Comprehensive training material for Local consultants and auditors

Indore foundry cluster

GEF-UNIDO-BEE Project

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

Prepared for:

Bureau of Energy Efficiency

The Energy and Resources Institute

...towards global sustainable development

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About this manual

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

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

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

1.0 Introduction

1.1 Background

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

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

This comprehensive training material for Indore foundry cluster is targeted at 'Local consultants and auditors' category. The material is structured in the following 4 modules.

Module 1	EE in compressed air and cooling water systems
Module 2	Energy Conservation (with focus on melting)
Module 3	Pollution Control System
Module 4	Financing schemes and DPR preparation for EE projects

2.0 Module 1 – Energy efficiency in compressed air and cooling water systems

2.1 Compressed air system

2.1.1 Background

Air compressor is a device, which is operated with the help of connected electrical motor or other mechanical device to compress and pressurize air as per the set operating condition. The pressurized air is stored in a receiver tank and distributed to the point of use through piping network.

In metal casting industries, the air compressors are mainly used to deliver service air to various connected utilities as employed in the process. The micro scale foundry use reciprocating air compressor as the demand is intermittent and very low. However the small scale foundries use one or multiple screw type air compressors for meeting the compressed air demand.

Compressed air is highly energy intensive as only 10 to 30% of the electrical energy consumption of an air compressor is usefully converted into compressed air and the balance is lost as unusable heat energy. A lifecycle cost assessment of compressed air system shows about 75% of total cost is towards energy. A number of studies have revealed that by proper management, energy saving in tune of 10 – 50% can be achieved in a compressed air system.

Reciprocating air compressor

Several types of reciprocating compressors are available, namely, single- or multi-stage, lubricating and non-lubricating, and single- and double-acting. Single-stage compressors are normally used for a pressure ratio of up to four, while multi-stage compressors are economical for situations above this ratio. Other associated advantages of multi-stage compressors are reduced air temperature and pressure differential, which reduces the load and stress on valves and piston rings. Non-lubricating compressors are especially used for providing air to the instruments and for processes that require oil-free air. Double-acting compressors are used for higher capacities, as the quantity of air delivered is twice the normal at a given speed. Reciprocating compressors are generally best suited for medium pressure and volume applications. They are comparatively cheap, rugged in design, and have fairly high efficiencies. The disadvantages with this type, however, are the pulsating output and higher installation costs due to relatively high vibrations.

Screw air compressor

Rotary screw compressors have several advantages over reciprocating compressors. They are inherently more reliable and require less maintenance as they have few moving parts. Further, the maximum temperature anywhere in the compressor does not exceed 100 oC, thus obviating the need for cooling the casing. In screw compressors, the suction and discharge valves are replaced by ports in the housing, and the piston is replaced by rotors. It consists of two helical rotors: an electric motor drives a rotor shaft, which in turn drives the other rotor. These compressors have less wear and tear and vibrations, and require smaller foundations. The advantages of a screw compressor are its smaller size, lighter weight, step-less capacity control, and less starting torque requirement. Also, the performance of screw compressors, unlike reciprocating and centrifugal compressors, is not affected by the presence of moisture in the suction air.

2.1.2 Performance assessment of compressed air system

Compressors are designed to deliver a fixed quantity of air at certain pressure. But, due to ageing, wear and tear or poor maintenance, compressor may not deliver the same volume of air as specified by the manufacturer in the nameplate. By performing the FAD (free air delivery) test, actual output of a compressor with reference to the inlet conditions can be assessed. The test determines the pumping capacity of the compressors in terms of FAD, i.e. air pumped at atmospheric conditions. Following tests are generally carried out for evaluating the operating capacity of compressors.

(i) Pump-up test
(ii) Suction velocity method

The pump-up test of a compressor needs isolation of the air receiver and compressor from rest of the plant, whereas the suction velocity method could be undertaken without isolating the compressor. Depending upon the operating conditions in the plant, suitable method is used to study the performance of the compressors. Apart from FAD, it is also advisable to check power consumption, the optimum pressure setting and carry out the air leak test in the air distribution network in the plant to evaluate the condition of the air distribution system. The methods of carrying these tests are explained below.

Measurement of FAD

Pump up test method

This test determines the pumping capacity of the compressors (reciprocating and screw) in terms of air pumped at atmospheric conditions. It requires the isolation of the air receiver from the system, and only the compressor, whose pumping capacity has to be determined, must be connected to it. The receiver must be drained before switching on the compressor. The time taken by the compressor to maintain the working pressure in the air receiver (compressor on time or on load time) must be observed. A minimum of three readings are required to calculate the average value of time. The volume of the pipeline between the compressor and the receiver must then be calculated. The capacity of the compressor can be calculated using the formula

$$FAD = \frac{(P_2 - P_1) \times V \times T_1}{P_1 \times t \times T_2}$$

Where,

FAD = actual pumping capacity of the compressor (m^3/minute),

V = total volume (m^3) = V´ + v,

V′ = volume of the receiver (m^3),

v = volume of the pipe line connected from air compressor to air receiver (m^3),

P_1 = atmospheric pressure (1.013 bar absolute),

P_2 = final pressure of the receiver (bar absolute),

$t = average\ time\ taken\ (minutes)\ \frac{t_1 + t_2 + t_3}{3}$

t_1, t_2, t_3 = time taken to fill the receiver at working pressure of the system.

T_1 = inlet air temperature in K

T_2 = compressed air exit temperature in K

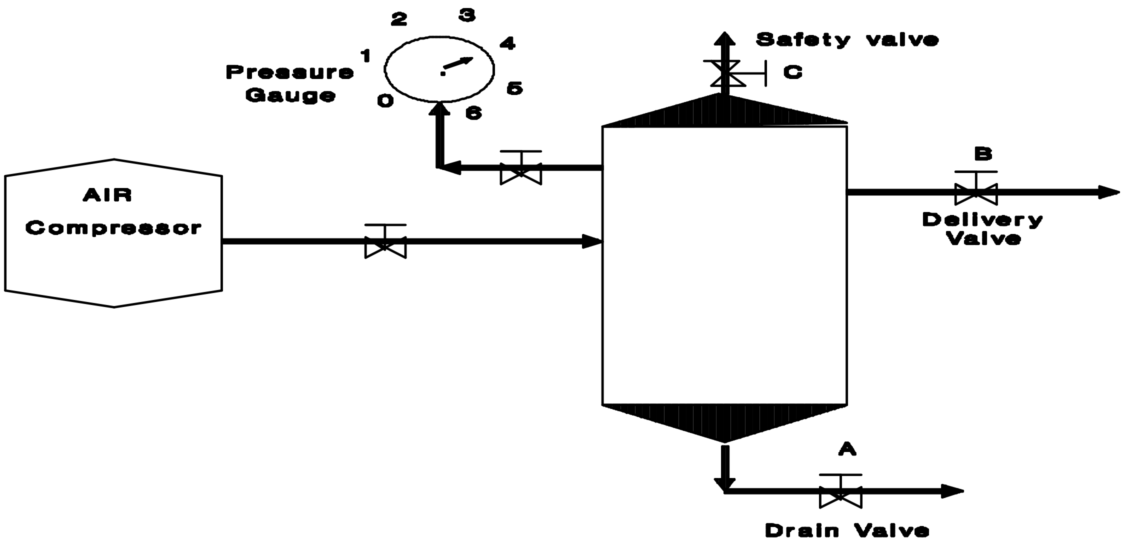


Figure 2.1.2: Pump up test schematics

Suction velocity method

This methodology is only used wherever compressor cannot be isolated from the system. In this method, velocity of inlet air to the compressor is measured at the entire suction filters area with multiple readings using hand held portable instrument. Actual free air delivery for the compressors is calculated after averaging it out the multiple measurements of suction velocity and multiplying it with the net open area of the filter's suction area.

After calculating FAD either by pump up test or suction velocity method, compare the value with the design value of FAD. If the difference is more than 20%, it is important to check the piston rings, cylinder bores, and so on.

Specific power consumption

It is always better to evaluate the compressors on the basis of the specific power consumption index. This is the actual shaft power to generate 1 Nm^3/minute (normal m^3 per minute, that is, 1 m^3 per minute at 1 bar, 0 °C and 0% RH) at 7 kg/cm^2 (g) or at any common pressure, when the compressor is running at full load. This ratio can be calculated when the actual electrical power input (not the rated power of motor) and the FAD in Nm^3/min are known.

$$Specific\ power\ (kW/Nm^3/minute) = \frac{(Actual\ power\ (kW)}{FAD\ (Nm^3/minute)}$$

Pressure setting

The discharge pressure should be kept at the minimum required for the process or the operation of pneumatic equipment for a number of reasons, including minimizing the power consumption. The compressor capacity also varies inversely with discharge pressure and the power consumption increases (table 2.1.2a). Another disadvantage of higher discharge pressure is the increased loading on the compressor piston rods and their subsequent failure. Maintaining a higher air pressure (generated for buffer storage) than operating pressure is a waste of energy and cost. Also, at higher pressure, air leakages from the same size of orifice increase. An increase in operating pressure by 1 kg/cm^2 can increase energy consumption by four per cent. On the other hand, lower air pressure than required reduces the productivity of pneumatic tools drastically. Most of the air tools are designed to operate at 90 psig. The performance of these tools reduces by 1–4% for every one psig drop in pressure.

Table 2.1.2a: Power consumption of compressors at different pressures

Pressure (kg/cm^2)	Free air delivery (Nm^3/min)	Shaft power (kW)	Specific power (kW/Nm^3/min)
3	19.60	87.0	4.44
4	18.30	92.6	5.06
7	19.30	123.0	6.37
8	19.22	128.0	6.66
10	19.87	150.0	7.55

Leakage test

The leakage in the compressed air system can be quantified by running the compressor with all the air-using equipment shut off. The time taken for the system to attain the desired pressure or for the compressor to unload can be noted. This pressure will fall because of leakages in the system and the compressor will come on load again. The time taken for this to happen is to be noted as well. The period for which the compressor is on or off load should be recorded at least thrice to calculate an average value. The leakages can be estimated as follows.

$$L = \frac{(FAD) \times t_1}{t_1 + t_2}$$

$$Power\ wasted\ in\ Rs/year = 1.17 \times Specific\ power\ consumption\ (kW/Nm^3/min) \times L \times operating\ hours/year \times Rs/kWh$$

Where,

Compressed air leakage

L = leakages (m^3/minute)
FAD = actual free air delivery of the compressor (m^3/minute)
t_1 = average on load time of compressor (second)
t_2 = average off load time of compressor (second)

A certain amount of wastage through leakage in any compressed system is inevitable, but air leakages above 5%, certainly needs in-depth study of the system. It is difficult to detect air leakages as they cannot be seen and smelt. While large leakages are easily detected by their hissing sound or by ultrasonic generated, it is difficult to detect small leakages, which can only be identified by applying soap solution on pipelines, joints, and so on. It is recommended that the entire distribution system be tested with soap solution once in six months. The air lost due to leakages can be quite significant depending on the air pressure. Table 2.1.2b gives the leakages through various orifice sizes and the resulting energy wastage at 7 kg/cm^2 air pressure.

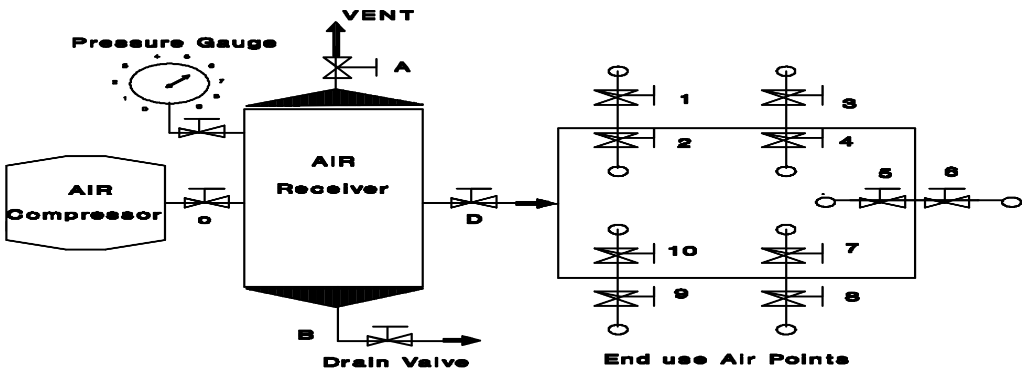


Figure 2.1.2a: Leakage test schematics

Table 2.1.2b: Power wastage from leakage of compressed air

Office diameter (inch)	Air leakage (Nm³/h)	Power wasted (kW)
1/64	0.721	0.08
1/32	2.88	0.31
1/16	11.53	1.26
1/8	46.20	5.04
¼	184.78	20.19

Typical energy balance of the air compressor is shown in figure below:

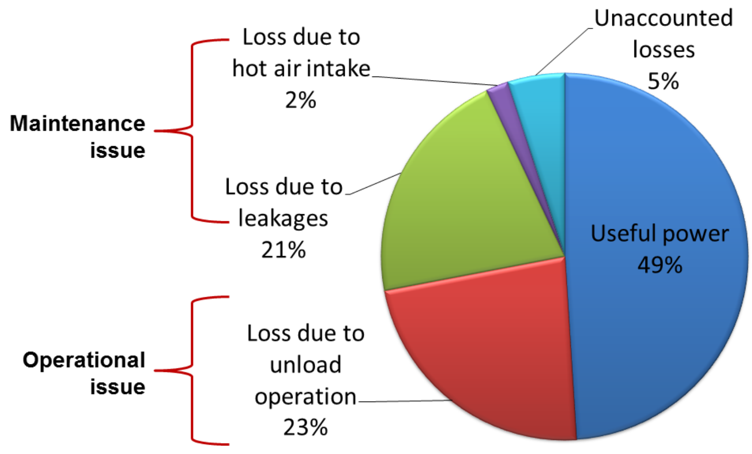


Figure 2.1.2b: Energy balance of air compressor

2.1.3 Replacement of in-efficient air compressor

EE compressor with VFD

Another foundry unit in Kolhapur foundry cluster manufactures and supplies CI and SG casting. The unit produces around 6000 metric tonne of casting per year. The corresponding annual energy consumption on that year was estimated to be around 493 toe costing 368 lakh rupees. The total CO_2 emission during the same period was estimated to be 5105 tonnes. The plant has two screw compressors for meeting the requirement of compressed air in the plant. Compressed air is mainly used to operate moulding machines, pneumatic grinders, mould cleaning and miscellaneous uses. The design specifications of existing compressors are given in table 2.1.3a.

Table 2.1.3a: Design details of existing compressors

Particular	Unit	Compressor 1	Compressor 2
Type		Screw	Screw
Operating mode		Load and unload	
Capacity	cfm	519.13	127.5
Pressure	kg/cm^2	7.6	7.6
Power	kW	75	30

Compressor 2 is a stand by system and 1 operates to meet plant requirement. Performance monitoring of the operating compressor was undertaken in detailed. Energy audit of the existing compressors in this unit revealed the possibilities of reducing energy consumption without disturbing compressed air requirement in the plant. The operating air compressor's motor has been re-wound thrice. The compressor was tripping many times while audit period. The power towards loading was 87kW. The specific energy consumption was measured 0.414kW/cfm while generating 210 cfm against design value of 520 cfm. The plant also admitted they are not able to meet full air requirement. Plant was having one 127.5 cfm air compressor in fairly good condition in other plant (not under use), it was recommended to run this for base load and install a new air compressor with VFD to meet variable load. The VFD will minimize compressor unload power consumption as per quantity of compressed air requirement by optimizing speed of motor. The details of new VFD compressor are: Capacity: 225 cfm, power 37 kW and 7.1 bar. With recommendation and implementing support from energy auditing agency in the cluster, the unit benefitted by modifying the existing air compressor system with new VFD based screw compressor in the plant. Table 2.1.3b provides the detailed techno-economic analysis of the recommended EE project.

Table 2.1.3b: Details of recommended EE compressor

Actual Parameters	Unit	Value
Loading Pressure	kg/cm²	5.9
Unloading Pressure	kg/cm²	6.6
Specific Power Consumption	kW/cfm	0.414
Operational hours	hours/year	7,200
Base load Screw compressor		
Capacity	cfm	127.5
Pressure		7.6
Power	kW	30
Specific Power Consumption	kW/cfm	0.190
Annual energy consumption	kWh/year	1,74,420
Air compressor with VFD	**Unit**	**Air Compressor**
Capacity	cfm	225
Pressure	kg/cm²	7.1
Power	kW	37
SPC	kW/cfm	0.180
Unload time per hour	Min	15.00
Saving per hour	kWh	3.13
Total Annual Energy Saving	kWh/year	1,08,930
CO_2 avoided	tCO_2/year	96.95
Monetary saving	lakh INR/year	7.37
Investment cost	lakh INR	8.48
Simple payback period	Year	1.15

Down-sizing of existing screw air compressor

During normal operation, compressor in a foundry unit is operating in unloading condition for about 61% of the cycle. The specific energy consumption was calculated to be 0.277 kW/cfm. It is recommended to install new air compressor of lower capacity. It will serve two purpose vis-à-vis improve reliability, as old compressor will be as stand by and reduce power consumption. The design specifications of compressor are given in table 2.1.3c.

Table 2.1.3c: Design details of existing compressor

Particular	Unit	Compressor 1

Type and make		Screw & Atlas Copco
Operating mode		Load and unload
Capacity	cfm	127.5
Pressure	kg/cm^2	7.5
Power	kW	30

The air compressor was loading for only 39% of time. The power consumption towards unload period was also high (14.3kW). It was recommended install a new air compressor of lower capacity. It would lead to reduced power consumption and will also improve reliability factor. The estimated annual energy savings in air compressor is 37,110 kWh equivalent to a monetary saving of Rs 2.60 lakh. The investment requirement is Rs 4.49 lakh with a simple payback period of 1.7 years. Cost benefit and saving estimation is given in table 2.1.3d.

Table 2.1.3d: Details of recommended on down-sizing of compressor

Actual Parameters	Unit	Value
Loading	%	39%
Unloading	%	61%
Loading	kW	30
Unloading	kW	14.30
Specific Power Consumption	kW/cfm	0.277
Hours of operation	hr/year	7200
Down-sizing of Air compressor	**Unit**	**Air Compressor**
Make		Kaeser ASD 32
Capacity	cfm	112
Pressure	kg/cm2	7.5
Power	kW	18.5
SPC	kW/cfm	0.170
FAD Generated	cfm	108.381
Annual Energy Consumption	kWh/year	1,09,484
Annual energy saving	kWh/year	37,110
Monetary saving	lakh INR/year	2.60
Investment	lakh INR	4.49
Simple Payback	years	1.91
CO_2 avoided	tCO_2/year	33.03

Replacement of reciprocating compressor by screw air compressor

During normal operation, in a foundry the reciprocating compressor is operating in unload position for above 52% of time. The power towards load time was 12.98 kW and that for unload period was 4.51 kW. The specific energy consumption of the air compressor was calculated to be 0.434 kW/cfm. The design specifications of existing compressor are given in table 2.1.3e.

Table 2.1.3e: Design details of existing compressor

Particular	Unit	Compressor 1
Type		Reciprocating
Operating mode		Load and unload
Capacity	cfm	34
Pressure	kg/cm^2	10
Power	kW	11

It is recommended to replace the air compressor with new screw air compressor. The specific energy consumption of the compressed air system will reduce. The specifications of recommended air compressor are: 57.2cfm, 7.5bar and 11kW. The estimated annual energy savings is 20,227 kWh equivalents to a monetary saving of Rs 1.46 lakh. The investment requirement is Rs 2.31 lakh with a simple payback period of 1.6 years. Cost benefit and saving estimation is given in table 2.1.3f.

Table 2.1.3f: Details of recommended on reciprocating to screw air compressor

Actual Parameters	Unit	Air Compressor
Loading	%	47.9%
Unloading	%	52.1%
Loading Pressure	kg/cm^2	7.5
Unloading Pressure	kg/cm^2	9.0
Loading	kW	12.98
Unloading	kW	4.51
Specific Power Consumption	kW/cfm	0.434
Hours of operation	hr/year	7200
New Screw Air Compressor	**Unit**	**Air Compressor**
Make		Atlas Copco
Model		GX-11-7.5P TM
Capacity	cfm	57.2
Pressure	kg/cm^2	7.5
Power	kW	11.0
SEC	kW/cfm	0.192
Generated CFM	cfm	29.92
Annual energy consumption	kWh/year	41,431
Energy savings	kWh/year	20,227
CO_2 avoided	tCO_2/year	18.00
Monetary saving	lakh INR/year	1.46
Investment cost	lakh INR	2.31
SPP	year	1.59

2.1.4 Retrofits in compressed air system

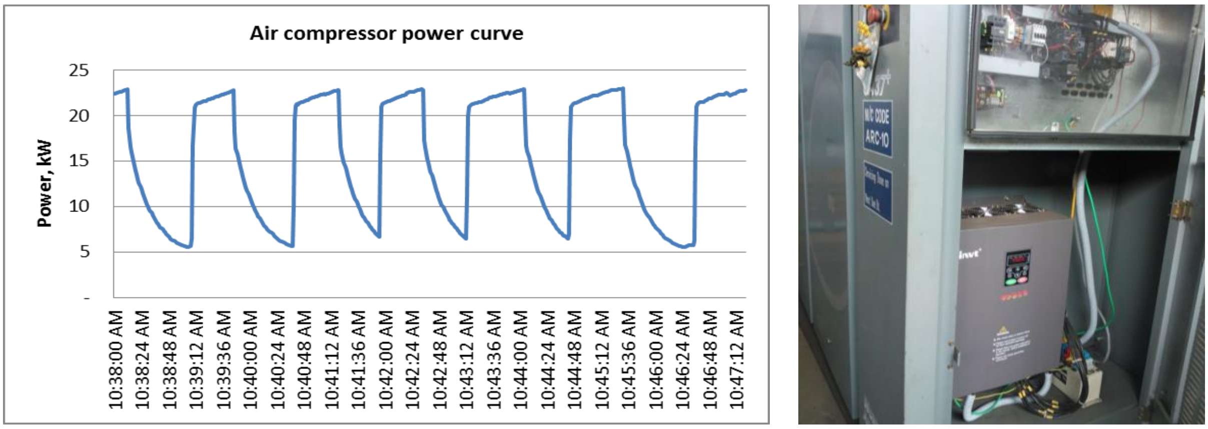
Retrofit of VFD on screw air compressor

A foundry in Belgaum cluster equipped with 25 hp screw air compressor. During normal operation, compressor is operating in unload position for about 59% of time. The power towards load time was 21.9 kW and that for unload period was 7.7 kW. The specific energy consumption of the air compressor was calculated to be 0.202 kW/cfm. The design specifications of existing compressors are given in table 2.1.4a.

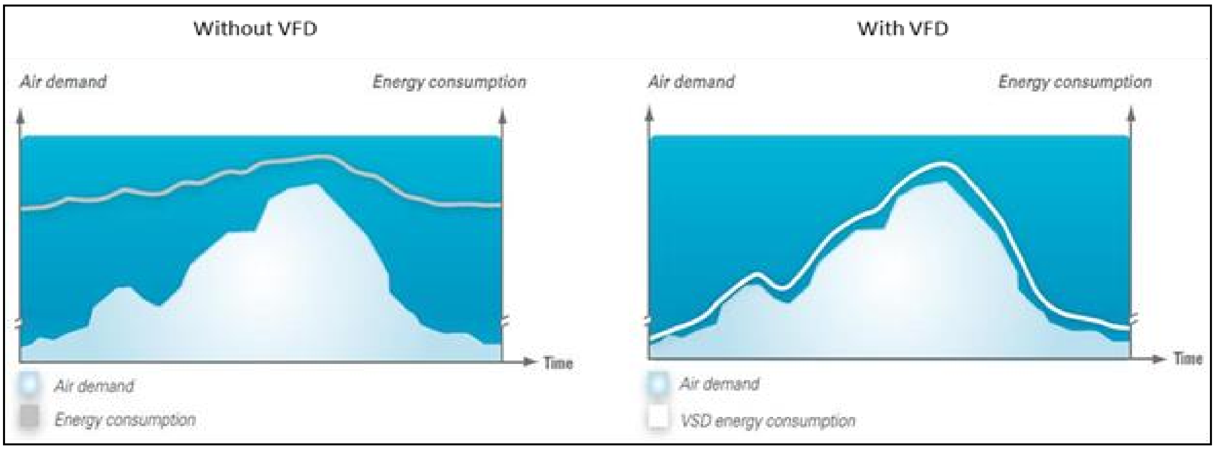
Table 2.1.4a: Design details of existing compressors

Particular	Unit	Compressor 1
Type and make		Screw & Atlas Copco
Operating mode		Load and unload
Capacity	cfm	114
Pressure	kg/cm^2	7.5
Power	kW	18

It is recommended to retrofit the air compressor with variable frequency drive (VFD) to minimize the unload power consumption. The VFD will minimize compressor unload power consumption as per quantity of compressed air requirement by optimizing speed of motor. It is recommended to load compressor around 85% of time. The estimated annual energy savings is 10816 kWh equivalents to a monetary saving of Rs 0.77 lakh. The investment requirement is Rs 1.24 lakh with a simple payback period of 1.6 years.



Power curve and VFD retrofit on air compressor



Compressor with and without VFD

Table 2.1.4b: Details of VFD retrofitting on compressor

Actual Parameters	Unit	Value
Suction Area	cm^2	50.3
Suction Velocity	m/s	10.2
FAD Generated	m^3/min	3.08
	cfm	108.6
Loading	%	41%
Unloading	%	59%
Loading pressure	bar	6.5
Unloading hours	bar	7.5
Loading	kW	21.9
Unloading	kW	7.7
Specific Power Consumption	kW/cfm	0.202
Operating hours	hour	3,600
VFD Retrofitting	**Unit**	**Value**
Unload power saving	%	15
Annual energy saving	kWh/year	10,816
	toe/year	0.93
Cost of electricity	INR/kWh	7.12
Monetary saving	lakh INR/year	0.77
Investment	lakh INR	1.24
SPP	year	1.6
CO_2 avoided	tCO_2/year	9.6

Sequence controller for air compressors

A foundry in Rajkot was equipped with three screw type air compressors of rating 55 kW, 37 kW and 22 kW respectively. There was no control mechanism in place to insure proper meeting of the demand. The compressors were running in ad-hoc basis, leading to high energy consumption (1029 kWh per day).

It was recommended to install a sequence controller for the air compressors with closed loop feedback from a pressure transducer installed at the receiver end. This led to sequential operation of air compressor and led to improved energy performance. The daily energy consumption in compressed air system came down to 775 kWh. The switching between the air compressors with and without sequence controller for meeting foundry demand is shown in figures below.

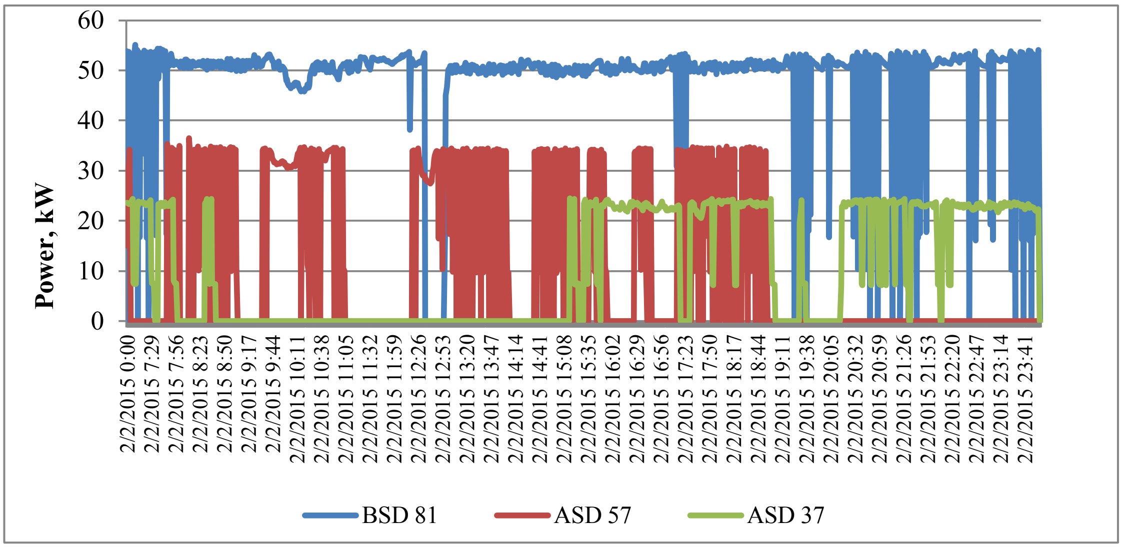


Figure 2.1.4a: Before sequence controller

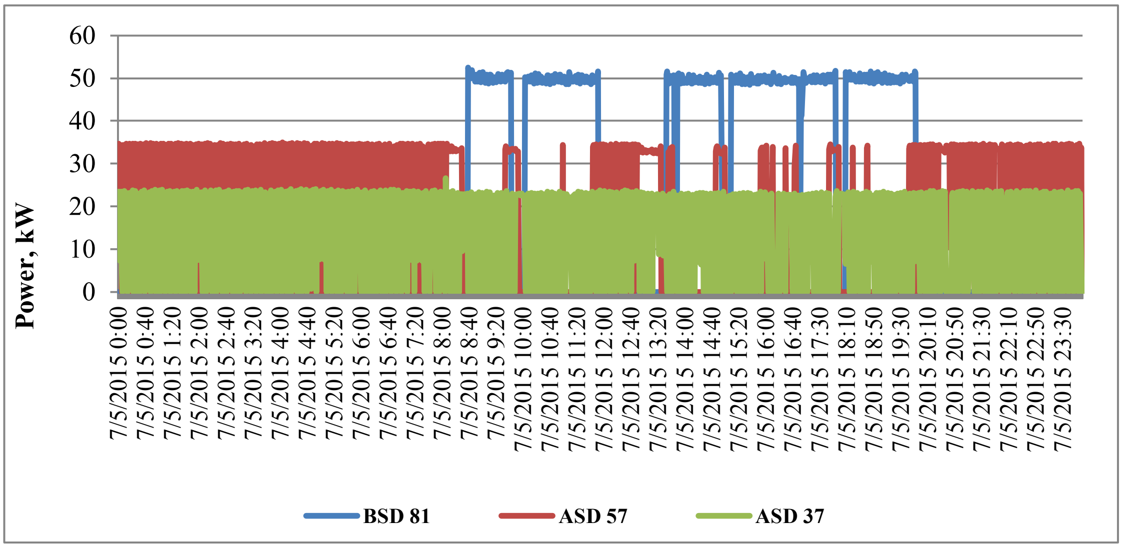


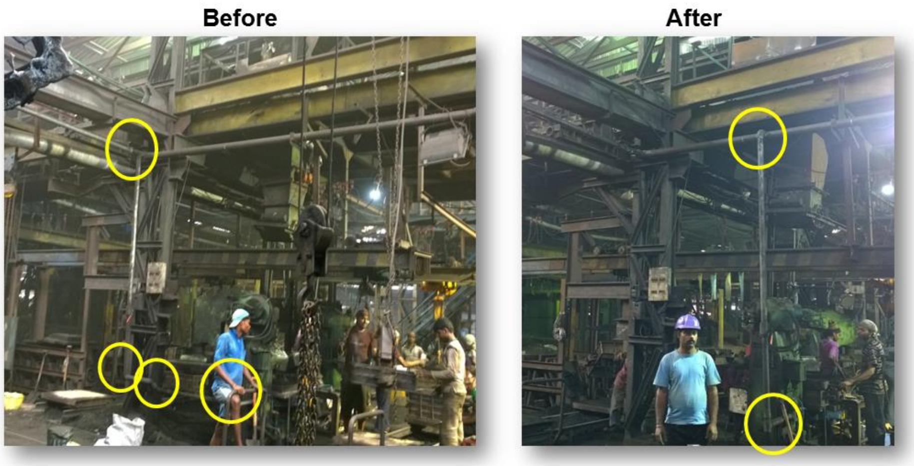
Figure 2.1.4b: After sequence controller

Compressed air network

Case study 1

A foundry in Howrah with annual production of about 3500 tonnes, was equipped with two screw type air compressors of 45 kW rating. The actual demand of the foundry was about 200 cfm of compressed air at 6 kg/cm^2 pressure. The plant was operating the air compressor at 9.6 kg/cm^2 pressure, owing to high level of losses in the compressed air network.

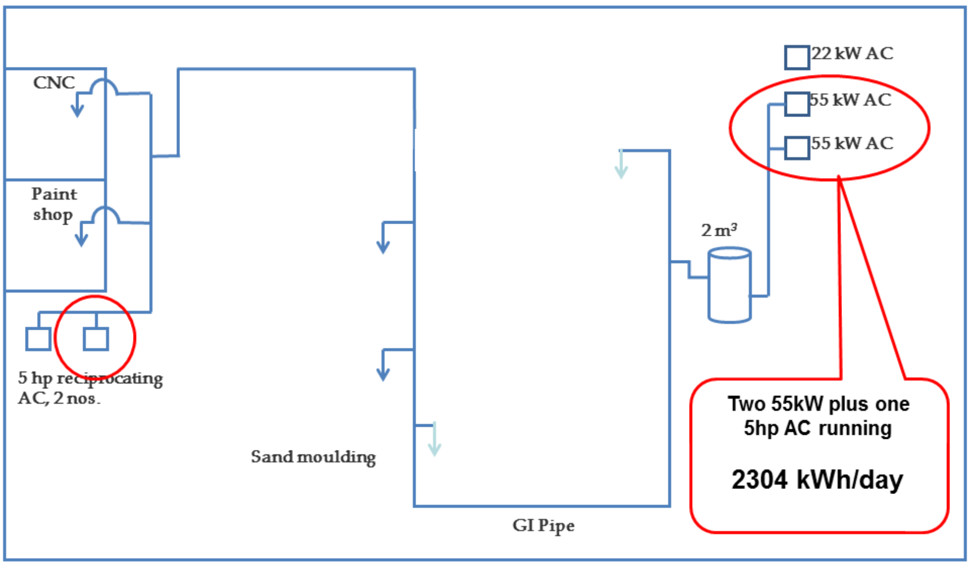
The compressed air piping around the moulding machine was found to have too many bends leading the loss of pressure. It was suggested to simplify the compressed air network and reduce the bends. The unit reduced the number of bends from four to two and brought down the compressor pressure by 0.8 kg/cm²; leading a direct energy saving of about 3.5%.



Improvement in compressed air network

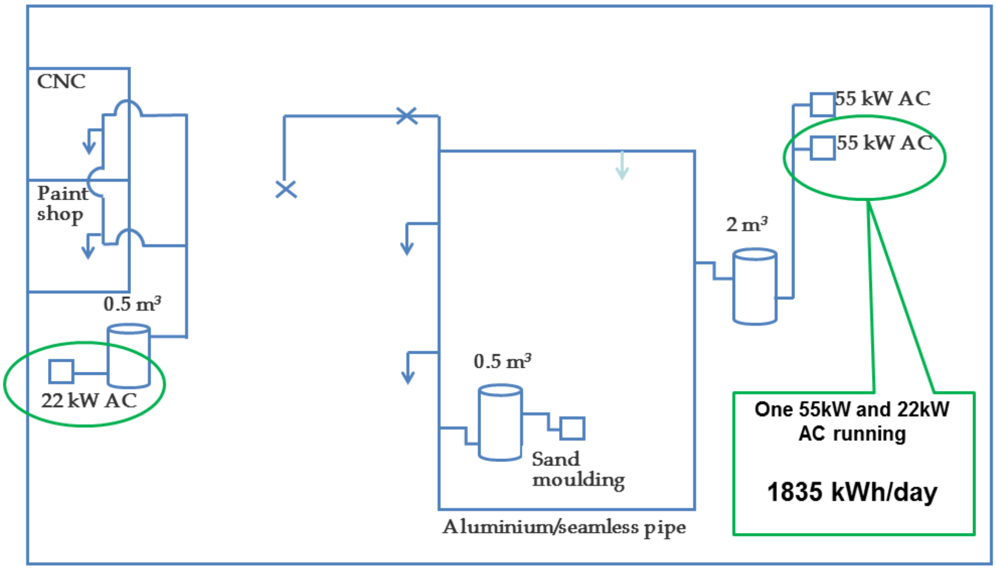
Case study 2

A foundry in Howrah with annual production of about 2550 tonnes, was equipped with two screw type air compressors of 55 kW rating, one of 22 kW rating and two 5hp in paint shop. The compressed air network of the unit is shown in figure. The foundry uses two 55 kW air compressor for meeting compressed air demand of the foundry section, whereas one 5 hp reciprocating compressor meets demand of paint shop along with tapping from centralized compressed air distribution network. The daily energy consumption is about 2304 kWh.



Compressed air network case study: before

It was recommended to the unit to replace GI piping with seamless CPVC piping for compressed air distribution and make a ring main to reduce pressure drop in the line. The modified network is shown in the figure. The daily energy saving was about 469 kWh.



Compressed air network case study: After

2.1.5 Best operating practices in compressed air system

Reduce the consumption of air

- There are always air leakages exists in the shop floor and which could be near to the equipment/application point and/or in the air piping distribution system
- Leakage test
  - ✓ Operate compressor at night, or holiday, and shut it down when achieving a predetermined pressure value.
  - ✓ When the compressor is shut down, due to the leakage, the pressure will automatically decrease. The amount of leakage can be known by measuring the time (T) taken to decrease the pressure by 1 bar.
  - ✓ Formula

$$Q = \frac{(P1 - P2) \times V}{Po(1.033) \times T}$$

  - ✓ Q=Volume of leakage (m^3/min)
  - ✓ P1= Predetermined pressure (kg/cm^2) (gauge pressure + 1.033kg/cm^2)
  - ✓ P2= Pressure after leakage (kg/cm^2) (gauge pressure + 1.033kg/cm^2)
  - ✓ T=Time taken to reduce pressure from P1 to P2 (min)
  - ✓ Po= Atmospheric air pressure(kg/cm^2)
  - ✓ V= Piping capacity (Mm^3) (In case of your company; 72.31m^3)
- There is a report that as much as 20% of leakage exists in a plant on average
- Since leakage directly leads to energy loss, it is the highest priority issue for air systems
- Be aware that leakage may occur anywhere.
  - ✓ Leakage from coupler

  - ✓ Leakage from pipe
  - ✓ Leakage from internal component of equipment
- For example, use of proper air nozzles for blowing will reduce the air consumption.
- So, reducing leakage is top-priority issue in air system.
- Recognizing that a leakage occurs from all places is required.
- The leakage with a sound is detected by using 'Leak Detector' e.g. Model-AAM-PWLEAK02
- However, cautions are required, since there is also the leakage with no sound.
- Leakage test can be carried out frequently to check the quantity of air leakages in the plant. The physical verification at joints of hoses, couplers will help to identify the air leakages, even soap solution can be poured at the joints for checking the air leakages.
- Leakage check test
  - ✓ Leakage check is performed at the night time or on holidays when the plant is not in operation.
  - ✓ Once the compressor is operated and raised up to predetermined pressure, then stop the compressor and measure the time required for pressure reduction of 1bar from the predetermined pressure.
  - ✓ Since all of this leads to waste of energy, there is a necessity for quick measures.
  - ✓ If in the above investigation, it is possible to calculate the amount of leakage, then leakage locations need to be identified in the next step.
  - ✓ As the amount of leakage can be calculated by the pressure drop calculation, after confirming the same the leakage areas can be identified and effective leakage reduction can be achieved.
  - ✓ Target reduction is half of the total ratio.
- Keeping that in mind, take measures from the most leakage prone areas.
- Leakage cannot be completely stopped with the one-time measures.
- Continuous monitoring is required.

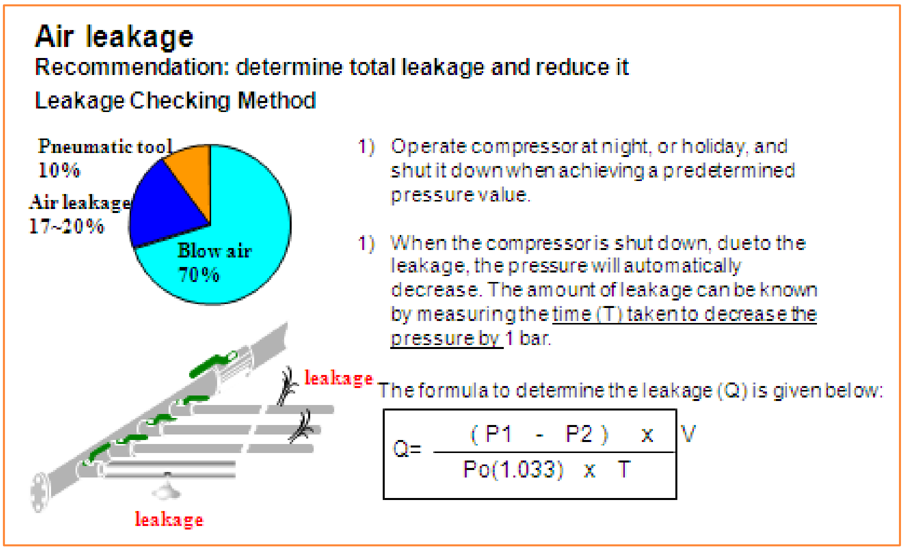


Figure 2.1.5a: Air leakage

Reduce air pressure and good air piping work

- There should be always pressure gauges installed in the air piping system for regular check of design and operating pressure of pressure gauges, if there is any fall in pressure for the existing set point of air compressor then there are huge leakages exists in the system and needs to identify the points

Example of pipes having many valves or bends, generate resistance and pressure loss.
Change the type of the valves (to the one with low resistance) or reduce bends as much as possible.

A pipe narrowed immediately after the air dryer. Generates resistance and pressure loss.
A riser pipe. Causes a backward flow of condensate, leading to an increasing number of mechanical troubles.

Figure 2.1.5b: Contents of Improvement Measures – Examination of Piping Work

- Increase pipe size to reduce pressure loss and important air piping work
  - ✓ Piping system
    How pressure loss changes if size changed?
    How pressure loss changes if valve structure differs?
  - ✓ Be sure to provide a drain connection for a riser pipe.
  - ✓ Installation to a collecting pipe must be made from above to prevent backflow. (Similarly, branch pipes must be installed from above.)
  - ✓ For a collecting pipe, give an inclination (1/100) from the upstream to the downstream. Attach a drain plug at the end of each pipe.
  - ✓ Buried piping makes it difficult not only to detect air leakage but also to repair
- If there is need for higher pressure for particular application or process or shop then increase pressure by use of booster compressor instead of increasing set pressure of the entire air compressor system
- Pipe size - for reduced pressure loss without large no. of bends with 4 – 5 m/s of velocity, helps is load/unload of air compressor, running hours, leakages etc. Types of valves ball valves and globe valves, in globe valves there are 60% more losses than gate valves.
- Use of hosepipes increases the pressure drop. Piping should not be underground and drain valves should be placed at lower position in pipelines. The filter size should be adequate so, that there is no pressure drop. Higher resistance causes pressure drops and also there is overloading of the air compressors resulting in frequent breakdowns. Piping should be used in looping for reduced pressure drops.

Figure 2.1.5c: Examples of recommended piping

- If adequate and large receiver size is used, there is energy saving about 3%. Proper ventilation of air compressor decreases the surrounding temperature resulting in less stoppage due to over temperature and energy saving with less inlet temperature. For indirect ventilations large size fans are required. Proper layout of air duct is required for ventilation. For various air pressure requirements in the plant, pressure boosters or booster air compressors can be used, which will eliminate the high-pressure generation at main air compressor.

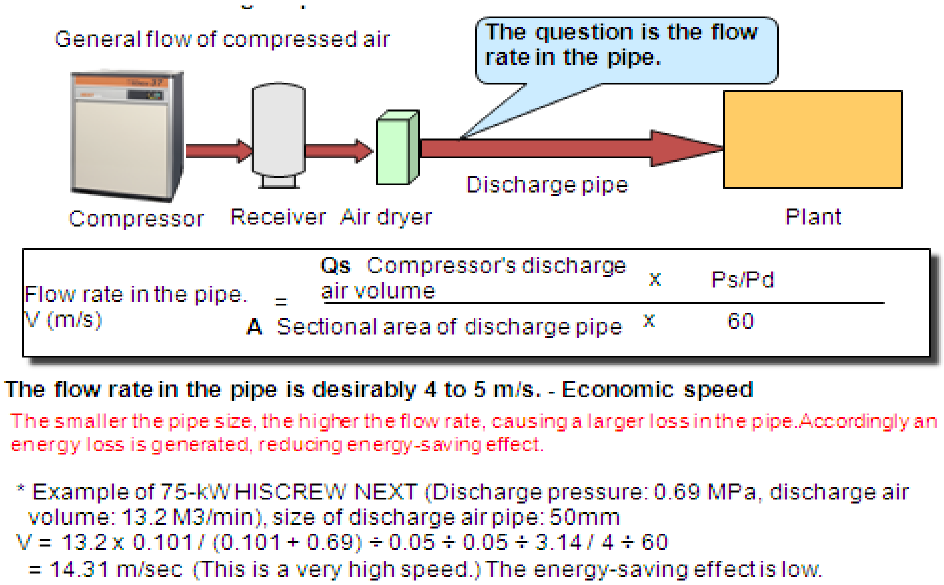


Figure 2.1.5d: Pressure loss through pipe and internal flow rate

Optimize the air compressor

- Pressure reduction by 1 bar will give energy saving of 6-8%.

- Air intake into the compressor room and better ventilation. (Pay attention to the gallery design - effective area)
  - ✓ Install the compressor in the direction so that a hermetically closed room or intake of contaminated air (oil, gas, etc.) is avoided.
  - ✓ Prevent the air discharged from the compressor room from being sent back into the room and circulating.
  - ✓ Discharge air in compressor room
  - ✓ Install the fan high on the wall of the compressor room.
  - ✓ When using a rain hood, take resistance into consideration when selecting a ventilating fan.
- Use of inverter type air compressors is important, as industry though are using inverter compressor are not getting desired energy savings. The continuous air compressor should be used at base load and inverter compressor should be used for variable load with proper pressure setting.
- Multiunit control can be used at the air compressor installations having more than 2 air compressors. Etc. He explained advantages/disadvantages of centralised and de-centralised air compressor systems.
- Plan/do/check/act is continuously required for energy efficiency requirement in compressed air system.

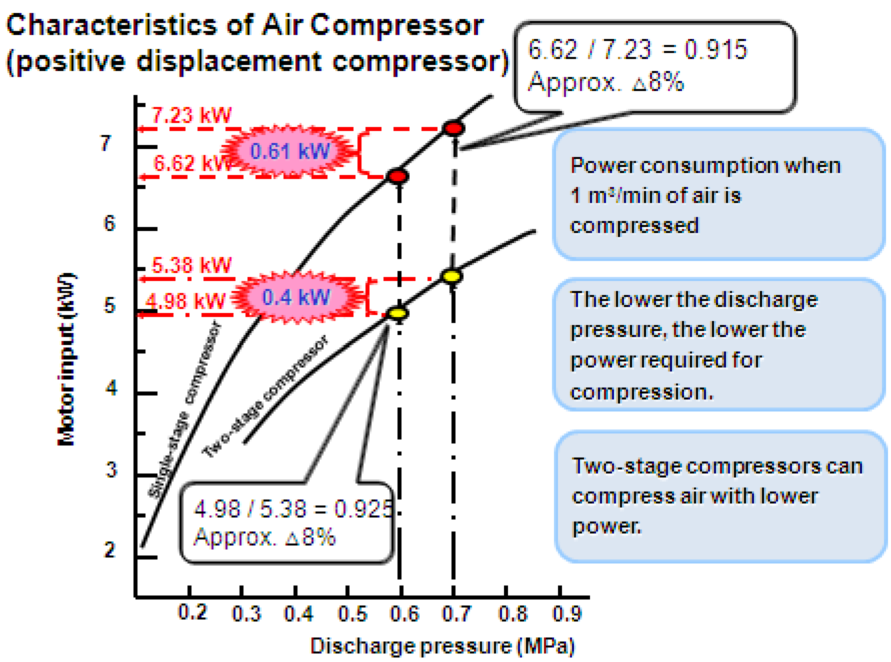


Figure 2.1.5e: Characteristics of air compressor

Some important points

- Life of air compressor in its life cycle is considered about 12 years life
- About pressure reduction ~6% saving is possible
- About centralized system, centralized system can be selected/ designed based on various factors like size, pressure and plant layout etc.

- About use of inverter type air compressor with percentage loading 50% to 90%, energy consumption cost savings of minimum 20% is possible even though there is less fluctuations in the compressor loading/unloading.
- About air receiver for high capacity air compressors, high capacity receiver could be used for Centrifugal air compressors which will give saving of 3 %.

Environment point in compressed air system

- Replacement of reciprocating air compressor and install low vibration, low noise level air compressors.
- Drain discharge according to the actual drain amount is required in order to efficiently avoid unnecessary damage to the environment and cost associated with generating process of compressed air.
- Intelligent electronic control system keeps the loss of compressed air and energy consumption to a minimum by BEKOMAT drain discharge equipped with capacity levelling sensor can be used for drain discharge.

Case study: Leakage loss

A foundry in Rajkot was able to bring down its compressed air leakages in the fettling shop by replacing the screw type connector of pneumatic line and the fettling machine with a aluminium crimping arrangement. This seals the pipe properly reducing the chances of leakages over the life of machine. The same is depicted in figure. The energy saving by reduction of compressed air leakages was in tune of 3 – 4%.

Before **After**

Air leakage case study

Case study: Cleaning of filter

A foundry in Howrah was using a 22 kW screw air compressor for meeting its compressed air demand. During study it was observed the filter was not cleaned for months. This led to an increase in specific power consumption of the air compressor by 2 kW per 100 cfm. The energy saving by proper cleaning of filter was in tune of 1 – 1.5%.

Air filter case study

Case study: Exhaust duct for air compressor

A foundry in Kolhapur cluster was equipped with 30 kW air compressor to meet compressed air demand. The compressor was placed in a closed room thus leading to a higher temperature. The suction air temperature of the air compressor was about 5 °C higher than the ambient temperature. It was recommended to install an exhaust duct for the air compressor to throw the hot air outside the compressor room. This led to an energy saving in compressor of about 1%.

Exhaust duct for air compressor

2.2 Cooling water system

2.2.1 Background

The foundry using induction furnace for melting have a dedicated cooling water circuit for meeting cooling demand of the coil and the also the power panel. The panel cooling and coil cooling is done using soft water i.e. demineralised water. A plate heat exchanger exchanges the heat from soft water to industrial raw water, which is circulated using another pump. Some foundry use this raw water pump to directly cool the water in a cooling tower, on the other hand a few units have hot well and cold well system, where another pump is incorporated for cooling tower water circulation.

Pump operating point

When a pump is installed in a system the effect can be illustrated graphically by superimposing pump and system curves. The operating point will always be where two curves intersect. Each centrifugal pump has a BEP at which its operating efficiency is highest and its radial bearing loads are lowest. At or near its BEP, a pump operates most cost effectively in terms of both energy efficiency and maintenance. In practical applications, operating a pump continuously at its BEP is not likely, because pumping systems usually have changing flow rate and system head requirements and demands. Selecting a pump with a BEP that is close to the system's normal operating range can result in significant operating cost savings.

The performance of a pump is typically described by a graph plotting the pressure generated by the pump (measured in terms of head) against flow rate. A performance curve for a typical centrifugal pump is shown in figure 2.2.1.

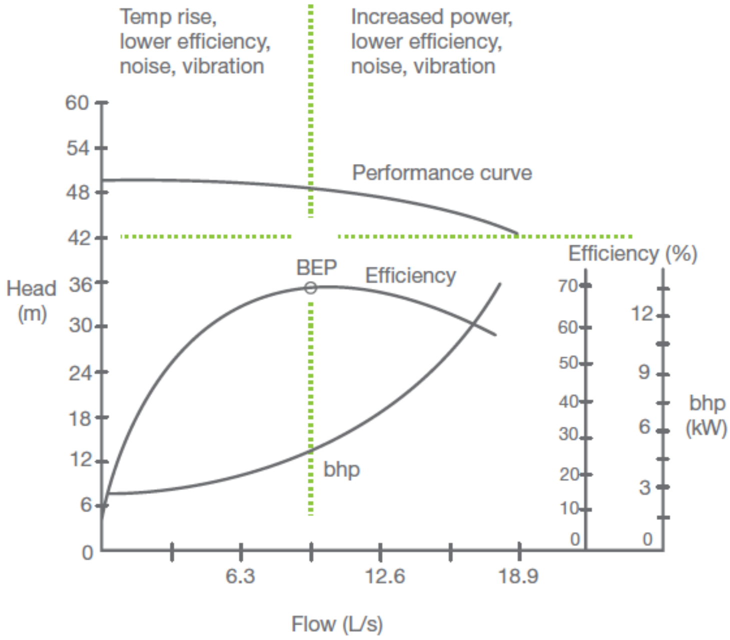


Figure 2.2.1: Pump operating point

If the actual system curve is different in reality to that calculated, the pump will operate at a flow and head different to that expected.

2.2.2 Performance assessment

Performance assessment of pumps

In metal casting industries, the pumps are mainly used to transfer water from reserve source point to user end as employed in the process and connected with the utilities to circulate the cooling water. The condition of an operating pump can be understood by calculating operating efficiency of the individual pump and comparing with design value. Efficiency of a pump can be estimated by the following relation.

$$Hydraulic\ power = \frac{Q\ (m^3/s)\ \{total\ head\ (hd - hs)\}\ (m)\ \times\ \rho\ (kg/m^3) \times g\ (m/sec^2)}{1000}$$

Where,

$h_1 - discharg\ head\ in\ metre, h_s - suction\ head\ in\ metre, \rho - density\ of\ the\ fluid\ in\ (kg/m^3, g - acceleration\ due\ to\ gravity.$

$$Pump\ shaft\ power, P_s(kW) = Electrical\ input\ power\ (kW) \times motor\ efficiency$$

$$Pump\ Efficiency\ (\%)\ = \frac{Hydraulic\ power, Pd \times 100}{Pump\ shaft\ power, Ps}$$

Best performance from a pump can be observed when a pump is operated at point where its operating curve intersects with system curve without any throttling at either stream of flow as shown in the figure 3.2.2a.

The pump performance will vary depending upon the operating parameters like RPM (N), input power (kW), head (H) and flow rate (Q). These operating parameters are linked with the following relationship.

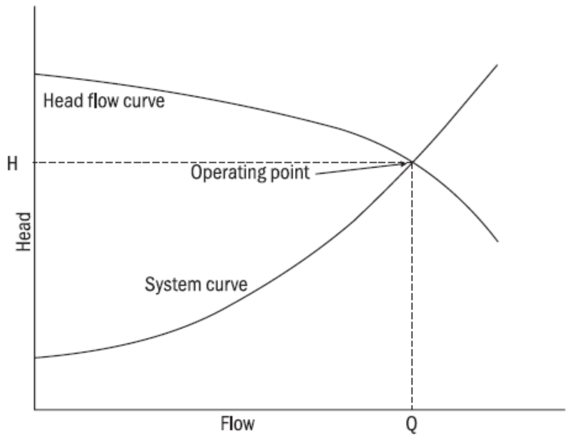


Figure 3.2.2a: Operating curve of a Pump

Flow: Flow is proportional to speed; $\frac{Q_1}{Q_2} = \frac{N_1}{N_2}$

Where, Q_1 is flow corresponding to speed N_1 and Q_2 is the flow corresponding to speed N_2

Head: Head is proportional to the square of speed; $\frac{H_1}{H_2} = \frac{(N_1)^2}{(N_2)^2}$

Power (kW): Power is proportional to the cube of speed; $\frac{kW_1}{kW_2} = \frac{(N_1)^3}{(N_2)^3}$

As can be seen from the above laws, doubling the speed of the centrifugal pump will increase the power consumption by eight times. Conversely a small reduction in speed will result in drastic reduction in power consumption. This forms the basis for energy conservation in centrifugal pumps with varying flow requirements. The table 2.2.2a provides the list of data that are required for calculating above mentioned performance indicators of a cooling tower.

Table 2.2.2a: List of operating parameters of pump

S No	Parameter
1	Power consumption (kW)
2	Suction head (metre)
3	Delivery head (metre)
4	Pump flow rate (kg/second)
5	Fluid temperature (°C)

Performance assessment of cooling tower

Cooling towers are mainly used in foundries to circulate cooling water to user end in the process to meet the desire requirement in the plant. It could be either natural draught or forced draught operation. Figure 2.2.2b shows the simple schematic view of water and air flow to a cooling tower.

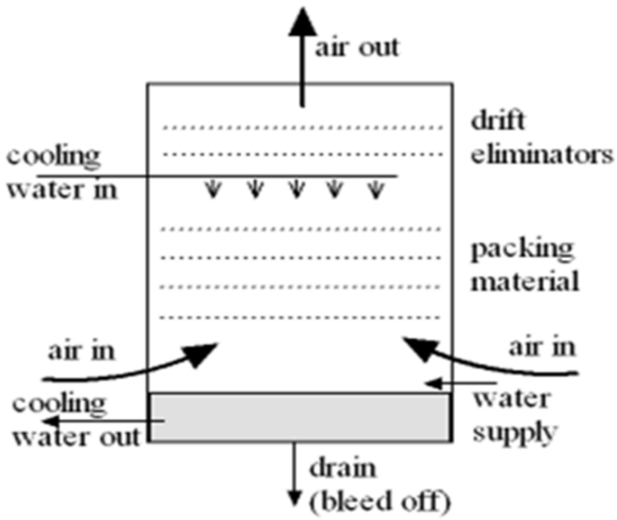


Figure 2.2.2b: Schematic view of cooling tower

The performance of cooling tower can be compared with the rated output with the actual output like range, approach, effectiveness, heat rejection capacity in TR, evaporation loss and make up water flow rate etc. Cooling duty water flow rate and its temperature helps to estimated difference performance of cooling tower. Some of the important performance indicators of cooling tower are represented in figure 3.2.2c. The relation to estimate range, approach and effectiveness for a given cooling tower are mentioned below:

$$Range = Entering\ cooling\ water\ temperature\ (return\ from\ process) - Leaving\ water\ temperature\ (supply\ to\ process)$$

$$Approach = Leaving\ cooling\ water\ temperature - Ambient\ wet\ bulb\ temperature$$

$$Effectiveness = \frac{Range}{(Range\ + Approach)}$$

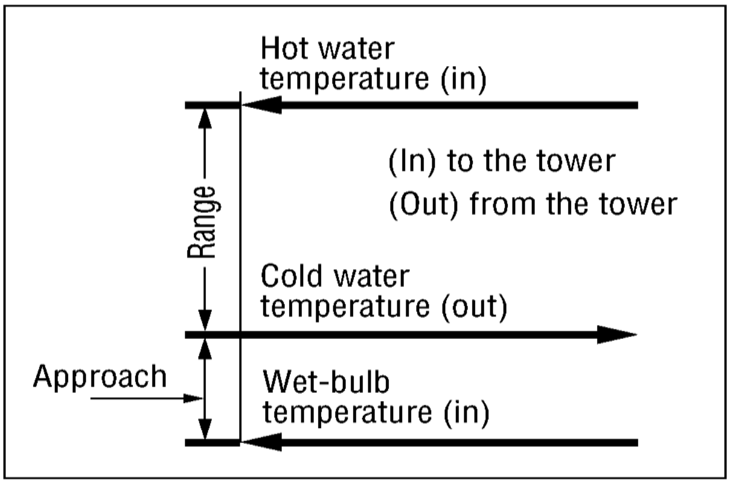


Figure 2.2.2c: Representation of cooling tower performance indicators

Heat rejected or cooling capacity; TR

$$TR = \frac{(mass\ of\ flow\ rate\ \times\ specific\ heat\ \times\ range)}{3024}$$

$$= \frac{(1000\ \times\ flow\ (m^3/h) \times\ cooling\ tower\ inlet\ and\ outlet\ temperature\ difference\ (T)}{3024}$$

Evaporation loss is the water quantity evaporated for cooling duty; as a thumb of rule for every 1 million of kcal heat rejected, the evaporation quantity could be worked out at 1.8 m^3

Blow down losses depend upon COC (cycles of concentration), where COC is the ratio of dissolved solids in circulating water to the dissolved solids in make-up water. The total make up water quantity is depended on the loss of circulating water in drift, evaporation and blow down.

$$Make\ up\ water\ quantity = drift\ loss + evaporation\ loss + blow\ down\ loss$$

The data required to be collected form cooling tower system for evaluating its performance are given below.

Table 2.2.2b: list of operating parameters of cooling tower system

S No	Parameter
1	Ambient dry bulb temperature (°C)
2	Ambient wet bulb temperature (°C)
3	Average Cooling water inlet temperature (°C)
4	Average Cooling water outlet temperature (°C)
5	Average Cooling duty water flow rate (m^3/hour)

2.2.3 Energy efficiency in pumps

Case study

In a foundry unit monthly production of 121 tonnes was equipped with a 500 kg, 350 kW induction furnace. The coil cooling pump of the furnace was mono-block type with 34% rated efficiency. The power consumption of furnace coil cooling pump was measured to be 4.5 kW. The water flow rate was measured to be 10.8 m^3/hr which is lower than the design flow of 14.4 m^3/hr. The overall efficiency of the pump is calculated to be 26% which is lower than design efficiency (34%).

The performance of an induction furnace is directly linked with the performance of its cooling water circuit. Therefore, it is recommended to replace the existing furnace coil cooling pump with an energy efficient pump. The cost benefit analysis of the EE pump is shown in table.

Table 2.2.3: Replacement of existing coil cooling pump with energy efficient pumps

Recommended Pump Specification	Units	Coil cooling pump for Furnace
Flow rate	m^3/hour	14.4
Differential Head	M	40.0
Efficiency	%	51.1%
Power proposed pump	kW	3.07
Power saving	kW	1.43
Operating period	hour	4,800
Annual Energy saving	kWh/year	6,856
Cost saving		
Annual Monetary Saving	Rs lakh / year	0.42
Investment	Rs lakh	0.55
Simple Payback Period	years	1.3
CO_2 emission avoided	tCO_2/year	6.7

The estimated annual energy savings in coil cooling pump is 6,856 kWh equivalents to a monetary saving of Rs 0.42 lakh. The investment requirement is Rs 0.55 lakh with a simple payback period of 1.3 years. The annual reduction is CO_2 emission is estimated to be 6.7 tCO_2.

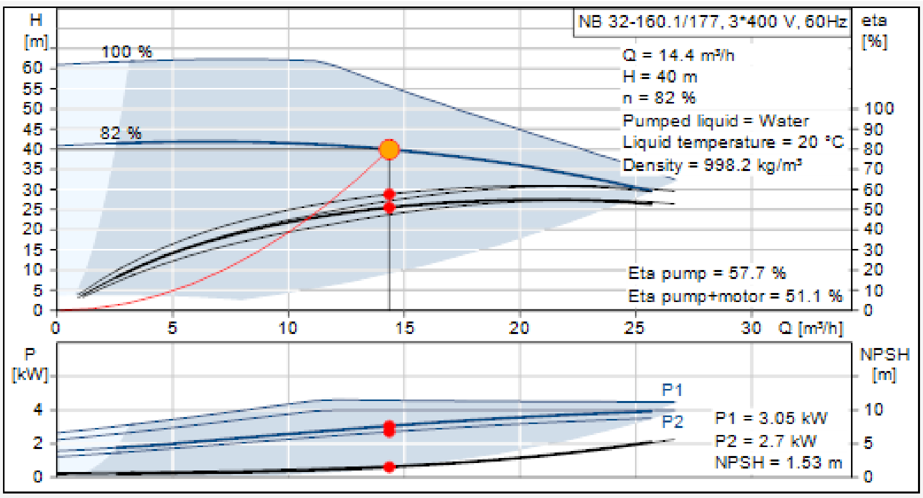
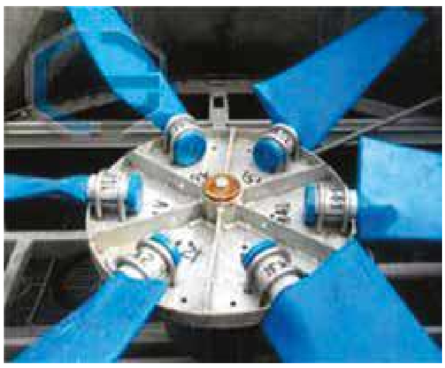


Figure 2.2.3: Proposed coil cooling pump

2.2.4 Energy efficiency in cooling tower

CASE STUDY: FRP Blades

The existing cooling tower in a foundry incorporates induced axial flow fans with aluminium blades. It is well known that aluminium blades are heavier and needs comparatively greater starting torque. The measured power of fan was 4.0 kW.



FRP blades

It is recommended to change the cooling tower fan blades from Aluminium to Fibre reinforced plastic. Usage of FRP blades instead of aluminium blades generates 20% savings. The metal blades in cooling tower fan can be replaced with 'fibre reinforced plastic' (FRP) blades, which are lighter. Use of FRP blades would reduce the power consumption of cooling tower system. It further increases the possibility of de-rating or re-sizing the motor capacity of cooling tower fan to a lower sized motor. The other advantages of FRP blade include high reliability and better performance due to lower failure rate.

The annual energy savings potential is 5,760 kWh equivalents to a monetary saving of Rs 0.45 lakh. The investment requirement is Rs 0.20 lakh with a simple payback period of 0.4 year.

Table 2.2.4: Replacement of existing coil cooling pump with energy efficient pumps

Fan power	kW	4.00
Replace Al blade by FRP blade		
Reduction in power by FRP	kW	0.80
Energy Saving	kWh/year	5,760
	toe/year	0.50
Energy cost	INR/kWh	7.89
Monetary Saving	lakh INR/year	0.45
CO_2 emission reduction	tCO_2/year	5.13
Investment	lakh INR	0.20
SPP	years	0.44

CASE STUDY: Thermostatic controller

The main function of a cooling tower is to reduce the temperature of incoming water based on wet bulb temperature and relative humidity of ambient conditions. A majority of the cooling towers are not equipped with automatic controls to regulate the fan operation. A few units control the cooling tower operations manually based on outlet temperatures of cooling water. The seasonal variations in ambient temperatures and relative humidity show that the cooling tower requires continuous monitoring of temperatures for effective operation. The maximum possible drop in temperature of cooling water is limited to the wet bulb temperature of the ambient conditions.

In place of manual operation, automatic controls are preferred. The most common system used in cooling towers is thermostatic controller. It senses the outlet temperature of the cooling water. The controller switches-on or off the fan automatically based on prevailing level of cooling water temperature.

The typical energy savings with installation of thermostatic controllers in cooling water circuit is about 5–10% depending on geographical location. Typically for a cooling tower the energy saving is in tune of 0.1 kWh per tonne of liquid metal.

2.2.5 Best operating practices in cooling water circuit

Indication that pumps is oversized

Following table 2.2.5 enlists the characteristics of an oversized pump and its reasoning:

Table 2.2.5: Characteristics of an oversized pump and its reasoning

Characteristics of an Oversized Pump	Description
Excessive flow noise	Oversized pumps cause flow-induced pipe vibrations, resulting in excessive noise and increased damage to pipework (including flanged connections, welds and piping supports)
Highly throttled flow control valves	Pumps tend to remain in more restrictive positions in systems with oversized pumps; this increases backpressure, further decreasing efficiency
Frequent replacement of bearings and seals	Increased backpressures from increased flow rates creates high radial and thrust bearing loads as well as high pressures on packing glands and mechanical seals
Heavy use of bypass lines	A system that heavily uses bypass lines indicates that the system has either Oversized pumps, is not balancing properly, or both
Intermittent pump operation	Pumps being used for purposes such as filling or emptying tanks that run very Intermittently indicate oversizing and hence suffer increased start/stop inefficiencies And wear, as well as increased piping friction

Pump wear and maintenance

Effective, regular pump maintenance keeps pumps operating efficiently and allows for early detection of problems in time to schedule repairs and to avoid early pump failures. Regular maintenance avoids losses in efficiency and capacity, which can occur long before a pump fails.

The main cause of wear and corrosion is high concentrations of particulates and low pH values. Wear can create a drop in wire to water efficiency of unmaintained pumps by around 10–12.5%. Much of the wear occurs in the first few years, until clearances become similar in magnitude to the abrading particulates. Referring to figure 2.2.5, it can be seen that it tends to level out after 10 years. Catastrophic failure can occur around 20 years.

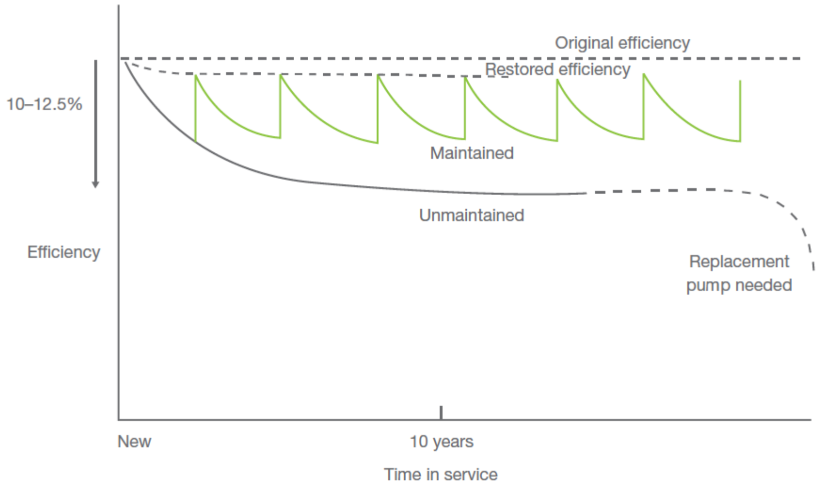


Figure 2.2.5: Average wear trends for maintained and unmaintained pumps

Common problems and measures to improve efficiency

Studies indicate that the average pumping efficiency in manufacturing plants can be less than 40%, with 10% of pumps operating below 10% efficiency. Oversized pumps and the use of throttled valves were identified as the two major contributors to the loss of efficiency. Energy savings in pumping systems of between 30% and 50% could be realized through equipment or control system changes. A pump's efficiency can also degrade during normal operation due to wear by as much as 10% to 25% before it is replaced.

Common Problem	Potential Measures to Improve Efficiency
Unnecessary demand on pumping system	Reduce demand on system
Oversized pumps	Select pump that operates near to BEP Change impeller Trim impeller Fit multiple-speed pump Use multiple-pump arrangements Fit lower speed pump/motor
Pump wear	Pump maintenance
Less efficient impeller	Change impeller
Inefficient pump throttling controls	As for oversized pumps Fit adjustable or variable-speed drive
Inefficient piping configuration	Change piping inefficiencies
Oversized motor	Change motor
Inefficient motor	Change to high-efficiency motor
Lack of monitoring and/or documentation	Install monitoring and conduct survey

Best operating practises summary

- Ensure adequate NPSH at site of installation.
- Ensure availability of basic instruments at pumps like pressure gauges, flow meters.
- Operate pumps near best efficiency point.

- Modify pumping system and pumps losses to minimize throttling.
- Adapt to wide load variation with variable speed drives or sequence 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.
- Increase fluid temperature to reduce pumping rates in case of heat exchangers.
- Repair seals and packing to minimize water loss by dripping
- Balance the system flows and reduce pump power requirements
- Avoid pumping head with a free return (gravity): Use siphone effect to advantage
- Conduct water balance 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 the operation of pumps to avoid throttling
- Provide booster pumps for few areas of higher head
- Replace od pumps by energy efficient pumps
- In case of over designed pump, provide variable speed drive, or downsize/replace impeller or replace with correct sized pump for efficient operation
- Optimize number of stages in multi-stage pump in case of head margins
- Reduce system resistance by pressure drop assessment and pipe size optimization

List of references

- Bureau of Energy Efficiency Guide Books – Compressed air system
- Bureau of Energy Efficiency Guide Books – Pumps and pumping system
- Bureau of Energy Efficiency Guide Books – Cooling tower
- TERI – Past studies on foundries

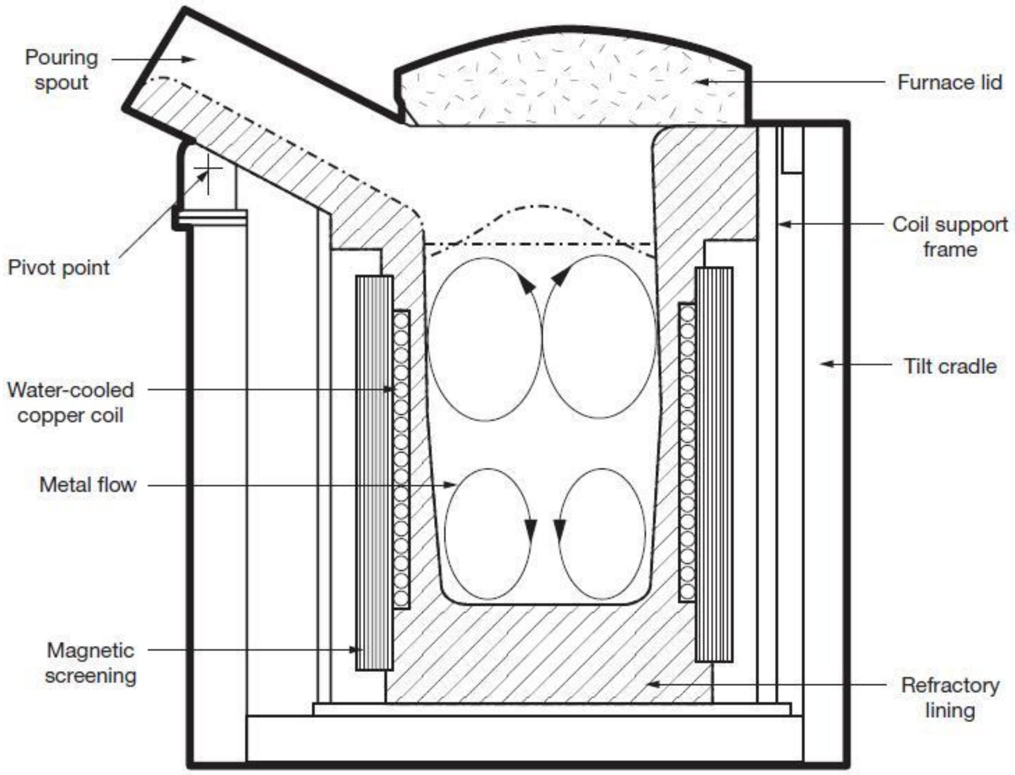
3.0 Module 2 – Energy conservation (with focus on melting)

3.1 Best operating practices in induction furnace

3.1.1 Introduction and working principle

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

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



Typical arrangement of coreless induction furnace

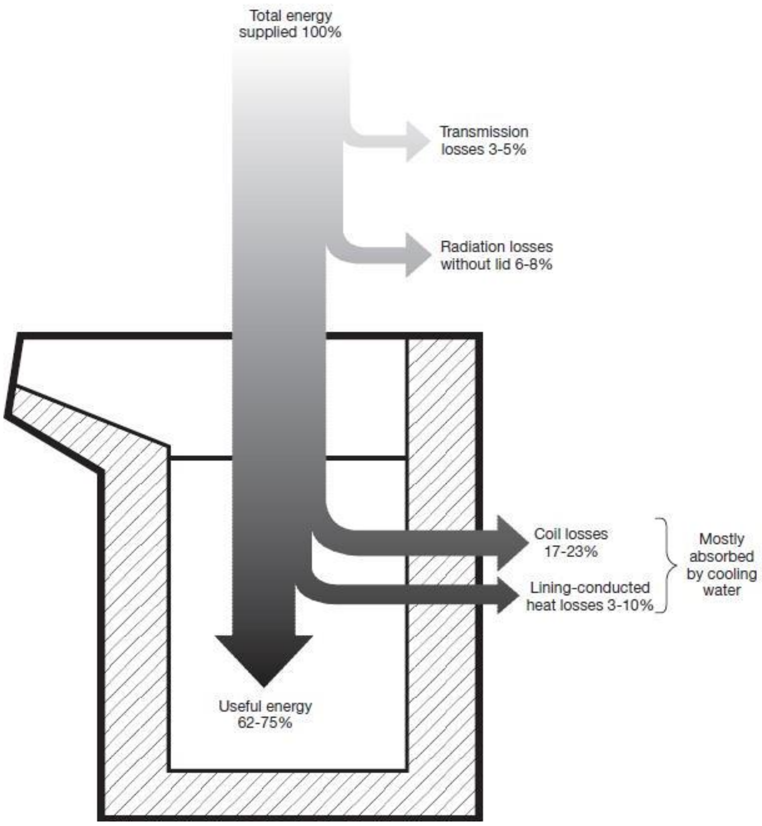
Source: BCIRA Efficient Melting in coreless induction furnace

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

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

3.1.2 Losses in induction furnace

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



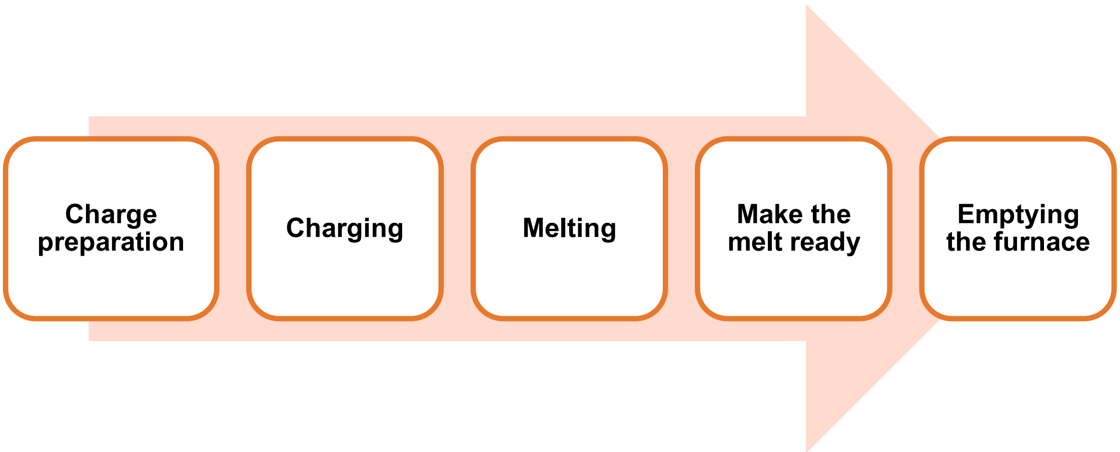
Sankey diagram of energy loss in coreless induction furnace

Source: BCIRA Efficient Melting in coreless induction furnace

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

3.1.3 Best operating practices

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



Steps of operation of induction furnace

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

Charge preparation and Charging

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

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

Melting and making melt ready

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

Emptying the furnace

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

Furnace lining

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

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

Energy monitoring and data analysis

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

Others

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

3.2 Replacement and retrofit options in induction furnace

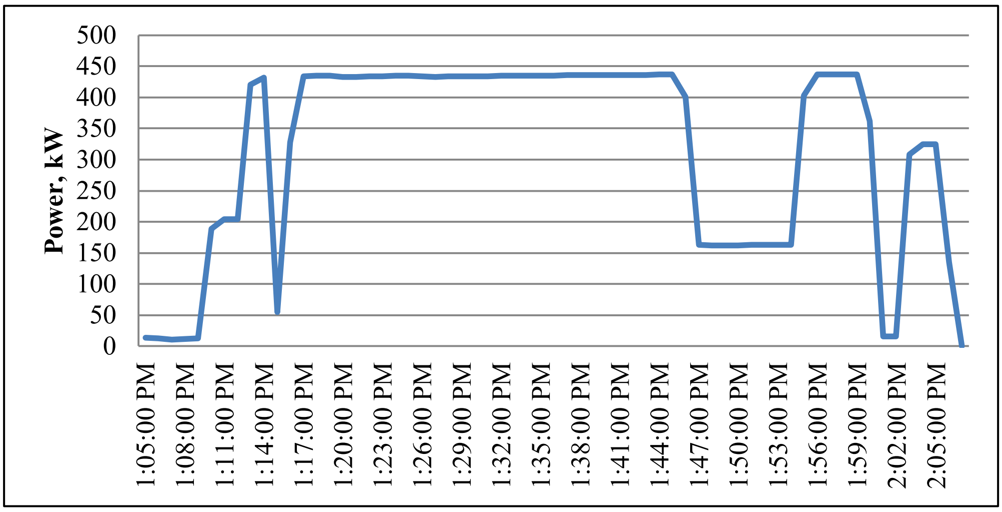
Melting is the heart of the foundry industry. A number of options are available for melting but induction furnace is by far the most famous and used furnace for melting.

3.2.1 Performance assessment of induction furnace

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

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

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



Power curve of a sample batch of melting in induction furnace

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

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

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

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

3.2.2 Replacement of in-efficient induction furnace

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

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

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

3.2.3 Retrofits in induction furnace

Lid mechanism for induction furnace

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

Different options for lid mechanism for induction furnace

Low cost automation in raw material charging

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

3.3 Case study – A foundry in Kolhapur

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

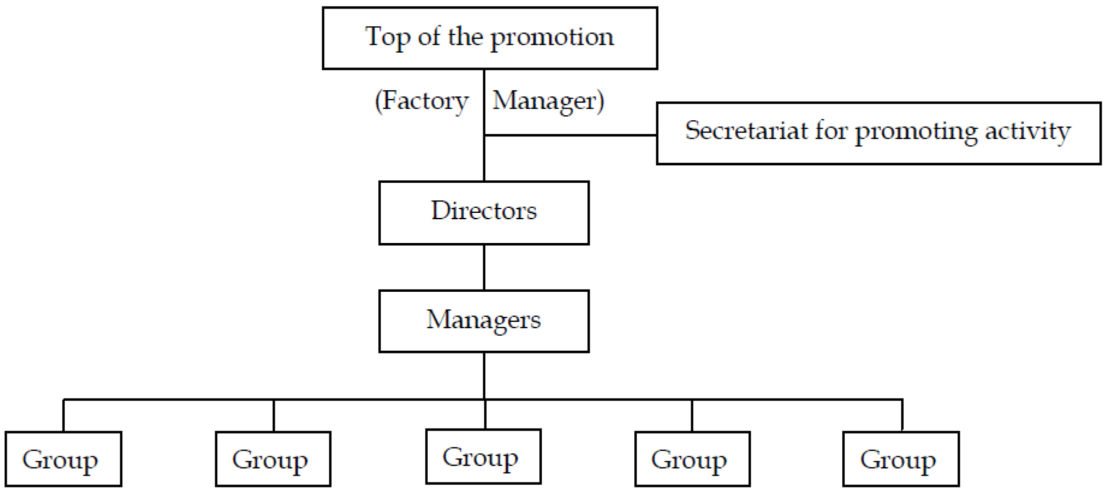
3.3.1 Background about the unit

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

3.3.2 Kaizen implementation methodology

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

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



Implementation support group

3.3.3 Data collection, visualization and analysis

Data collection

A number data pertaining to melting operation in induction furnace were collected. A standard format was prepared in agreement with the foundry and data was collected on heat-wise basis for months. The present case study data of 545 heats of FG220 grade casting is presented. A sample format of data collection sheet is shown in table 4.3.3a, b & c.

Table 3.3.3a Data collection format – Part 1

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

Table 3.3.3b Data collection format – Part 2

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

Table 3.3.3c Data collection format – Part 3

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

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

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

Visualization and analysis of data

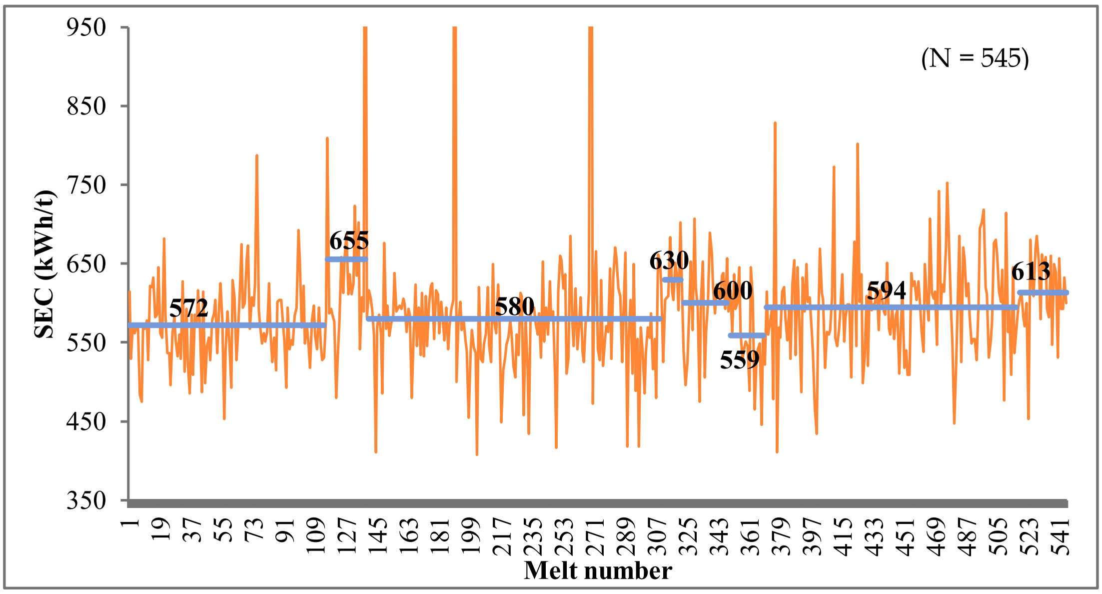
A number data visualization tools were utilized to analyse the date collected. The following analysis was conducted to improve understanding of the induction furnace operation:

Table 3.3.3d: Data analysis vs. visualization tool

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

Melt no. vs. SEC (Line graph)

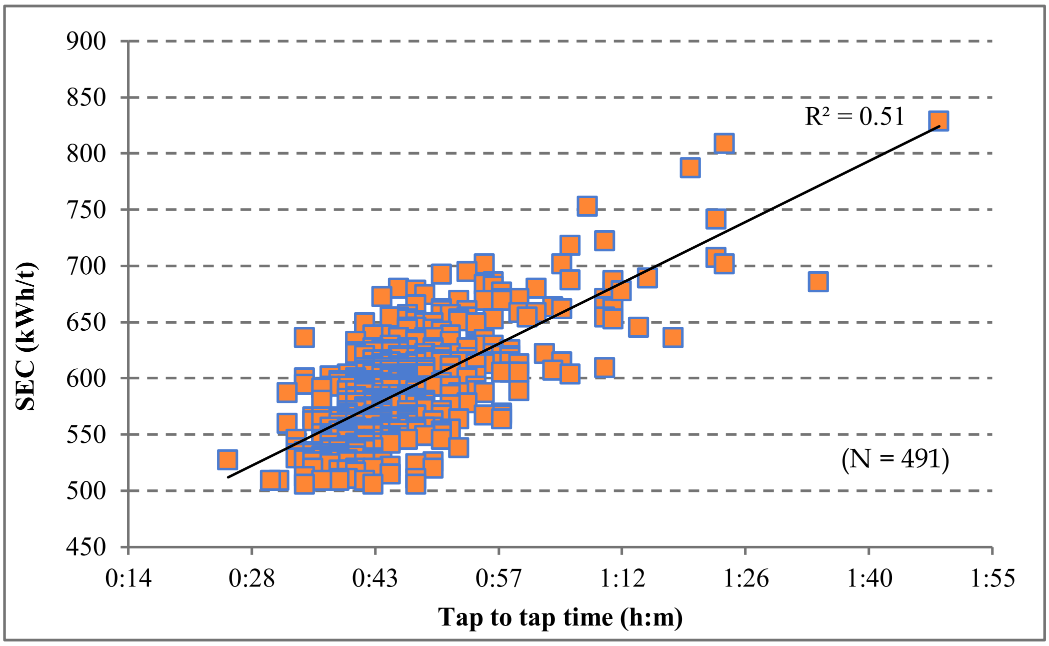
A total of 545 heats of FG220 grade melting were recorded. A line graph was plotted for SEC vs. melt number. Local averages were highlighted to show the variation in SEC over time. The local averages of SEC varied from 655 to 559 kWh per tonne.



Melt number vs. SEC

TTT vs. SEC (Scatter plot)

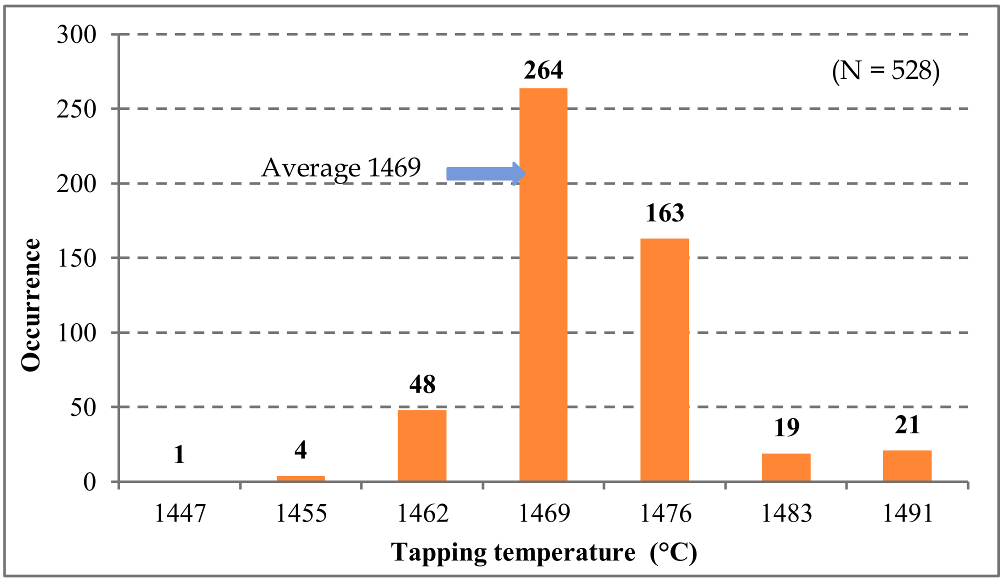
The tap-to-tap time of the heat varied depending on a number of parameters such as raw material availability, rate of charging, readiness of moulds, and delay in chemistry adjustment. A scatter was plotted for tap-to-tap time vs. the specific energy consumption. The cold start heat were omitted from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



Tap to tap time vs. SEC

Tapping temperature occurrence (Histogram)

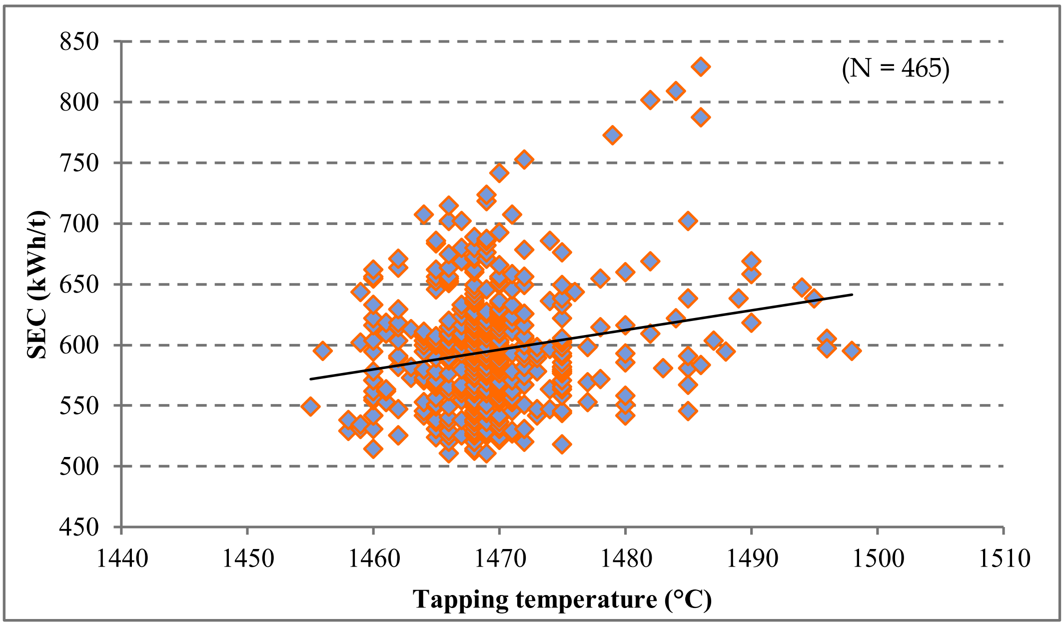
A total of 528 heats were observed were tapping temperatures data was available. The range of tapping temperature was from 1442 to 1527 °C, with a median at 1469 °C. The data was evenly balanced as the mean and the median were same. The frequency of occurrence of tapping temperature in range of one standard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



Tapping temperature occurrence

Tapping temperature vs. SEC (Scatter plot)

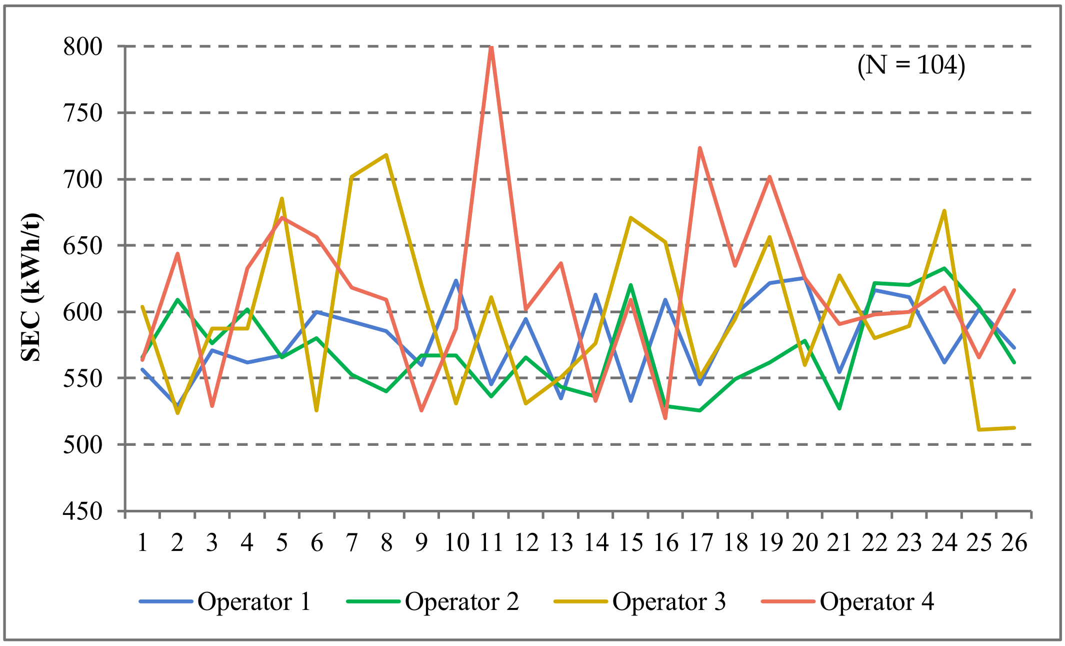
The tapping temperature required for FG220 grade was in range of 1465 – 1475 °C. The SEC of the furnace is believed to have strong correlation with tapping temperature. A scatter plot for 465 heats for tapping temperature and specific energy consumption is shown in figure.



Tapping temperature vs. SEC

SEC vs. operator (Line graph)

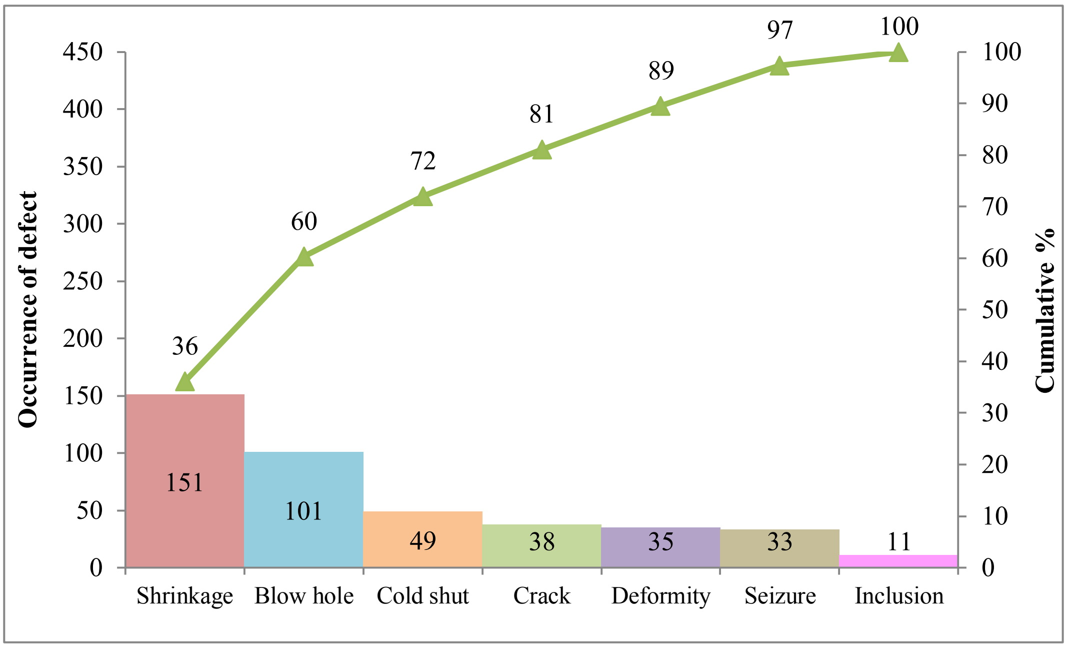
The plant had employed a total of four operators. They took different shifts. Two operators i.e. Operator 1 and Operator 2 were experienced and it reflected in their operation, their respective SEC for a sample of 26 heats was 588 and 584 kWh per tonne. The other two operators were young and new to induction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



Operator vs. SEC

Rejection occurrence (Pareto chart)

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



Rejection analysis

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

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

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

3.3.4 Activities for implementation

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

Table 3.3.4: Proposal of activities

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

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

△ *Taking an action carefully and thoroughly*

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

Installation of induction furnace energy monitoring system

Lid mechanism for induction furnace crucible

Proper sizing of pump and improving energy efficiency

Removal of obstruction to cooling tower air intake and FRP blades

Pictorial view of a few implementations

3.3.5 Results

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

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

References

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

6. Kaizen activity manual, IGES and TERI, 2013

4.0 Module 3 – Pollution control system

4.1 Foundry process

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

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

Table 4.1: Emissions from different processes of the foundry

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

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

4.2 Present environmental standards

Existing emission standards for foundries prescribed by Central Pollution Control Board (CPCB) are given in table 4.2a below.

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

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

Note:

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

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

Emission standard for SO_2 from cupola furnace is prescribed to be 300 mg/Nm^3 at 12% CO_2 correction as referred in MOEF notification dated 2nd April, 1996, New Delhi. To achieve the standard, foundries may intake scrubber, followed by a stack of height six times the diameter of cupola beyond charging door. In case due to some technical reasons, installation of scrubber is not possible, the value of SO_2 to the ambient air has to be effected through the stack height. The rule to be called the Environmental (Protection) Act, 1996.

Standards in other countries

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

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

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

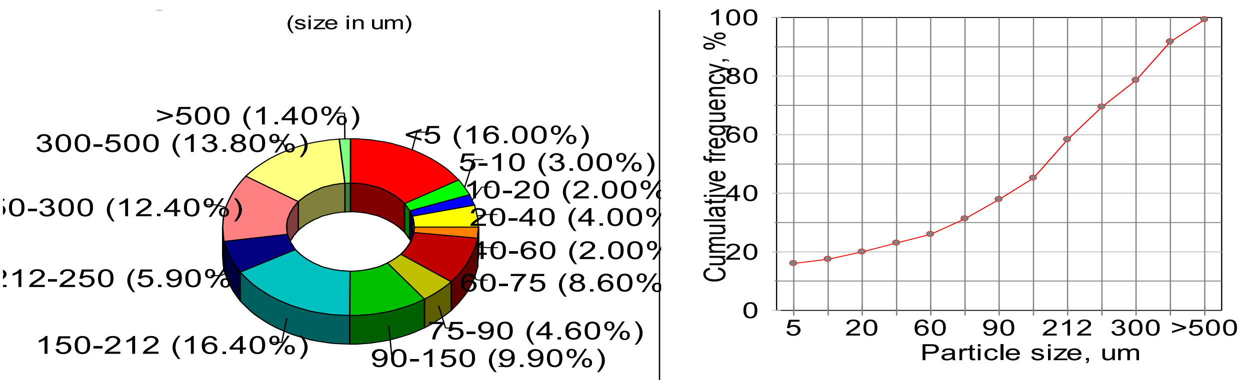
Type	Pollutant	Concentration (mg//Nm³)
Hot and cold blast		
Existing hot blast cupola (1991) Existing hot blast cupola (1997)	Particulate matter	115 100
Existing cold blast cupola Capacity : less than 4 tonne/hr 4 tonne/hr and more (1991) 4 tonne/hr and more (1997)	Particulate matter	 No standard 115 100

4.3 Measurements

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

Table 4.3: Emission measurements at two units

Unit	Location	Particulate matter emission, g/Nm³
Foundry 1	Below scrubber, charging door open	1.17
	Below scrubber, charging door open	2.20
	Below scrubber, charging door closed	5.66
	Above scrubber, charging door open	0.56
	Above scrubber, charging door open	2.44
Foundry 2	Sampling port, charging door open	1.38
	Sampling port, charging door closed	2.77
	Sampling port, charging door open	3.94



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

4.4 PCS design vis-a-vis standards

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

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

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

Table 4.4: Various pollution control options for cupola foundries

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

4.5 Commonly used PCS

Cyclone

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

Wet arrester or cap

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

Multicyclone

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

Venturi Scrubber

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

Fabric Filter

- Most efficient type suited for cupola furnace
- Needs fan for cooling of exhaust gas
- Can remove 0.2 µm size particles with 99% efficiency
- Costly but cannot remove SO_2

More details of these PCS are given below:-

Cyclone

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

Wet arrester or cap

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

Multicyclone

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

Venturi scrubber

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

Fabric filter

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

Table 4.5: Comparison of Collection Methods

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

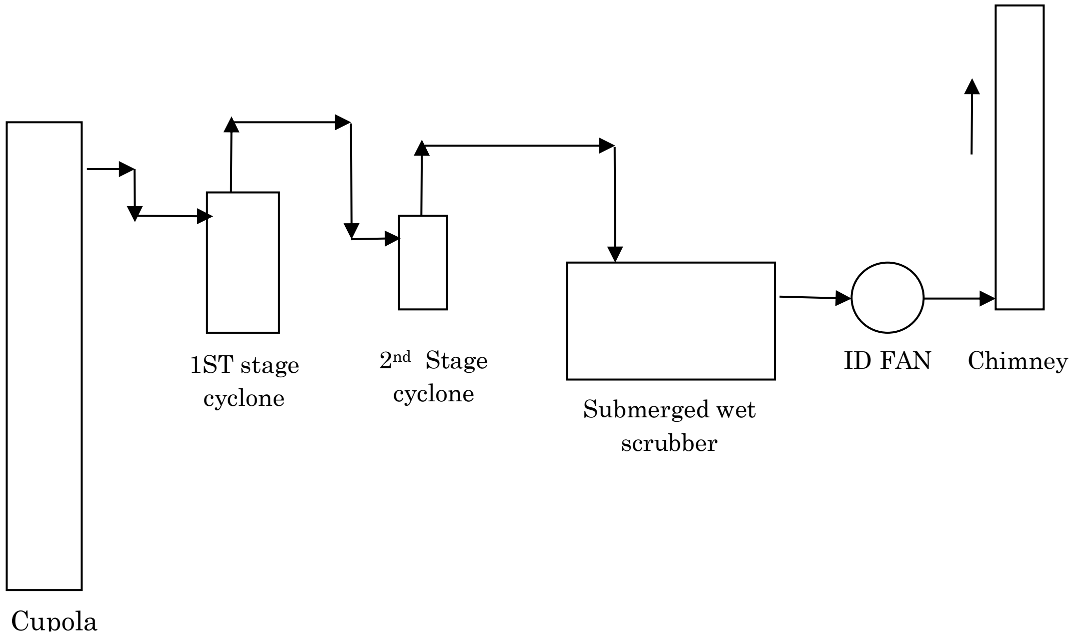
It is clear from the above discussion that venturi scrubber and bag filter can meet the standard of 150 mg/Nm^3 prescribed for particulate matter with greater degree of certainty. Bag filter cannot remove SO_2 whereas, venturi scrubber is very effective for controlling SO_2 emission. Multi cyclone can meet the emission standard of 450 mg/Nm^3 prescribed for particulate matter with certainty. It cannot control SO_2 emission. Wet cap can be suitable for meeting 450 mg/Nm^3 standard but presence of higher percentage of finer particulates might be difficult for meeting the said standard with certainty. Many units have installed dry cyclone after intervention of Supreme Court in Howrah cluster. A very clear direction needs to come from PCB towards installation of pollution control system for different capacity cupola.

4.6 Technologies used in different foundry clusters

4.6.1 Pollution control system used in Howrah foundry cluster

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

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

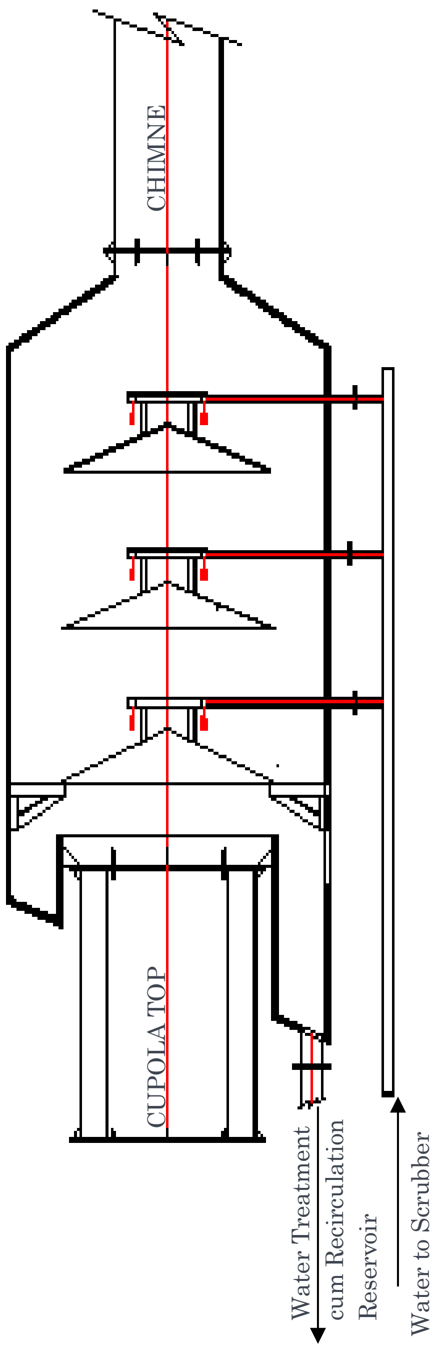


pass through the devices in series before release to the atmosphere.

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

4.6.2 Cupola wet cap (3-stage scrubber)

The 3-stage scrubber called Cupola Wet Cap is positioned just above the Cupola top shell and just before the Chimney (figure 4.6.2). scrubber apparatus is provided for recovering or removing entrained particulate matter from gases comprising a settling basin, a wet scrubber mounted over the settling basin, the scrubber having a tower free of a bottom wall so as to be completely open at the bottom to said settling basin and open at the top to exhaust and open adjacent to its bottom to a source of said gases. Liquid spray means are mounted in the tower for spraying liquid counter current into contact with the gases rising in the tower to remove the particulate matter by gravity directly to the settling basin. The tower has an outer shell and an elastic liner. Means are provided for introducing a pressurized medium between the liner and the shell to distort the liner to loosen accumulated matter therefrom for discharge by gravity directly to the basin. The elastic liner is porous to permit discharge of at least some of the pressurized medium through the liner to aid in removal of the accumulated matter from the liner. The liquid spray means also includes a plurality of circular conduits located adjacent to the inner surface of the liner, the conduits containing apertures for discharging spray liquid into the gases and also tangentially along the surface of the liner to aid in removal of the accumulated matter from



the liner.

Figure 4.6.2: Cupola wet cap

4.6.3 Twin cyclone separator

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

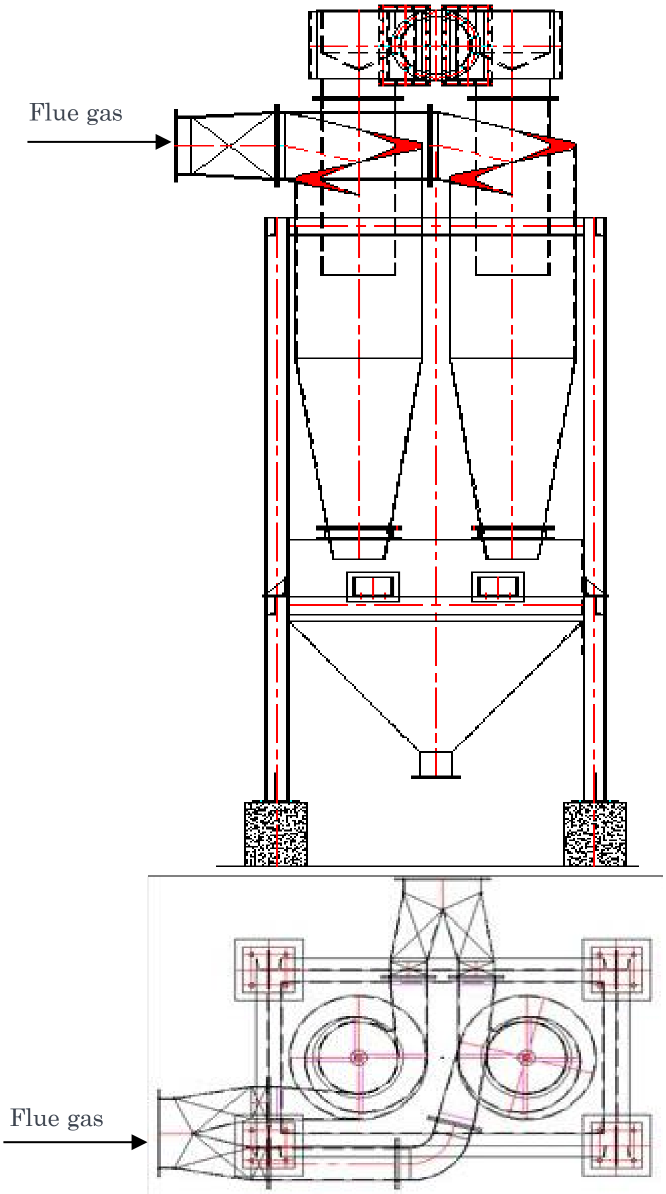


Figure 4.6.3: Twin cyclone separator

4.6.4 Pollution control system used in Punjab foundry cluster

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

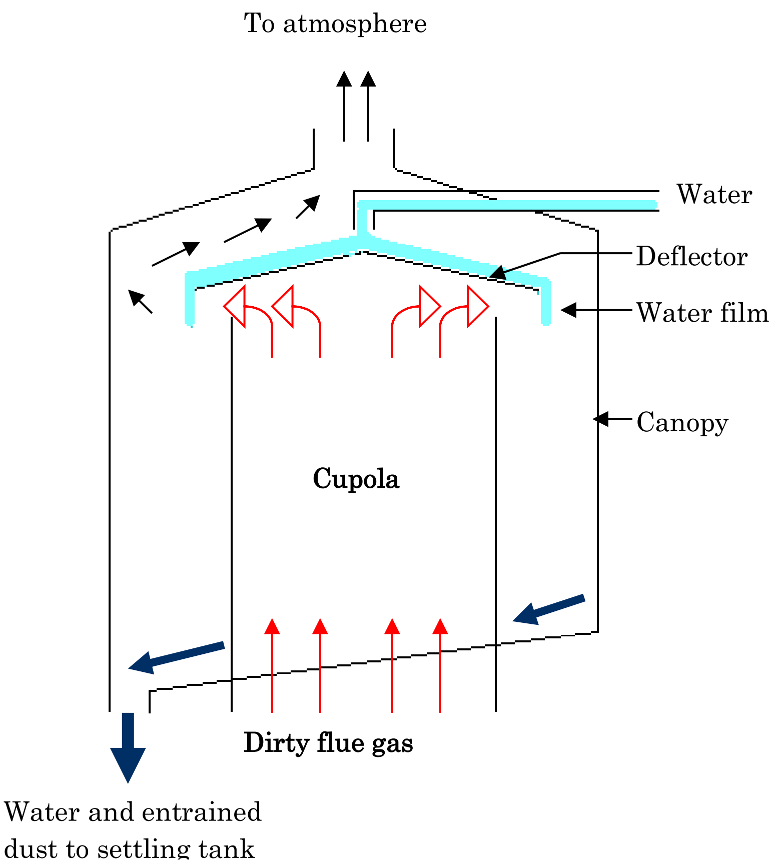


Figure 4.6.4: Cross current scrubber technology

4.6.5 TERI venturi scrubber design

The analysis by TERI reveals that cupola stack gases contain a significant percentage of fine particulates. The most effective pollution control device to bring down these particulate emissions to below 150 mg/Nm^3 is the venturi scrubber (Figure 5.6.6a). Figure 5.6.6b shows a schematic of the venturi scrubber system. Salient features of the venturi scrubber design are listed below.

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

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

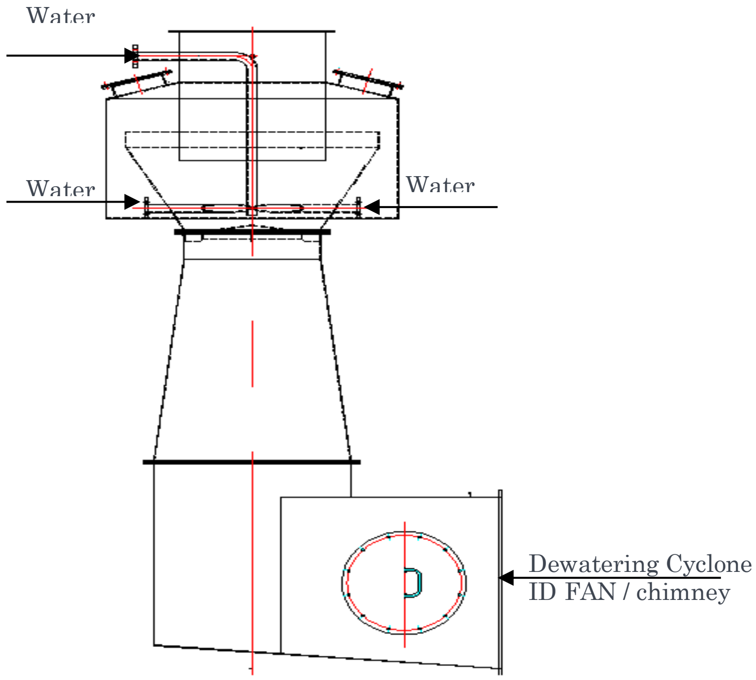


Figure 4.6.5a: TERI venturi scrubber design

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

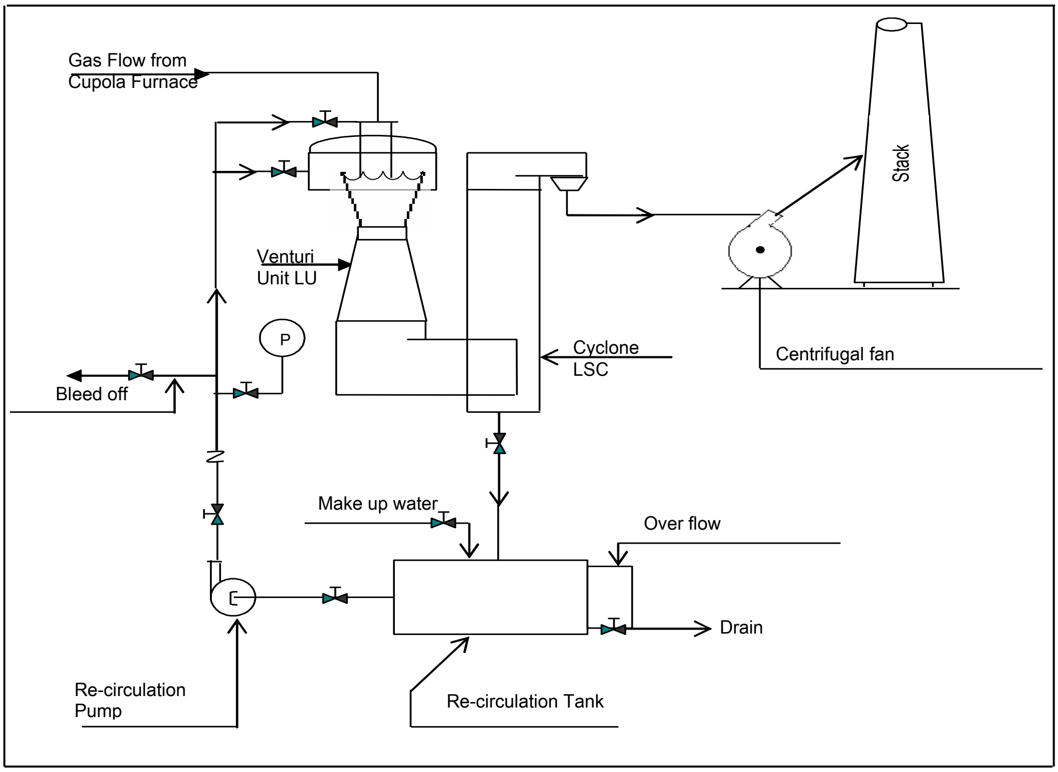


Figure 4.6.5b: Schematic of the venturi scrubber system

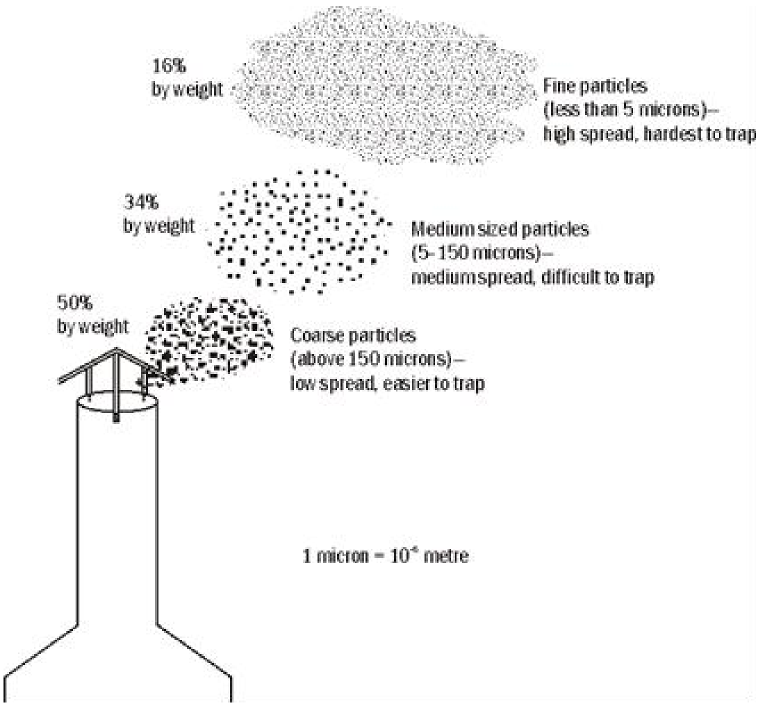


Figure 4.6.5c: Comparison of particulate emission levels

4.7 Legal framework

Central Pollution Control Board has responsibility to lay down standards for a stream or well and for air quality, planning and execution of nationwide programmes for the prevention, control or abatement of water and air pollution, and ensure compliance with the provisions of Environment (Protection) Act, 1986. State pollution control boards has responsibility to ensure compliance with the provisions of the relevant Acts, lay down or modify effluent and emission standards and ensure legal action against defaulters.

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

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

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

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

4.8 Solutions/action plan

One of the major reasons for general reluctance to foundries to adopt pollution control is the high pollution control costs. Since pollution control costs do not increase at the same rate as plant output the additional cost per ton of castings due to installation of pollution device for a small foundry is be very high. This calls for some policy changes, so that small foundries are self-motivated to adopt pollution control.

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

a) **Institutional development of foundry associations**
   Technical and financial help should be given to foundry associations so that they are geared to conduct environmental measurements, design pollution control equipment, and provide all technical advice in matters of design, fabrication, procurement and installation, so that individual foundries do not have to experiment with different designs.
b) **Concessions in sales tax on pollution control equipment**
   To reduce the cost of pollution control equipment, sales tax exemption on materials and equipment's required for pollution control device could be granted.
c) **Facility of loans on easy terms**
   To partially meet the financing of expensive pollution control devices, an environment service company exclusively for small scale foundry could be established. This has been discussed in more detail below in financing of PCS.

Policy Issues

Acceptable accuracy for emission value

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

Velocity and temperature measurement of flue gas

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

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

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

Maximum stack height

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

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

Sharing of PCS

Multi cyclone/wet cap can meet the standard of 450 mg/m^3 whereas venturi scrubber/bag filter can meet the standard of 150 mg/m^3 as prescribed for cupola with greater degree of certainty. Since all these pollution control systems are very costly, it may be difficult for single unit to install the system. It is very important to have some policy where a group of foundries situated adjacent might be allowed to share their pollution control system. The stack height would be adjusted accordingly based on number of units are using the system and the maximum ground level concentration.

Measurement condition

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

Measurement time

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

Measurement port/stand

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

Particle size analysis

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

Financing of PCS

There is a general reluctance of foundries to borrow money from financial institutions and banks. Lack of professional manpower, proper accounting practices and tedious documentation required, inhibit foundry owners in approaching banks for loan. To partially meet the financing of expensive pollution control devices, an environment service company exclusively for small scale foundry could be established. The company could be set-up with initial financial assistance from foundry associations, bilateral or multilateral organisations. The bottlenecks for borrowing money could be eliminated by making loan disbursement easier and providing guidance through the foundry associations.

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

5.1 Introduction

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

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

5.1.1 Average rate of return (ARR)

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

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

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

Guideline- Invest in a project with higher ARR

5.1.2 Return on investment (ROI)

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

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

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

Discounted value of energy savings

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

Guideline: Invest in a project with higher ROI

5.1.3 Simple payback period (SPP)

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

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

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

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

The limitations of SPP tool are:

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

Guideline: Invest in a project with small SPP

5.1.4 Net Present Value (NPV)

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

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

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

Where,

FV – future value of energy savings

i - interest or discount rate or hurdle value

n – number of years under analysis

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

NPV = total PV- Initial cost of investment

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

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

Guideline:

NPV > 0 : Should be accepted

NPV = 0 : Should be accepted if the project has some strategic value
NPV < 0 : Should not be accepted

5.1.5 Internal rate of return (IRR)

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

The formula for IRR is

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

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

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

Guideline: Invest in a project with high IRR

5.2 Major financial schemes for MSMEs in India

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

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

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

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

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

5.2.1 National Manufacturing Competitiveness Programme (NMCP)

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

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

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

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

5.2.2 CLCSS Scheme

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

5.2.3 Credit Guarantee Scheme

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

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

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

Operating authority - The office of Development Commissioner, MoMSME
Eligibility criteria – SPV comprising at least 25 registered located in the cluster
Financial support - 70 % by Central Government and balance 30 % by SPV /State government for project value up to Rs 15 Crores.

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

5.3 Various credit lines and bank schemes for financing of EE

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

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

5.4 Preparation of detailed project report (DPR)

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

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

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

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

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

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

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

A typical outline of the content page of a DPR is provided in table 5.4. It is understood that the DPRs will be structured keeping in view their acceptability to financial institutions/ banks.

Table 5.4: Typical contents page of DPR

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

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

5.5 Step by step approach for loan application

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

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

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

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