सूक्ष्म, लघु एवं मध्यम उद्यम
MICRO, SMALL & MEDIUM ENTERPRISES

UNITED NATIONS
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GLOBAL ENVIRONMENT FACILITY
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ENERGY IS LIFE
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Bureau of Energy Efficiency

Ministry of New and Renewable Energy
सत्यमेव जयते

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

A GEF-UNIDO-BEE Project

Best Operating Practices

Khurja Ceramic Cluster

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Developed specifically for units in the MSME cluster selected under GEF-UNIDO-BEE Project.

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Conceptualized by PMU, GEF-UNIDO-BEE Project

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सत्यमेव जयते

ENERGY IS LIFE
BEE
CONSERVE IT

ऊर्जा दक्षता ब्यूरो
(भारत सरकार, विद्युत मंत्रालय)

BUREAU OF ENERGY EFFICIENCY
(Government of India, Ministry of Power)

FOREWORD

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

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

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

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

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

New Delhi (Abhay Bakre)

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

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ABOUT THE DOCUMENT

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

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

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

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CHAPTER 1: Introduction

1.1. Objective

Energy efficiency can be a potent weapon to address the issue of increasing energy costs as well as reducing the production cost in manufacturing industry and achieving business sustainability. Energy efficient operation of processes and equipment, and conducting periodic planned maintenance in industries are some of the most cost effective methods for improving energy efficiency. Besides these measures, the need is to have trained manpower that can run the plant in a seamless manner by forecasting process / equipment improvement and needs well ahead of any impending break-down.

This can be achieved by simply following some best operating practices which require no or very low investments. This needs to be employed right from equipment to process level, and the plant staff needs to be well trained to effectively follow and carry out these best practices in day-to-day running of the plant. The major benefits of adopting and following good practices are:

- Manpower is well trained to identify equipment / process flaws and taking remedial actions
- Low cost with negligible investment
- Easily installed by in-house personnel
- Faster return on investment
- Less complex engineering analysis

1.2. Approach

This best operating practice manual is focused to discuss the common operating, energy efficiency practices and technologies for major energy intensive equipment / processes commonly used by most of the units; and that can be followed and implemented at the component, process, system, and organizational levels in various units within the cluster. The information contained in this manual is intended to help the plant managers to reduce energy consumption in their units in a cost-effective manner, while meeting regulatory requirements and maintaining the quality of products manufactured.

Given the dynamic nature of the production process followed in the units, this guide addresses most common operating problems, issues and bottlenecks (with regards to energy efficiency) being faced by the units within the cluster. To overcome those challenges, it provides notes on best operation and maintenance practices that can be followed. Once implemented, these practices will help not only in improving the operating energy efficiency levels of these equipment / processes, but also in reducing operational downtime.

Although the recommendations in this manual are more of a generalized nature, individual plants can draw references from them to suit their respective production practices.

1.3. About Khurja Ceramic Cluster

The ceramic industry of Khurja cluster consists of 3 distinct types of units, manufacturing insulators, pottery and crockery wares. Although the final products of all the 3 types of units are different, their production process is almost similar. The figure below shows the main products manufactured by various MSME units of Khurja ceramic cluster:

Figure 1: Different types of products manufactured by ceramic units of Khurja – Insulators, Pottery, Crockery

Although, the size of the units may differ, the production process followed by most of them is similar in nature; and is shown in the figure below:

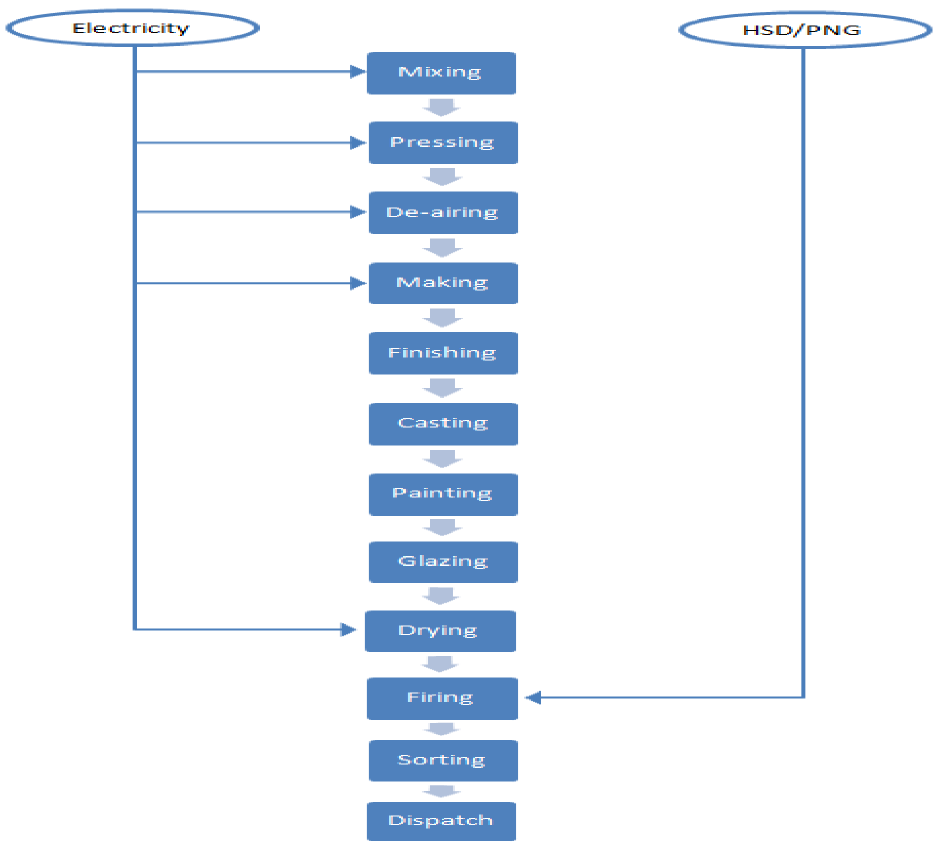

Figure 2: Process flow

Some of the common practices that can be followed by the units are:

- Monitoring of energy consumption by each equipment and maintaining a log book for the same
- Monitoring of electrical parameters for effective load management
- Good housekeeping practices along with periodic checks and maintenance of equipment
- Providing proper insulation to equipment like kilns etc.

Normally most of the plants did not take proper housekeeping measures to upkeep these equipment, which results in their poor operating efficiencies. By adopting better maintenance and housekeeping practices, each unit can reduce its energy bills by at least 3 to 5%. This does not require high level of engineering competency or complex engineering designs, and can be implemented with very minimum or no investments. Simple measures like recording and maintaining log-books of fuel consumption, material input to furnace, identifying and plugging leakages in compressed air pipelines, periodic and filters of air-compressors, proper lubrication of moving / rotating equipment etc. can be implemented even by un-skilled workmen of the shop floor level.

CHAPTER 2: Best Operating Practices – Tunnel Kiln

In ceramic industry, kiln is one of the main energy consuming equipment. If the total plant energy consumption scenario is taken into account, kilns account for about 85% of the total energy. This figure clearly indicates that through proper energy conservation and better operating practices the energy consumption in kiln can be brought down to a considerable limit. The figure below shows a tunnel kiln used in Khurja ceramic cluster.

Figure 3: Tunnel Kiln in operation

Some of the suggested best operating practices that can be employed are:

2.1. Measurement of fuel consumption

Accurate measurement of fuel consumption of the kiln and maintaining proper log of records of the same on a shift / daily-basis is essential for efforts to improve operating efficiency of the kilns. Without records of fuel consumption, any effort towards efficiency improvement shall not bear fruits, as fuel consumption is the major energy input to the kiln.

Presently in Khurja, no flow meters are installed at any of the kilns. In absence of flow meters, the fuel (HSD) consumption is measured on a daily basis by measuring the level of the day tanks of individual kilns (or the fuel tank common for the plant – for both kiln and DG sets) using dip scales.

Presently, fuel consumption records are not maintained for the kilns. None of the plants using HSD as kiln fuel has installed online flow meters. However, the plants using PNG as kiln fuel have flow meters installed by the PNG supplier. The plants using HSD use the fuel purchase records to calculate the monthly and yearly fuel consumption.

In the absence of online flow meter, it is important that at the start of the day, the kiln operator should ensure that the day-tank of the kiln is filled (with fuel) to the adequate level and the same should be marked using dip stick. After intervals of one or two hours or on a shift / daily basis, whichever is convenient based on fuel consumption history of that particular kiln, the final fuel level reading must be taken and fuel consumption calculated. Fuel consumption for each hour or for each shift needs to be recorded and fuel consumption reports with respect to production (for the particular duration) for the kiln needs to be made and specific fuel consumption per ton of production needs to be calculated. Based on these reports, best performance of kilns needs to be drawn and the kiln parameters maintained in achieving the best performance need to be recorded. These parameters can be then made the benchmark parameters to be set for achieving best operating specific fuel consumption.

Apart from above, it is also recommended to install online flow meters for the individual kilns. This will result in reducing measurement errors of fuel consumption of individual kilns using dip scale method.

Figure 4: Fuel flow meter

2.2. Measurement of kiln production

Along with the fuel consumption, the material output from kiln in ton/hour or ton/shift also needs to be measured and monitored to calculate specific fuel consumption per unit of production. The parameters that need to be measured monitored and recorded in the log books on an hourly / shift basis are:

- Fuel firing rate(liters/hour or SCM/hour)
- Weight of material input (kg)
- Temperature of various zones of kiln (deg C)

The production values have to be recorded both on the basis of weight and also on the number of pieces coming out of the kiln. In Khurja, same kiln is used to heat materials of various sizes, shapes and weights based on the various types of products manufactured. The fuel consumption for different types, sizes and weights of products heated in the same kiln shall vary and so shall the kiln efficiency. Along with the weight of materials loaded, the dead weight of the kiln car also needs to be measured and recorded.

As a general practice in the ceramic units, the total weight of products heated in the tunnel kilns is not meticulously measured, but rather the value of total weight of products heated is generalized based on the past experience of weights of products of similar shapes, sizes and specifications.

This is not a good operating practice and it is recommended that the number of products (materials) coming out of the kiln be manually counted. Also, the weight of a sample number of materials be measured and the average weight of the sample be taken to arrive at the total weight of materials heated.

Proper recording of production from individual kilns will also help in estimating the operating efficiencies of each of them. Based on the same, the reasons for good or not-so-good performance of all the kilns can be investigated more precisely. Various factors like inefficiency or slackness on the part of the workmen operating the kilns, improper loading of materials on the kiln car, too much heat loss due to poor insulation, dead weight of the kiln car, late response by the operator to lower the fuel flow to any auxiliary burner when temperature of a particular portion / zone of the kiln has been reached, etc. could be the reasons for poor operation of kilns or high fuel consumption by the kilns. Remedial actions for the reasons resulting in poor performance of a kiln can then be taken to improve its efficiency.

It is recommended to install calibrated load cells to measure the weight of the materials at inlet and outlet of the kiln. Load cells must also be kept for measurement of the dead weight of the kiln cars on which the ceramic materials are loaded.

2.3. Proper loading of the kiln

The kiln should be loaded close to its maximum capacity due to the following.

- If the kiln is under loaded, a smaller fraction of the available heat will be taken up by the material and therefore efficiency will be low.
- Kiln loading should be at-least above 60%. In case production is low, due to market conditions or other, then to maintain high loading percentages in kilns, two separate kilns of different capacities (one big and one small) can be installed and may be used accordingly during low and high demand conditions.

Proper loading of the charge on the kiln car is desirable because:

- It receives maximum amount of radiation from hot surfaces of the heating chambers and the flames produced.
- The hot gases are efficiently circulated around the heat receiving surfaces.

2.4. Maintaining optimum excess air for combustion

It is necessary to maintain optimum excess air levels in combustion air supplied for proper combustion of fuel. The excess air level in combustion air is calculated based on the oxygen content in the flue gases. The theoretical air required for combustion of any fuel can be known from the ultimate analysis of the fuel. All combustion processes require a certain amount of excess air in addition to the theoretical air supplied. Excess air supplied needs to be maintained at optimum levels, as too much of excess air results in excessive heat loss through the flue gases whereas too little excess air results in incomplete combustion of fuel and formation of black colored smoke in flue gases.

In most of the tunnel kilns in Khurja, fuel is fired with too much of excess air. This results in formation of excess flue gases, taking away the heat produced from the combustion and increasing the fuel consumption. This also results in the formation of excess GHG emissions.

Presently, there are no proper automation and no excess air control system installed in the tunnel kilns to maintain the optimum excess air levels. Fuel is fired from the existing main burners and also from the auxiliary burners. No air flow control mechanism is in place for maintaining proper combustion of the fuel. It was found that the oxygen levels in flue gases of tunnel kilns using both PNG fired and HSD fired in various units were above 10% which indicates high amount of excess air supplied than required. This also indicates high amount of heat loss due to dry flue gases in the kilns. Without proper control systems in place, adequate excess air levels cannot be maintained.

Kiln operation is dynamic in nature and based on various parameters (like weight of material, weight and material of kiln car, temperature attained in kiln, insulation status of the kiln, etc.) the excess air levels to be supplied by the FD fan (blower) changes continuously. Presently, combustion air being supplied in kilns is controlled by damper, but this results in pressure drops in the combustion air ducts thereby increasing power consumption by the blowers. So, damper control for regulating combustion air supplied is not a good solution.

It is recommended to install on-line oxygen sensor in the flue gas path (in chimney) and use a PID controller and VFD on the FD fan. The online oxygen sensor will measure the oxygen level in the flue gas and send signal to the FD fan through PID controller. Based on the signals received, the FD fan will auto regulate its speed based on the VFD control, thereby regulating the flow of combustion air required by the kiln at a particular point of time.

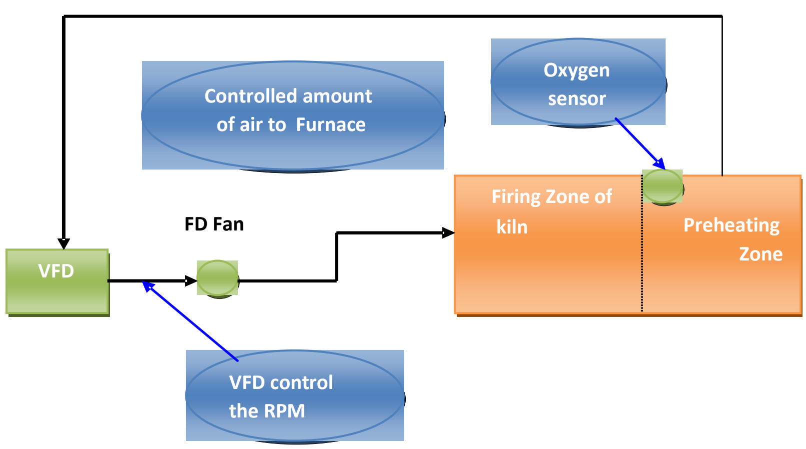

Figure 5: Excess air control in kiln

2.5. Maintaining adequate kiln temperature

In Khurja ceramic cluster, continuous pusher type tunnel kilns are in operation, which use HSD, FO or PNG as the fuel. The kilns are used to heat the raw materials (usually, ceramic pottery, crockery or insulators) to about 1200°C.

It has been observed that a number of units did not have temperature control system in the kilns. Fuel is fired continuously and the combustion air is supplied by the FD fan, but there is no system to monitor and control their flow. Thermocouples are installed at various locations in all the 3 zones of the kiln – pre-heating zone, heating zone and cooling zone. The temperatures measured by the thermocouples are displayed on the main operating panel of the kiln, but no automatic systems to reduce / increase fuel flow through burners or reduce / increase combustion air flow are installed in most of the units.

If the measured temperature at some part of the kiln goes high or low as indicated by the temperature indicator panel, the kiln operator would manually increase or decrease the fuel flow from the auxillary burner of that area using its turn-down ratio. The kiln would be operated in that condition for a certain period of time till the temperature of that location decreases to certain set limits when again the operator would switch the burner fuel flow to maximum to again attain the set temperature.

This is not the best method because if there is any delay on the part of the operator to switch on or off any of the burner(s), when temperature of any particular area was reached and exceeded certain set limits, it will result in fuel firing by that burner at the same rate although it is required to fire fuel at a reduced flow rate. This will cause increase in fuel consumption and also over-heat the material, thereby causing damage to the quality.

It is recommended to install proper temperature monitoring and control system in the kilns by linking the thermocouples and temperature indicator system with fuel firing and air flow system using PID controllers. In such a system, once the requisite kiln temperature is reached in some area, the fuel and combustion air supply to that area can be reduced to desired levels, and later on increased when the temperature falls below a certain level. This will also help to determine if the material is under-fired or over-fired, thereby maintaining the desired quality of the material.

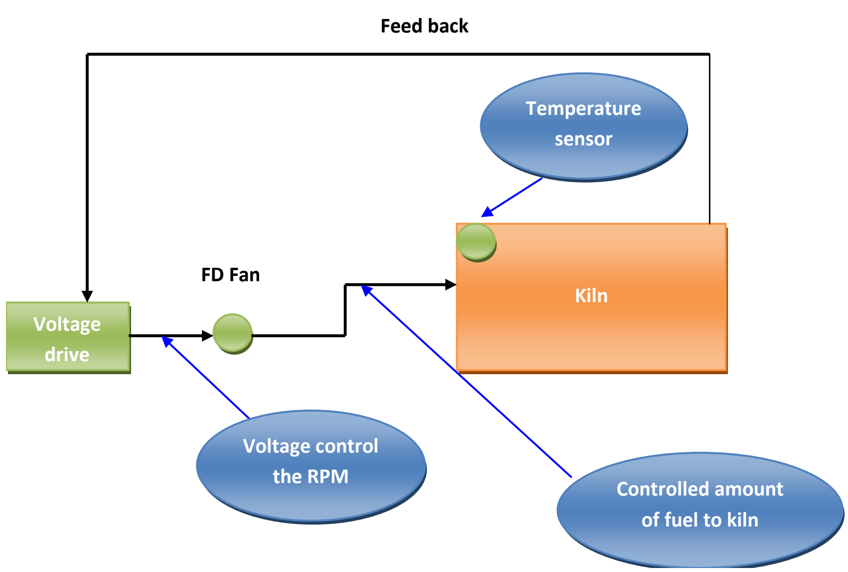

Figure 6: Temperature control in kiln

2.6. Maintaining adequate surface temperature of kiln

In most of the tunnel kilns, the surface temperature is in the range of 90°C (mainly on the surface of heating zones of the kilns) which is high and it should be brought down to 45-50°C to reduce heat losses due to radiation and convection from kiln surfaces, and thus increase kiln's efficiency. Providing adequate refractory (**firebricks**) and insulation (**glass wool**) to the kiln and proper maintenance of the same helps to retain the useful heat within the kiln and avoid heat loss due to radiation and convection from the kiln's walls and roofs.

Proper insulation is achieved by providing a layer of material with low heat conductivity between the internal hot surface of a kiln and the external surface, thus keeping the temperature of the external surface low. The choice of an insulating material must be based on its ability to resist heat conductivity on the highest temperature it can withstand. Firebrick is the most common form of refractory material. Glass wool is the most common insulation provided on kilns and they are wrapped with aluminum foils providing additional layer of insulation.

Figure 7: Good insulation in tunnel kiln

2.7. Reduction in losses due to cracks and other openings in kilns

Opening loss mainly includes the radiation and convection heat losses through small openings in the kilns. The loss can be minimized by periodic checks on walls, cracks and other damages once in every 2-3 months. Air curtains can be installed at the charging and discharging doors of kilns in order to reduce the heat loss from the charging and exit doors of the kilns.

2.8. Use of separate blowers for combustion and air curtains

In Khurja cluster, each kiln have 2-3 air curtains installed in the pre-heating and cooling zones each. In the cooling zones, the air curtains are used to supply cold air (ambient) for cooling the materials which came out of the heating zone. In the pre-heating zone, the purpose of the air-curtains is to segregate that zone into areas of high heat and low heat; and also to prevent thermal shock for the materials entering the kiln which was at ambient temperature. The temperature of pre-heating zones varies from 200-600°C.

One common blower supplies ambient air for the air curtains as well as for combustion of fuel. Supplying both the airs (for air curtains and for combustion) using one common blower could not be termed as a good practice, as their flow and pressure requirements can vary based on the specific system requirements at any given point in time of kiln operation.

It is, therefore, recommended to supply the two different airs for different applications using two separate smaller sized blowers which will help in better control of the individual blower operation based on the system requirements at different times of kiln operation.

2.9. Installation of waste heat recovery units (WHR)

The hot flue gases coming out of the firing zone, traveled through the pre-heating zone. In this zone, the heat content in hot flue gases (800℃ near the firing zone or end of pre-heating zone and ~200℃ near the chimney or start of pre-heating zone) is used to pre-heat the ceramic materials. All the kilns use natural draft (absence of induced draft fan).

The flue gas temperature drops while travelling through the pre-heating zone because apart from the gradual drop in its temperature, the inflow of ambient air at atmospheric temperature (through air-curtains) also affects this drop. In the chimney (at start of pre-heating zone where the stock enters), the flue gas temperature is about 200 - 215℃ for various kilns. The heat content in this flue gas is low and could be used to pre-dry ceramic materials entering the pre-heating zone, which will help to increase productivity and also save energy marginally. Presently, this material is being dried under natural ambient conditions or by using ceiling fans.

Care should, however, be taken to design the pre-drying of materials in such a way so as to avoid any pressure drops in the flue gases since all kilns being operated in Khurja are of natural draft type. The following points should be taken into account while deciding to install a new pre-drying chamber

- The pre-heating zone is already designed as a recuperator for pre-heating ceramic materials before they enter the firing zone.
- The installation of an additional recuperator for pre-drying ceramic materials could lead to pressure drop in the flue gas flow.
- The presence of air-curtains (2-3 numbers) at various distance in the pre-heating zone, dilutes the heat in the flue gases in that zone. This results in low temperature of flue gas at chimney. The presence of air curtains in pre-heating zone is very much necessary from quality point of view, as this helps in avoiding thermal shock to the ceramic material entering the kiln.

2.10. Maintaining adequate kiln draft

It is desirable to maintain slight positive draft inside the kiln due to the points below:

- If negative pressures exist in the kiln, air infiltration occurs through the cracks and openings thereby affecting air-fuel ratio control.
- Neglecting kiln pressure results in problems of cold material and non-uniform material temperatures, resulting in production loss due to rejects.
- Slight positive pressure should be maintained in the kiln, as negative draft could result in leaping out of flames, overheating of the refractories (in firing zone) leading to reduced brick life, increased kiln maintenance.

CHAPTER 3: Best Operating Practices - Ball Mill

A Ball Mill grinds materials by rotating a cylinder with steel grinding balls, causing the balls to fall back into the cylinder and onto the materials to be grinded. The rotation is usually between 4 to 20 revolutions per minute, depending upon the diameter of the mill. Larger the diameter, slower will be the rotation.

Figure 8: Ball mill in operation

3.1. Media

Media size is a key factor in deciding the performance of the mill. As a general rule, the media should be 4 to 10 times the size of the largest agglomerate to have sufficient flatness for the hammer-like effect required. The most effective grinding will be accomplished by the smallest media, as it offers more contact per mill revolution. Larger media will have greater impact energy and may generate excessive heat in the mill if this energy is not efficiently consumed in the grinding action. However, this extra energy will be useful when large or tough particles are to be grinded. A mill must periodically be recharged. A bead that has lost half of its diameter has also lost 87.5% of its mass. Reduced mass sharply reduces the media's impact energy. Generally, three or more different sizes of media are used in the ball mills.

Good practice calls for mills to be filled from 45 to 55% of their total volume. To minimize excessive ball and shell wear, full charges (45 to 55%) or charges not less than 45% are recommended. At values lower than 45%, media tends to slip on the shell unless lifter bars are used.

Key properties of grinding media are size, density, hardness, and composition.

- **Size**: The smaller the media particles, the smaller the particle size of the final product. At the same time, the grinding media particles should be substantially larger than the largest pieces of material to be grinded.

- **<u>Density</u>**: The media should be denser than the material being ground. It becomes a problem if the grinding media floats on top of the material to be grinded.
- **<u>Hardness</u>**: The grinding media needs to be durable enough to grind the material, but where possible it should not be so tough that it also wears down the tumbler at a fast pace.
- **<u>Composition</u>**: Various grinding applications have special requirements. Some of these requirements are based on the fact that some of the grinding media will be in the finished product. Others are based on how the media will react with the material being grinded.

3.2. Material charge

For dry milling, it is generally recommended that a material charge occupying 25% of the mill cylinder will give the best results. This loading permits the grinding media to make effective contact with the material charge.

For wet milling, it is recommended that a minimum charge of 25% of total mill volume be maintained, with good results obtained by filling the mill from 30% to 40% of its total volume.

3.2.1. Critical speed of the Mill

If the peripheral speed of the mill is too much, it begins to act like a centrifuge and the balls do not fall back, but stay on the perimeter of the mill. The point where the mill becomes a centrifuge is called the "Critical Speed"; and the ball mills usually operate most efficiently at 65% to 75% of the critical speed. Normally, 70% of the critical speed is the nominal operating speed in which thorough mixing and crushing takes place. If the rotating speed is above or below the nominal operating speed, a variable frequency drive can be installed to the drive for regulating the speed of rotation which can reduce electricity consumption. The formula to calculate the critical speed of a ball mill is:

$$CS = \frac{76.63}{\sqrt{D}}$$

where CS = Critical Speed in revolutions per minute
D = inside mill diameter in feet

3.2.2. Initial conditioning of new mills

Pebble or ball mill lined mills must be “grinded” to remove loose or excess material. It is best to use a cheap material, such as a charge of fine sand and 50% water, or scrap product with the media charge for this operation, followed by a thorough rinsing. The time required is usually 1 to 5 hours. If the mill is not clean after one treatment, the cleaning operation should be repeated.

3.3. Mill cleaning methods

One of the most important factors in reducing batch contamination is the cleaning procedure. A good method for cleaning is to dump a moderate amount of solvent into the mill, run it for one minute, and then dump immediately to avoid settling out of solids. Several washes may be necessary to do the job. It should be noted that while cleaning a mill, the media and lining can wear excessively if the period of mill rotation during the cleaning is excessive. When cleaning the mill, it is advisable to keep the rotation time under one minute.

Points to be checked regularly for smooth operation of the ball mill:

- Where contamination is a critical problem, ceramic should first be run wet with grinding media plus sand for 8 hours or so, to knock lose or wear down any particles that might contaminate the first batch.
- Wear on interior surfaces of mill linings will be more evenly distributed, and result in longer mill life by reversing grinding direction of rotation on a regular basis.
- Fresh charges of new media should be left running in a mill with sand to condition the media prior to its first use to lessen the chance of contaminating the batch.
- The level of grinding media should be checked frequently. If it falls below operating level, the required grinding media should be added.
- About once a year the charge should be dumped and inspected. All grinding media which are excessively worn should be removed and replaced with new media. Added media should consist of the largest size initially used.
- An approximate indication of the rate of wear of a mill can be noted down by making a caliper measurement, using some fixed points on the outside surface of the mill for reference.
- When ball mills have obviously lost a noticeable percentage of their original wall thickness, cracking can be expected in a relatively short time. The application of a few lengths of tape around the circumference will ensure that the mill will not catastrophically break in two.
- When a ball mill has lost approximately 35% of its initial weight, it should not be used for unmonitored milling. This degree of weight loss indicates that it is nearing the end of its useful life.
- All lubricating points should be checked at least once every 4 hours. The temperature of the bearing grease should not be higher than 55°C, when the ball mill stays in operation.
- The temperature of transmission bearing and the reducer should not be higher than 60°C, when the ball mill stays in normal operation.
- The ball mill should operate smoothly without strong vibration and its motor current should not have abnormal fluctuations.
- The connecting fasteners should not be loose. The combined parts should not have oil leakage, water leakage and material leakage.

CHAPTER 4: Best Operating Practices - Filter Press, Diaphragm Pump and Pug Mill

Filter press, diaphragm pump and pug mill are the 3 equipment used in the ceramic units of Khurja for preparation of ceramic cakes before they are converted into desired shapes. The equipment and their best operating practices are described below.

4.1. Filter press

Filter press comprises a set of vertical, juxtaposed recessed plates, presses against each other by hydraulic jacks at one end of the set. The pressure applied to the joint face of each filtering plate must withstand the chamber's internal pressure developed by the sludge pumping system. This vertical plate layout forms water-tight filtration chambers allowing easy mechanization for discharge of the cakes.

Orifices feed the sludge to be filtered under pressure in the filtration chamber. They are usually placed at the center of the plates allowing a proper distribution of flow, right pressure and better drainage of sludge within the chamber. Solid sludge gradually accumulates in the filtration chamber until the final compacted cake is formed. The filtrate is collected at the back of the filtration support and carried away by internal ducts. The figure below shows the filter plate operation.

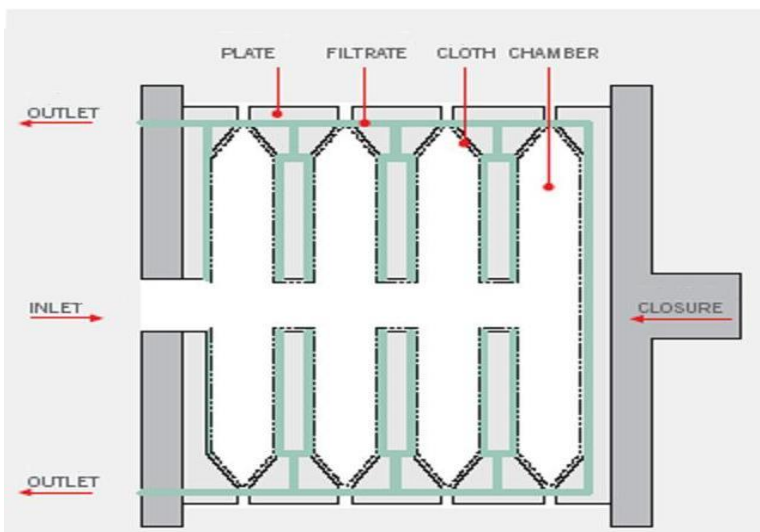

Figure 9: Filter Press

The following procedures can be followed to keep the filter press in good operating condition:

- ❖ Regularly check the joints, bearings, lead screws, gears and other components. Keep the assorted parts clean and lubricated to ensure flexible action.
- ❖ Regularly check the sealing surfaces of the filter plates to ensure smoothness and cleanness. Before pressing, carefully check the filter cloth to ensure that it is without fold, not damaged, and placed flat to guarantee the filtration effect.

- Frequently wash the filter cloth to ensure proper filtration process. Washing of filter cloth should be carried out after every 15-30 processing operations. For mid or larger units, this can be done using water sprayers at very high pressures (80-100 bar). Washing is synchronized with separation of plates.

4.2. Diaphragm pumps

The diaphragm pump, though having lesser annual energy consumption when compared to a tunnel kiln or a ball mill, is one of the most common and most neglected equipment in the ceramic units of Khurja. The diaphragm pump is used to supply the liquid slurry from the underground agitator tank to the filter press. There are many reasons for sub-standard performance of a diaphragm pump, including application demands, fluid composition, pump specifications, leakage, debris, and general wear and tear.

For **proper operation** of a diaphragm pump, it is necessary that the pump is placed on a firm, level foundation above the source of the liquid. This is necessary in order to check proper valve operation and pump performance. It is necessary to leave sufficient space around the pump for future servicing. Best pump operation is achieved by locating the pump as close as possible to the liquid source. Care must be taken that the pump does not exceed static discharge head abilities of the pumping unit.

While **starting the pump**, it is to be checked that the pump gear box, engine crankcase, and engine gear box are filled to the proper level. The diaphragm pump is normally designed to prime itself in a few minutes. High suction lifts will require additional time and will reduce the performance of the pump. In order to facilitate priming at high suction lifts, it may be advantageous to stop the pump after a few minutes of operation and fill the pump body with liquid.

While **operating the pump** under normal conditions, the diaphragm pump is capable of handling water up to a 20 ft. suction lift. This pump will operate best with some pressure on the discharge side, and if operating with the discharge below the pump, the discharge hose can be carried over a barrel. Should the pulsating effect of the pump become objectionable, maybe the air chambers are required. However, if the pump was supplied with in-built air chambers, it may be possible that the air chambers have become waterlogged. In such a situation, it is recommended to drain the excess liquid from the chambers and tighten all plugs securely after draining.

Pump hose connections, piping, strainers and controls: It is recommended that connections at the easily accessible suction port should be made with strongly reinforced suction hose, so that it does not collapse during operation. Collapsible hose may be used on the discharge side.

It is recommended that all piping, especially the suction line, should be as short as possible with the fewest elbows to reduce friction loss. It is important that suction piping should continuously rise to the pump to avoid air pockets. Gate valves should not be used on the discharge side for flow control.

It is advisable to install pump strainers. This can be attached to the suction line to prevent stones and foreign debris from clogging the pump. A large overall straining area is necessary and should be kept clear of debris. When there is little liquid (slurry) to be pumped, the motor speed may be reduced with a variable speed drive (VFD). It is recommended to operate the pump between 48 and 60 strokes per minute for efficient lubrication and cooling of the engine.

4.3. Pug mill

A typical pug-mill consists of a horizontal box-like chamber with a top inlet and a bottom discharge at the other end, 2 shafts with opposing paddles, and a drive assembly. Pug mills in Khurja cluster are used to extrude clay bodies prior to shaping processes, and are fitted with vacuum system that ensures the extruded clay bodies have no entrapped air. The figure below shows pug mills used in Khurja cluster.

Figure 10: Pug mills in operation

The following practices can be followed for proper operation of the pug mills:

- The material to be loaded in pug mill should be kept in close proximity to the machine so that the process remains continuous and the entry of air in the system is prevented.
- The no-loading / unloading time of the motor should be reduced, i.e. when there is no material in the machine for the process, the machine should be turned off (in case speed control systems are not installed). It is recommended to accumulate sufficient quantity of material to be fed to the pug mill so that the operation is as much continuous as possible.
- It is recommended to maintain proper and requisite vacuum in the system and monitoring the same by installation of a (vacuum) pressure gauge, so that the de-aeration process takes place properly, which reduces the chances of entrapped air in the material that causes cracks in the finished product when it is heated in the kilns. Formation of cracks on the finished product will result in it being rejected, thereby causing production, material and energy loss.
- A VFD can be installed with the vacuum pump of the pug mill to reduce energy consumption during periods of no load or under loads.

CHAPTER 5: Best Operating Practices - Motors

Most of the processes in the ceramic industries are equipped with motors. The total energy consumed by motors is 50 -60 % of the total plant electrical energy. All the motors can perform efficiently when they are used and operated properly. As the load varies, the efficiency also varies.

5.1. Regular upkeep and operation

- **Preventing under-loading of motors.** If the motor is under loaded, i.e. it is operating at loads below 40%, change from star-delta to permanent star mode is an inexpensive and effective measure, as it requires only reconfiguring of wiring at terminal box and resetting the over current relay. It helps in a voltage reduction of √3 times.
- **Properly lubricate moving parts.** Some motors have sealed bearings that require no servicing. For others, regular lubrication will avoid unnecessary wear. It should be ensured to apply appropriate types and quantities of lubricant, as applying too little or too much can harm the motor components.
- **Keep motor couplings properly aligned.** Correct shaft alignment ensures smooth & efficient transmission of power from the motor to the load. Incorrect alignment puts strain on bearings and shafts, shortening their lives and reducing system efficiency. Shaft alignment should be checked and adjusted regularly; should be parallel and directly in line with each other. Many couplings have hard rubber inserts that can degrade, so rubber dust on the equipment base may indicate problems.
- **Properly align tension belts and pulleys when they are installed, and inspect them regularly to ensure that alignment and tension stay within tolerances.** Abnormal wear patterns on belts may indicate problems. Loose belts may squeal and will slip on the pulley, generating heat. Correctly tensioned pulleys run cool. Excessive tension strains bearings and shafts, and shortens their lives.
- **Maintain bearings by keeping them clean, lubricated, and loaded within tolerances.** Proper belt tension or shaft alignment minimizes strain on the bearings and helps them achieve their expected life.
- Proper attention needs to be given to bearings on motors equipped with VFDs. These can be prone to shaft currents, which can cause serious damage to the bearings.
- **Check for proper supply voltages.** Unbalanced power, i.e. three-phase motors where the supply voltage to the phases varies by more than 1%—can lead to overheating and reduced motor life. Also, situations where the supply voltage is much higher or lower than the motor's rated voltage lead to same problem.
- **Avoid painting motor housings.** Paint acts as insulation, increasing operating temperatures and shortening motor life. One coat of paint has little effect, but years of paint buildup can have significant effect.
- **Periodically inspect commutators visually.** Potential problems with commutators (which are only required for DC motors with brushes) will be seen as discolorations, flat spots, or burn marks. Color patterns can be normal as long as they appear around the entire

commutator. If problems are noticed, the commutator should be removed and repaired, or other key components should be replaced.

5.2. Energy monitoring and record keeping

- **Maintain an up-to-date motor inventory.** The inventory should include all substantial motors, but can begin with the largest and those with the longest run times. This inventory lets facility managers make informed choices about replacement, either before or after a motor fails. Field-testing motors before they fail can help ensure that replacements are properly sized.

- **Keep maintenance logs.** These logs should contain vital information such as the make, model, serial number, type, and specifications of each motor; the locations and specifications for belts, pulleys, etc.; and a historical record of maintenance activities. This helps the maintenance staff remember when tests, inspections, or servicing are due. It also allows the staff to quickly identify spare parts or replacements when needed. In addition, comparing recent test results to past values can provide early indications of reduced motor performance.

5.3. Smart replacement strategies

- **When a motor fails, use an appropriately sized replacement.** Many motors are oversized for their applications, resulting in poor motor efficiency and excessive energy use. If a motor fails, it should be replaced with a similar sized, energy-efficient motor. Doing so will reduce the operating costs, since the new motor should operate closer to its point of maximum efficiency (generally around 75% of the motor's rated horsepower). In these situations, it should be verified that the new motor can still provide sufficient output under all operating conditions. For replacing a failed motor with a new energy-efficient model, the planning should be made in advance. Stocking premium-efficiency replacements for critical motors can help avoid the hasty replacement of a failed motor with a standard efficiency model that happens to be the only one available on short notice. Maintenance staff can decide which motors warrant such advanced planning.

- **Replace, rather than rewind, motors when appropriate.** Many motors have been repaired more than once, with a typical loss of nearly 1% in efficiency at each rewind. These motors may be much less efficient than their nominal ratings, making them good candidates for replacement when they next fail. It is more common to rewind larger motors due to their high capital cost. But these motors usually operate at very high duty, and even a modest efficiency improvement may make it worthwhile to replace them with new, premium-efficiency motors rather than repairing them.

Table 1: Maintenance schedule for motors

Description	***Comments***	***Maintenance Frequency***
Motor use/ sequencing	Turn off or sequence unnecessary motors.	Weekly
Overall visual inspection	Verify equipment is operating and safety systems are in place.	Weekly
Check bearings and drive belts	Inspect for wear, and adjustment, repair, or replace as necessary.	Weekly
Motor alignment	Look for rubber or steel savings under couplings, or listen for odd noises as these may indicate a problem.	Weekly
Motor condition	Check condition by analyzing temperature or vibration, and compare to baseline values.	Quarterly (or as needed on weekly inspections)
Cleaning	Remove dust and dirt to facilitate cooling.	Quarterly
Check lubrication	Ensure bearings are lubricated as recommended by manufacturer.	Annually (or based on run hours)
Check mountings	Secure any loose mountings.	Annually
Check terminal tightness	Tighten any loose connections.	Annually
Check for balanced three-phase power	Troubleshoot unbalanced motor circuit and fix problems if the voltage imbalance exceeds 1%.	Annually
Check for over – or – under voltage conditions	Troubleshoot motor circuit and fix problems if the supply voltage differs significantly from rated voltages.	Annually

5.4. De-merits of motor re-winding

Generally two types of windings are used in the motors.

1. ***Lap winding*** - It is the winding in which successive coils overlap each other. It is named "Lap" winding because it doubles or laps back with its succeeding coils.
2. ***Wave Winding***- In wave winding, a conductor under one pole is connected at the back to a conductor which occupies an almost corresponding position under the next pole which is of opposite polarity.

When a motor is designed for a specific mechanical output, the electrical specifications are also designed accordingly.

1. The type of winding in the stator is also designed as per application. If the requirement of voltage is high, then wave winding is preferred and when requirement of current is high then lap winding is preferred.
2. The number of turns of copper or aluminum coil in one span or pole pitch is fixed. When a motor is designed, then the total number of turns is fixed for generating a specific amount of magnetic field inside the stator.
3. When motor is designed, then the air gap between rotor and stator is also fixed and it is uniform in interior peripheral of stator with rotor.

When the motor is re-wounded after some period of time, following technical problems will occur:

1. It may so happen that the air gap in a re-wounded motor may not be uniform. This is due to the fact that the person repairing the motor was trying to maintain the requisite numbers of turns in one span or pole pitch.
2. The number of turns in all three phase is not uniform; due to this, flux generating current is also not uniform or same for the three phases of the motor.
3. The leakage of flux is generated because of mismatching or fitting of the conductor on the rotor.
4. Sometimes the rotor axis is not fixed, due to which the overall flux is less than or greater than the design flux.

Due to one or combination of the above, the electrical power consumption of a re-wounded motor increases and its efficiency decreases.

CHAPTER 6: Best Operating Practices – Pumping System

6.1. Introduction

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

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

Figure 11: Centrifugal pump

6.2. Efficient pumping system operation

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

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

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

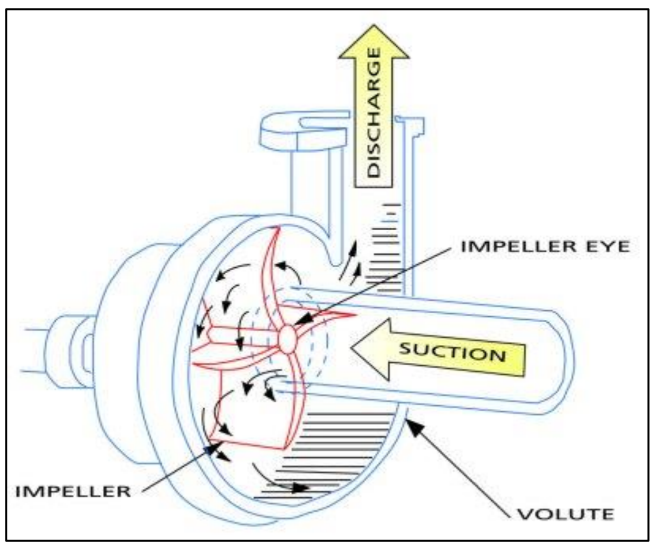

Figure 12: Sectional view of a pump

Common symptoms that indicate opportunities for energy efficiency in pumps are given in the table below:

Table 2: Symptoms that indicate potential opportunity for energy savings

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

6.3. Best operating practices for pumps

BOP 1: Location of pump

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

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

BOP 2: Measurement and control

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

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

BOP 3: Use of variable speed drives

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

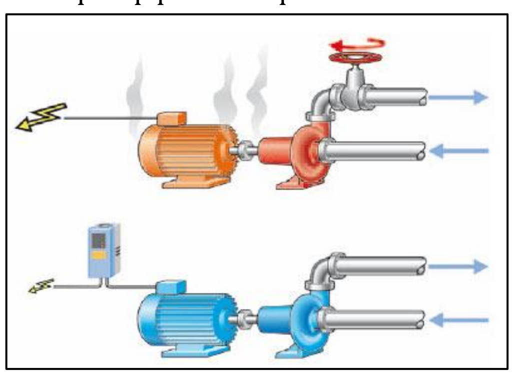

Figure 13: Pictorial depiction of use of VFDs in pumps

➲ BOP 4: Pumping system design consideration

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

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

6.4. Do's and Don'ts in pump operation

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

Table 3: Summary of best operating practices for efficient operation of motors in ceramic units

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

CHAPTER 7: Best Operating Practices - Compressed Air System

7.1. Introduction

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

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

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

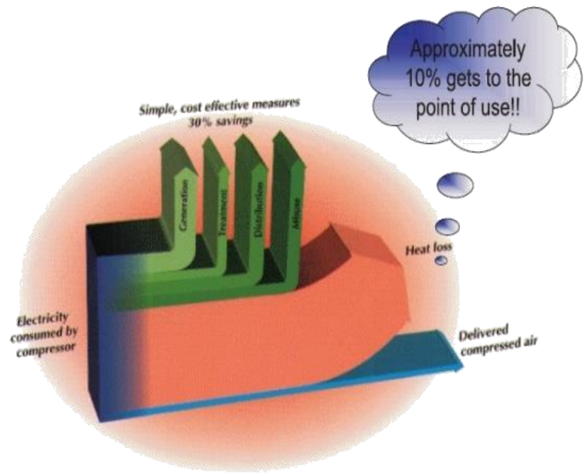

Figure 14: Sankey diagram of compressed air system

7.2. Best operating practices for compressed air system

Some practices that will optimize air compression are listed below:

BOP 1: Location of the compressor

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

- Locate the compressor away from heat sources such as kilns, dryers and other items of equipment that radiate heat. The following table below shows the relative power savings that result from a decrease in intake air temperature.
- The compressor should be located such that it draws cool ambient air from outside because the temperature of the air inside the compressor room is high. While extending the air intake from the

Figure 15: Compressed Air System

outside of the building, minimize excess pressure drop in the suction line by selecting a duct of large diameter with the smallest number of bends.

- The compressor should be placed where there is no particulate matter. Do not place the compressor near spray coating booths, sewing machines, the buffing section, etc.
- Any moisture in the inlet air to the compressor will affect its performance adversely. The compressor should be placed away from equipment which may add moisture to the atmosphere, for example, rinsing lines, cooling towers, dryer exhaust, etc. If the compressed air is moist the components of the compressed air system will corrode. Also, the specific power consumption will increase.

BOP 2: Delivering air at the lowest practical pressure

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

BOP 3: Ensuring cool air intake

- As a thumb rule, *"Every 4^{0}C rise in inlet air temperature results in a higher energy consumption by 1 % to achieve equivalent output".* Hence, cool air intake leads to a more efficient compression (see Table 4).

Table 4: Effect of intake air temperature on power consumption

Inlet Temperature (^{0}C)	Relative Air Delivery (^{0}C)	Power Saved (%)
10.0	102.0	+1.4
15.5	100.0	Nil
21.1	98.1	-1.3
26.6	96.3	-2.5
32.2	94.1	-4.0
37.7	92.8	-5.0
43.3	91.2	-5.8

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

BOP 4: Ensuring dust free air intake

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

Table 5: Effect of pressure drop across inlet filter on power consumption

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

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

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

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

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

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

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

Table 6 below shows the loss in Free Air Delivery (FAD) through orifices of different sizes in a compressed air grid.

Table 6: Discharge of air (m3/min) through orifice (Orifice constant Cd =1.0.)

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

For leakage test in compressed air system, following table 7 may be referred.

Table 7: Compressed Air Leakage Trial Format

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

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

Percentage Leakage Calculation:

Total Cycle Time = (E) + (I)

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

Interpretation:

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

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

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

NOTE :

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

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

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

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

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

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

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

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

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

BOP 11: Compressor lubrication

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

BOP 12: Minimize the pressure drop

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

Table 8 below shows typical energy wastage on account of pressure drop created by smaller pipe.

Table 8: Typical energy wastage due to smaller pipe diameter for 170 m³/hr (100 cfm flow)

Pipe Nominal Bore (mm)	Pressure drop (kg/ cm²) per 100 meters of pipe length	Equivalent power losses (kW)
40	1.84	9.5
50	0.66	3.4
65	0.22	1.2
80	0.04	0.2
100	0.02	0.1

7.3. Do's and Don'ts in compressed air system

Table 9 below summarizes the general do's and don'ts for operation of compressor and compressed air system:

Table 9: Summary of best operating practices for efficient operation of compressors in ceramic units

Do's	Don'ts
• Try to locate the compressor suction pipe away from heat sources and moisture sources.	• Don't use valves to reduce the pressure in the compressed air grid because it wastes the energy that is consumed in building up the excess pressure. Compressed air pressure must be set at the point of generation.
• Clean the air filters regularly for minimizing pressure drop.	• Don't leave compressed air leaks unattended. Conduct leakage test once in a month.
• Use proper size of pipe for distribution of compressed air.	• Don't allow the compressors to run with loose or vibrating belts.
• Segregate users of compressed air on the basis of the pressure they require for proper operation.	• Avoid over sizing - match the connected load.
• Reduce air compressor discharge pressure to the lowest acceptable setting. (Reduction of 1 kg/cm² air pressure (8 kg/cm² to 7 kg/cm²) would result in 9% input power savings. This will also reduce compressed air leakage rates by 10%)	• Do not use back-up air compressor unless it is essential.
• Minimize purges, leaks, excessive pressure drops, and condensation accumulation.	• Do not use refrigerated and heated air dryers when the air compressor is off.
• Take air compressor intake air from the coolest (but not air conditioned) location.	• Do not use air/oil separators that are fouled.
• Monitor pressure drops across suction and discharge filters and clean or replace filters promptly upon alarm.	• Do not use fouled heat exchanger

CHAPTER 8: Best Operating Practices - Electrical Distribution, Lighting & DG System

8.1. Electrical distribution

- Phase/line voltage and line current monitoring of the transformer by analog/digital voltmeter and ammeter helps to check the proper balancing of voltage and current in the electrical distribution line to avoid unbalancing situation in the system which affects the performance of the equipment and break-down in the manufacturing process.
- Proper arrangements should be made for cooling of transformers, electrical panels and drive panels to avoid unwanted shutdown and accident. This also improves the safety of the equipment as well as the safety of workers.
- Secondary side cable size of the transformer to the equipment should be proper as per the load demand to avoid over heating of the cable which can cause accidents.
- Periodic check-up of the capacitor banks are required to maintain the power factor (PF). De-rated capacitor banks should be immediately replaced to maintain the PF close to unity. Improved PF will reduce the demand (kVA) from grid and also reduce the line losses leading to energy savings.
- Continuously monitoring electrical parameters like V, I, PF, kW and kWh by installing energy monitoring system at each process, incomer side thereby loading of the system can be found out and help in proper load and energy management.
- Load sharing of transformers: If more than one transformer is there in the unit, shifting of load from one transformer to the other, thereby making the transformers to operate at nearby 50% load. This will lead to reduction in losses and increase in efficiency.

8.2. Lighting

- Schedule to clean the lighting fixtures periodically, i.e. removing dirt from the luminaries, occasionally cleaning and repainting the walls and ceiling of the room; and occasionally cleaning air supply vents to prevent unnecessary dirt distribution.
- Proper record of the lighting inventory helps to identify the failure frequency and new installation to choose better lighting fixture in terms of life and energy consumption.
- Separate feeder for lighting to monitor the energy consumption and to operate at required voltage (single phase at 220 V) can bring energy savings and decrease the failure rate of the lighting fixtures.

8.3. DG system

- In DG, log sheets should be maintained properly which includes fuel consumption, number of hours of operation and total number of units generated, etc. Using these parameters, specific fuel consumption (SFC) or specific energy generation ratio (SEGR) of the DG could be found which will help in performance study of the DG regularly.

- Digital energy meter with parameters of V, I, PF, kVA, kW, Hz and kWh will help continuous monitoring on DG for proper load and energy management. DG on loading of less than 30% load is operated very inefficiently and increases the specific energy generation ratio (SEGR). There is also requirement of frequency (Hz) monitoring of DG (less than 50 Hz) to maintain the SEGR. Sometime DGs are operated at more than 50Hz which results in poor SEGR.
- If 2 DGs are there, during light load condition, instead of operating two simultaneously, single DG should be operated at a slightly higher load and keeping the other shut.
- The air filter should be checked and cleaned periodically; otherwise it will lower the combustion efficiency of the DG.

ABOUT PROJECT

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

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

Project Component

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

Project Activities

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

Project Beneficiaries

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

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

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

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