment Casting
   b) Sand Casting
   c) ____________
3. **Installed Capacity:** ____________
4. **Operating hrs per day :** 08
5. **Connected Load:** 288 **(kVA or kW please specify)**
6. **Supply Voltage:** 430. **Volt**
7. **Annual Energy Consumption/ Production:**

Financial Year (April to March)	2012	2013	2014
Coke consumed (tons)	—	—	—
Cost of coke (in Rs. Lakhs)	—	—	—
Electrical units consumed (In kWh)	569924	587010	479270
Electricity charges (In Rs. Lakhs)	45,65,182	41,10,904	34,36,537
LDO/HSD/ FO consumption (kL)	—	—	—
Fuel Cost (In Rs. Lakhs)	—	—	—
Production (Tones)	123.556	131.303	132.107

*Unit specific questionnaire were sent to units prior to the conduction of energy audits. Some portion of the questionnaire was not filled or left blank by the units, due to lack of understanding. However, data used for the energy audit calculations and reporting were subsequently collected during the physical visit of the energy audit team to the site.

15. Any Energy Efficient Technology installed in the unit:

Technology	Specification	Cost	Year of Installation

16. Any Energy Efficient Technology the management wants to implement in the unit:

Technology	Cost	Use
Variable speed drive	2 Lacs	
in Air Comp.		

17. Any factory expansion plan:

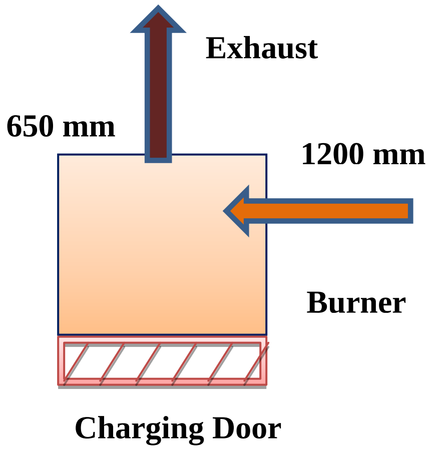
Calculations of Modified Re-heating Furnace

Present Shell Heating Furnace Details

Shell Heating Furnace Dimensions	= 1.2 m x 1.2 m x 1 .2 m
Floor Area	= 1.2 m x 1.2 m
	= 1.44 m^2
Shell Dimensions	= 0.2 m x 0.3 m x 0.8 m
Shell Capacity (Height per Shell)	= 8 kg of metal
Shell Area	= 0.2 m x 0.3 m
	= 0.06 m^2
No. of Shell can be placed on furnace floor	= 1.44/0.06
	= 24 pcs
No. of rows	= 1.2/0.2
	= 6
No. of Column	= 1.2/0.3
	= 4
Nos. of Shell can be staked	= 3
Total Nos. of Shell can be accommodated	= 24 x 4
	= 72 pcs
Total weight of molten metal	= 72 x 8
	= 576 kg
Induction Furnace Capacity	= 300 kg

Shell heating furnace capacity is 1.92 times more than Induction furnace capacity. It is proposed to make the furnace half the present size and use one burner instead of two burners. This will reduced the fuel oil consumption almost half.

Proposed Shell Heating Furnace:



Proposed furnace size	= 0.65 m x 1.2 m x 1 .2 m
Single burner size	= 24
Floor area of proposed shell heating furnace	= 0.65 m x 1.2 m
	= 0.78 m^2

Nos. of shell can be placed	= 0.78/0.06
	= 13 pcs
Total Nos. of shell can be accommodated	= 13 x 3
	= 39
Total weight of molten metal required	= 39 x 8
	= 312 kg
Which matches the Induction furnace capacity	
Fuel Savings:	
Present Fuel consumption (for Two burners)	= 37.16 liter/hrs.
Time taken per heat	= 45 minutes
Total fuel consumption	= 27.87 liter/heating
Proposed fuel consumption (for one burner)	= 18.3 liter/hrs.
Time taken per heat	= 52 minutes @ 15% more time
Total fuel consumption	= 15.86 liter/heating
Fuel saving	= 12.01 liter/heating
Percentage fuel saving	**= 43 %**

Material Log Book – Induction Furnace

<table>
<tr><td>Furnace ID:</td><td colspan="2">……………………………</td><td>Date</td><td colspan="2">…………………</td><td>Charge Number …………</td><td>Material Type</td><td>…………………</td></tr>
<tr><td colspan="6"><u>Time Details</u></td><td colspan="3"><u>Material Input</u></td></tr>
<tr><td colspan="2">Melting</td><td colspan="2">Holding</td><td colspan="2">Pouring</td><td rowspan="2">SN</td><td rowspan="2">Material Type</td><td rowspan="2">Quantity (kg)</td></tr>
<tr><td>Start Time (A)</td><td>…………</td><td>Start Time (D)</td><td>………</td><td>Start Time (G)</td><td>………</td></tr>
<tr><td>End Time (B)</td><td>…………</td><td>End Time (E)</td><td>………</td><td>End Time (H)</td><td>………</td><td>1</td><td>……………………………………</td><td>……………...</td></tr>
<tr><td>Total time
(C) = (B) – (A)</td><td>…………</td><td>Total time
(F) = (D) – (C)</td><td>………</td><td>Total time
(I) = (F) – (E)</td><td>………</td><td>2</td><td>……………………………………</td><td>……………...</td></tr>
<tr><td colspan="6"><u>Temperature Details</u></td><td>3</td><td>……………………………………</td><td>……………...</td></tr>
<tr><td colspan="3">Melting Temperature (°C)</td><td colspan="3">……………………</td><td>4</td><td>……………………………………</td><td>……………...</td></tr>
<tr><td colspan="3">Tapping Temperature (°C)</td><td colspan="3">……………………</td><td>5</td><td>……………………………………</td><td>……………...</td></tr>
<tr><td colspan="3">Pouring Temperature (°C) at start of pouring</td><td colspan="3">…………………….</td><td>6</td><td>……………………………………</td><td>……………...</td></tr>
<tr><td colspan="3">Pouring Temperature (°C) at end of pouring</td><td colspan="3">…………………….</td><td>7</td><td>……………………………………</td><td>……………...</td></tr>
<tr><td colspan="6"><u>Electricity Consumption (kWh)</u></td><td colspan="2">Total Input Material (M)</td><td>……………...</td></tr>
<tr><td colspan="3">Initial Reading (J)</td><td colspan="3">……………………...</td><td colspan="2">Total Material Output (N)</td><td>……………...</td></tr>
<tr><td colspan="3">Final Reading* (K)</td><td colspan="3">……………………...</td><td colspan="2">Material Lost (O) = (J) – (I)</td><td>……………...</td></tr>
<tr><td colspan="3">Total Electricity consumption (L) = (K)-(J)</td><td colspan="3">……………………...</td><td colspan="2">Specific Electricity consumption (kWh/tons) (P) = (L) * 1000l (M)</td><td>……………...</td></tr>
<tr><td colspan="9">Remarks: Please capture any other information related to operation like reason for furnace holding, higher time taken for furnace holding etc…</td></tr>
</table>

Annexure 4:

Best Operating Practice-Induction Furnace

Following are the best practices to be followed for efficient operation of induction furnaces

- Maintain log records of type and quantity of scrap material being used and electricity consumed for every charge
- Loading of scrap material should always be done till the induction furnace coil height.
- As far as possible, no overheating of material beyond the required temperature should be carried out as it directly consumes energy.
- Holding of furnace should be avoided by proper planning of moulds / shells in advance.
- Heel metal in the induction furnace should be avoided.
- During pouring and scrap composition measurement, power supply to the induction furnace should be reduced to around 25% of the full capacity.

Best Operating Practice

COMPRESSOR 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 SHOULDBE TAKEN WITH BALL VALVES AT OPEN POSITION

2 : READING SHOULD BE CONSISTENT

Annexure 6:

Furnace Efficiency Calculations

Parameter	Unit	Value
Mass of Material per Piece	kg	1.5
Total Number of Pieces Heated per Cycle	Nos.	35
Total Mass of Material being Heated	kg	58.5
Specific Heat of Material	kJ/kg ^{0}C	0.67
Mass of Laddle	kg	6
Specific Heat of Laddle Material	kJ/kg ^{0}C	1.1
Fuel Consumption per Cycle (of 45 minutes)	kg/hr	20.25
Calorific Value of Kerosene Oil	kCal/kg	11100
Initial Temperature of Moulds	^{0}C	40
Final Temperature	^{0}C	1070
Total Input Energy	kW	261
Total Heat Energy	kW	17.5
Furnace Efficiency	%	6.69