Comprehensive training material for EE/RE system suppliers Coimbatore 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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Contents

About this manual

This manual provides, in a direct and simple manner, guidance on improving energy efficiency for local service providers (LSPs) in the 'EE/RE system suppliers' 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. Energy conservation, Pollution control system and Lean manufacturing. 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 Coimbatore Foundry Cluster between February to April 2018 under the GEF-UNIDO-BEE Project "Capacity Building of Local Service Providers".

1.0 Introduction

1.1 Background

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

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

This comprehensive training material for Coimbatore foundry cluster is targeted at 'EE/RE system suppliers' category. The material is structured in the following 4 modules.

Module 1	Energy conservation
Module 2	Pollution control system
Module 3	Lean manufacturing
Module 4	Financing schemes and DPR preparation for EE projects

2.0 Module 1 - Energy conservation

2.1 Melting – 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.

2.1.1 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 2.1.1.

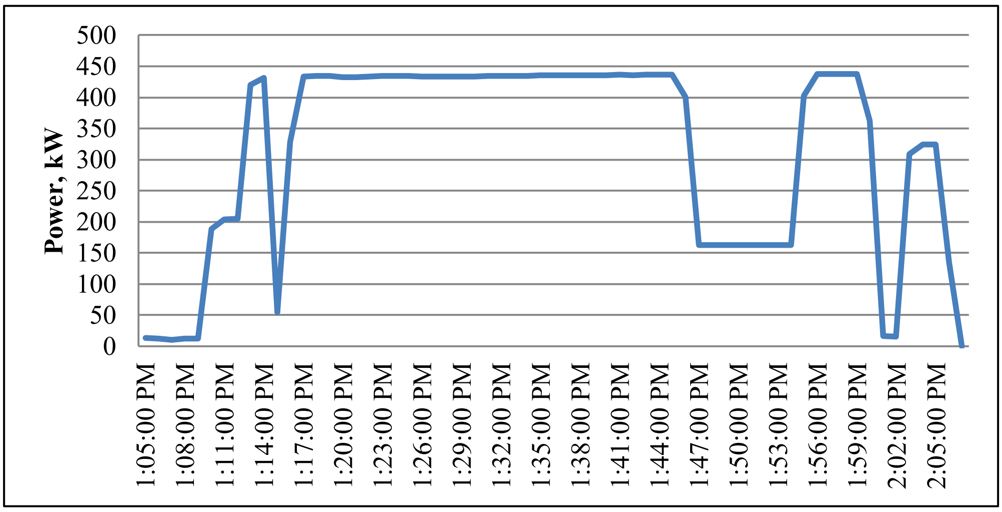


Figure 2.1.1: Power curve of a sample batch of melting in induction furnace

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.

2.1.2 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

2.1.3 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.

Figure 2.1.3: 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.

2.1.4 Best operating practices in induction furnace

Charge preparation and charging

- The raw material must be weighed and arranged on melt floor near to furnace before starting the melting.
- Charge must be free from sand, dirt and oil/grease. Rusty scrap not only takes more time to melt but also contains less metal per charging. For every 1% slag formed at 1500 °C energy loss is 10 kWh per tonne.
- 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 2 to 5 % sand by weight.
- Keeping exact weight of alloys ready, as alloys are very expensive proper handling will not only reduce wastage but also reduce time lost in alloying.
- The maximum size of single piece of metal/scrap should not be more than 1/3rd. of diameter of furnace crucible. It avoids problem of bridging. Moreover, each charge should be about 10% of crucible volume.
- There should be no or less sharp edges, particularly in case of heavy and bulky scrap, as this may damage the refractory.
- Furnace should never be charged beyond the coil level. It should be noted that as furnace lining wears out the charging may slightly increase.
- Proper charge sequence must be followed. Bigger size metal first followed by smaller size and gaps must be filled by turnings and boring.
- Limit the use of baled steel scrap and loose borings (machining chips).

- Use charge driers and pre-heaters to remove moisture and pre-heat the charge. Vibro-feeders for furnace are equipped with vibrating medium and they could be fuel fired to pre-heat charge and remove oil/grease.
- Avoid introduction of wet or damp metal in melt, this may cause explosion

Figure 2.1.4a: Vibrating feeder for induction furnace

Figure 2.1.4b: Tum blast for runner and risers

Melting and making melt ready

- Always run the furnace with full power. This not only reduces batch duration but also improves energy efficiency. E.g. 500 kg, 550 kW furnace, when run at full power melt may be ready in 35 minutes but if not at full it may take over 45 minutes.
- Use lid mechanism for furnace crucible, radiation heat loss accounts for 4 – 6 % 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, as shown in figure 2.1.4. Typical slag build-up occurs near neck, above coil level where agitation effect is less. Quantity of flux used for slag removal is important. Typically flux consumption should be less than 1 kg per tonne of metal.
- 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.

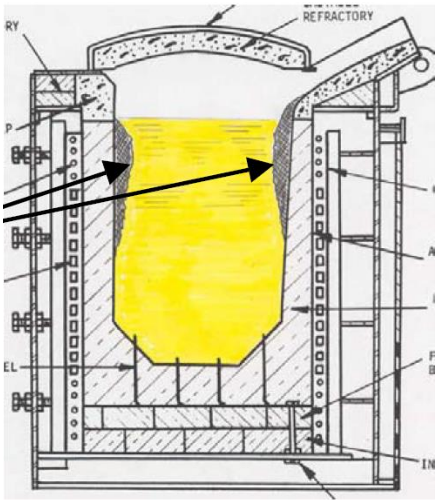


Figure 2.1.4c: Slag build-up near furnace crucible neck

- Process control through melt processor leads to less interruptions. Typically reduce interruptions by 2 to 4 minutes. 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 by 50 °C can increase furnace specific energy consumption by 25 kWh per tonne.

Emptying the furnace

- Plant layout plays an important role in determining distance travelled by molten metal in ladle and the temperature drop.
- Optimize of the ladle size to minimize the heat losses and empty the furnace in the shortest time.
- Plan melting according to moulding capacity. Metal should never wait for mould rather mould should be ready before metal.
- Use of ladle pre-heater. Using molten metal to pre-heat ladle expensive.
- Quantity of liquid metal returned to furnace must be as low as possible.
- Glass-wool or ceramic-wool cover for pouring ladle to minimize temperature drop.
- Minimize plant breakdown by implementing a planned maintenance schedule.

Figure 2.1.4d: Mono-rail and manual

Furnace lining

- Select the correct lining material.
- Do not increase lining thickness at bottom or sidewalls. Increase in lining means reducing capacity of furnace and increase power consumption.
- 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.
- Coil cement should be smooth, in straight line and having thickness of 3 to 5 mm.
- While performing lining ensures 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 in conjuncture with tapping temperature and quantity of metal tapped.
- Energy monitoring is the first step for achieving energy saving.

Others

- Effective raw material storage is important for optimum performance of the furnace. E.g. Bundled scrap is stored on mud floor, thus it will lead to dust and moisture pick-up
- Coil cooling and panel cooling water's temperature and flow rate must be monitored.
- 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.

2.2 Compressed air system

2.2.1 Background

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

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

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 ^{o}C, 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.

2.2.2 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

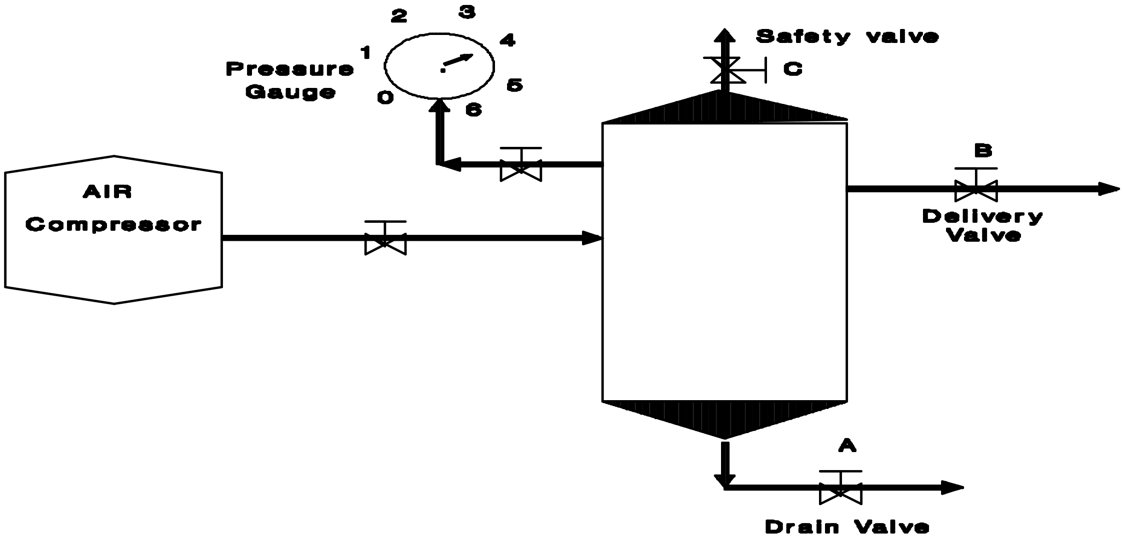


Figure 2.1.3a: Pump up test schematics

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. 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.

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,
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.

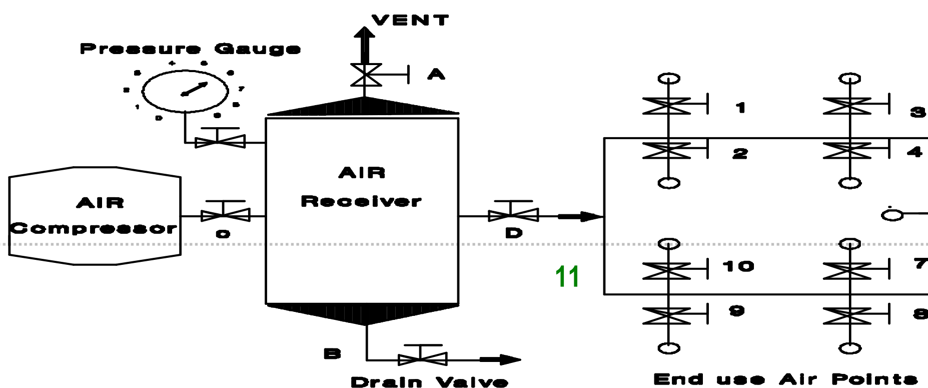


Figure 2.1.3b: Leakage test schematics

2.2.3 Replacement of in-efficient air compressor

EE compressor with VFD

Table 2.2.3a provides the detailed techno-economic analysis of a typical EE project of replacing an existing air compressor new VFD based screw compressor.

Table 2.2.3a: Details of recommended EE compressor

Actual Parameters	Unit	Value
Loading Pressure	kg/cm^2	5.9
Unloading Pressure	kg/cm^2	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/cm^2	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
Monetary saving	lakh INR/year	7.37
Investment cost	lakh INR	8.48
Simple payback period	Year	1.15

Replacement of reciprocating compressor by screw air compressor

A typical foundry was using an air compressor of the specifications given in table 2.2.3b.

Table 2.2.3b: 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

The cost benefit and saving by rreplacing the air compressor with new screw air compressor estimation is given in table 2.2.3c.

Table 2.2.3c: Details of recommended on reciprocating to screw air compressor

Actual Parameters	Unit	Air Compressor
Loading	%	47.9%
Unloading	%	52.1%
Loading Pressure	kg/cm²	7.5
Unloading Pressure	kg/cm²	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/cm²	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
Monetary saving	lakh INR/year	1.46
Investment cost	lakh INR	2.31
SPP	year	1.59

2.2.4 Retrofits in compressed air system

Retrofit of VFD on screw air compressor

The design specifications of existing compressors are given in table 2.2.4a.

Table 2.2.4a: 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/cm²	7.5
Power	kW	18

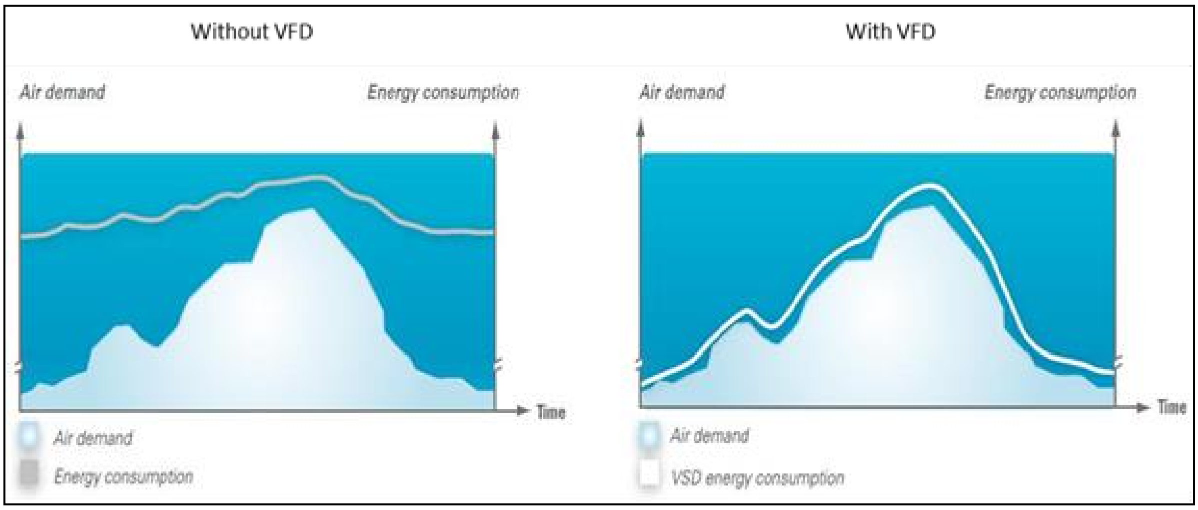


Figure 2.2.4a: Air demand and energy consumption with and without VFD

Retrofitting the air compressor with variable frequency drive (VFD) resulted in the energy savings as given in table 2.2.4b.

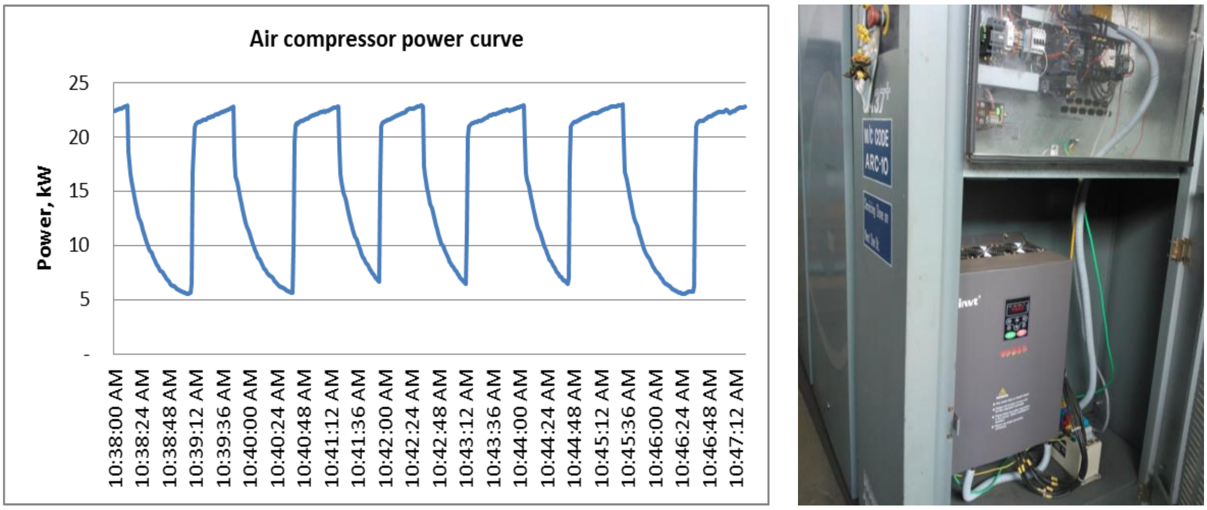


Figure 2.2.4b: Air compressor power curve after installation of VFD

Table 2.2.4b: 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

Sequence controller for air compressors

A foundry 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 figure 2.2.4c & d.

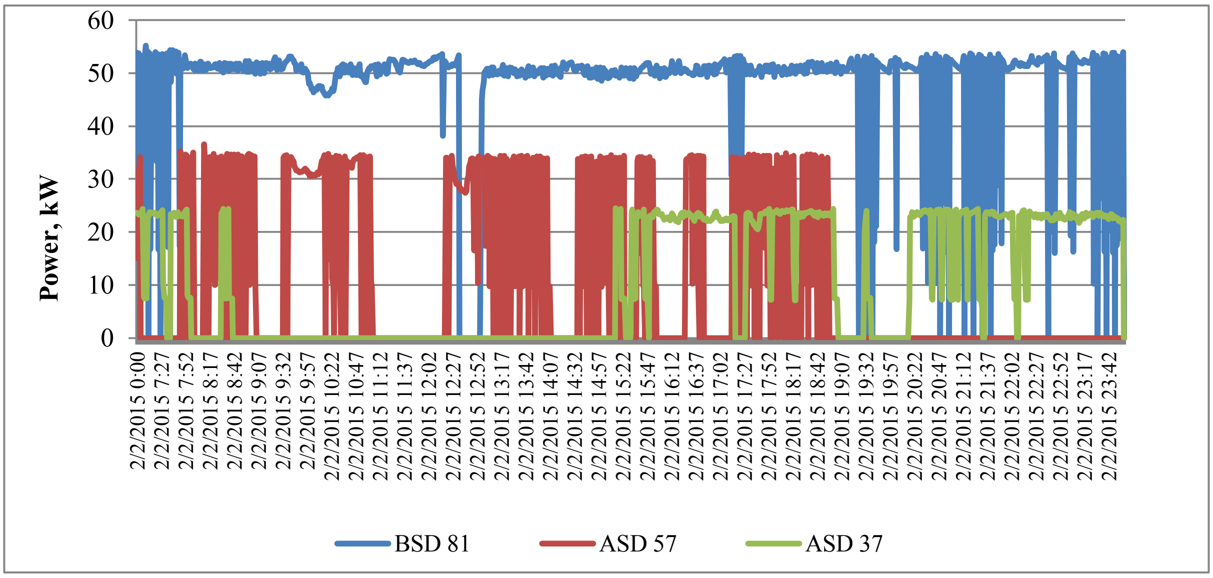


Figure 2.2.4c: Before sequence controller

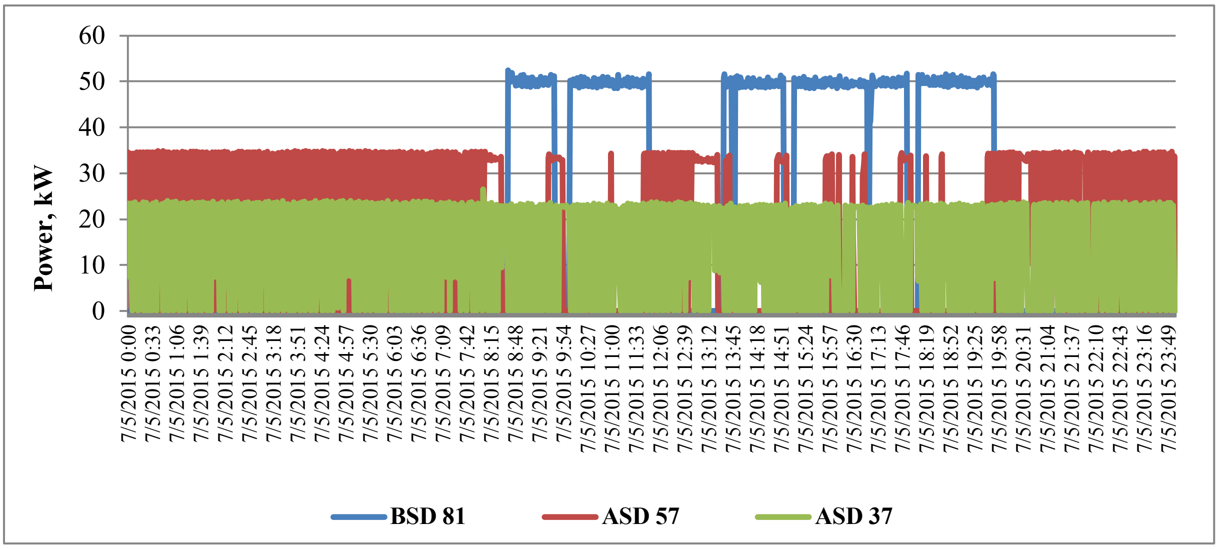


Figure 2.2.4d: After sequence controller

2.3 Cooling water system

2.3.1 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.

2.3.2 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 2.3.2.

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.

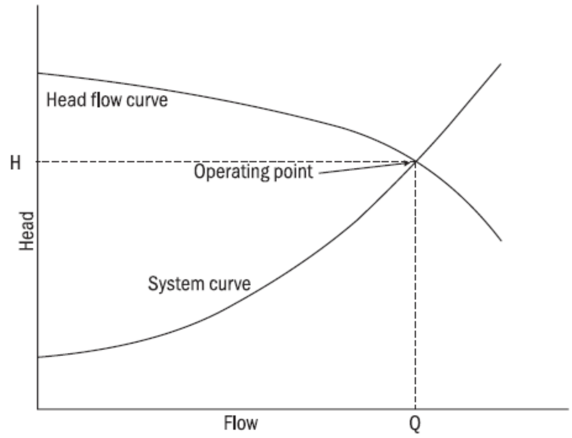


Figure 2.3.2: Operating curve of a Pump

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 2.3.2 provides the list of data that are required for calculating above mentioned performance indicators of a cooling tower.

Table 2.3.2: 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)

2.3.3 Energy efficiency in pumps

The performance of an induction furnace is directly linked with the performance of its cooling water circuit. Therefore, it is recommended to replace inefficient coil cooling pump with an energy efficient pump. The cost benefit analysis of the EE pump is shown in table 2.3.3.

Table 2.3.3: Replacement of inefficient 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

List of references

Bureau of Energy Efficiency Guide Books on the following topics – Compressed air system, Pumps and pumping system, Cooling tower and Furnace

TERI – Past studies on foundries

3.0 Module 2 – Pollution control system

3.1 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 3.1: 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 core-making processes.

3.2 Present environmental standards

Existing emission standards for foundries prescribed by Central Pollution Control Board (CPCB) are given in table 3.2a below.

Table 3.2a: Existing emission standards for foundries prescribed by CPCB

Type	Pollutant	Concentration (mg//Nm^3)
i. Cupola capacity (melting rate) : less than 3 Mt/hr 3 Mt and above	 Particulate matter Particulate matter	 450 150
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 3.2b below. The existing standard promulgated only for particulate matter but no standards for gaseous pollutants.

Table 3.2b: Emission standard for foundry prescribed by EPA, UK

Type	Pollutant	Concentration (mg//Nm^3)
New cupola (Oct,1991): Hot and cold blast New cupola (April,1997): Hot and cold blast	Particulate matter	100 20
Existing hot blast cupola (1991) Existing hot blast cupola (1997)	Particulate matter	115 100

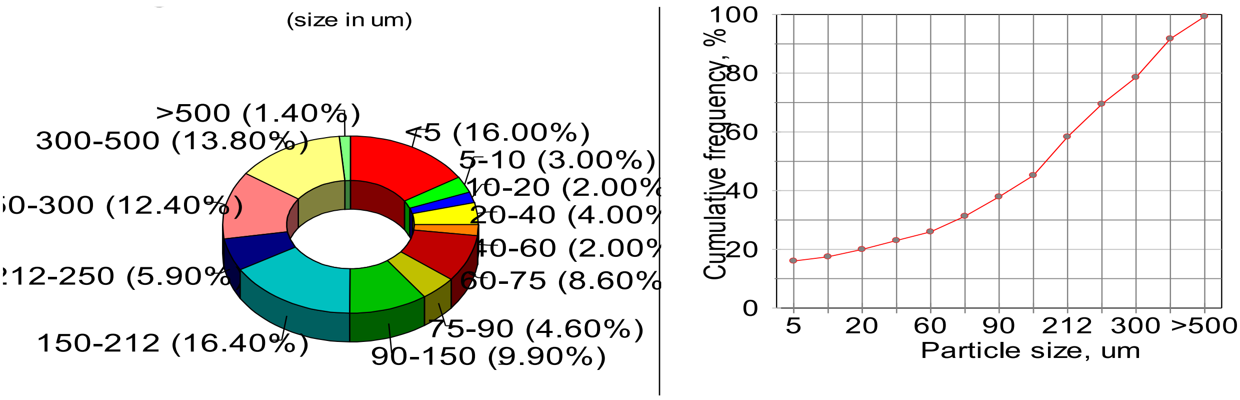
Type	Pollutant	Concentration (mg//Nm³)
Existing cold blast cupola Capacity : less than 4 tonne/hr 4 tonne/hr and more (1991) 4 tonne/hr and more (1997)	Particulate matter	 No standard 115 100

3.3 Measurements

Typical emission levels from cupola are presented in table 3.3. The particle size distribution of the flue gas analysed by centrifugal dust classifier are given in figure below.

Table 3.3: 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

3.4 PCS design vis-à-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 3.4.

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 3.4: 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

3.5 Commonly used PCS

Cyclone

- Not effective for controlling finer size particles (< 10 µm)
- Very difficult to meet emission standard of 450 mg/m³ 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/m³ standard but not for 150 mg/m³ 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/m³ 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/m³ by cyclone particularly when ash content in coke fluctuates so widely between 20 to 40%. So there would be always uncertainty to meet the prescribed CPCB standard by dry cyclone.

Moreover, emission standard for SO_2 for cupola furnace has also been prescribed by CPCB which is not possible to control by dry cyclone.

Wet arrester or cap

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

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 3.5: Comparison of Collection Methods

Method	Ability to give invisibl emission	Typical weight of Dust	Cost Index	Power Index	Water Pollution	Comment

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.

3.6 Technologies used in different foundry clusters

3.6.1 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.3.6.1), 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.

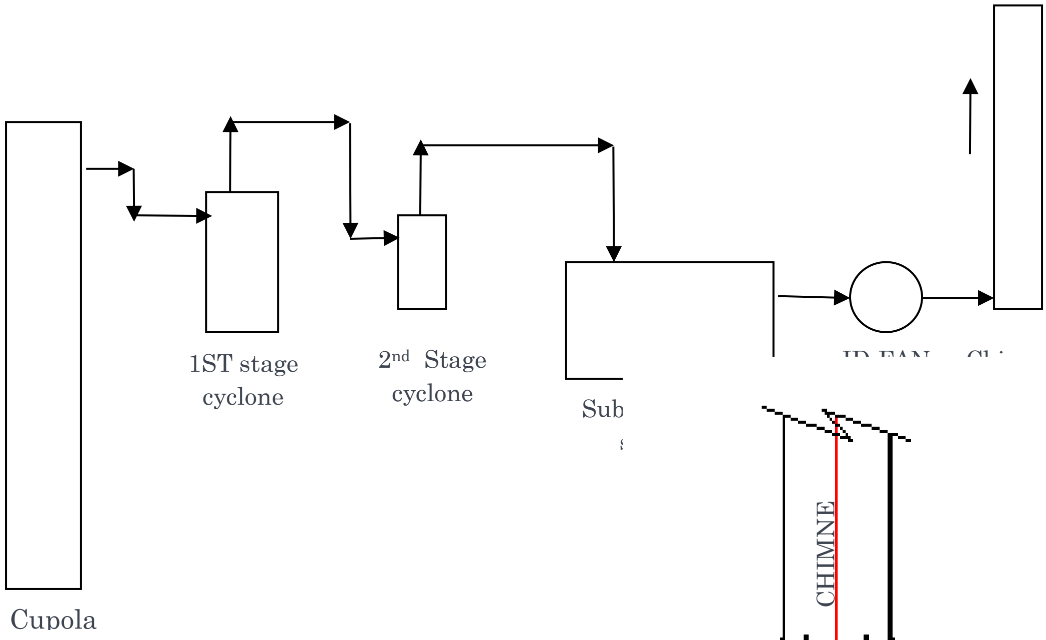
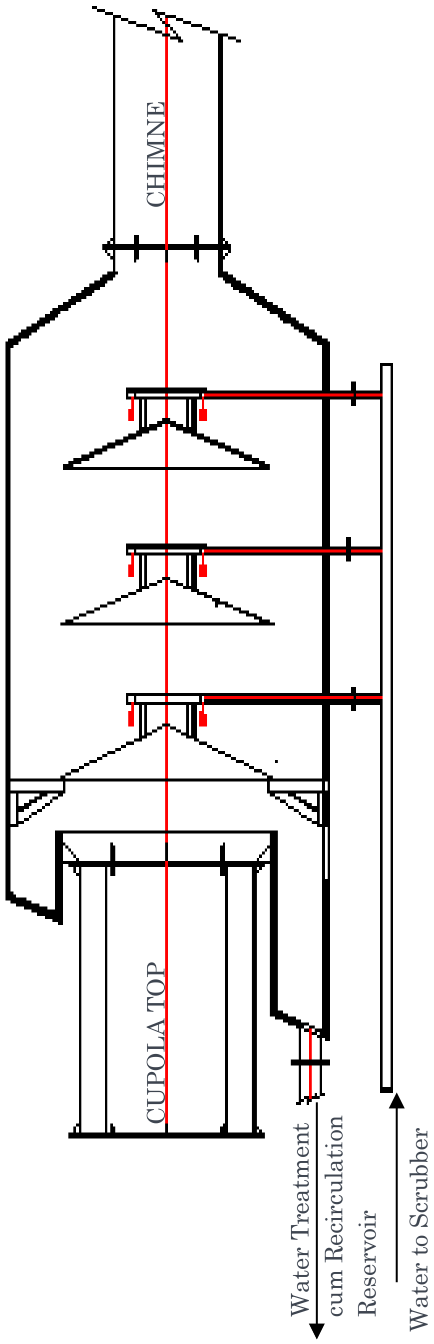


Figure. 3.6.1: The schematic flow diagram of the flue gas path through the control devices

3.6.2Cupola 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 3.6.2). 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 3.6.2: Cupola wet cap

3.6.3 Twin cyclone separator

This is a type of multi-cyclone separator with two cyclones placed parallel to one another (figure 3.6.3). 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.

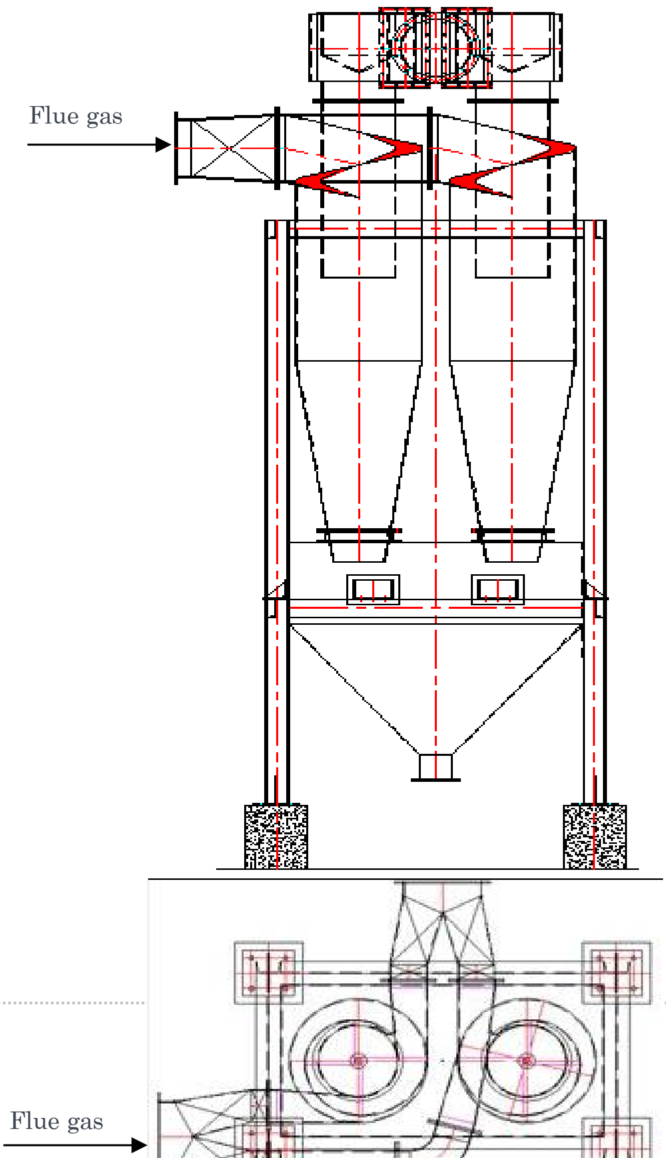


Figure 3.6.3: Twin cyclone separator

3.6.4 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 3.6.4) 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.

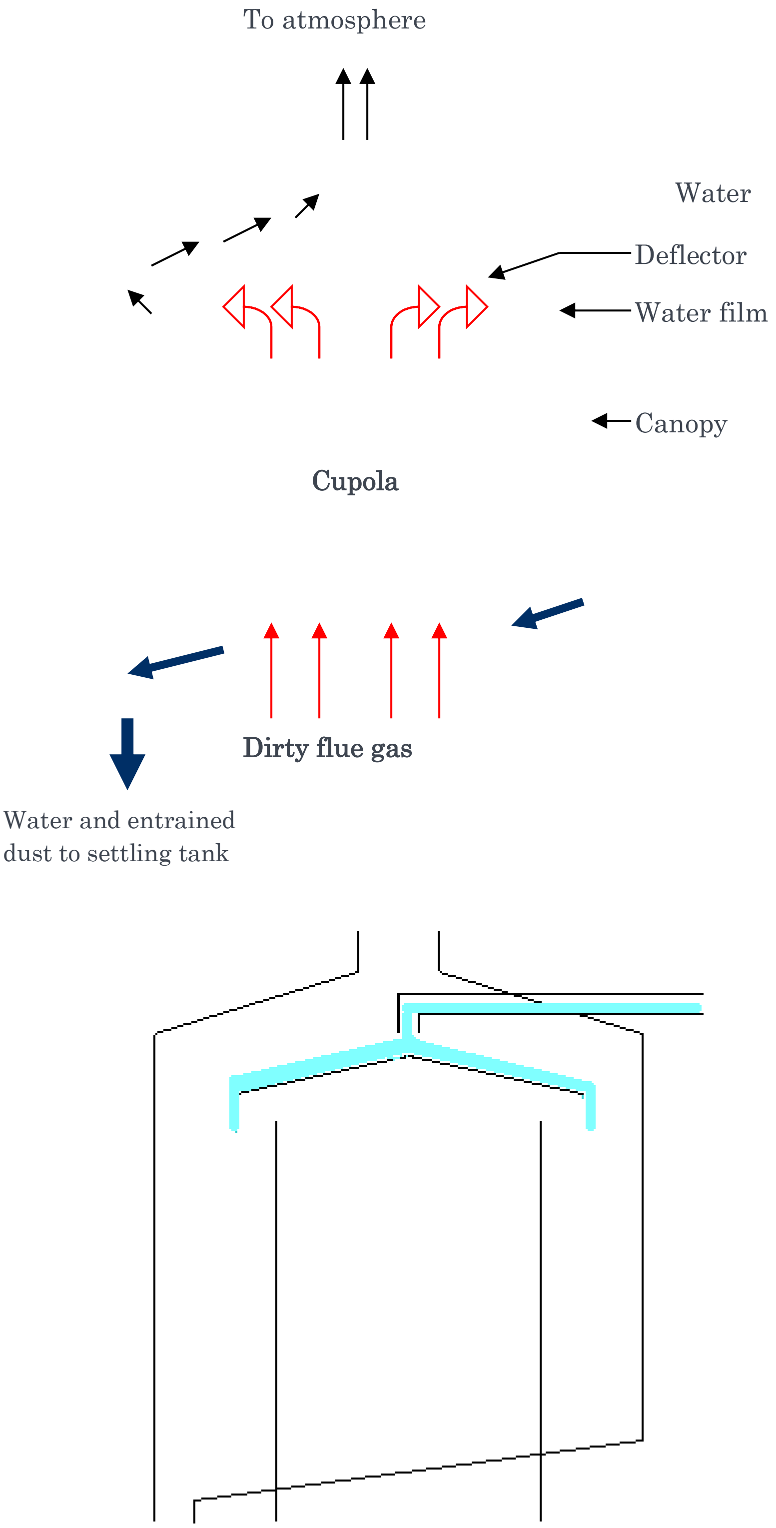


Figure 3.6.4: Cross current scrubber technology

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.

3.6.5 Coimbatore Foundry Cluster

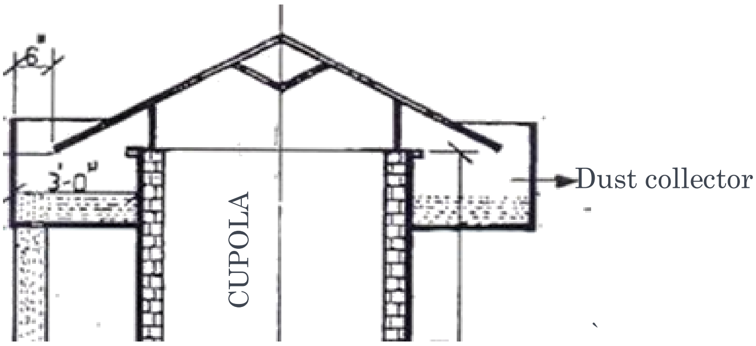


Figure 2.6.5: Dry Scrubber

Total number of Foundries in the cluster: 400
Number of Cupola Furnace using Foundries: 225
Type of PCS used:

1. Dry Scrubber (Chinese Hat Type) figure 3.6.5, Cost of Dry Scrubber : Rs. 50,000 to 75,000
2. Wet Scrubber, Cost of Wet Scrubber : Rs. 1.5 lakhs to 2 lakhs

3.6.6 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 3.6.6a). Figure 3.6.5b 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

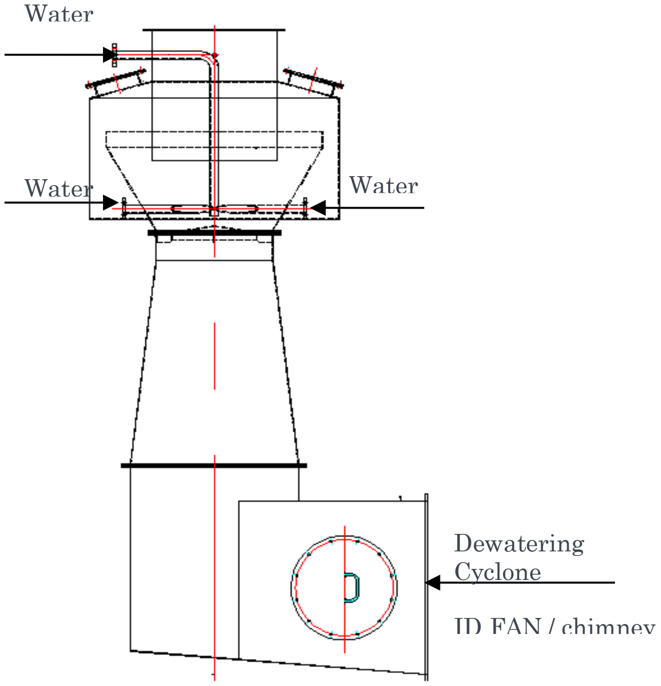


Figure 3.6.6a: TERI venturi scrubber design

- 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

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/Nm^3; well below the most stringent emission norm of 150 mg/Nm^3. Figure 3.6.6c shows a comparison of particulate emission levels of (a) cupola without PCS (2000 mg/Nm^3); (b) with commonly used PCS (500 mg/Nm^3); and (c) with demonstration venturi scrubber (50 mg/Nm^3).

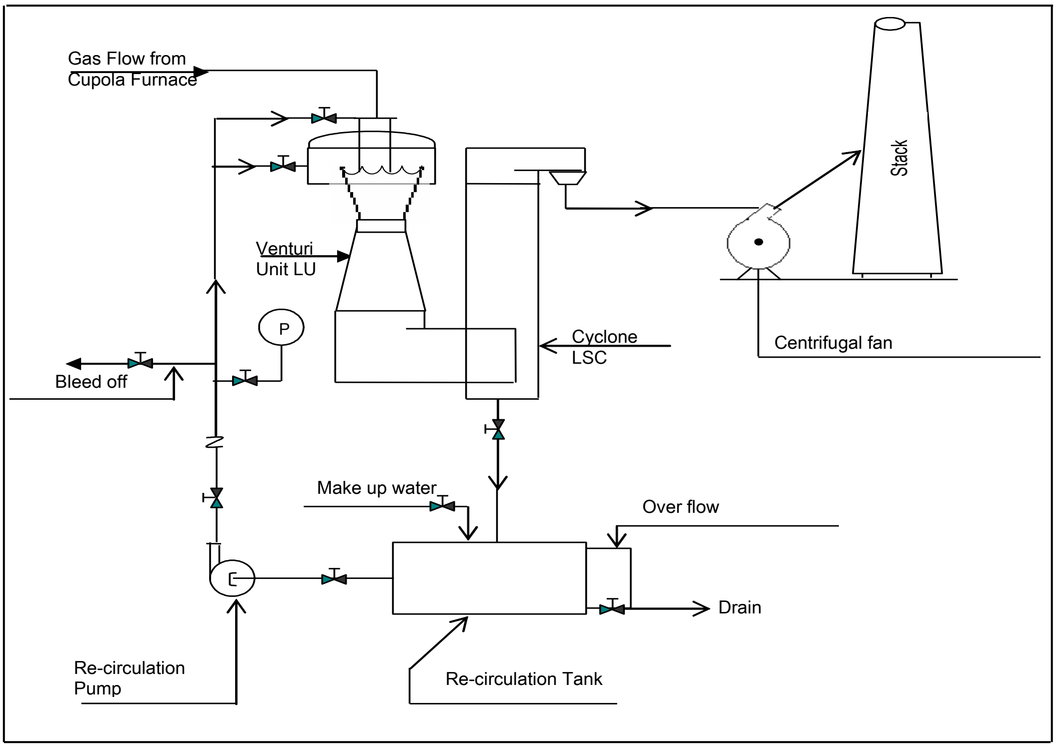


Figure 3.6.6b: Schematic of the venturi scrubber system

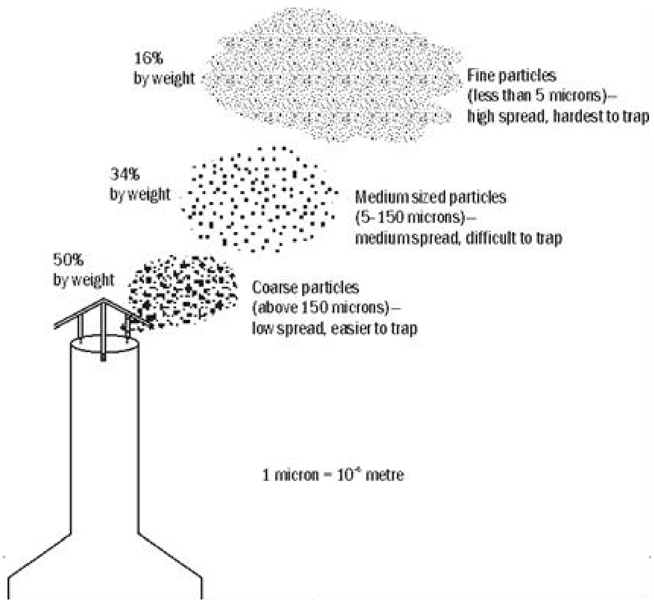


Figure 3.6.6c: Comparison of particulate emission levels

3.7 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 to 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.

3.8 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.

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 ration 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 at least 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 polutants. 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 blowdown period. Measurement during blowdown period would not be truely representative since duration is much shorter in comparison to total melting campaign. The extremely high temperature of the top gas during blowdown which might ruin the PCS. Besides, the unstable conditions during blowdown 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 to obtain 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, lazer based Melvern 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 eronous 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 tedoius documentation required, inhibit foundry owners in approaching banks for loan. To partially meet the financing of expensive pollution control devices, an environment service company exclusively for small scale foundry could be established. The company could be set-up with initial financial assistance from foundry associations, bilateral or multilateral organisations. The bottlenecks for borrowing money could be eliminated by making loan disbursement easier and providing guidance through the foundry associations.

References

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

4.0 Module 3 – Lean manufacturing

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

4.1 Objective

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

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

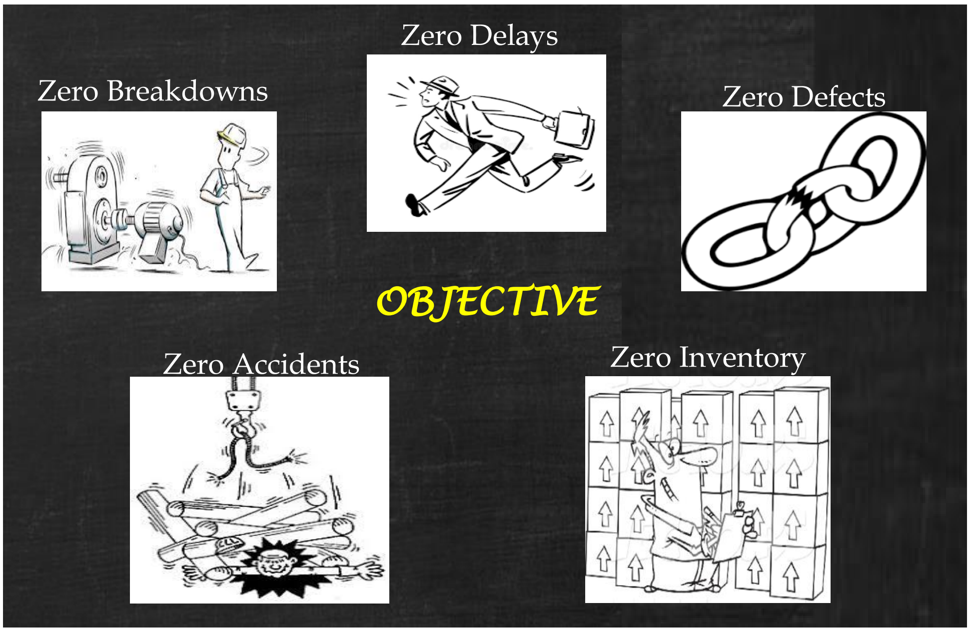


Figure 4.1: Objectives of lean manufacturing

4.2 Methodology

First recognize that there is no "one path" in lean manufacturing. Training on Lean Implementation is a multi-dimensional activity. There are number of lean tools, which could be adopted by the unit to reduce wastes, improve overall operating practises and increase productivity. It is not as simple as just creating a list of lean tools and methodologies, and learning how to use them. Every organization is different from each other. Many of the lean tools like one piece flow, Kanban, Cellular manufacturing, batch size reduction, Heijunka are not universally applicable. Managerial judgment will have to be applied to determine techniques and methods to implement which reflects business realities of the organization.

Depending upon the availability of material and human resources, an organization may or may not engage a consultant. The Ministry of Micro, Small and Medium Enterprises, GoI also provides support for implementation of lean manufacturing in MSMEs under Lean Manufacturing Competitiveness Scheme. There are technical associations, consultants in your area which provides services to implement lean manufacturing.

In the long run, the achievement and maintaining the results will depend on knowledge of organization's own team. Therefore the implementation of lean manufacturing should begin with a broad based capacity building plan. When a company decides to implement Lean they should start by creating a position of a Lean Leader or even better by creating a Lean Leadership organization. These leaders should be trained and become Lean Practitioners capable of teaching, coaching and mentoring the implementation of Lean. Lean Practitioners should than teach all managers and supervisors not only the knowledge of Lean tools and methodologies, but also their roles and responsibilities. All managers and supervisors must know how to manage in a Lean environment and apply this knowledge daily. All managers and supervisors must be made accountable for a success or a failure of the Lean implementation process. This is not optional – either you are in or you are out. Too many times a task of implementing Lean is assigned to an individual from manufacturing, engineering or a quality department without proper support and training in place.

The best way to learn lean principles is on-the job training. Some tools and methodologies can be presented in a classroom; some must include exercises, a practical portion of training and the others you can learn only by applying them - learning by doing. All training activities must conclude with a demonstration by participants that they have learned and understand how to use the new process.

Delivery of this training modules should be synchronized and follow a well-defined sequence. Participants are not allowed to skip any level of training. Participants advance to the next level of training only by successfully passing the course – demonstrating that they have required knowledge and skills. This can be done by writing a final exam, or by selecting and implementing a project.

Training module is grouped into three levels of advancement. Each course is designed for a specific audience. Some of this training should be mandatory; some of it could be made available to the employees who are interested in learning and advancing on their own. The three levels are:

- Level I (Basic) – Principles of Lean
- Level II (Intermediate) – Activities Based Training
- Level III (Advanced) – Sustaining and Improving

4.3 Level - I (Basic)

4.3.1 Principles of lean

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

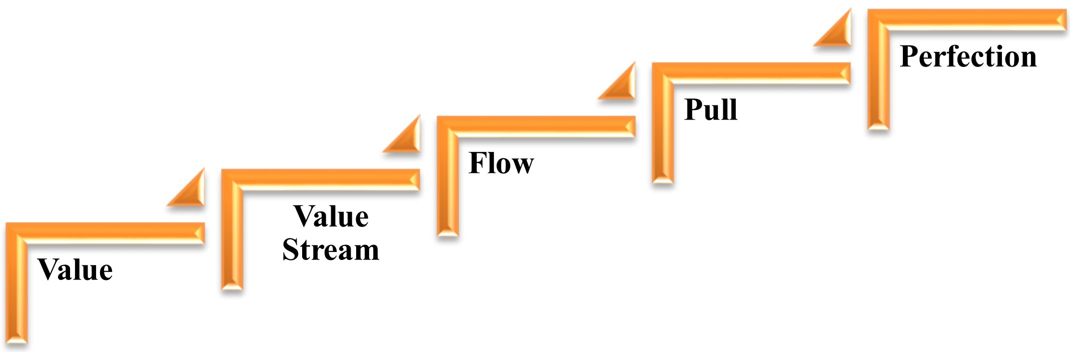


Figure 4.3.1: Five principles of lean

1. *Value*

The lean approach begins with a detailed understanding of what value the customer assigns to product and services. Always be sure to determine value from the customer perspective (not yours!) and by product family. Value goes hand-in-hand with what customers are willing to pay for a product. When manufacturing any product, as a manufacturer, you should consider value as what the customer needs.

At many times, manufacturers tend to think that value is created from what they think is best. However, they forget that the end user of their products is the customer. Therefore, if you want to create the highest value in your product, you have to find ways of determining customer needs. There are different ways that you can use to identify the various customer needs before manufacturing your product:

- Quality function deployment
- Brainstorming
- Identifying market gaps
- Providing different choices and identifying the most preferred choice
- Issuing out questionnaires

Engage only in activities that improve the value of your product or service to the customers to minimise or eliminate wastage. Remember, your customers are the key determinant of what value means to your products. Involving them in creating value of your products is inevitable.

2. *The value stream*

In order to create value, you will have to go through various processes. These processes involves the entire flow of a product's life-cycle from the origin of the raw materials used to make the product through to the customer's cost of using and ultimately disposing of the product.

These processes engage steps that add value and others that do not add value. In order to identify non-value added steps, there must be an accurate and complete understanding of the value stream. Any steps that don't create value should be eliminated. Flagged process steps that create no value due to technology or manufacturing limitations become opportunities for improvement.

3. *Flow*

After identifying value-adding processes, it important to ensure a smooth flow of these processes as the raw material is being processed to suit the customer needs. The lean manufacturing principle of flow is about creating a value chain with no interruption in the production process and a state where each activity is fully in step with every other.

Creating a value stream is essentially important in that the processes would continue even after reshuffling of employees. This is because there is a perfectly designed way of going through all these processes. The first visible effect of converting from departments and batches to product teams and flow is that the time required to go from concept to launch, sale to delivery, and raw material to the customer falls dramatically.

4. *Pull*

The lean principle of pull helps ensure flow by making sure that nothing is made ahead of time, building up work-in-process inventory and stopping the synchronized flow. Rather than using the traditional manufacturing approach of pushing work through, based on a forecast and schedule, the pull approach dictates that nothing is made until the customer orders it. This principle requires you to set out ways that will make the customers look for the product rather than pushing the product to them. If you did not design the product to suit your customer's needs, you would have a hard time persuading customers to purchase your product.

To achieve this requires great flexibility and very short cycle times of design, production, and delivery of the products and services. It also requires efficient communication system at each step in the value chain what is required of them today, based upon the customer's needs. Pull eliminates work-in-progress inventory and waste from incorrect production forecasts.

5. *Perfection*

The final lean manufacturing principle is seeking perfection. The idea of total quality management is; to remove the root causes of poor quality systematically and continuously from the production processes so that the plant and its products are moving towards perfection. The relentless pursuit of perfection is what drives users of the approach to dig deeper, measure more, and change more often than their competitors.

As organizations begin to accurately specify value, identify the entire value stream, make the value-creating steps for specific products flow continuously and let customers pull value from the enterprise, something very odd begins to happen. It dawns on those involved that there is no end in the process of reducing effort, time, space, cost and mistakes while offering a product which is ever more nearly what the customer actually wants.

4.3.2 Elimination of wastes

The identification and elimination of wastes from the value stream is the central theme of the Lean Manufacturing philosophy. Lean manufacturing is a dynamic and constantly improving process dependent on the understanding and involvement of all the company's employees. Successful implementation requires that all employees be capable of identification and elimination of wastes from their work. Waste exists in all types of work and at all levels of the organisation. Effectiveness is a result of efficient integration of Man, Material and Machines at the workplace.
There are eight categories of wastes that should be monitored in the factory:

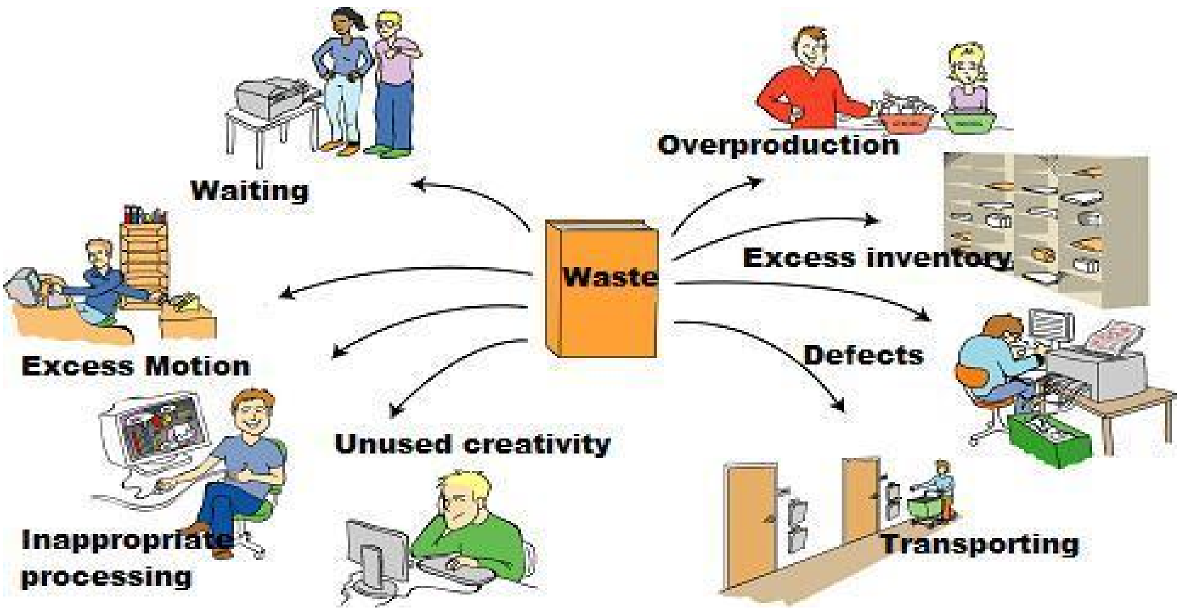


Figure 4.3.2: Eight wastes of lean

1. Overproduction – More production than customer demand

Characteristics:

- Batch Processing
- Building ahead
- Complicated inventory management
- Excess equipment/Oversized equipment
- Excess scrap due to obsolescence
- Excess Storage racks
- Inflated workforce
- Large lot sizes
- Large Work in Progress/Finished goods inventory
- Unbalanced Material Flow

Causes:

- Automation in the wrong places
- Cost accounting practices
- Incapable processes
- Poor planning
- Lack of communication
- Lengthy setup times
- Local optimisation
- Low uptimes

Identification:

- Are we making extra copies, more than needed?
- Are we printing, faxing, e-mailing more than what is needed?
- Are we entering repetitive information on multiple work documents or forms?
- Are we ordering more tests or services than what is required by the customer?
- Are we purchasing items just in-case they are needed?
- Are we preparing reports/products that are not used or read?
- Are we having meetings without the necessary information for action?

2. Waiting – Ideal time that occurs when co-dependent events are not fully synchronised

Characteristics:

- Ideal operators waiting for equipment
- Lack of operator concern for equipment breakdowns
- Production bottlenecks
- Production waiting for operators
- Unplanned equipment downtimes

Causes:

- Inconsistent work methods
- Lack of proper equipment/materials
- Long setup times
- Low man/machine effectiveness
- Poor equipment maintenance
- Skills monopolies

Identification:

- Are there excessive signatures or approvals required?
- Is there too much dependency on others to complete a task?
- Are there delays in receiving information?
- Are there any technical problems causing delays?
- Equipment downtime or response time causing delays?
- Are there cross-departmental resource commitment issues?

3. Inventory (work in progress) – High supply levels and work in progress inventories

Characteristics:

- Additional Material handling resources (Men, equipment, racks, storage space)
- Extensive rework of finished goods
- Extra space for receiving docks
- Long lead times for design changes
- Storage space congestion

Causes:

- Inaccurate forecasting system
- Incapable processes
- Incapable suppliers
- Local Optimisation
- Long changeover times
- Poor inventory planning
- Poor inventory tracking
- Unbalanced production processes

Identification:

- Do we have any obsolete dies in the area?
- Do we have obsolete equipment in the area?
- Is there batch processing of the product?
- Are files awaiting task completion by other?
- Are there delays in receiving information?
- Are we purchasing excessive supplies of any kind?

4. Transportation – Any material movement that does not directly support immediate production

Characteristics:

- Complex inventory management
- Difficult & inaccurate inventory counts
- Excessive transportation equipment and shortage of associated parking spaces
- Excessive material racks
- Poor storage to production floor space ratio
- High rate of material transport damage
- Multiple material storage locations

Causes:

- Improper facility layout
- Large buffers and in process Kanbans
- Large lot processing
- Poor scheduling
- Large lot purchasing
- Poor production planning
- Poor workplace organisation

Identification:

- Are we delivering material/tools/documents that are not required?
- Are we doing excessive filing of work documents or filing documents that will never be used again?
- Are we requiring multiple approvals?
- Are we hand delivering items manually that can be sent on forklift?

5. Over-processing – Redundant work which adds no value to the product

Characteristics:

- Endless product/Process Refinement
- Excessive copies/Excessive Information
- Redundant reviews & approvals
- Unclear customer specifications
- Process Bottlenecks

Causes:

- Decision making at inappropriate levels
- Inefficient policies and procedures
- Spurious Quality control
- Lack of customer input concerning requirements
- Poor configuration control

Identification:

- Is there a lack of visual controls?
- Are we doing more work than is required for that process?
- Are we producing repetitive documents from scratch?
- Do we have a poor recording system?
- Are we too many approvals required for action?
- Are we entering repetitive information?

6. Motion – Any movement of people which does not contribute added value to the product

Characteristics:

- Excess moving equipment
- Excessive reaching or bending
- Excessive tool gathering
- Unnecessary complicated procedure
- Widely dispersed materials/tools/ equipment

Causes:

- Ineffective equipment/plant layout
- Lack of visual controls
- Poor process documentation
- Poor workplace organisation

Identification:

- Are we making multiple trips to the tool crib at the beginning of job work?
- Are we searching for required dies in storage areas?
- Are we misplacing equipment/accessories?
- Are we reaching for commonly used tools?
- Are we constantly reviewing the same manuals for information?
- Are we hand carrying paper work to another process or department regularly?

7. Defects/rework – Time spent in finding and fixing production mistakes

Characteristics:

- Complex material flows
- Excess finished goods inventory
- Excessive manpower to inspect/ rework/repair
- Questionable quality
- High customer complaints /returns
- High scrap rates
- Poor production schedule performance
- Reactive organisation

Causes:

- Excessive variation
- High inventory levels
- Inadequate tools/equipment
- Incapable/Incompatible processes
- Insufficient training
- Poor layouts/Unnecessary handling

Identification:

- Do we have any product errors?
- Is there a lack of standardized procedures?
- Do we ever lose tools/accessories?
- Do we ever encounter incorrect information on a document?
- Do we have pricing, quoting, billing, or coding errors?

8. Skills – Under-utilizing capabilities, delegating tasks with inadequate training

Characteristics:

- Poor team building
- Inefficient time management
- Slower Improvements
- Ineffective communication
- Unskilled manpower
- Poor coordination

Causes:

- Insufficient training
- Lack of employee reward/ recognition system
- Improper delegation of tasks
- Poor leadership
- No employee suggestion scheme

Identification:

- Are we spending time on correcting errors and defects?
- Are we not involving employees in process improvement?
- Are we in positions we were trained to do?
- Can we assist other areas when work is slow in an area?
- Can we be trained to do more within the organization?

- Are you restricting or not offering training on technical resources?

4.4 Level II (Intermediate) – Activities based training

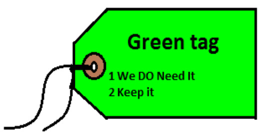
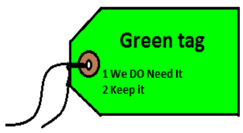
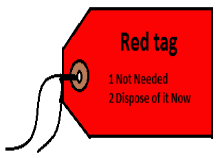
4.4.1 5 S – Workplace organization

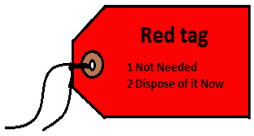
5S is a technique originated from Japan and it was first developed by Hiroyuki Hirano in 1980s. The 5S philosophy focuses on simplification of the work environment, effective workplace organization, and reduction of waste while improving safety and quality. It allows the enhancement of efficiency and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

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

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

Table 4.1: Tagging criteria & recommended action.

Priority	Frequency of use	Action Required	Tag
High	Daily	Store at the workplace, where it is needed and is easily assessable	
Medium	Once per week, once per month	Store together, near the workplace	 OR 
Low	Less than once per year	Throw away, or store away from the workplace	 OR 

No	Unusable items	Throw away	

Before	*After*
	

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

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

Before	*After*
	

Shine – The third step in the 5S process initiates a work ethic of keeping everything clean and in order at all times. Examples of shine include wiping machinery, sweeping, tightening loose belts or bolts, cleaning gauges and indicators, tracking the source of leaks, overheating or undue noise, and organizing papers and books on office desks and shelves.

Systematic cleaning provides a way to inspect, by doing a clean sweep around a work area. This means visually as well as with a broom or rags. The idea is make the job of doing daily cleaning and inspections easier.

The steps of systematic cleaning are:

- Identify points to check for performance
- Determine acceptable performance
- Mark equipment and controls with visual indicators (e.g., gauges show the correct range)
- Conduct daily cleaning and visual checks

Before	*After*
	

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

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

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

- Determine the 5S level of achievement - the overall grade

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

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

4.4.2 Value Stream Mapping (VSM)

Value Stream mapping is a first key practical step towards learning and implementing Lean. The purpose of Value Stream mapping is not to produce a "map" of a value stream. The purpose of VSM is to open our eyes to existing problems and issues, to identify shortfalls and process breakdowns and to identify opportunities for improvement.

Value stream mapping is a flowchart method to illustrate, analyse and improve the steps required to deliver a product or service. A key part of lean methodology, VSM reviews the flow of process steps and information from origin to delivery to the customer. As with other types of flowcharts, it uses a system of symbols to depict various work activities and information flows. In this respect, Value stream mapping helps an organization to identify the non-value-adding elements in a targeted process and brings a product or a group of products that use the same resources through the main flows, from raw material to the arms of customers.

Objectives:

Value stream mapping is a powerful method to ferret out waste in any process, not just manufacturing. Detail each significant process step and evaluate how it's adding value—or not adding value—from the customer's standpoint. Focus on value keeps the analysis targeted to what really matters, allowing the company to compete most effectively in the market. Foreseeing or facing any competitive threat, lean practitioners can make good use of VSM to produce the most value for the customer in the most efficient way possible. It can and should be used on an on-going basis for continuous improvement, bringing better and better process steps on line. VSM allows you to see not only the waste, but the source or cause of the waste.

- Visualization of material and information flows
- Facilitate the identification and elimination of wastes and sources of wastes
- Support the prioritization of continuous improvement activities at the value stream
- Support constraint analysis
- Provide common platform for process evaluation

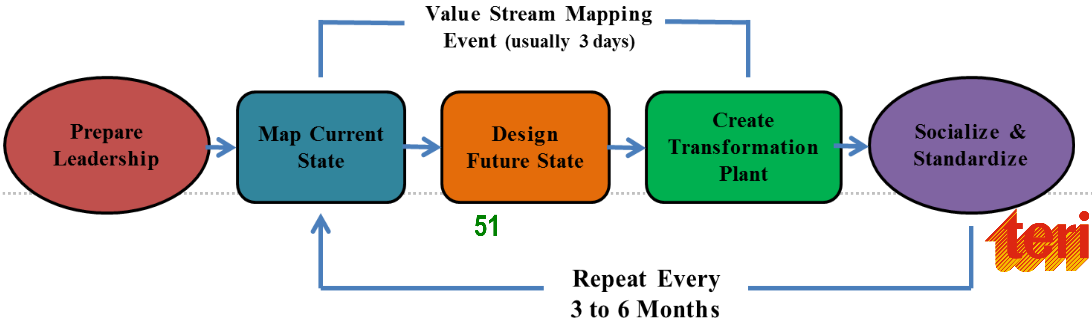


Figure 4.4.2: Value stream mapping

Methodology

While Value Stream Mapping is core to lean methods, it often requires a substantial investment of people and time to do it, and if not applied wisely, it can be wasteful in itself. It requires team members skilled in carrying out advanced VSM, and it may take days, weeks or even months to carry out some involved mapping projects. Think of it as a powerful tool central to lean methods, but not every circumstance lends itself to value stream mapping. You need to balance potential value with the work necessary to conduct the VSM.

You might choose to start small, with a limited focus and a limited budget, get the win and then move on to something more complex and potentially rewarding.

1. **Identify the product** or product family to be studied and improved. You typically put together a team to do the mapping and analysis, depending on the size of the initiative. If inexperienced, the team will need training in VSM.
2. **Get leadership's buy-in** for the value stream mapping project, given the potential costs involved. It's possible you might use a smaller VSM, showing potential improvement, to help gain leadership's buy-in for a fuller look.
3. **Determine the problem for the value stream** for this product, from the customer's standpoint. Make sure the customers' concerns are clearly understood, since they are the ones defining value. It's possible that customers might be demanding a price reduction based on competitors, or that quality control problems are reducing value, or that production delays are causing customers to look elsewhere.
4. **Bound the process**, which means determining the limits or scope of your map. For example, if you're doing lean manufacturing, are you going from raw materials to final product delivered to the customer? Or are you starting with one problematic part of the value stream?
5. **Now, do the VSM walk, as outlined in upcoming steps 6-11**. Walk (or directly experience) the process steps and information flow required for processing of product. Some VSM practitioners do the walk in reverse, starting with the customer. You might do the walk multiple times to gather more information, filling in any gaps.
6. **Define the process steps**, keeping within the boundaries you've just defined as you do your walk. In lean manufacturing, all of the steps might take place in a single location that inventory enters and then leaves. You aren't listing out every specific task that could be done by process mapping. You are studying work activities and information flows that produce customer value or don't. It's vital to record the reality of your observations, and not rely on information from employees who may have a vested interest in explaining away a problem. The purpose is to document each significant step required to create the product's value.
7. **Collect process data on your walk**. This is where you start evaluating the performance of each step of the process. Examples are inventory type and size, cycle time, change-over time, machinery or process uptime and downtime, number of workers, shifts worked, available working hours and batch size. All of these could result in finding

efficiencies and cutting waste. Add that process data to the data boxes of your Value Stream Map.

8. **Evaluate the process steps**. You also use data boxes for this information. We want to know whether the process step is:
   a) **Valuable,** meaning it creates value from the customer's standpoint. You might just ask the customer if he cares whether a step is left out.
   b) **Capable**, the degree to which there's a high-quality result every time.
   c) **Available**, the degree to which the process step is available when needed.
   d) **Adequate**, the degree to which capacity exists to meet customer demands. This often ties in with analysis of constraints, bottlenecks, excess capacity and excess inventory.
   e) **Flexible**, the degree to which a process step can switch over quickly and inexpensively from one member of a product family to another.
9. **Map the movement of the product and information flows**. Look for three key things:
   a) **Flow vs. Stagnation**. The ideal is for the product to never stop moving. This can be measured by inventory levels.
   b) **Push vs. Pull**. This shows how production information is handled. In the ideal value stream, no information is required except for a signal at the top of the stream to make the next product. In reality, however, there are disconnects between parts of the stream. This is dealt with by having the steps able to signal each other as to upcoming needs.
   c) **Level vs. Erratic**. This shows the degree to which the process has been smoothed out for efficiency. This addresses the lean manufacturing concepts of **mura** (unevenness), **muri** (overburdening of the value stream to keep up) and **muda** (waste.) It's also vital to understand the overall flow of information and communication in the value stream. Producing a product or service of value to the customer means we need to understand the communication touch points. Examples include how customers order the product, how suppliers are contacted, and how we ensure that customers get what they want.
10. **Count the inventory**. Inventory and overproduction can be an extensive cause of waste. Take special note that inventory may be scattered in a makeshift manner.
11. **Create a timeline**. Map out process times and lead times for inventory through our process steps. By monitoring inventory levels at each step, we can find inefficiencies and non-value-adding items in our production.
12. **Now, reflect on the Value Stream Map** to see things that might not have been entirely apparent at first. Use the information you've collected in the data boxes and timeline to find the waste. This could be problems such as excess inventory, too much downtime, long process times or setup times, or quality problems resulting in rework.
13. **Then, create a future state Value Stream Map and/or ideal state Value Stream Map**. Instead of just attacking each problem point individually, now sketch out an ideal state VSM, illustrating goals for the items that lead to a leaner, more effective process. This vision needs to be agreed upon by the leadership and becomes the ultimate goal of the VSM project. The Value Stream Maps are used to communicate and guide the work.

Sometimes a series of future state Value Stream Maps are drafted before reaching the ideal state Value Stream Map.

14. **Using the Value Streams Maps as your basis, create an implementation plan and carry it out**. Consistently monitor the results in key metrics, and implement further adjustments as necessary. You are on the path to continuous improvement.

4.4.3 Visual Management (Andon)

Visual Management is defined as a set of techniques for creating a visual workplace, embracing visual communication and control throughout the work environment. Visual management is a way to visually communicate expectations, performance, standards or warnings in a way that requires little or no prior training to interpret.

There are six categories of visual management that allow increasing control of standards, performance and quality. It starts out at simple communication of facts and works up to using visual controls to prevent errors occurring. The categories are:

1. Share information
2. Share Standards
3. Build Standards
4. Warn about abnormalities
5. Stop abnormalities
6. Prevent abnormalities

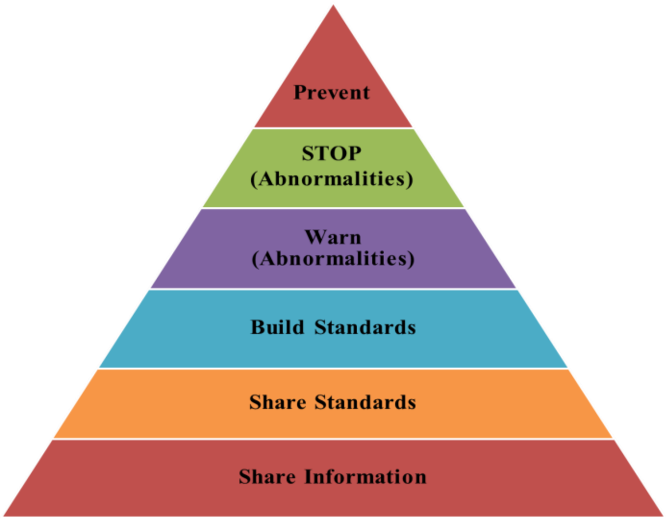


Figure 4.4.3: Pyramid of Visual management

Visual display

Visual display serves as a method for improving communication between members of a work group. Visual display, as indicated in the graphic above includes sharing of information and standards for the group.

Ideally, team members themselves should maintain a display of area performance metrics, schedules, improvement actions, cross-shift management issues training matrices and other useful group. For example visual displays could include:

- Standard Work Instructions
- Performance information
- Status of current issues/actions lists
- Safety Instruction
- Details of Team leaders & members
- Manpower tracking boards

- Schedules of Maintenance, Calibration & other support activities
- Product and process information
- Customer requirements information
- Site level display board
- Designated and clearly marked parts storage locations
- Posting Maintenance schedules
- Inventory record board
- Pictures and information about final products

Visual controls

The objective of the use of visual controls is to actually guide or control the actions of the team by visual means. Visual control is often achieved through the use of notice boards prominently displayed in the workplace. These boards are updated frequently and used to control production or specific products. The board below is used to highlight where issues exist on specific tasks and display an imbalance in the allocation of work to manpower.

Visual control is also referred to as "management by sight", in basic terms it means:

- Anything that doesn't belong is obvious
- Anything that is in the wrong place is obvious
- Anything that is unsafe is obvious
- Anything that is out of sequence is obvious
- Too many or too few is obvious

Benefits

The most immediate benefit of the introduction of visual management is that it exposes abnormalities i.e. situations where standards are not being met. In addition, the following benefits are associated with the practical use of visual management.

- Facilitates employee autonomy – clearly sets expectations, empowering employees by giving them responsibility for their own work areas
- Serves to eliminate wastes such as searching and errors due to miscommunication or lack of communication of organisational targets
- Promotes prevention because it's easier to see when the work situation is not in control
- Fosters continuous improvement through regular monitoring of performance, detection of issues and associated problem solving
- Leads to information sharing automatically once the visual displays are kept up-to-date

4.4.4 Total productive maintenance

Total Productive Maintenance is a systematic well defined methodology to not only eliminate equipment breakdowns but also to eliminate any quality defects. TPM is often defined as productive maintenance involving total employee participation and it must be carried out on a company wide basis. Unfortunately many companies confuse TPM with Preventive Maintenance (PM) and leave the repairs and improvements to equipment and processes to a specialized group of engineers and maintenance personnel.

The purpose of a TPM program is to aim at maximizing equipment efficiency not only from the profitability point of view but also from the operator point of view. It establishes a thorough system of preventive maintenance plans and procedures for the equipment's life span. Once these plans are developed it identifies all levels of responsibilities for operators, engineers, maintenance and supervisors. Operators in the area are responsible for conducting TPM and supervisors are responsible for following and maintaining this process.

The eight pillars of TPM are mostly focused on proactive and preventative techniques for improving equipment reliability.

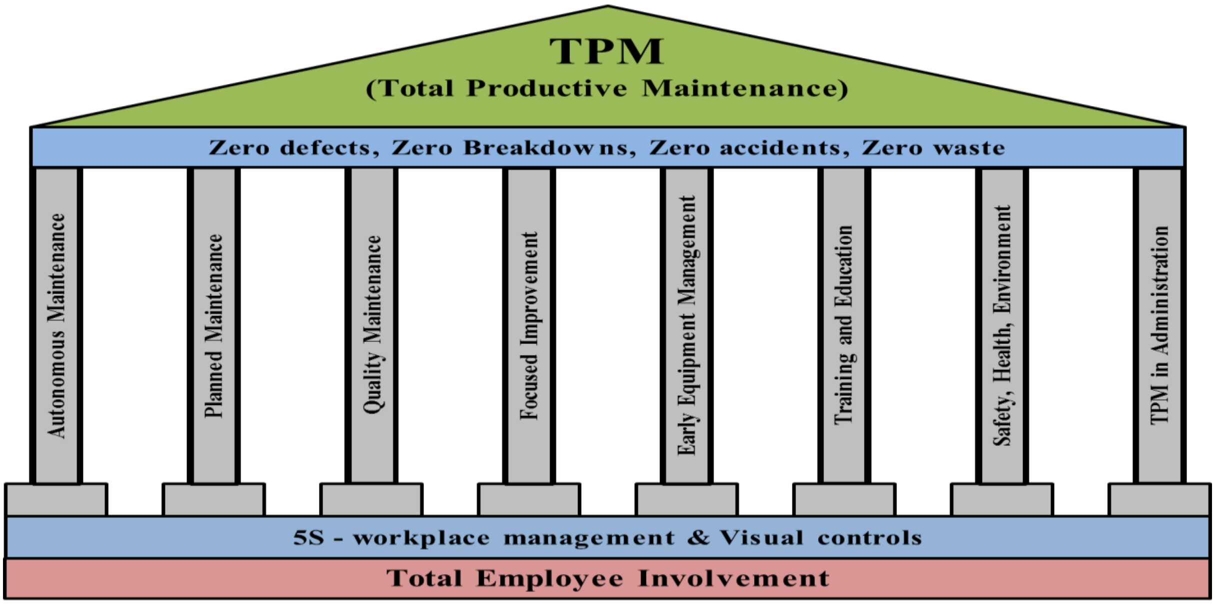


Figure 4.4.4: House of TPM

Table 4.4.4: Description & benefits of TPM

Pillar	Description	Benefits
Autonomous maintenance	Places responsibility for routine maintenance, such as cleaning, lubricating, and inspection, in the hands of operators	• Gives operators greater "ownership" of their equipment • Increases operators' knowledge of their equipment • Ensures equipment is well-cleaned and lubricated • Identifies emergent issues before they become failures • Frees maintenance personnel for higher-level tasks

Pillar	Description	Benefits
Planned maintenance	Schedules maintenance tasks based on predicted and/or measured failure rates	• Significantly reduces instances of unplanned stop time • Enables most maintenance to be planned for times when equipment is not scheduled for production • Reduces inventory through better control of wear-prone and failure-prone parts
Quality maintenance	Design error detection and prevention into production processes. Apply Root Cause Analysis to eliminate recurring sources of quality defects	• Specifically targets quality issues with improvement projects focused on removing root sources of defects • Reduces number of defects • Reduces cost by catching defects early (it is expensive and unreliable to find defects through inspection)
Focused improvement	Have small groups of employees work together proactively to achieve regular, incremental improvements in equipment operation	• Recurring problems are identified and resolved by cross-functional teams • Combines the collective talents of a company to create an engine for continuous improvement
Early equipment management	Directs practical knowledge and understanding of manufacturing equipment gained through TPM towards improving the design of new equipment	• New equipment reaches planned performance levels much faster due to fewer start-up issues • Maintenance is simpler and more robust due to practical review and employee involvement prior to installation
Training and education	Fill in knowledge gaps necessary to achieve TPM goals. Applies to operators, maintenance personnel and managers.	• Operators develop skills to routinely maintain equipment and identify emerging problems • Maintenance personnel learn techniques for proactive and preventative maintenance • Managers are trained on TPM principles as well as on employee coaching and development
Safety, Health, Environment	Maintain a safe and healthy working environment.	• Eliminates potential health and safety risks, resulting in a safer workplace • Specifically targets the goal of an accident-free workplace
TPM in Administration	Apply TPM techniques to administrative functions	• Extends TPM benefits beyond the plant floor by addressing waste in administrative functions • Supports production through improved administrative operations (e.g. order processing, procurement, and scheduling)

4.4.5 SMED/quick changeover

Machine capacity utilization is a key goal in achieving minimum time consumption. Changeover procedure during casting process is recognized as possible area for reducing time consumption. SMED - single minute exchange of dies is a lean tool to reduce changeover or set-up time to less than 10 minutes.

Changeover time is defined as the time elapsed between the last good piece of product being produced and the first good piece of next product being produced. The SMED method has been improved by additional procedures simultaneously applying the 5S method. Their contribution is evident in recognition of internal and external activities, particularly while transferring internal activities into external ones in as many numbers as possible, by minimizing at the same moment the internal ones.

The most basic cornerstone of any setup reduction is to first understand the difference between external and internal activities:

- **Internal elements:** operations that must be performed while the machine/process is stopped
- **External elements:** operations that can be performed while the machine/process is still running

The implementation must be started by closely observing the changeover process so that the distinctions between internal and external elements are made clear. Once the difference is understood, the process of converting internal to external can be initiated. The key is to complete all preparatory work before starting the changeover, eliminate search-and-find work and have tools & materials arranged beforehand.

Machine settings should be standardised, machine stops or visual marks should be put in place to eliminate the time wasted due to "trial-and-error" adjustments to get the settings correct. On large machines is may be possible to establish "Parallel" steps, which are completed at the same time by two people, one at the front and one behind the machine. For example,

- Functional fixtures and jigs should be used, such as motion fasteners, levered or one-turn fasteners or interlocking wedges or slots
- Eliminate adjustments by using pre-set pins, guides, notches etc.
- Eliminate the need to leave the machine by delivering material to the point-of-use via external suppliers or dedicated material allocators

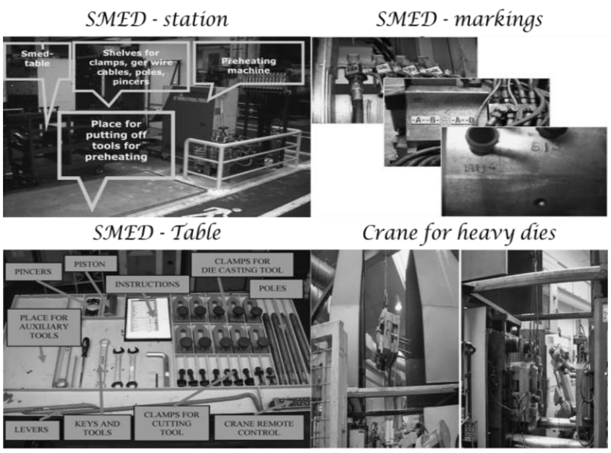


Figure 4.4.5: SMED implementation

4.5 Level III (Advanced) –

Sustaining and Improving

4.5.1 Kaizen - continuous improvement

The Japanese word KAIZEN simply means "change for better". It is a Japanese business philosophy of continuous improvement of working practices, personal efficiency. This is where all the knowledge of Lean methodologies, tools and process is put to an ultimate test of generating cost reductions and improvements to quality, efficiency and performance.

The purpose of Kaizen training is to identify problems and opportunities and to implement changes needed to achieve very specific management objectives. The objective is not only to learn how to identify and implement improvements, but is also to develop the processes and procedures necessary to sustain the new methodology.

Two kaizen approaches have been distinguished:

- Flow Kaizen: Oriented towards the flow of materials and information, and is often identified with the re-organization of an entire production area
- Process Kaizen: The improvement of individual work stands

Kaizen is a strategy where employees at all levels of a company work together proactively to achieve regular, incremental improvements to the manufacturing process. In a sense, it combines the collective talents within a company to create a powerful engine for improvement.

Kaizen is part action plan and part philosophy.

- As an action plan, Kaizen is about organizing events focused on improving specific areas within the company. These events involve teams of employees at all levels, with an especially strong emphasis on involving plant floor employees
- As a philosophy, Kaizen is about building a culture where all employees are actively engaged in suggesting and implementing improvements to the company. In truly lean companies, it becomes a natural way of thinking for both managers and plant floor employees.

Kaizen events

A typical Kaizen event goes something like this:

1. Set goals and provide any necessary background.
2. Review the current state and develop a plan for improvements.
3. Implement improvements.
4. Review and fix what doesn't work.
5. Report results and determine any follow-up items.

This type of cycle is frequently referred to as PDCA (Plan, Do, Check, and Act). PDCA brings a scientific approach to making improvements:

- Plan (develop a hypothesis)
- Do (run experiment)
- Check (evaluate results)
- Act (refine your experiment; then start a new cycle)

Kaizen philosophy

Kaizen as an action plan is exactly what develops Kaizen as a philosophy. When Kaizen is applied as an action plan through a consistent and sustained program of successful Kaizen events, it teaches employees to think differently about their work. In other words, consistent application of Kaizen as an action plan creates tremendous long-term value by developing the culture that is needed for truly effective continuous improvement.

4.6 Case study

A case study in xyz foundry for waste reduction with process activity mapping is carried out to identify the process flow and non-value adding activities. The study is focused only on foundry production line (Line 1 namely KOYO production line) which contributes to 98% of the castings of the foundry. The value stream mapping tool is used to analyse both the flow of materials and the flow of information. The line is semi-automated and the casting goes through various processes drums, conveyors, sand separation, sand preparation, knock out, shot blasting etc. Mapping the value stream activities of other products would give similar results with small differences in numerical values as some castings are simple, requires hot/cold box process while some are complex requiring cold/hot box process. However the bottleneck product is selected for the study. This study is a case study applied for the foundry processes which are continuous processes as production lines are semi-automated and the analysis uses the process activity mapping tool. This tool is selected with questionnaires, interviews and brainstorming sessions with manager and operators on the shop floor. Marketing, production planning & control department, pattern shop has helped us to give past record values of foundry production line for e.g. marketing dept. has given monthly customer order, production planning dept. has given the total foundry layout, pattern shop has given classification of simple and complicated jobs depending upon their work experience etc. The process flow is shown in figure 4.6a.

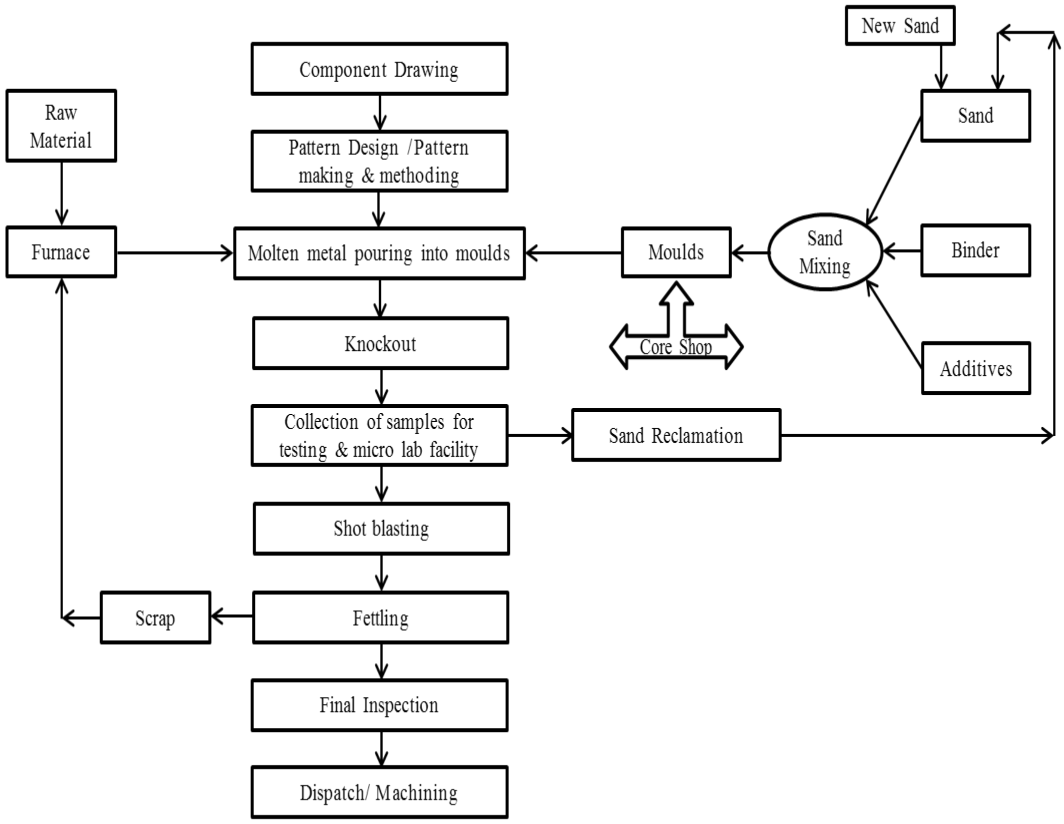


Figure 4.6a: Foundry process flow chart

The time study is carried out by the stopwatch for 45 days on the shop floor of the foundry. The study have gone through each and every process on the production line-1 by recording the travelling distances of men, materials, time taken by each activity, number of operators and workers right from raw material to final product dispatch.

Current state map is prepared keeping in view of the lean manufacturing principles. A few assumptions are also made for preparation of current state map. From past sales data at the industry under study, it is known that maximum demand of product 2,884 may reach up to 3,300 per month. The current state map captures information at a particular instance, which may vary from shift to shift. For the sake of analysis, the shift and operator-wise variation (which may be there) is not considered. Effective numbers of working days are 26 per month, number of shifts per day is three and working hours per shift are eight. Available working time per day is 86,400 seconds. Takt time can be calculated as;

Takt time = {(Available working time per day (seconds)/customer demand per day (units)}
= {(86,400/ (3,300/26)} = 681 seconds

From current state map, Value added time as a % of total time in plant = {(13497.54/ (15 Day X 24 hrs./day X 60 min/hr.)} = 0.62 %.

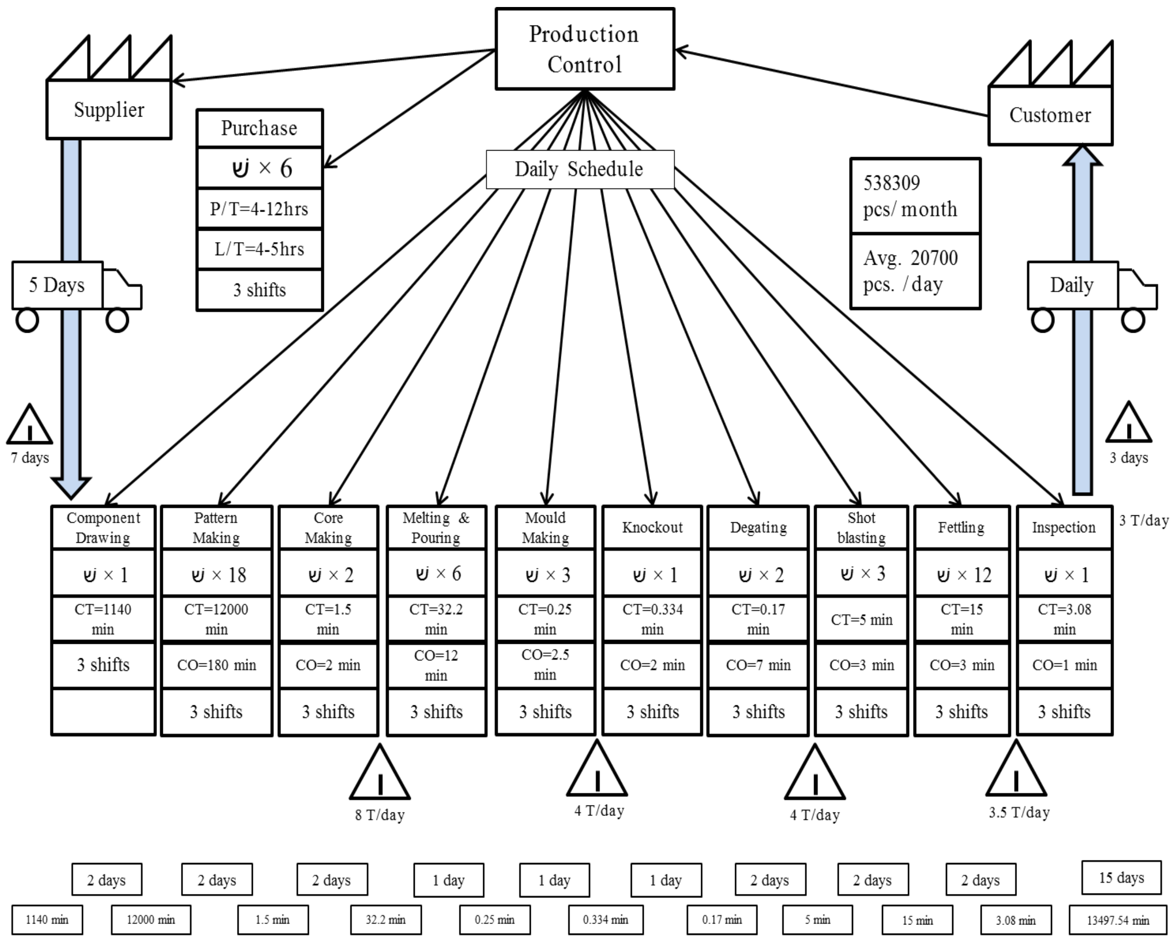


Figure 4.6b: Current state map

For future state map the following areas in which wastes like work in progress (WIP), Inappropriate processing, bad layout etc. are identified and presented separately in corresponding process. After that the wastes are converted into standard wastes and techniques of waste elimination are described in latter part. First the processes in which the identified wastes exists are,

Identification of Wastes in the above foundry processes:

(i) Pattern Making:

a. Patterns must be finished, edges, burrs should be removed

(ii) Core making:

a. Three cavity core boxes for component-1 were not enough to complete production requirement
b. Core Box of two cavities & core for component-2 was solid creating gasses problem in castings and not enough to complete production requirement
c. One cavity core boxes for component-3 was not enough to complete the production requirement

(iii) Moulding:

a. Spill over of dust in turn affecting the environment in mould sand plant
b. Moulding sand hopper was damaged so that sand leakage was more in the mould making section

(iv) Shot Blasting:

a. Due to machine breakdown of 3-4 days, work in process (WIP) is more in this section

(v) Fettling:

a. Mixing up of different parts due to bad layout
b. Poor housekeeping leads to low productivity
c. High transportation of parts

Classification of wastes into standard forms and techniques of elimination adopted is provided in table 4.6.

Table 4.6: Classification of wastes and techniques of elimination

Operations	Waste	Type	Technique of Elimination
Pattern Making	Patterns must be finished, edges, burrs should be removed	Inappropriate Processing	• Abrasive grinding brush introduced
Core Making	Three cavity core boxes for component-1 were not enough	Machine Error	• Design and Process Review • Core Box with ten cavities is made
	Box of two cavities and core for component-2 was solid creating gasses problem in castings	Machine Error	• Design and Process Review • Core Box with six cavities is made
	One cavity core box for component-3 was not enough	Machine Error	• Design and Process Review • Core Box with Two cavities is made
Moulding	Spill over of dust in environment	Machine Error	• Design and Process Review • Containers were provided for collecting the dust
	Moulding sand hopper was damaged causing sand leakage	Machine Error	• Design and Process Review • Hopper welding with proper direction was done
Shot Blasting	Machine breakdown caused more work in process (WIP)	Waiting	• Total productive Maintenance (TPM) or Preventive Maintenance
Fettling	Mix up of different parts due to poor layout	Waiting	• Part Specific self-concept was adopted, 5S was used
	Low productivity due to bad poor housekeeping	Waiting	• Part Specific self-concept, 5S was used
	High transportation of parts	Transportation	• Cellular Manufacturing or Group technology

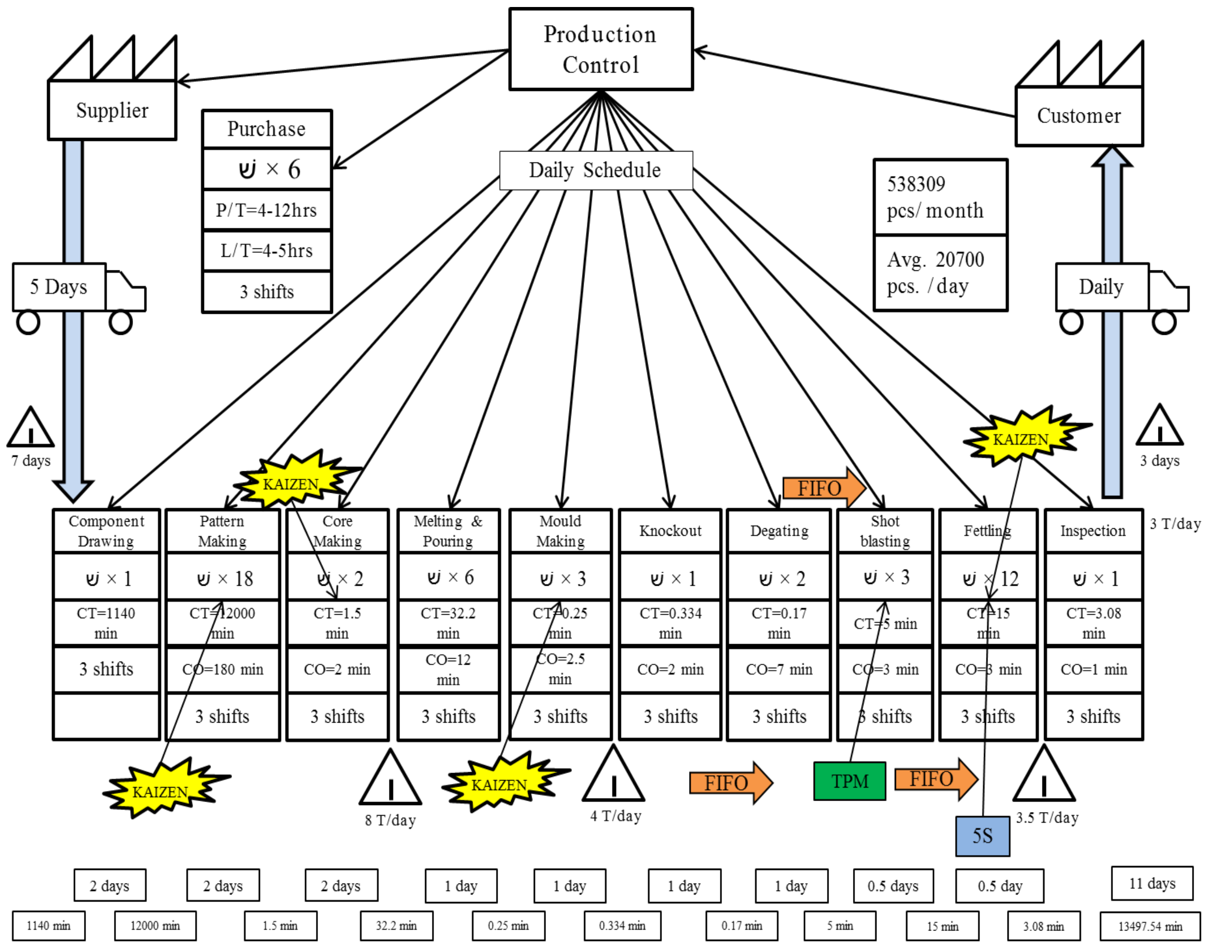


Figure 4.6c: Future state map

From future state map, value added time as a % of total time in plant = {(13497.54 / (11 Day × 24 hrs/day × 60 min/hr)} = 0.85 %.

The future state map indicates average 23% waste reduction in the critical areas of unnecessary inventory, transportation and waiting with implementation of waste elimination techniques identified for improvement.

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

Table 4.1: Typical contents page of DPR

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

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

5.5 Step by step approach for loan application

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

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

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

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