Comprehensive training material for technology providers Morbi Ceramic 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

Suggested Format for Citation

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GEF-UNIDO-BEE Project, Bureau of Energy Efficiency, 2018

"Capacity Building of Local Service Providers"

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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 'technology providers' category.

The aim is to build their capacities and equip them with the necessary knowledge and skills and to provide background information and tips regards energy efficiency (EE)/renewable energy (RE) options in important ceramic manufacturing process viz. Good practices in motor rewinding & electrical maintenance, Energy efficient and Renewable Energy (EE/RE) technologies and Energy efficiency in Kiln and associated systems. 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 Morbi Ceramic Cluster between March to June 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 ceramic clusters are targeted under the assignment – Morbi, Thangadh and Khurja.

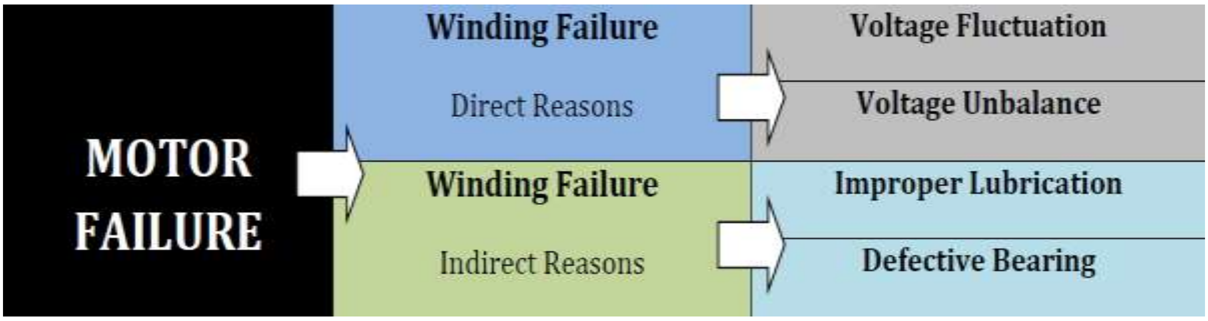
This comprehensive training material for Indore foundry cluster is targeted at 'technology providers' category. The material is structured in the following 4 modules.

Module 1	Good practices in motor rewinding & electrical maintenance
Module 2	Energy efficient and Renewable Energy (EE/RE) technologies
Module 3	Energy efficiency in Kiln and associated systems
Module 4	Financing schemes and DPR preparation for EE projects

2.0 Module 1 - Good practices in motor rewinding

2.1 Reasons of motor failure

Electric motors fail for a variety of reasons. Certain components of motors degrade with time and operating stress. Electrical insulation weakens over time with exposure to voltage unbalance, over and under-voltage, voltage disturbances, and temperature. Contacts between moving surfaces cause wear. Wear is affected by dirt, moisture, and corrosive fumes and is greatly accelerated when lubricant is misapplied, becomes overheated or contaminated, or is not replaced at regular intervals. When any components are degraded beyond the point of economical repair, the motor's economic life is ended. The major cause of motor failure is shown in figure.



Power quality is one of the major issues leading to motor failure. Fluctuating/low voltage from the supply side (in LT industries) and voltage imbalance (due to major concentration of single phase loads) at the motor side are identified as the major reasons of on motor failure. This seems to be the cause of winding failure because of high winding temperature resulted by high current and subsequent insulation failure. Apart from the above, O&M practices like improper lubrication or/and defective bearing (selection and installation) also play role in winding failure. This is because of high inrush current in order to overcome the friction loss. It is highly felt that awareness creation must be done among the practicing engineers on how to reduce the chances of voltage imbalance at the motor end and frictional loss in motor bearings.

Poor housekeeping and cleanliness of workplace are also other reasons contributing to failure of the motor during operation in ceramic industries. The housekeeping activities like proper maintenance of motor inventories spare parts, cleanliness of name plates/motor body surface, proper ventilation and cabling, cleanliness of MCC panels and motor junction box are very important for healthy running of the motor. Apart from this quality of earthing are important areas which should not be ignored at the unit end. A poor earthing may not necessarily result in failure of the motor but is an important part of electrical safety. Best practices in

Highest efficiency motors use thin laminations of high quality steel, coated with a microfilm of varnish and these were found to exhibit no increased loss over the test range of 350 – 400°C

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No load losses, stator copper losses are caused by heating from the current flow through the stator winding. Techniques for reducing these losses include optimizing the stator slot design. Rotor losses are caused by rotor currents and iron losses.

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Replacement bearing & lubricants should be to the original specification and repairers should be aware that high efficiency motors

housekeeping will certainly improve the motor health further in MSMEs cluster.

2.2 Overview of possible motor Losses

The loss in efficiency on rewinding depends on the techniques, processes and skill used to perform the rewind. Based on largely on a handful of studies of mostly smaller motors (up to 30 hp or 22.5 kW), they often assert that efficiency drops 1-5% when a motor is rewound-even more with repeated rewinds. It is usually between 1 and 2%.

In general, there are three factors affecting the efficiency of rewound motors

- **Increase in Iron Losses:** An increase in the iron losses can be caused
- **Mechanical stress in the core** will increase the hysteresis loss, as might happen if the core is fitted into a new frame with an undersized bore. The practice of hammering stator teeth back into place after stripping will result in increased hysteresis locally as a result of the residual stress. Eddy current loss will increase if the insulation between adjacent laminations is damaged, for example by burring together by filing or by accidental impact.
- **Thermal damage to the core:** thermal damage to the oxide or varnish insulation between the laminations is normally regarded as the usual cause of increased iron loss following a rewind. New work in which the increased loss after rewind under carefully controlled conditions for a number of motors was measured has shown that for conventional steels the temperature should not exceed 380°C. Losses increase very rapidly at higher temperatures.
- Most motors are designed to run with flux densities in the stator and rotor core just over the knee of the magnetisation curve. If the winding characteristics

are changed after rewind, for example if the numbers of turns are reduced, the flux density and hence the loss will increase.

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

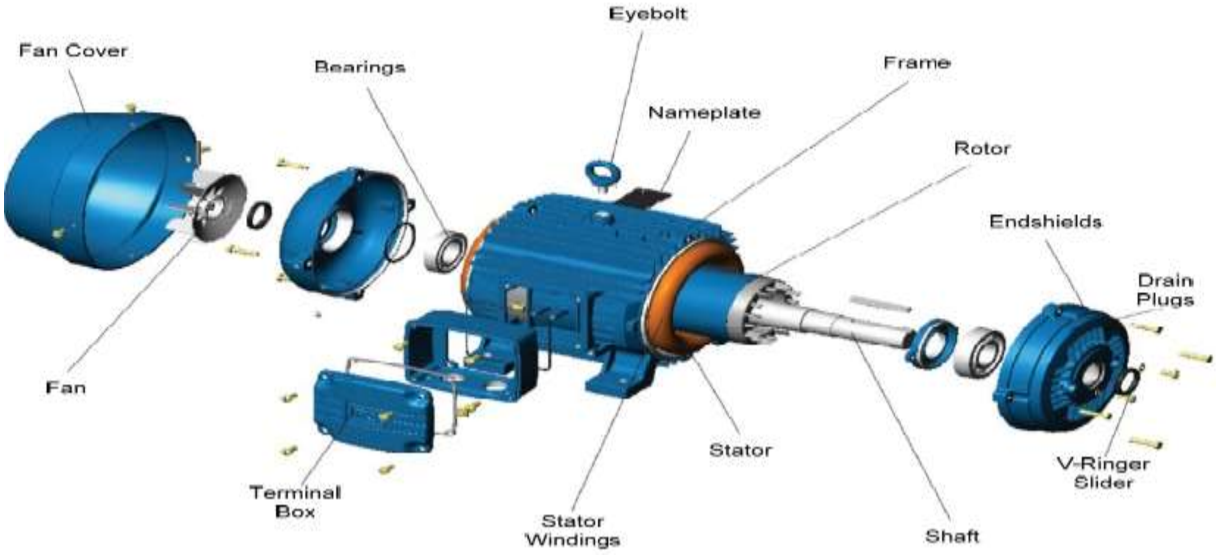
- These losses are reduced for example by increasing the size of the conductive bars and end rings to produce lower resistance. Stray load losses are the result of leakage fluxes induced by load currents. These can be decreased by improving slot geometry of rewound motors.

- **Mechanical Considerations:** The concentricity of rotor and stator is very important. It is common practice **to metal spray shafts or bearing housings** which have been damaged in service. This is acceptable only if special care is taken to preserve concentricity – errors which result in a minimum to **maximum gap ratio greater than 1:1.25** will adversely affect efficiency.

2.3 Best practices in motor rewinding

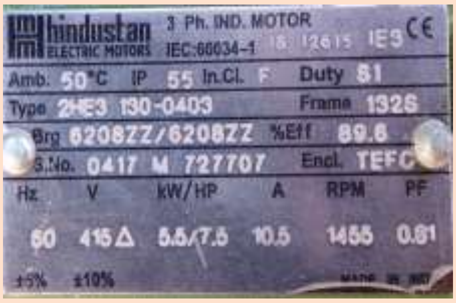
Most repair processes, if done improperly, can reduce motor efficiency. Conversely, doing them well will maintain and may even improve efficiency. It is also important to keep clear, concise written records throughout the repair process.

The following sections provide good practice procedures for each stage of the repair process, beginning with the preliminary inspection and dismantling the motors. The key recommended steps and standard/good practices is given in table below



STEPS OF REPAIR PROCESSES

- Preliminary inspection
- Dismantling the motor
- Removing old winding
- Cleaning the core
- Rewinding the motor
- Reassembling the motor

Recommended procedure	Key steps	Observations
Preliminary inspection (The preliminary inspection forms an important part of the complete motor repair record and may yield vital clues about the cause of failure. Sometimes it is obvious from its outward appearance that the returned motor is not repairable and that a new one must be supplied. More often, however, the motor must be dismantled before this decision can be made.)	Motor nameplate(s) data	• Keep record of all data on the nameplate. • Check whether motor is IE efficiency class (as per IS12615). 
	Results of external inspection	• General condition–old/new, dirty/clean, etc. • Cooling air ducts clear/ obstructed – may have caused overheating. • Shaft discolored (brown /blue) – sign of rotor overheating or bearing seizure. • Parts missing, damaged or previously replaced/ repaired - e.g., seals, stator cooling ribs, fan, fan cover, terminal box, etc.
	User/Customer input	• Customers may be able to provide: • Operating environment – temperature, vibration, etc. • Type of driven equipment. • How many hours/day motor runs. • Approximate motor load. • How often it is started. • type of starter used • Rewinding history • How long the motor has operated since new (or since last rewind). • Unusual events–e.g., power outage, lightning strike, water damage, problem with driven equipment, etc.
Dismantling the motor (It is essential to dismantle the motor carefully and to keep adequate records to ensure that if the motor is repaired it can be reassembled correctly. Place all parts that are not to be repaired in a suitable bin or	Terminal box position, layout and connections.	• Record markings on both winding leads and terminals. • Record positions of any links between terminals (make sketch). • Check that insulation on winding leads immediately adjacent to terminals does not show any signs of overheating (discoloration or

Recommended procedure	Key steps	Observations
tray that is labeled with the motor serial number or job card number.)		brittleness). If it does, replace the leads. • Confirm that all terminals are firmly crimped or brazed to winding leads. • Record size & type of lead wire. • Record lug size and style.
	Orientation of end brackets and bearing caps.	• End brackets and bearing caps should be installed in exactly the same positions as originally fitted. • Mark all end brackets and stator frames at both ends of the motor (punch marking components with a center punch) before dismantling the motor
	Bearing sizes, types and clearances.	• Bearing enclosure • Fit and tolerance • Precision class • Internal clearance • Load application • Type of lubricant
	Axial position of rotor relative to stator (drive end - DE or opposite drive end - ODE).	• Rotor should be centered axially within the stator core. • If it is displaced axially, centering forces will exert pressure on the bearings. • If it is displaced beyond the end of the stator core, magnetizing current will increase. • Note position of axial thrust washer when dismantling the motor (i.e., DE or ODE).
	Orientation of shaft with respect to the main terminal box.	• Document the mounting position of the shaft in relation to the leads (F1 or F2). • There many ways to do this. Some repairers describe this as "leads left facing shaft" or "shaft right facing leads."
	Careful rotor removal to prevent damage to air gap surfaces or winding.	• Rotor presents a considerable overhung load when one end bracket has been removed. • Allowing it to scrape along the stator bore during rotor removal can damage the air gap surfaces of both stator and rotor and increase losses. Winding damage can also result. • An effective way to remove and replace rotors in horizontal motors

Recommended procedure	Key steps	Observations
		is by using a rotor removal tool
	Internal inspection	• Water or dirt ingress. • Condition of stator and rotor cores–damage or overheating. • Condition of winding–discoloration, type of failure.
	Mechanical damage to components or signs of misuse.	• Damage to fan or fan cover • Damaged or blocked cooling ducts/channels/ribs • Shaft discoloration adjacent to either bearing (overload or misalignment)
	Motors with contamination	• If the exterior is packed full of contaminants, address maintenance procedures or consider a different enclosure. • If the winding is packed full of contaminants, the enclosure may not be suitable for the operating environment.
Removing the old winding and cleaning the core (Although removal of old winding and cleaning core are necessarily carried out sequentially, recording the winding details is a coordinated activity carried out both before and during winding removal. Likewise, core loss testing is carried out at fixed points throughout the process.)	Recording the winding details on appropriate data cards or sheets	• Winding configuration (lap, concentric, single, two or three layers, etc.) • Number of slots & poles • Number of phases • Number, size & marking of leads • Turns/coil • Grouping • Coil pitch & Connections • Coil extension/overhang–connection end • Coil extension–non-connection end • Number and size of wires in each coil
	Core loss testing	• Make sure the tests are conducted well within the manufacturer's recommended operating range for the tester being used. Carry out tests: - Before burnout - After the core has been cleaned prior to rewinding. • Remember that figures obtained are comparative, not actual losses. • If the core loss increases by more than 20%: - Make sure the settings of the core loss tester have not been changed and repeat the test.

Recommended procedure	Key steps	Observations
		- If the repeat test confirms the increased loss, repair the core or consider replacing it.
	Removing old winding 	• Step 1–Cut off one coil extension (usually opposite connection end): Cut off coil extension of the winding as close to stator core as possible without damaging the stator core. • Step 2–Remove the old stator winding: Varnish and insulation must be broken down before windings to be removed. • To be with a controlled temperature burnout oven. Coils must be heated sufficiently to burn out old insulation from windings without damaging interlaminar insulation. • It is important to set the oven temperature to monitor the temperature of the stator core. (See figure). • Key points–removing the old windings o Cut off one coil extension using a winding cut-off machine. o Burn out old insulation at appropriate temperature in a controlled-temperature burnout oven set to monitor core temperature. o Do not overheat the core. Remove the winding without damaging the core.
	Cleaning the stator core in preparation for rewinding	• Key points–cleaning the stator core: o Careful scraping with a sharp

<table>
<tr><th>Recommended procedure</th><th>Key steps</th><th>Observations</th></tr>
<tr><td></td><td></td><td>knife.
o High-pressure washing.
o Blasting with a mildly abrasive material.
o Brushing with medium/soft wire brush.
• After cleaning the slots:
o Reposition damaged teeth
o Repair minor damage to air gap surfaces
• Replace or reinsulate and rebuild cores if major damage has occurred</td></tr>
</table>

After performing the inspection and removal the winding, if choosing the replacement of winding the repairer has two options:

- Copy (duplicate) the winding already in the motor (provided it is the manufacturer's original).
- Choose a different style of winding that will perform as well as or better than the original.

> Though, that in some designs, the coil extension is critical for heat dissipation. If it is too short, the temperature of the winding may rise, causing I^2R losses to increase.

At this stage, the repairers have opportunity to redesign the motors to make them more energy efficient. Most of the time, however, the best way to maintain motor efficiency is to duplicate the original winding, while increasing the copper cross sectional area as much as possible and keeping the end turns as short as possible (certainly no longer than those of the original winding).

When production volume justifies the cost, motor manufacturers use automatic coil winding and inserting machinery to produce motors with concentric coil groups. Repairers often find lap windings much quicker and easier to install.

This section therefore sets out the basic rules (in terms of maintaining efficiency) for just two types of rewind:

- A "copy" (or duplicate) rewind
- Changing the original concentric winding to a conventional lap winding

Recommended procedure	Key steps	Observations

Rewinding the motor	Copy (duplicate) rewinding	• If the details of old winding have been recorded, and provided that it is the manufacturer's original winding, the core can now be prepared for rewinding.
		• Even though the coil pitch (or pitches), turns/coil and the connections will be the same as those of the original winding, two changes could be made that will help to maintain or even slightly improve the efficiency of the rewound motor:
		  • Minimize the length of the coil extensions.
		  • Increase the copper cross-sectional area in each coil.
		• Key points–copy rewinding
		  o Check that old winding is manufacturer's original.
		  o Use same winding configuration.
		  o Keep coil extensions as short as practical.
		  o Same (preferably less) length of overhang.
		  o Use same coil pitch (or pitches).
		  o Use same turns/coil.
		  o Use same (preferably larger) copper cross-sectional area.
		  o Use same or shorter mean length of turn (MLT).

Recommended procedure	Key steps	Observations
		o Use same or lower winding resistance (temperature corrected).
	Minimize the length of the coil extensions	• It is important to keep the coil extensions as short as possible. • Attention to the following rules will prevent this: o Keep the coil extensions within the measured dimensions of the original winding. o Do not extend the slot insulation beyond the slot ends any more than is necessary to prevent strain on the slot cell. o Do not extend the straight portions of the coil sides any farther than is necessary to clear the slot insulation. • Reducing the length of the coil extension will reduce the amount of copper in the winding and reduce losses.
	Changing to a two-layer lap winding	• Repairers often prefer to use lap windings because all coils are the same. This is acceptable if the new winding has the same flux/pole as the original. • Single-layer lap windings are sometimes used for small to medium-sized motors, because the coils are easier to insert and no separators are required. This allows more room for copper. • Double-layer windings distribute flux through the core better than single-layer windings. Replacing a double-layer winding with a single-layer winding will certainly reduce motor efficiency, so it is not recommended. • Lap windings should be appropriately short-pitched (i.e., the coil pitch must be less than the pole pitch unless the winding has only one coil per group).
Completing the winding (After fully inserting the winding, connect the coils and leads to match the original connections exactly (if a copy or duplicate rewind) or appropriately for the replacement lap winding. Use connection leads that are as large as practical and mark all of them correctly. Brace the coil extension either as the manufacturer's original winding or better (i.e., more rigid). After checking	Winding resistance tests	• Measure resistance of first coil group wound and compare it with the calculated resistance. If possible, measure the resistance of a coil group from the original winding for comparison. • Measure the ambient air temperature (Ta) with the winding at room temperature. Correct both resistances to a convenient common reference temperature (normally 25°C) using the formula:

Recommended procedure	Key steps	Observations
the coil extensions a final time, perform winding resistance, insulation resistance, phase balance and voltage withstand tests)		 $$R_x = \left(\frac{234.5 + 25}{234.5 + T_a}\right) \times \text{Measured resistance}$$ Where R_x = corrected winding resistance T_a = ambient air temperature • The corrected value of resistance of the new coil group must be equal to or lower than that of the original coil group. • When the stator is fully wound, measure and record the resistance of each phase (or between leads) as well as the ambient temperature. Resistance of each should be equal within 5% (See figure)
	Phase balance (or surge comparison) tests	• Perform on completed winding before impregnation. • Test compares decay rate of identical voltage pulses applied simultaneously for 2 winding phases. • Trace pattern indicates phases identical (okay–identical traces) or different (fault–traces do not match). • Trace pattern gives guidance to type of fault (see equipment manufacturer's guide).
	Impregnation	• Impregnating the winding with varnish and subsequently air drying or baking this varnish until it is cured serves the several purposes: o It provides a mechanical bond between conductors. o It increases the dielectric rating of the insulation. o It protects the winding from moisture and contamination. o It fills the air spaces between conductors (particularly in the slots). • Lower winding temperature = lower resistance = lower I^2R losses

List of references

International Copper Association India (Effect of Repair/Rewinding On Motor Efficiency © 2003, Electrical Apparatus Service Association, Inc.)

3.0 Module 2 – Energy efficient and Renewable Energy (EE/RE) technologies

3.1 EE and RE technologies

3.1.1 Energy conservation of thermal energy

Considering the fuel reserves and increasing competition, it is essential to adopt energy conservation measures to improve overall efficiency, reduce operating cost/production cost and minimise the load on energy resources. The efficiency of a kiln will depend on how efficient the combustion system is and secondly how best the generated heat is utilized. Use of standard and good quality fuel improves overall performance of the firing system. Around 5 - 15% energy saving is possible from kilns used in ceramic industries. Some of the potential energy conservation measures (ECMs) for thermal system are listed below.

- Optimum kiln design to ensure capacity utilization to the tune of 98%
- Use of optimum product thickness to reduce heat load for sintering
- Complete combustion with minimum excess air.
- Proper heat distribution.
- Operating the kiln at desired temperature.
- Reducing heat losses from the openings.
- Minimizing wall losses by improving kiln insulation.
- Waste heat recovery from fuel gasses and utilization for drying green products
- Control of Chimney draught and kiln pressure
- Use pre-heating of spray dryer input slurry either solar or electrical heat pump
- Biomass / briquette firing in hot air generation
- Fuel switch over with better option in spray dryer
- Switching to continuous type kilns from intermittent type
- Adopting best operating practices including optimizing of excess air levels
- Use of hot air from cooling zone to preheat input material
- Energy efficient burner that can handle pre-heated combustion air at higher temperature
- Arresting air infiltration in kilns and spray drier system
- Use of lubricants and proper maintenance

Application of ECMs and absolute energy saving would largely depend on the base case scenario and relevant parameters likes operating efficiency of equipment, operating hour, operating load, landing fuel price etc. Some of the applications of ECMs are described below.

Use of low thermal mass material in kiln fabrication and material movement

Heavy refractory cars and saggers are generally used for carrying ceramic products inside the kiln. The dead weight of the refractories is quite high (around 24%). These refractories which do not take part in reactions in formation of ceramic products, are subjected to alternate heating and cooling cycles, thereby losing substantial portion of heat input. These heavier refractory cars and saggers can be replaced effectively with low thermal mass cars and decker plates (23 – 24 % weight reduction is possible), which would help in reducing heat losses substantially. The estimated energy saving with use of low thermal mass cars is about 5-10%.

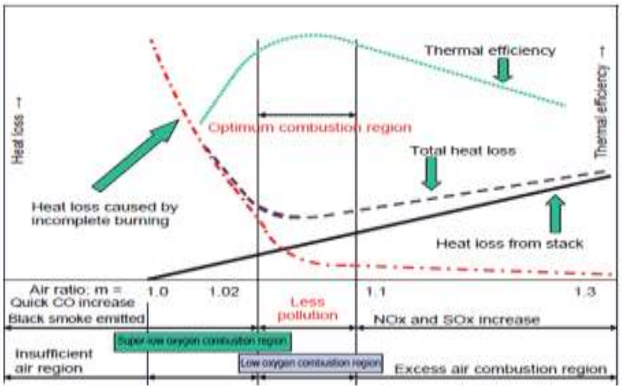
- Use of low thermal mass for kiln cart to **reduces the thermal weight** of the kiln considerably
- Weight reduction in kiln car saves significant amount of energy and also **improve material to car weight ratio**
- Reduces excess the **thermal energy storage** in the kiln furniture (**Roller**)
- Ultralite insulating material with supporting block gives proper support and increase the strength of the kiln base
- Replacing refractory bricks with hollow ceramic coated pipes at the supporting pillars for holding racks
- Dead weight can be cut down to 15 to 25% of the existing weight

Advantages of ultralite insulating material

- High open porosity
- Low thermal mass
- Low permeability
- Low thermal conductivity
- Low bulk density
- Lightweight

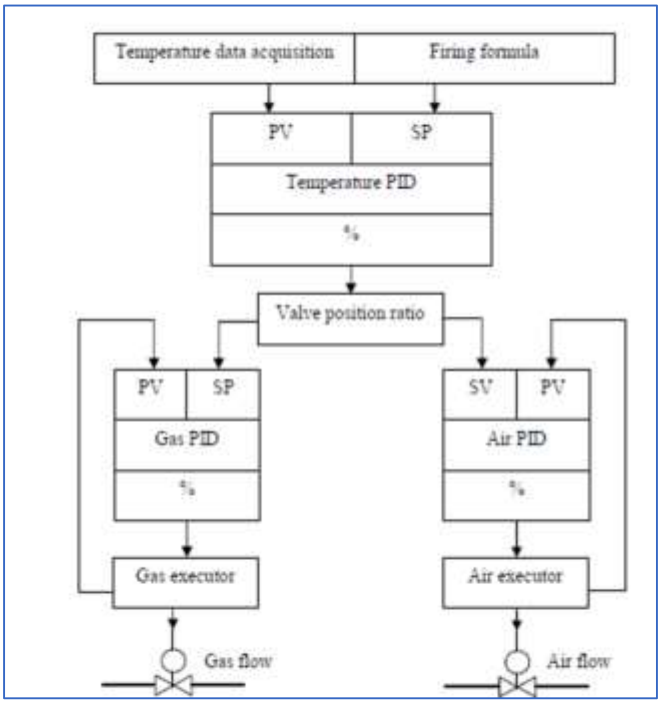
Maintain the required air to fuel ratio for proper combustion of fuel

Kilns are important segment in ceramic industries and accounting for about 50-65% of energy consumption. Various operating parameters such as temperatures, draft, retention time and material arrangement, etc. may vary with the type of kilns used. More the air is used to burn the fuel, more is the heat wasted in heating air. Air, slightly in excess of ideal stoichiometric (or theoretical) fuel to air ratio is required for complete combustion and to reduce NOx emissions; it is dependent on the type of fuel. However, excess air beyond the optimum range (an efficient natural gas burner however requires 2% to 3% excess oxygen, or 10% to 15% excess air in the flue gas, to burn fuel without forming carbon monoxide) may substantially decrease combustion efficiency as it leads to generation of excessive waste gases. The effect of excess air level and flue gas temperature on dry flue gas losses is shown in graph



The relationship between the air-to-fuel ratio and wasted heat energy provides a basis for control system design. In most of the cases, real combustion processes have inadequate mixing of air with fuel. Also, the gases tend to flow so quickly that the air and fuel mix have limited contact time in the combustion zone. As such, if air is fed in exact theoretical or stoichiometric proportion to the fuel, it will still lead to incomplete combustion. Automatic burner assembly generally performs in a manner similar to the graph. The cost associated with operating at increased air-to-fuel ratio is the energy wasted in heating additional air volume. Yet, if the air-to-fuel ratio is decreased, losses due to incomplete combustion and emission will increase rapidly.

Kiln thermal parameters controller comprises kiln temperature, pressure and atmosphere controlling. In different stages, the control act differently, in firing process, PLC control inverter adjust the combustion fan to change air flowing in air hose. Electric valve of fire nozzle is set by numerical program to setup kiln atmosphere during heating process.



In the cooling stage, NG is shut down and each fire valves/nozzle is closed automatically. The temperature controller switch to the cooling control mode and the system enters cooling stage. In this period, air general pipe is controlled by opening degree.

Fire nozzles are divided into two groups. In order to reduce cost, temperature valve position automatic control is used as shown in Figure. Each gas general hose has gas solenoid valve and each group of gas general hose and combustion general hose is installed with electric executor. This compares the air-fuel ratio practical value (PV measured by thermocouples) with set value (SV) and controls gas executor and combustion executor by PID regulator. Temperature PID controller controls firing by controlling air flow and gas flow which are accomplished by the opening degree of combustion air valves and gas valves. The benefits of combustion control system will be:

- Reduce excess fuel consumption.
- Reduce blower power consumption
- Increases exhaust temperature
- Give higher benefits in preheated combustion air as well as in dryer applications

Reduction of the excess air flow rate leads to a reduction in kiln energy consumption, though this operation must be performed with care, because other kiln operating parameters could be affected. It has been experimentally verified that 2% reduction in the oxidising air flow rate entails a decrease of the order of 5% in the natural gas flow rate.

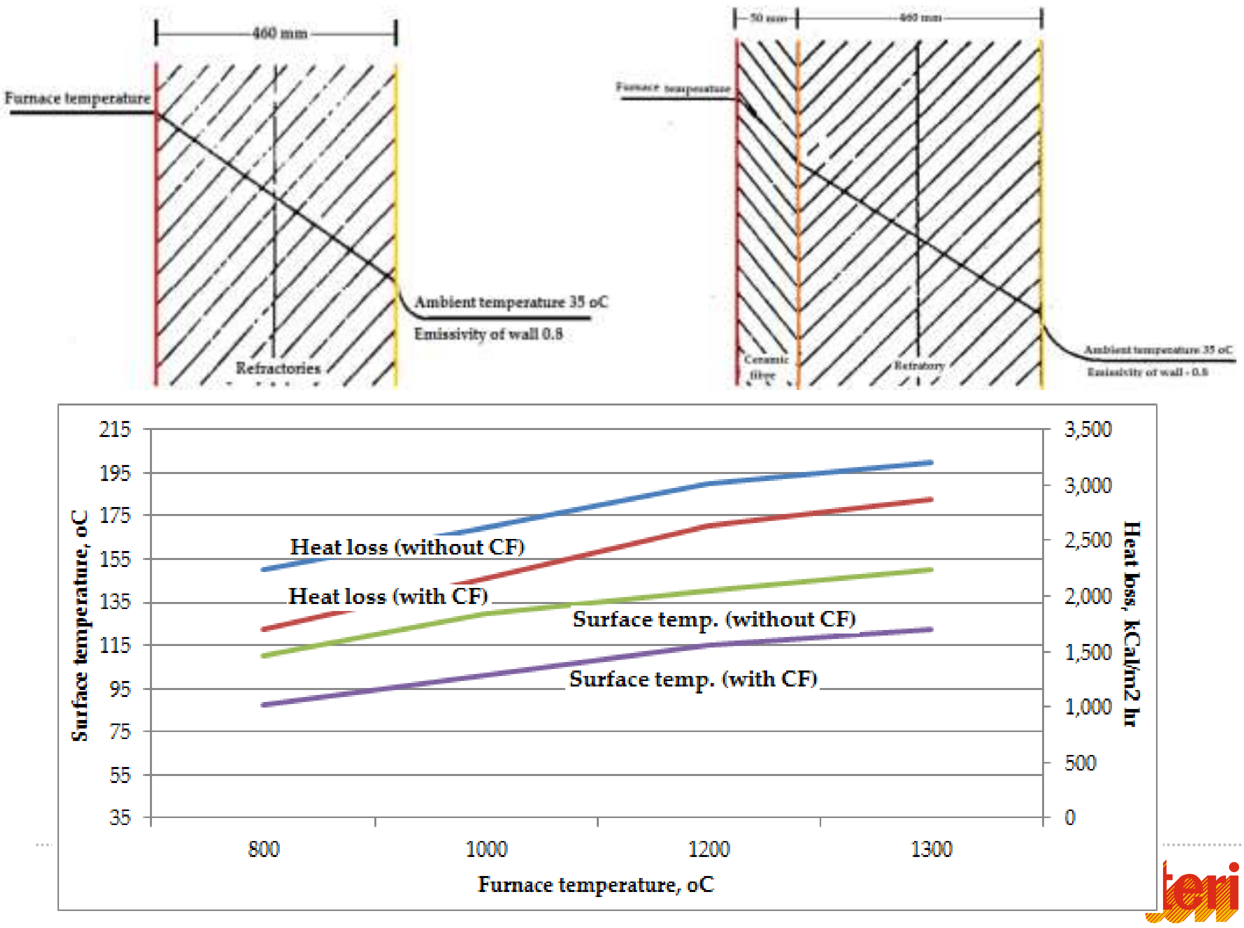
(*Source: Manual on Energy Conservation Measures in Ceramic Industry, BEE SME Programme*)

Improved insulation of kiln

The heat loss from a kiln structure can be divided into (i) radiation loss through openings and surface of the body, (ii) heat accumulation loss to internal insulation and supports composing the body. Improvement in the radiation heat loss from surfaces can be achieved by reinforcing its insulation. This includes (i) covering of internal wall surface with ceramic fibre insulation, and (ii) covering external wall surface with ceramic fiber or rock wool insulation.

The temperature gradient i.e. difference between the hot face temperature (hot face temperature is the temperature of the surface in contact with the flue gas or heated combustion air) and surface temperature will be a critical factor for reduction in heat loss by reinforcement of insulation. The hot face temperature is used to determine refractory or insulation thickness and heat transmitted. The design temperature is used to specify the service temperature limit of refractory materials.

The potential energy savings for insulating the firing zone of kiln may be up to 2-5%. However the capital investment required for reinforcement of insulation may be higher



Effect of insulation in a kiln: Heat loss vs surface temperature indicating long payback period.

Use of hot air of cooling zone of kiln directly as a combustion air

Hot air from cooling zone of kiln has a temperature of about 250-300 ^{o}C. Use of this hot air directly for combustion of fuel (NG or PG) can result in significant savings in fuel consumption in the kiln.

(*Source: Manual on Energy Conservation Measures in Ceramic Industry, BEE SME Programme*)

Use of energy efficient & high preheated air temperature burners

Use of high velocity energy efficient burner's and high preheated air temperature burners further improves kiln efficiency. Observed maximum preheated air temperature in the kiln in Morbi cluster is 250 ^{0}C, whereas current burner technology accepts air preheat temperature upto 600 ^{0}C. This offers good opportunity for high temperature waste heat recovery. Higher the combustion air temperature, lower will be the fuel consumption in the kiln.

(*Source: Manual on Energy Conservation Measures in Ceramic Industry, BEE SME Programme*)

Energy conservation of electrical energy

Share of electrical energy consumption may be less but absolute quantity is very high. There are cost effective feasible measures, which could reduce energy consumption in ceramic industries. Some of the potential ECMs to save electrical energy are mentioned below.

- Continuous multi-stage or vibro ball milling system to replace conventional ball milling / blunger
- Installation of load sensor on conveyor belt to control auto on off depending upon the load availability on the belt
- Energy efficient motors with VFD for variable load applications or demand fluctuates like ball mill, blunger, agitating tank, dedusting and centralize vacuum cleaning, compressor, belt conveyor etc.
- Cogeneration system to reduce electrical as well thermal energy consumption
- Automatic hydraulic press system with interfacing and interlocking to switch off chiller system when hydraulic press is non-operative
- avoid idle operation of hydraulic press pump
- Auto interlock between brushing dust collection blowers and glazing lines
- Energy efficient utilities and lighting system
- Switch over electrical heating system to low cost primary fuel heating system
- Sensor based intelligent water tap
- Level controller for water pumping system for auto on -off

Some of the applications of ECMs are described below.

Application of energy efficient motors & VFDs

Generally, most of the existing motors in ceramic industries are age old and very inefficient due old model apart from wear and tear in use. The electrical energy conservation measures in a ceramic unit include use of energy efficient motors in polishing area, replacement of smaller motors with a single large motor, adopting energy efficient motors and VFD (variable frequency drives) in agitating tanks, material conveyor, spray dryer, kiln blower, press and compressor sections and use of energy efficient hydraulic pumps. These measures would help in achieving energy saving between 8-15%.

Replacement of V belts by energy efficient flat belts

Replacement of V-belts with flat belts or grooved V-belts can typically save 4-6% of the transmitted energy. There is potential for these savings in ball mills & agitators.
(*Source: Manual on Energy Conservation Measures in Ceramic Industry, BEE SME Programme*)

Energy efficiency in compressed air system

Compressed air is used widely in ceramic industry and is often considered the "fourth utility" at many facilities. It is further extremely inefficient at part load. Improving and maintaining compressed air system performance requires not only addressing individual components, but also analyzing both the supply and demand sides of the system and how they interact. Various energy saving opportunities to optimize the compressed air use and electricity consumption are as follows:

Supply and demand sides of compressed air system

Review air demand: Before taking initiatives to improve the compressed air system, it is necessary to determine the air demand or requirements of the manufacturing facility. To obtain demand profile, the air delivery from compressor section must be measured at various points over a period of time (to take care of load variations). It is also necessary to monitor system pressure and power consumption at the same points and time in order to see how the flow, pressure and power consumption change over time. This profile should be obtained over a typical production cycle so that demand on compressed air system can be seen at all stages.

The air compressors provided in rolling industries mainly use load/unload mode (online/offline control) of operation. During unload condition, it keeps the motor running continuously, but unloads the compressor when the discharge pressure is adequate. Unloaded power consumption of air compressor is significant of their full load power demand (Screw: 30-40% and Reciprocating: 15 -20%), while producing no useful compressed air output.

To minimize the electricity consumption during unload, variable speed option is an appropriate solution. VSD enabled compressors should be considered for trim (or swing) duty as they are typically the most efficient control mechanism to cater to partial loads. Capable of supplying a constant pressure through a wide control range, energy consumption and flow of a VSD compressor is almost directly proportional to the speed. This can result in energy savings over comparable fixed speed units when compressors are partially loaded.

Pressure profile: Higher the generation pressure of compressed air, higher will be the power consumption. Different tools and process operations require different pressures. Required pressure levels must take into account system losses from dryers, separators, filters, and piping.

A rule of thumb, for every 2 psi increase in discharge pressure, energy consumption will increase by approximately 1 percent at full output flow.

There is also another penalty for higher-than-needed pressure. Raising the compressor discharge pressure increases the demand of every unregulated usage, including leaks, open blowing, etc.

Set pressure = maximum pressure required at end use + minimum pressure drop

Compressed air system leaks: Compressed air leaks can be a significant contributor of wasted energy in a compressed air system, and in some instances lead to productivity losses. It is not unusual to encounter 20-40% of a compressor's output as air leaks in typical industrial facilities. Although leaks can occur in any part of the distribution system, the most common areas/ points of leaks include couplings, hoses, tubes, fittings, pipe joints, quick disconnects, filters, regulators, lubricators, condensate traps, valves, flanges, packing, thread sealants and points of use devices.

Leakage rates are a function of the supply pressure in an uncontrolled system and increase with higher system pressures. Leakage rates are also proportional to the square of the orifice diameter (refer table). Proper installation and preventive (detection and repair) maintenance of compressed air distribution network and associated system can reduce leaks to less than 10% of a plant's compressed air generation.

Leakage rates* (cfm) for different supply pressure and approximately equivalent office sizes

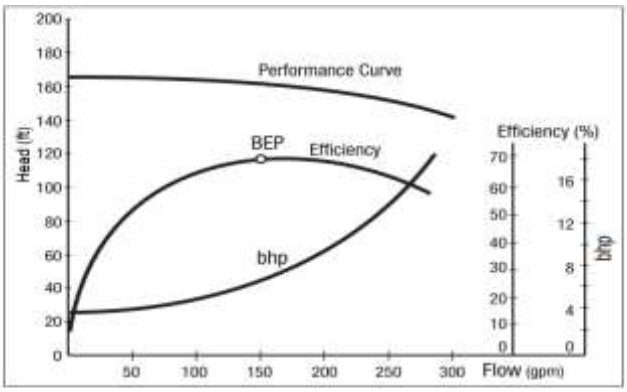
Pressure	Office Diameter (inches)					
(psig)	1/64	1/32	1/16	1/8	1/4	3/8
70	0.3	1.2	4.8	19.2	76.7	173
80	0.33	1.3	5.4	21.4	85.7	193
90	0.37	1.5	5.9	23.8	94.8	213
100	0.41	1.6	6.5	26.0	104	234
125	0.49	2.0	7.9	31.6	126	284

*For well-rounded orifices, multiply the values by 0.97, and for sharp-edged orifices, multiply the values by 0.61

In addition to being a source of wasted energy, leaks can also be reasons to other operating losses. There is strong "cause and effect" relationship between the number and magnitude of air leaks with the overall compressed air system pressure. For example, lower air pressure can affect air tools and equipment by reducing the mechanical output and decreasing the productivity.

An ultrasonic leak detector is probably the most appropriate equipment to detect air leakages. An ultrasonic sensor focuses on the ultrasonic elements in the noise. Because ultrasound is a short wave signal, the sound level will be loudest at the leak site. These detectors are generally unaffected by background noises in the audible range because these signals are filtered out.

Energy efficiency in pumps



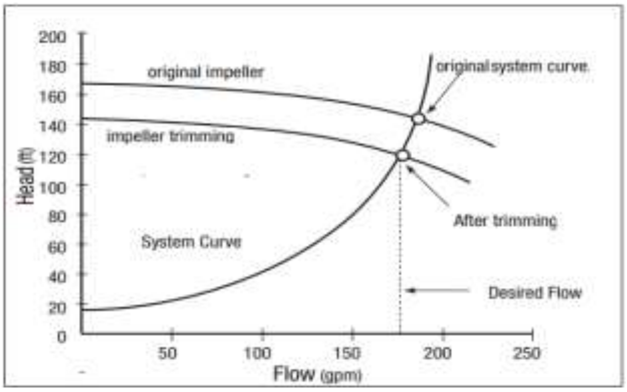
Best efficiency point in pump operation

Pumps are used mainly in the finishing section of the ceramic industries (except sanitary ware). Inefficient operation of pumping system can be caused by a number of problems such as improper pump selection, poor system design, excessive wear-ring clearances and wasteful flow control practices. Indications of inefficient system operation include high energy costs, excessive noise in the pipes and across valves and high maintenance requirements. Each pump has a best efficiency point (BEP) at which its operating efficiency is the highest and its radial bearing loads are lowest (except for pumps with concentric case designs). At its BEP, a pump operates most cost-effectively in terms of both energy efficiency and maintenance. Operating a pump at a point well away from its BEP may accelerate wear in bearings, mechanical seals and other parts. In practice, it is difficult to keep a pump operating consistently at this point because systems usually have changing demands. However, keeping a pump operating within a reasonable range of its BEP lowers overall system operating costs.

Another critical criterion to maintain the efficiency of pump is speed. The pump speed is usually an important consideration in system design. It is perhaps best determined by evaluating the effectiveness of similar pumps in other applications. In the absence of such experience, pump speed can be estimated by using specific speed which can be used in two different references: impeller specific speed and pump suction specific speed.

The energy efficiency methods which can be used to maintain the efficiency in pumps without replacement are given below.

Impeller trimming: Impeller trimming refers to the process of machining the diameter of impeller to reduce the energy added to the system fluid. It can be a useful correction to pumps that, through overly conservative design practices or changes in system loads, are oversized for their application. The industry may consider trimming of impeller while any of the following conditions occur:

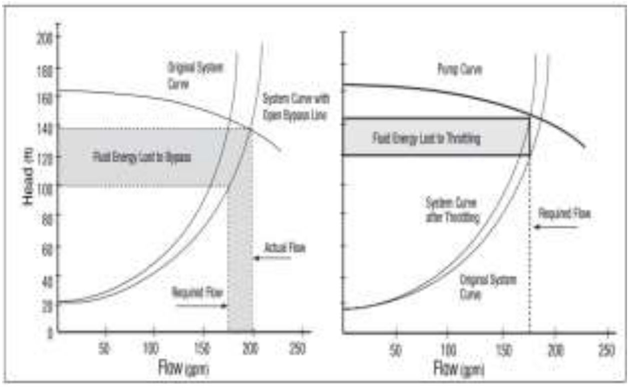


Effect of impeller trimming

- Many system bypass valves are open, indicating that excess flow is made to system equipment
- High levels of noise or vibration indicate excessive flow
- Excessive throttling is needed to control flow through the system or process
- A pump is operating far from its design point.

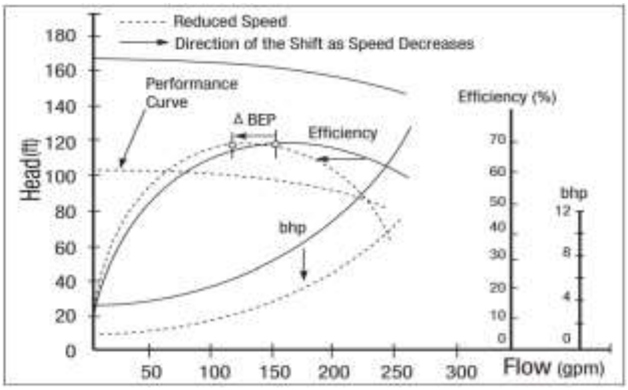
Trimming an impeller changes its operating efficiency, and the non-linearities of the affinity laws with respect to impeller machining complicate predictions of pump performance. Consequently, impeller diameters are rarely reduced below 70% of their original size.

Adjustable Speed Drives: Centrifugal pumps are often operated over a wide range of conditions. For example, many process cooling systems experience variable loads caused by changes in ambient conditions, product shape & size and production demands. To accommodate demand changes, flow can be controlled by any of these four methods - bypass lines, throttle valves, multiple pump arrangements or pump speed adjustments. The pump characteristics and loss in power due to throttling and bypass mechanism is shown in figure.



Pump characteristic curve

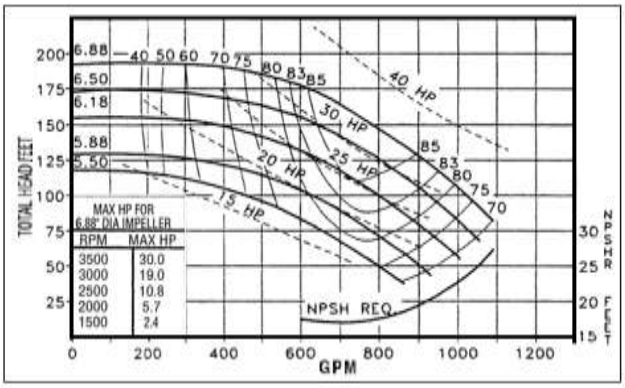
To maintain the desired flow rate efficiently, speed adjustment is the most efficient means of control. Reducing the pump speed means less energy is imparted to the fluid and less energy needs than the throttling or bypass method. There are two primary ways of reducing the pump speed: using



Characteristic curves with ASD

multiple-speed pump motors and using adjustable speed drives (ASDs). The ASDs allow pump speed adjustments to be made over a continuous range, avoiding the need to jump from one speed to another. ASDs control pump speeds using different types of mechanical and electrical systems. Mechanical ASDs include hydraulic clutches, fluid couplings, and adjustable belts and pulleys. Electrical ASDs include eddy current clutches, wound-rotor motor controllers and variable frequency drives (VFDs). VFDs adjust the electrical frequency of the power supplied to a motor to change the speed.

Energy efficient centrifugal pump: Centrifugal pumps handle high flow rates, provide smooth, non-pulsating delivery, and regulate flow rate over a wide range without damaging the pump. Centrifugal pumps have few moving parts, and hence the wear caused by normal operation is minimal. They are also compact and easily disassembled for maintenance. The design of an efficient pumping system depends on relationships between fluid flow rate, piping layout, control techniques, and pump selection.



Characteristic curves for centrifugal pumps

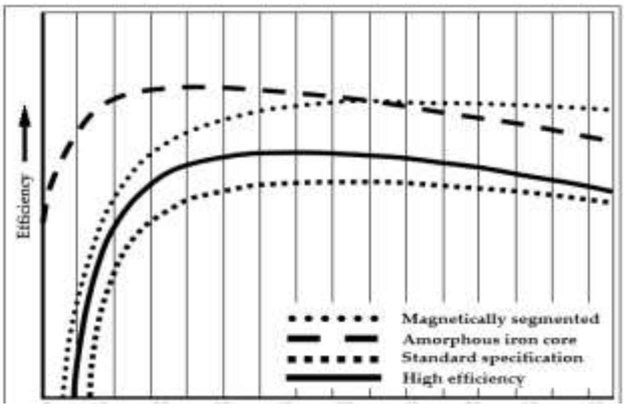
Before selection of a pump, it is necessary to examine its performance curve, which is indicated by a head - flow rate or operating curve. The curve shows the pump capacity (flow rate) against total developed head. It also shows the design efficiency, required input power and suction head requirements (net positive suction head requirement) over a range of flow rates. Pump curves also indicate pump size and type, operating speed and impeller size. It further shows the best efficiency point (BEP). The pump operates most cost effectively when the operating point is close to the BEP.

To minimize energy consumption, the pump should be selected in such a manner that the system curve intersects the pump curve within 20% of its BEP. The impeller of the pump should be selected in the mid-range; it can be trimmed or replaced to meet higher or lower flow rate as per requirements.

Energy efficiency in distribution transformers

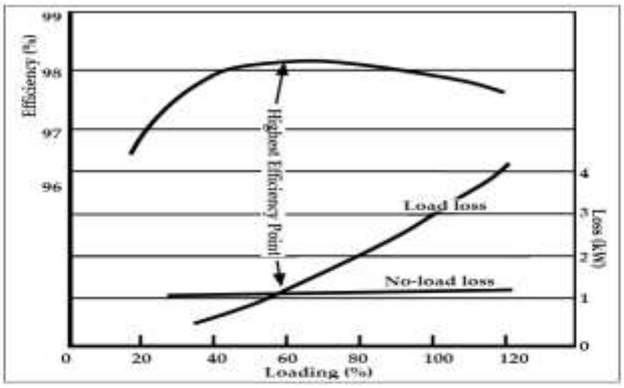
After transmission and distribution of electrical energy, facility level distribution transformers represent the next highest source of energy losses. Distribution transformers are relatively easy to replace and manage (in comparison with other technologies used in industrial facilities), and the efficiency can be easily measured and sustained. Taking life cycle cost into account, installation of high efficiency transformers is an economically sound investment despite higher initial cost. Other benefits include reduced emissions, improved reliability and potentially longer service life.

- **Ultra-high efficiency transformers:** Transformers are continuous operating system for any facility and therefore reduction in losses is a matter of importance. The development in transformers in last decade has led to the appearance of ultra-high efficiency transformers, which have lower energy losses as compared to conventional transformers. To reduce the iron losses (no-load losses), following iron core material technologies have been developed:



Efficiencies of ultra-high efficiency

  - High-orientation silicon steel sheet
  - Laminated iron core of thinner silicon steel coil material
  - Magnetically segmented silicon steel coil sheet
  - Amorphous iron cores



No-load and load losses in transformers

With the use of efficient iron core materials, a no-load loss reduces considerably in comparison to transformers using conventional core material. Other advantages of ultra-high efficiency transformers include no fire risk, no risk of escape of pollutants or fire-hazardous substances, long lifetime, high mechanical strength and reduced emissions.

Power management system / transformer quantity controller: There are two types of transformer losses, i.e. no-load loss and load loss (copper loss). The no-load losses are certain amount of losses regardless of the existence of load on the transformer. If there are one or more transformers with same primary and secondary voltage, the total losses may be optimized by shifting the load of low load transformer to other transformer.

To achieve the maximum benefits of parallel transformer system, PLC based power management system (PMS) may be adopted. The transformer can be operated with highest possible efficiency

Parallel operation of transformers

when the no-load loss and the load loss become equal. Therefore, if one or more transformers are operated in parallel and if the load is fluctuating, PMS controls the losses by adhering to efficiency characteristic of each transformer and automatically controls the number of transformers and the combination of the transformers required according to the load fluctuation.

Lighting system

In ceramic units, energy consumption for illumination also has considerable share. Typical method to optimize energy use in lighting may be upgradation of existing system or adoption of new and efficient technologies. The use of automation in the existing facility may save up to the extent of 50% of energy use by providing the right amount of light. These control system can also help to provide safer, more productive work environment. High efficiency lamps and ballasts, new and efficient light technologies (LED, Induction lamps, compact fluorescent lamps etc.) and use of reflectors may lead to significant reduction in operational cost.

Product	The initial purchase cost for the lighting system	Beyond first cost, compare performance: service life, lumen maintenance, and color rendering and stability
Energy	Annual operating hours multiplied by electrical cost	Consider product wattages as well as light output & lamp performance
Maintenance	Includes manpower and relamping costs	Longer-life lamps that maintain colour stability and lumen output can reduce maintenance
Disposal	The end-of-life cost, including disposal and recycling of lamps, ballasts and fixtures	Another area where longer-life lamps benefit industrial facility owners, by reducing waste and cost

Lighting control: Quality lighting is an important aspect in steel rolling industries, and is often an ignored area. Light control has the ability to regulate the level and quality of light in a given space for specific tasks or situations. The lighting control systems include timer and inverter based dimmer control systems to optimize the use of daylight operation. Optimum control of task specific lighting not only enhances the comfort level of work stations but it also helps to save energy by using light when and where it is needed most.

Lamp type	Lumens per watt	Rated life (hours)	Color rendering index, CRI	Color temperature, °K
T8 high-performance fluorescent with electronic ballasts	86 – 96+	24,000 to 42,000+	80 to 85	3,000 to 6,500
T5 with electronic ballasts	86 – 96+	30,000 to 40,000	80 to 85	3,000 to 5,000
T5HO with electronic ballasts	86 – 96+	30,000 to 40,000	80 to 85	2,700 to 5,000
Compact fluorescent lamps (hard-wired)	43 – 71	6,000 to 12,000	80 to 85	2,700 to 5,000
LED replacement lamps	50 – 100+	25,000 to 50,000+	80 to 90+	2,700 to 6,000+
LED, new fixtures	Up to 100+	50,000 to 100,000	80 to 90+	2,700 to 6,000+
Electronic HID	60 – 80	20,000	65 to 90	2,900 to 4,000
Induction (filament less)	60 – 75+	100,000	80 to 90+	3,000 to 4,000+

High efficiency lighting: Recent technological advancements have introduced a new era of energy efficient lighting products. Replacement of the existing lighting with most advanced light sources and fixtures may save upto 50% on lighting energy use, while benefiting from the best in lighting quality. Energy efficient lighting offers additional benefits such as reduced load on air conditioning and ventilation system, better life and is compatible with advance control & automation.

3.1.2 Adoption of renewable energy

Preheating slurry using solar dryer/ heat pump

The slurry entering spray dryer is generally enters at ambient conditions. The slurry can be preheated using solar dryer or heat pump which would help in reducing the energy consumption in spray dryer by about 5%.

Rooftop solar system

Solar Power, a clean renewable resource with zero emission, has got tremendous potential of energy which can be harnessed using a variety of devices. With recent developments, solar energy systems are easily available for industrial use with the added advantage of minimum maintenance. The average solar irradiation in Gujarat state is 5.82 kWh/m^2/day and Uttar Pradesh is 4.27 kWh/m^2/day.

A grid connected photovoltaic system will be interacted with utility grid. The main advantage of this system is that power can be drawn from the utility grid and when power is not available from grid, PV system can supplement that power. These grid connected systems are designed with battery or without battery storage. These systems consist of the following:

- Solar panels mounted on the roof or in open spaces. Photovoltaic modules produce direct current (DC) electrical power.
- Batteries to store DC energy generated by the solar panels.
- Charge controller to prevent overcharging the battery.
- Specially designed inverter to transform the PV generated DC electricity to the grid electricity (which is of AC) at the grid voltage.

3.2 Government Schemes and Policy

3.2.1 Credit Linked Capital Subsidy Scheme (CLCSS)

The objective of the Scheme is to facilitate technology up-gradation in MSEs by providing an upfront capital subsidy of 15 per cent (on institutional finance of upto Rs 1 crore availed by them) for induction of well-established and improved technology in the specified 51 subsectors/ products approved. In other words the major objective is to upgrade their plant & machinery with state-of-the-art technology, with or without expansion and also for new MSMEs which have set up their facilities with appropriate eligible and proven technology duly approved under scheme guidelines. List of Technologies is available at www.dcmsme.gov.in

(Source: http://www.dcmsme.gov.in/schemes/credit_link_scheme.htm)

3.2.2 Credit Guarantee Fund Trust for MSE

This scheme will cover both term loan and working capital facility upto Rs.100 lacs. Under this scheme, loan will be sanctioned without any collateral security or third party guarantee. For more details of the scheme visit www.cgtmse.in

(Source: https://www.cgtmse.in)

3.2.3 Technology Up-gradation Scheme for Micro Small and Medium Enterprises (MSMEs)

The first objective of the scheme is to sensitize and encourage the manufacturing MSME sector in India to the use of Energy Efficient Technologies and Manufacturing Processes so as to reduce cost of production and emissions of GHGs.

The second objective of the scheme is to create awareness and encourage the MSMEs to acquire Product Certification/ Licenses from National/ International Bodies.
(Source: http://www.dcmsme.gov.in/schemes/TEQUPDetail.htm)

3.2.4 Assistance for Saving in Consumption of Energy & Water (Gujarat state)

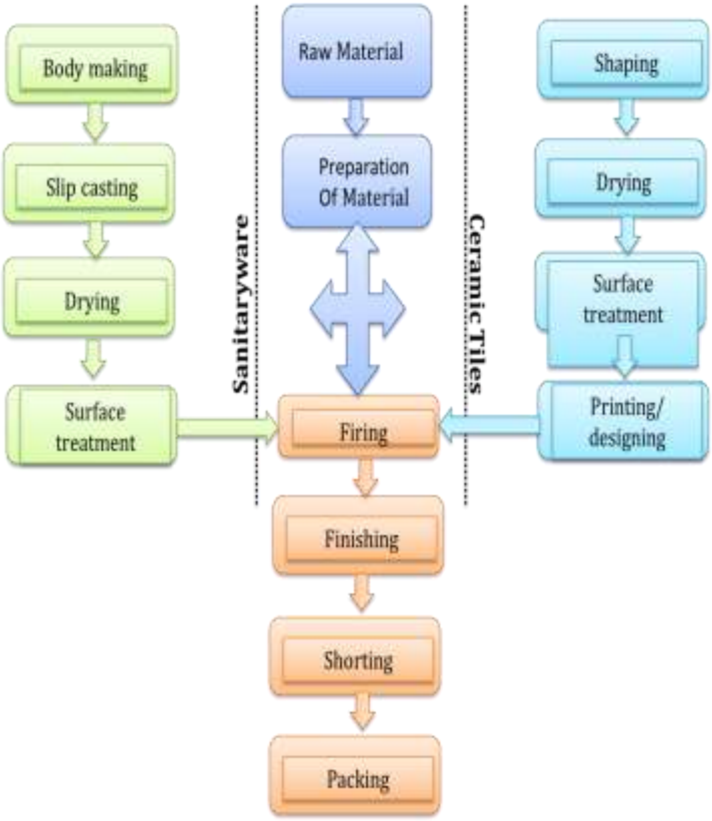
- The existing as well as new enterprise taking action for saving in consumption of Energy and Water will be eligible for assistance under this scheme
- The Enterprises which are registered as an industrial unit under MSME Development act, 2006 with respective DIC are eligible to get benefit
- 75% cost of energy/water audit conducted in a unit by a recognized institution/consultant subject to a limit of Rs. 50,000.
- 25% of cost of equipment subject to maximum Rs. 20 lakhs per project. Only one time assistance will be eligible during the operative period of the scheme

(Source: https://ic.gujarat.gov.in/assistance-for-saving-in-consumption-of-energy.aspx)

4.0 Module 3 – Energy efficiency in Kiln and associated systems

4.1 Drying Process and Equipment

In the process of ceramic manufacturing, the major energy is drawn into the drying process and its associated auxiliaries. The thermal energy used in the drying process is primarily from natural gas. Other than the thermal energy, electricity is also used in driving the associated auxiliaries such as fans, blowers and material handling systems. In a ceramic manufacturing process, the thermal energy share is about 60-70%, whereas the electrical share is about 30-40%. Thus, it is very essential to adopt automation and new and energy efficient technologies/practices to optimise the cost of operation as well as minimising the emissions.



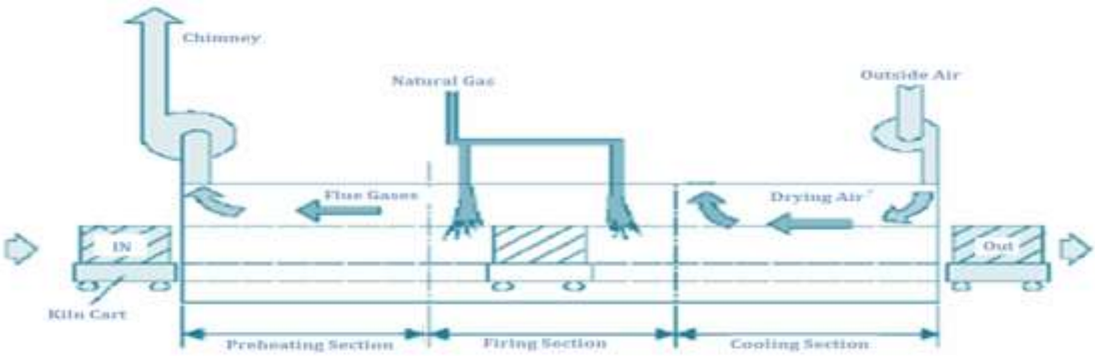
In the ceramic clusters, mainly tunnel kiln and roller kiln are employed. In sanitaryware manufacturing, pusher type tunnel kilns are most common and in tiles manufacturing, roller kilns are installed.

4.1.1 Types of kilns

Tunnel kiln

Tunnel kiln is a continuous moving ware kiln in which the clay products to be fired are passed on cars through a long horizontal tunnel. The firing of products occurs at the central part of the kiln. The tunnel kiln is considered to be the most advanced ceramic and brick products making technology. The main advantages of tunnel kiln technology lay its ability to fire a wide variety of clay products, better control over the firing process and high quality of the products.

The tunnel kiln is, as the name shows, a narrow and long tunnel having the rails in both sides at the bottom. The wares loaded on the kiln cars are charged through the entrance of the tunnel and route continuously through the pre-heating, firing and cooling zones, and then discharged from the exit as shown in figure



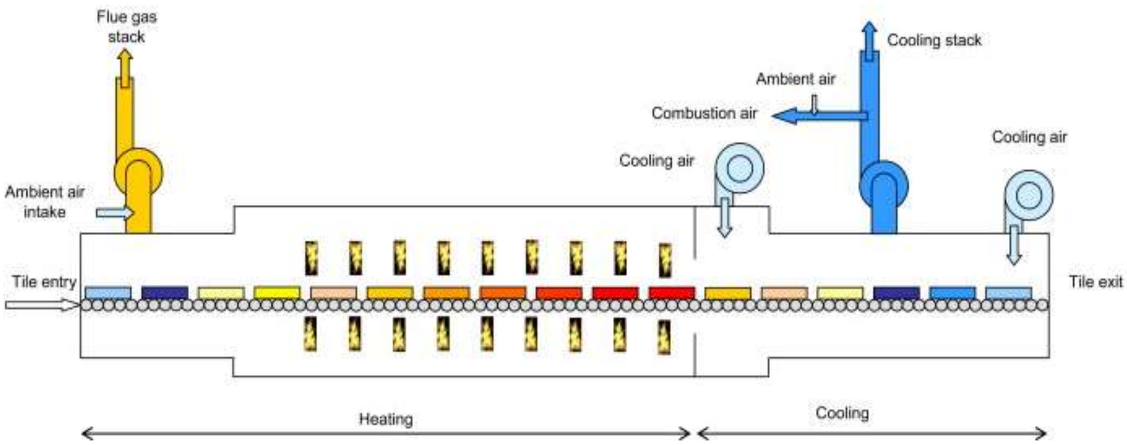
The combustion gas and air always flow from the kiln exit to the entrance such that the adjustment of one firebox affects not only the firing zone but also the pre-heating zone. Especially at reducing firing, the adjustment requires the most care and experience considering various factors; the border of oxidizing and reducing zones and that of reducing and neutral zones, the effect of cooling air to firing zone, the relation between the temperature and atmosphere in reducing zones, etc.

In such type of kilns heavy refractory carts and saggers are generally carry ceramic products through the different temperature zones of the kiln. These carts are generally heavy carts made up of refectory materials which do not take part in any reactions in formation of ceramic products, are subjected to alternate heating and cooling cycles. The general specifications of tunnel kiln commonly used in sanitary ware manufacturing process are given in table below.

Parameters	Units	Type - 1	Type – 2	Type - 3
Internal kiln width	m	2.62	3.04	3.45
Useful car width	m	2.42	2.83	3.23
Car length	m	1.4	1.4	1.4
Useful car length	m	1.38	1.38	1.38
Useful loading height	m	0.8-1.1	0.8-1.1	0.8-1.1
Useful car area	m^2	3.35	3.92	4.48
Kiln length	m	45-90	45-100	60-110
Maximum temperature	oC	1350	1350	1350
Indicative firing cycle	Hours	10-14	10-14	10-14
Indicative specific consumption	Kcal/kg	1100-1300	1100-1300	1100-1300

Roller kiln

In such type of kiln the product movement is governed through silicon carbide based roller. It is a continuous kiln where in the product flow is continuous though different temperature zones. Controlling of is mostly though temperate based controlled installed in different temperature zones.



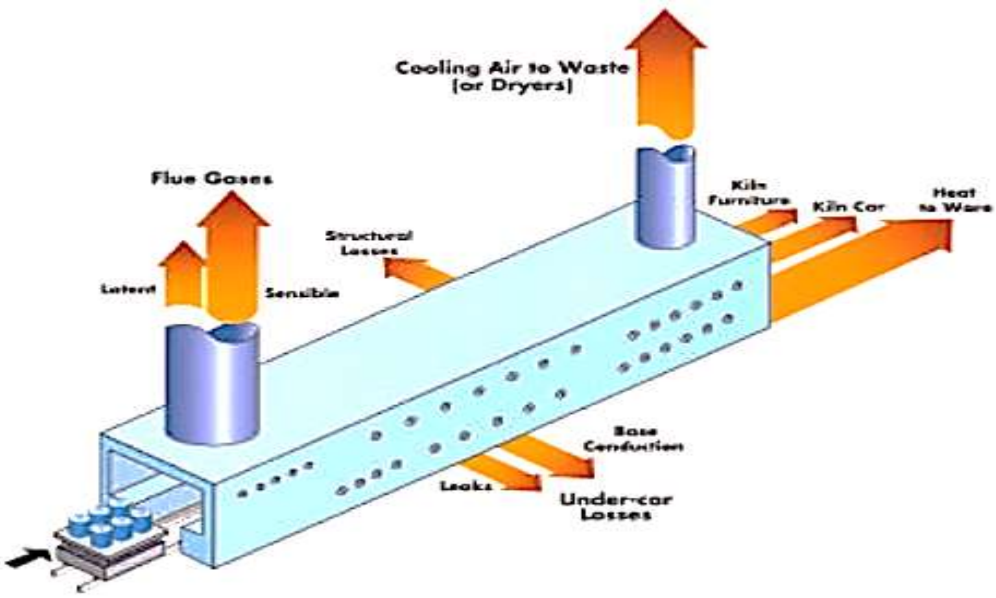
In ceramic tiles manufacturing process, there are different types of kilns but the most appropriate and the most efficient kiln is the roller kiln. This type of kiln is continuous firing kiln with ceramic rollers which transport ceramic tiles at different firing temperature with uniform temperature distribution. Usually the temperature in the inlet does not vary significantly with the outlet of the preheating zone and the temperature is usually highest at its 3rd quarter's section. The temperature of the kiln outlet is also control to prevent thermal shock which may result to breakage of resulting tiles.

Table 5.1.1: Basic kiln details

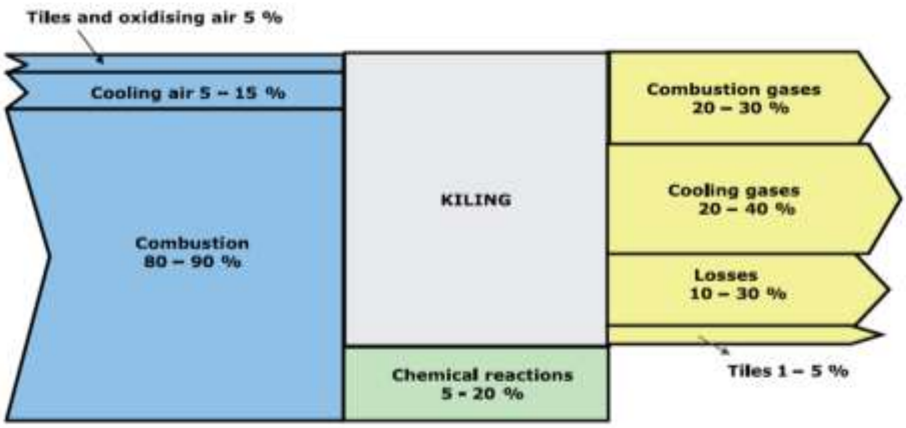
Parameters	Units	Type 1	Type 2
Maximum temperature	^{0}C	1250	1250
Channel width	m	2.6	2.85
Optimum load width	m	2.36	2.6
Indicative length	m	65-180	75-200

4.1.2 Heat balance of kiln

Heat balance of the kiln is a mean to determine the thermal efficiency of the system and compare the relative heat losses. By making comparison with an identical process, areas of inefficiency can be identified, where a change in operational control or equipment could lead to improvement in thermal efficiency of the kiln.



It may be observed that about 50% of the energy is lost through the kiln combustion flue gas and cooling gas stacks. In the present scenario the residual heat of the gases from the cooling stack is mainly reused. Since these gases consist of air without pollutants result from the direct contact of the air used to reduce the tile temperature in the cooling zone. Other losses like radiation, losses due to composition of fuel accounts for about (10 to 30%). The heat losses clearly indicate significant potential to reduce the consumption of energy resources as well as scope to improve the competitiveness of the ceramic sector.



5.1.3 Energy conservation and technology options

This section provides detailed assessment of appropriate energy efficient (EE) technologies that would lead to improvement in the performance of kiln and its associated equipment. In the ceramic manufacturing process, kiln account for about 60-70% of the total primary energy consumption in the form of thermal energy. Hence it is one of the focus areas for application of new and efficient technologies. The efficiency of the kiln depends not only on its design parameters but also on operation and requirements for uniform heating.

Characteristic diagram of energy optimization, maintenance practices and control system in kiln

The basic concepts of energy conservation in kiln include optimization of combustion, rationalization of heating and cooling, minimization of structural heat losses and recovery of waste heat in flue gases.

The following section provides an overview of technologies that can play a vital role to optimize energy consumption, temperature profile and other operational aspects to improve the quality of the end product.

4.1.4 Energy conservation of thermal energy

Considering the fuel reserves and increasing competition, it is essential to adopt energy conservation measures to improve overall efficiency, reduce operating cost/production cost and minimise the load on energy resources. The efficiency of a kiln will depend on how efficient the combustion system is and secondly how best the generated heat is utilized. Use of standard and good quality fuel improves overall performance of the firing system. Around 5 - 15% energy saving is possible from kilns used in ceramic industries. Some of the potential energy conservation measures (ECMs) for thermal system are listed below.

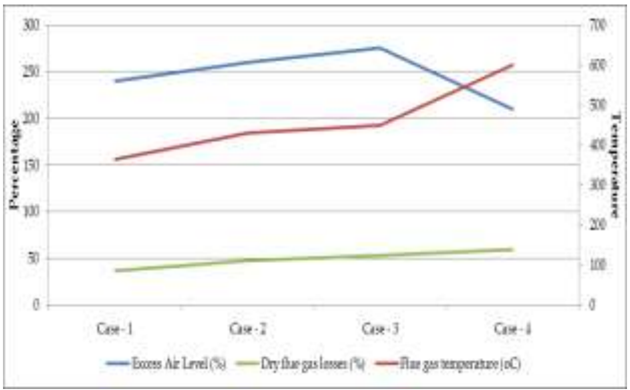
- Optimum kiln design to ensure capacity utilization to the tune of 98%
- Use of optimum product thickness to reduce heat load for sintering
- Complete combustion with minimum excess air.
- Proper heat distribution.
- Operating the kiln at desired temperature.
- Reducing heat losses from the openings.
- Minimizing wall losses by improving kiln insulation.
- Waste heat recovery from fuel gasses and utilization for drying green products
- Control of Chimney draught and kiln pressure
- Use pre-heating of spray dryer input slurry either solar or electrical heat pump
- Biomass / briquette firing in hot air generation
- Fuel switch over with better option in spray dryer
- Switching to continuous type kilns from intermittent type
- Adopting best operating practices including optimizing of excess air levels
- Use of hot air from cooling zone to preheat input material
- Energy efficient burner that can handle pre-heated combustion air at higher temperature
- Arresting air infiltration in kilns and spray drier system
- Use of lubricants and proper maintenance

Application of ECMs and absolute energy saving would largely depend on the base case scenario and relevant parameters likes operating efficiency of equipment, operating hour, operating load, landing fuel price etc. Some of the applications of ECMs are described below.

Air to fuel ratio control in combustion system

Kilns are important segment in ceramic industries and accounting for about 50-65% of energy consumption. Various operating parameters such as temperatures, draft, retention time and material arrangement, etc. may vary with the type of kilns used. Best operating practices are employed to reduce SEC level of a kiln. The operating parameters of kiln along with associated auxiliaries must be maintained appropriately close to design/standard values. BOPs have significant influence on energy use and changes in operating practices within the limitations of kiln design and associated equipment may help in reducing specific energy consumption.

Monitoring of operating parameters and periodic maintenance are essential elements for achieving optimum performance and energy use. It is significant to monitor the performance of kiln parameters in order to identify the need for careful attention for maintenance which can help to sustain efficient use of energy. In addition to regular maintenance and fine-tuning/ calibration of associated control system, it is also recommended to undertake rigorous monitoring of kiln on a regular basis. The plant may prepare schedule for examining the set points and calibration of the kiln control system as well as the auxiliaries. The recommended period for the calibration is generally 6-12 months depending on the sensitivity of the system/sensors used and the level of the periodic maintenance schedule adopted. Such type of practices would help operator/supervisor to analyze the specific energy use and also indicate the deteriorations or improvements in performance. This section provides the O&M practices essential to be followed and BOPs that are applicable for different types of kiln.



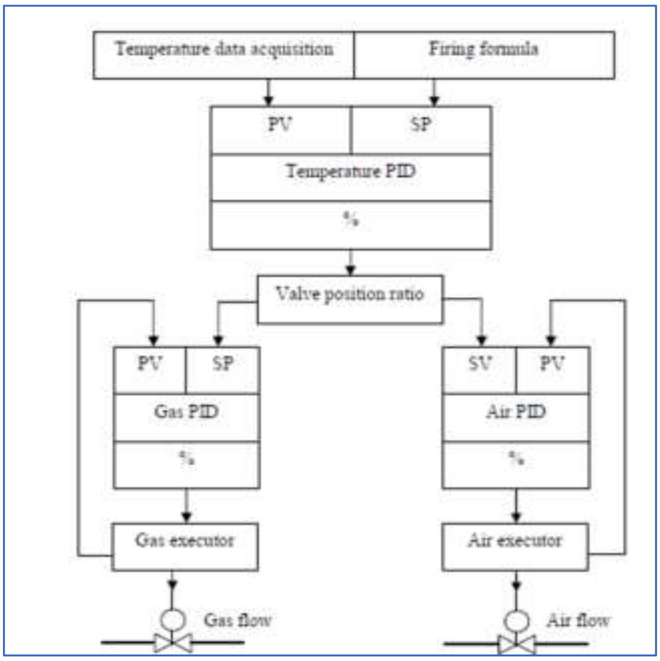
Excess air vs dry flue gas loss

More the air is used to burn the fuel, more is the heat wasted in heating air. Air, slightly in excess of ideal stoichiometric (or theoretical) fuel to air ratio is required for complete combustion and to reduce NOx emissions; it is dependent on the type of fuel. However, excess air beyond the optimum range (an efficient natural gas burner however requires 2% to 3% excess oxygen, or 10% to 15% excess air in the flue gas, to burn fuel without forming carbon monoxide) may substantially decrease combustion efficiency as it leads to generation of excessive waste gases. The effect of excess air level and flue gas temperature on dry flue gas losses is shown in graph

The relationship between the air-to-fuel ratio and wasted heat energy provides a basis for control system design. In most of the cases, real combustion processes have inadequate mixing of air with fuel. Also, the gases tend to flow so quickly that the air and fuel mix have limited contact time in the combustion zone. As such, if air is fed in exact theoretical or stoichiometric proportion to the fuel, it will still lead to incomplete combustion. Automatic burner assembly generally performs in a manner similar to the graph. The cost associated with operating at increased air-to-fuel ratio is the energy wasted in heating additional air volume. Yet, if the air-to-fuel ratio is decreased, losses due to incomplete combustion and emission will increase rapidly.

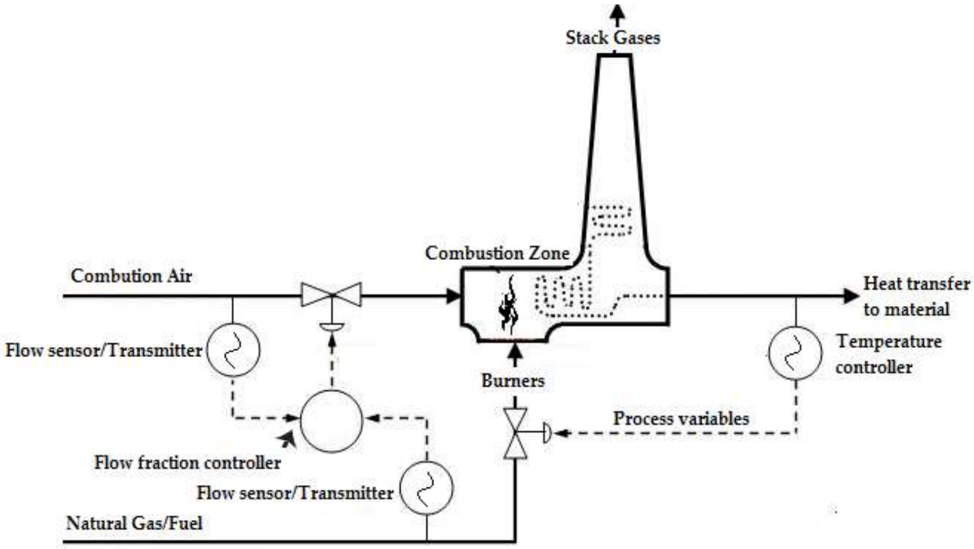
Too Little Air Increases Pollution and Wastes Fuel	Too Much Air Wastes Fuel
If the air-to-fuel ratio is too small, there will not be enough oxygen available to completely convert the hydrocarbon fuel to carbon dioxide and water. Too small air-to-fuel ratio leads to incomplete combustion of fuel. As the availability of oxygen decreases, noxious exhaust gases including carbon monoxide will be formed first. As the air-to-fuel ratio decreases further, partially burned and unburned fuel may appear in the exhaust stack, often revealing itself as smoke and soot.	The issue that makes operation of a combustion process so interesting is that if feed air to the combustion zone is high (if the air-to-fuel ratio is too high), waste of fuel, though in a wholly different manner. Once enough oxygen available in the burn zone to complete combustion of fuel, it would have addressed the pollution portion of combustion chemistry equation. However, any air fed to the process above and beyond that amount becomes an additional process load to be heated.
Incomplete combustion also means wasting expensive fuel. Fuel that does not burn to provide useful heat energy, including carbon monoxide that could yield energy as it converts to carbon dioxide, literally flows up to exhaust stack as lost profit.	As the air-to-fuel ratio increases above that needed for complete combustion, the extra nitrogen and unneeded oxygen absorb heat energy, decreasing the temperature of flame and gases in combustion zone. As the operating temperature drops, less extraction of useful heat energy for intended applications.

Kiln thermal parameters controller comprises kiln temperature, pressure and atmosphere controlling. In different stages, the control act differently, in firing process, PLC control inverter adjust the combustion fan to change air flowing in air hose. Electric valve of fire nozzle is set by numerical program to setup kiln atmosphere during heating process.



In the cooling stage, NG is shut down and each fire valves/nozzle is closed automatically. The temperature controller switch to the cooling control mode and the system enters cooling stage. In this period, air general pipe is controlled by opening degree.

Fire nozzles are divided into two groups. In order to reduce cost, temperature valve position automatic control is used as shown in Figure. Each gas general hose has gas solenoid valve



Typical air-to-fuel control system

and each group of gas general hose and combustion general hose is installed with electric executor. This compares the air-fuel ratio practical value (PV measured by thermocouples) with set value (SV) and controls gas executor and combustion executor by PID regulator. Temperature PID controller controls firing by controlling air flow and gas flow which are accomplished by the opening degree of combustion air valves and gas valves.

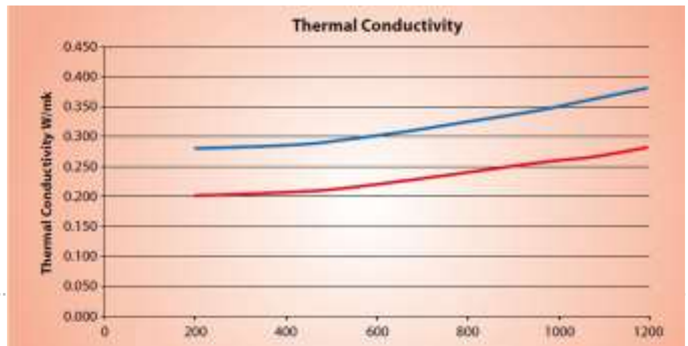
Benefits of combustion control

- Reduce excess fuel consumption.
- Reduce blower power consumption
- Increases exhaust temperature
- Give higher benefits in preheated combustion air as well as in dryer applications

Reduction of the excess air flow rate leads to a reduction in kiln energy consumption, though this operation must be performed with care, because other kiln operating parameters could be affected. It has been experimentally verified that 2% reduction in the oxidising air flow rate entails a decrease of the order of 5% in the natural gas flow rate.

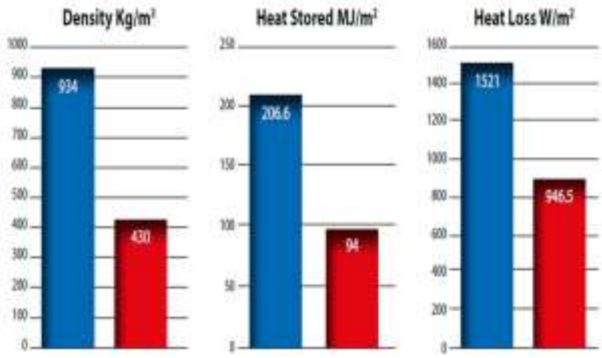
Use of low thermal mass material

Heavy refractory cars and saggers are generally used for carrying ceramic products inside the kiln. The dead weight of the refractories is quite high (around 24%). These refractories which



do not take part in reactions in formation of ceramic products, are subjected to alternate heating and cooling cycles, thereby losing substantial portion of heat input. These heavier refractory cars and saggers can be replaced effectively with low thermal mass cars and decker plates (23 – 24 % weight reduction is possible), which would help in reducing heat losses substantially. The estimated energy saving with use of low thermal mass cars is about 5-10%.

- Use of low thermal mass for kiln cart to **reduces the thermal weight** of the kiln considerably
- Weight reduction in kiln car saves significant amount of energy and also **improve material to car weight ratio**
- Reduces excess the **thermal energy storage** in the kiln furniture (**Roller**)
- Ultralite insulating material with supporting block gives proper support and increase the strength of the kiln base
- Replacing refractory bricks with hollow ceramic coated pipes at the supporting pillars for holding racks
- Dead weight can be cut down to 15 to 25% of the existing weight

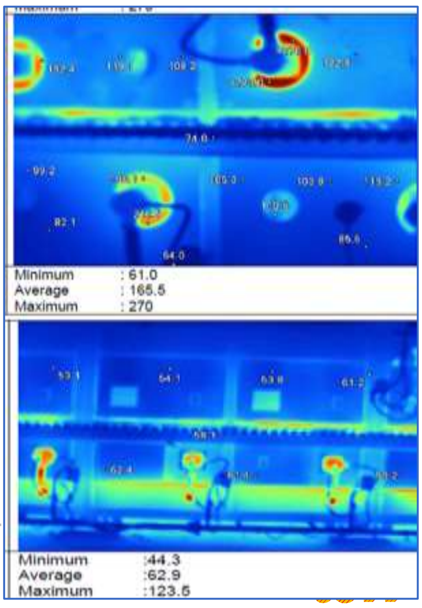


Advantages of ultralite insulating material

- High open porosity
- Low thermal mass
- Low permeability
- Low thermal conductivity
- Low bulk density
- Lightweight

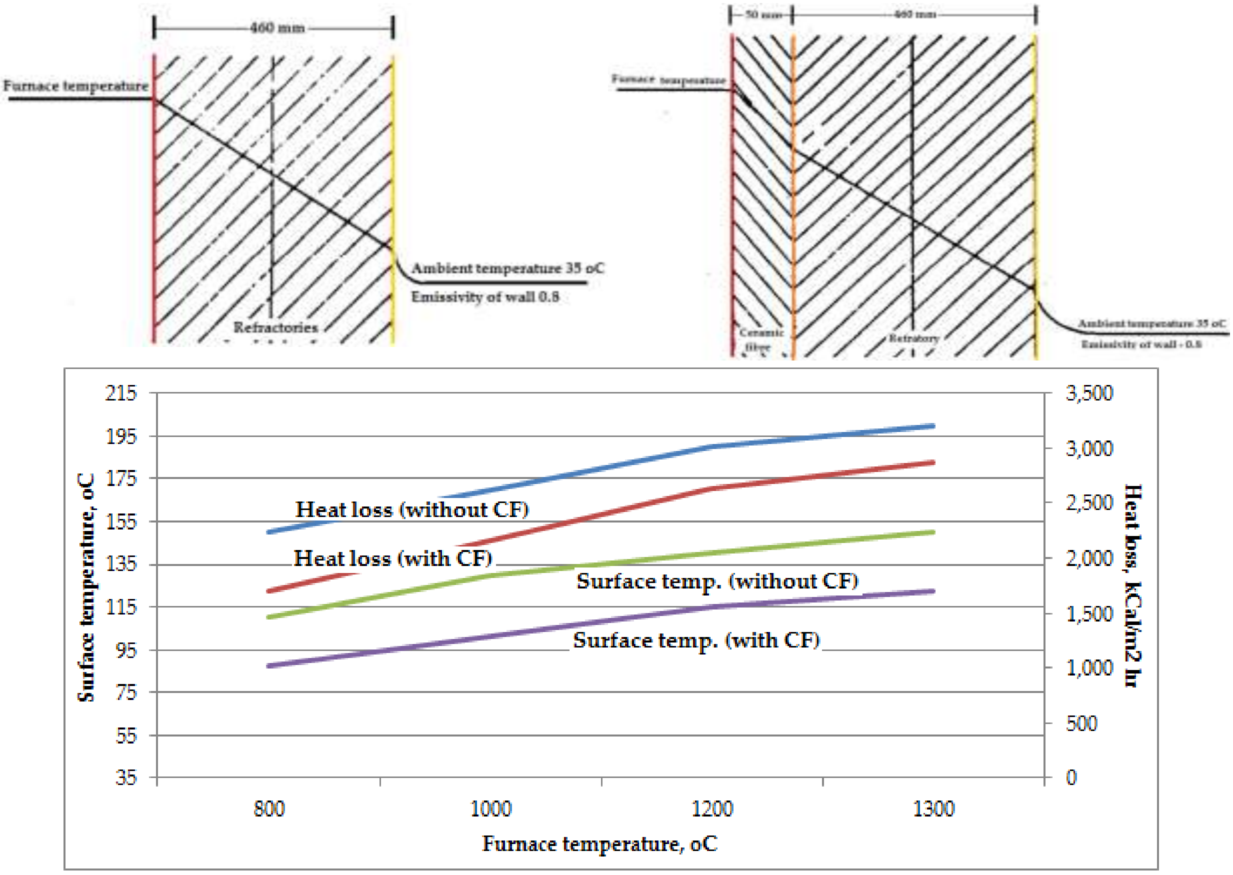
Improved insulation and refractories of kiln

The efficiency of a kiln is directly dependent of the method of combustion and heat stored within the structure. Apart from the dry flue gas losses, a substantial amount (8–13%) of heat is also lost from walls and material charging and discharging ends. The heat loss from structure can be divided into (i) radiation loss through openings and surface of the body, (ii) loss through roller/car, (iii) heat accumulation loss to internal insulation and supports composing the body. The heat accumulation loss can be ignored for a continuous operation kiln having minimal change in the operating temperature.



Improvement in the radiation heat loss from surfaces can be achieved by reinforcing its insulation. This includes (i) covering of internal wall surface with ceramic fibre insulation, and (ii) covering external wall surface with ceramic fiber or rock wool insulation.

The temperature gradient i.e. difference between the hot face temperature (hot face temperature is the temperature of the refractory surface in contact with the flue gas or heated combustion air) and surface temperature will be a critical factor for reduction in heat loss by reinforcement of insulation. The hot face temperature is used to determine refractory or insulation thickness and heat transmitted. The design temperature is used to specify the service temperature limit of refractory materials.



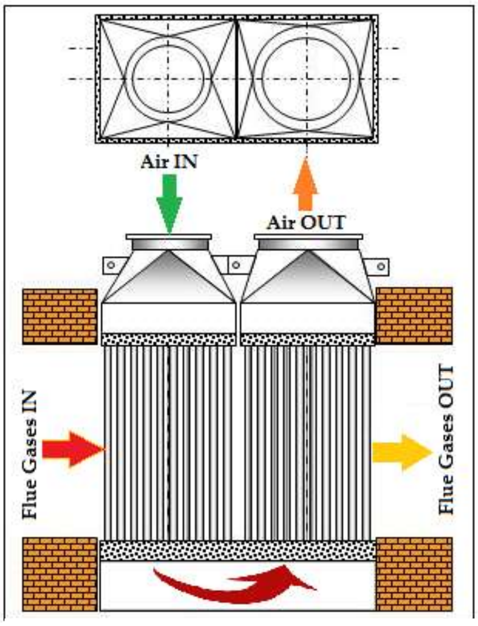
Effect of insulation in a kiln: Heat loss vs surface temperature

Use of better insulation material would further help in improving the thermal efficiency of kilns. The overall energy saving potential of kilns is about 2–3%.

Waste heat recovery in kiln

In the existing practices, the quantity of heat taken away from a kiln by high temperature flue gases is quite large. This can be reduced by adopting two methods, one is to reduce the volume of exhaust gas, and the other is to reduce the temperature of exhaust gas. The former is optimization of air-fuel ratio. The second method is through recovering waste heat available in outgoing flue gas. One of the conventional, economical and convenient methods is use of centralized recuperator system for preheating of combustion air.

Recuperator is a mechanical device in which heat exchange takes place between the flue gases and the combustion air through metallic or ceramic walls. Ducts or tubes carry the air for combustion for preheating whereas the other side contains the waste heat (flue gas) stream. There are many types of the waste heat recovery recuperator depending on the application. The most common types of recuperator include metallic radiation recuperator, convection recuperator, hybrid recuperator and ceramic recuperator.



Convection recuperator (tube heat exchanger)

The most commonly recuperator used is convection type. Convection recuperator (also referred to as "flue" or "canal" recuperator) is tubular heat exchangers that utilize convection heat transfer to preheat combustion air for the purpose of saving fuel. By recovering heat from the hot waste gas exiting the kiln and transferring it to combustion air feeding the burners, fuel usage can be reduced up to 5-15%.

Use of energy efficient & high preheated air temperature burners

Use of high velocity energy efficient burner's and high preheated air temperature burners further improves kiln efficiency. Observed maximum preheated air temperature in the kiln in Morbi cluster is 250 0C, whereas current burner technology accepts air preheat temperature upto 600 0C. This offers good opportunity for high temperature waste heat recovery. Higher the combustion air temperature, lower will be the fuel consumption in the kiln.
(Source: Manual on Energy Conservation Measures in Ceramic Industry, BEE SME Programme)

4.1.5 Other key recommendations/tools

Optimum capacity utilization

The capacity utilization (commonly known as "loading") of a kiln is one of the key factors affecting the efficiency. The loading of a kiln includes preparation of material to feed, amount of material placed, arrangement inside the kiln and the residence time inside the kiln.

Optimum arrangement of load

The feedstock on the hearth should be arranged in such a manner that:

- ✓ It receives maximum amount of radiation from the hot surfaces of the heating chambers and flames
- ✓ Hot gases are efficiently circulated around the heat receiving surfaces of the materials

Stock should not be placed in the following positions:

- ☒ In the direct path of the burners or where impingement flame is likely to occur
- ☒ In an area that is likely to cause a blockage or restriction of the flue system of the kiln
- ☒ Close to any door openings where cold spots are likely to develop

Raw Material Processing

- ✓ Purchase the right materials, it will save the energy and costs that would otherwise have to be incurred to treat them in the unit
- ✓ Raw material is transported to the processing areas by conveyers: do not let the conveyor ON when there is no material to be transported.
- ✓ Fit timer switches on all the grinding machines so that they automatically switch
- ✓ off after processing of the raw material

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

5.1 Introduction

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

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

5.1.1 Average rate of return (ARR)

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

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

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

Guideline- Invest in a project with higher ARR

5.1.2 Return on investment (ROI)

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

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

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

Discounted value of energy savings

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

Guideline: Invest in a project with higher ROI

5.1.3 Simple payback period (SPP)

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

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

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

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

The limitations of SPP tool are:

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

Guideline: Invest in a project with small SPP

5.1.4 Net Present Value (NPV)

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

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

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

Where,
FV – future value of energy savings
i - interest or discount rate or hurdle value
n – number of years under analysis

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

NPV = total PV- Initial cost of investment

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

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

Guideline:

NPV > 0 : Should be accepted
NPV = 0 : Should be accepted if the project has some strategic value

NPV < 0 : Should not be accepted

5.1.5 Internal rate of return (IRR)

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

The formula for IRR is

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

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

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

Guideline: Invest in a project with high IRR

5.2 Major financial schemes for MSMEs in India

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

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

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

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

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

5.2.1 National Manufacturing Competitiveness Programme (NMCP)

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

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

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

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

5.2.2 CLCSS Scheme

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

5.2.3 Credit Guarantee Scheme

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

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

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

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

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

5.3 Various credit lines and bank schemes for financing of EE

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

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

5.4 Preparation of detailed project report (DPR)

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

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

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

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

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

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

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

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

Table 5.4: Typical contents page of DPR

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

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

5.5 Step by step approach for loan application

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

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

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

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