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MICRO, SMALL & MEDIUM ENTERPRISES

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Ministry of New and Renewable Energy

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

A GEF-UNIDO-BEE Project

Best Operating Practices

Gujarat Dairy Cluster

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

Disclaimer

This document has been developed after an extensive consultation with a number of experts and on the basis of BOP documents developed by expert energy auditing agencies engaged earlier under the project. The information contained in this document is indicative and is for information purposes only. BEE disclaim any liability for any kind of loss whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly, resulting from the publication, or reliance on this document.

Conceptualized by PMU, GEF-UNIDO-BEE Project

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Director General

ENERGY IS LIFE
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ऊर्जा दक्षता ब्यूरो
(भारत सरकार, विद्युत मंत्रालय)
BUREAU OF ENERGY EFFICIENCY
(Government of India, Ministry of Power)

सत्यमेव जयते

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.

Contents

CHAPTER 1: Introduction

1.1. Brief about the project

GEF-UNIDO-BEE project titled "Promoting energy efficiency and renewable energy in selected Micro Small and Medium Enterprises (MSME) clusters in India" is developing and promoting market environment for introducing energy efficiency and renewable energy in process applications in 12 selected energy-intensive MSME clusters in India which includes Gujarat Dairy cluster also. The overall motive of this project is to improve the productivity and competitiveness of units as well as to reduce carbon emissions and improve the local environment.

Gujarat Dairy cluster is one of the selected cluster under the project wherein the units are being supported to adopt energy efficient and renewable energy technologies and practices. Gujarat Co-operative Milk Marketing Federation Limited (GCMMF) is the cluster level project partner association which has collaborated to carry out the activities in the cluster.

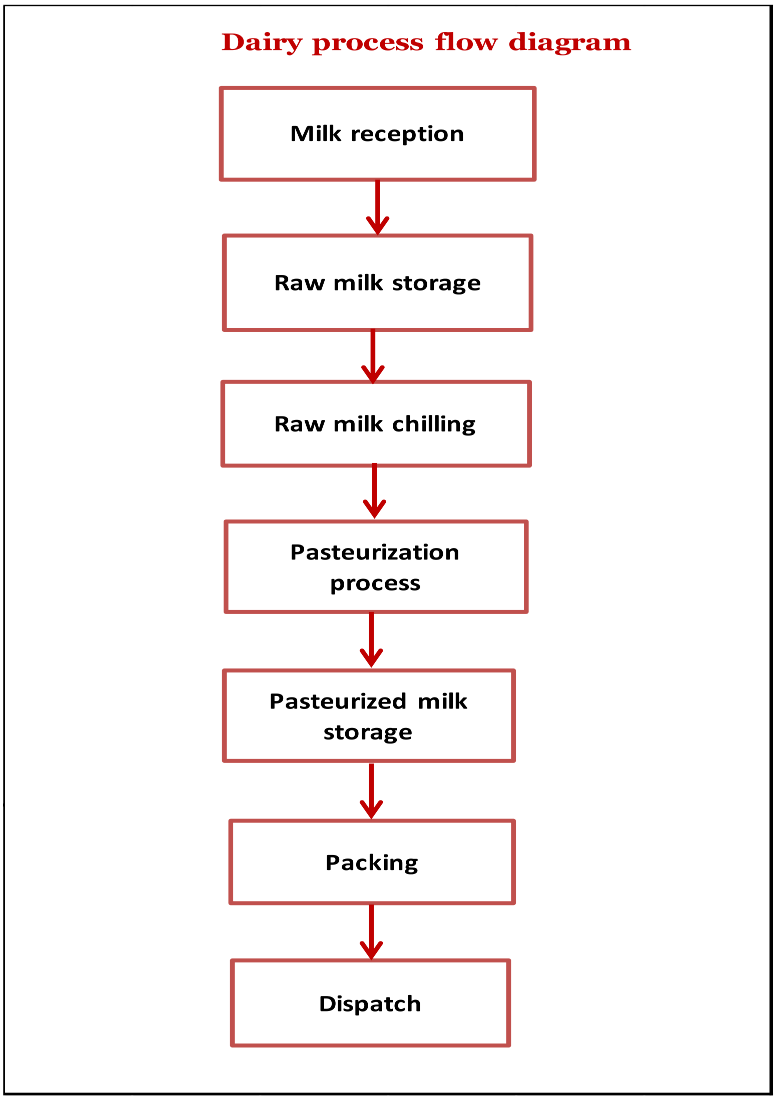
1.2. Brief about the cluster and production process

Gujarat Cooperative Milk Marketing Federation Ltd. (GCMMF), is India's largest food product marketing organization. Its daily milk procurement is approx. 16.97 million liters/day from 18,545 village milk cooperative societies, 18 member unions covering 33 districts, and 3.6 million milk producer members.

It is the apex organization of the Dairy Cooperatives of Gujarat, popularly known as 'AMUL', which aims to provide remunerative returns to the farmers and also serve the interest of consumers by providing quality products. Amul spurred India's white revolution, which made India as world's largest producer of milk and milk products which comprises milk, milk powder, health beverages, ghee, butter, cheese, Pizza cheese, ice-cream, paneer, chocolates and traditional Indian sweets, etc.

Process flow for dairy industry:

From process point of view, refrigeration is the major energy consuming load in the plant, followed by other utilities like boiler, compressed air system, pumping system and others. A typical process flow for dairy industry in Gujarat is depicted next:


Dairy process flow diagram
Milk reception
Raw milk storage
Raw milk chilling
Pasteurization process
Pasteurized milk storage
Packing
Dispatch

CHAPTER 2: Best Operating Practices - Chilled Water Pumps

Refrigeration is one of the major load in any dairy industry and usually consumes around 50% of total electricity consumption of the plant. Most of the dairy plants in the Gujarat cluster are having centralized refrigeration system, through which cooling requirement of all processes within dairy plant are catered. As there is a centralized refrigeration system, so there are centralized chilled water supply pumps for pumping chilled water to all processes in dairy.

As dairy plant manufactures different types of milk and milk products; each product has a dedicated plant and process system. During normal working days, few processes are working and while some may not be working or may be under CIP. Each process in plant will have requirement of chilled water for process cooling and due to variation in plant operation and process CIP; there will be continuous variations in chilled water requirement from user end.

It is observed that even though there is variation in chilled water requirement from user end; most of the dairy plants in Gujarat cluster operate chilled water pumps at a constant speed. So in case any process at user end is not working, then chilled water supply valve to that user end is closed automatically. However, this closing of valve at one process will make excess chilled water to flow to other nearby processes, which is not required.

Hence, installation of **VFD on chilled water pump with header pressure feedback control** to VFD will reduce speed of chilled water pump whenever there is a reduction in chilled water demand from user end and increases speed of pump whenever there is increase in chilled water demand.

The advantages of VFD installation on chilled water pumps are as follows:

- Reduction in chilled water pump power consumption
- Reduction in refrigeration compressor load, due to avoidance of unwanted heat pickup from chilled water from user end due to excess chilled water flow.

CHAPTER 3: Best Operating Practices - Maintain Correct Water Flow and Temperature across Condenser

Condenser is a very important part of the refrigeration system. Hot refrigerant after getting compressed in compressor needs to be cooled to condensing temperature in the condenser through use of condenser water. The condenser system comprises of following equipment:

- Cooling tower or evaporative condenser
- Cooling water pumps
- PHE condenser

Cooling tower in condenser system will cool return water coming from PHE condenser after extracting heat from refrigerant. Supply water (cooled water or basin water) from cooling tower is pumped back to PHE condenser by condenser water pumps. In PHE condensers, heat exchange happens between hot refrigerant and supply water.

Maintaining correct water flow and condensing temperature in condenser PHE is necessary for better heat transfer between supply water and hot refrigerant. Better heat transfer will reduce temperature of refrigerant to condensing temperature. If refrigerant is not getting cooled properly in PHE condenser then it will increase refrigerant discharge pressure at compressors thereby increasing compressor power consumption.

Most of the plants in Gujarat dairy cluster are found to be having problems in maintaining correct water flow and condensing temperature in condenser PHE. It was observed that no maintenance was carried out in cooling tower/evaporative condenser fills. Usually, dust from atmosphere settles down on cooling tower fills and obstruct heat transfer between return condenser water and air. Due to depositions on fills, condenser water does not cool properly, which in turn will not cool hot refrigerant properly in PHE condenser. Cleaning fills and replacing with new fills at regular intervals is mandatory to maintain condenser water temperature.

Similar to condenser water temperature; water flow is also a critical parameter which needs to be maintained across PHE condenser. Water flow across PHE needs to be maintained as per design, since reduction in water flow leads to poor heat transfer between refrigerant and supply condenser water.

In order to maintain correct water flow and temperature across condenser, it is recommended to take following steps:

- Clean condenser fills and change fills on regular intervals (Recommended to clean fills once in three months and change when damaged).
- Operate cooling water pumps as per design water flow rate requirement of PHE condenser.
- Clean PHE condenser on regular intervals (Recommended to clean PHE condenser once in a year).

Implementing above measures will improve the performance of complete condenser water system in any refrigeration system. Improving performance of condenser water system will cool hot refrigerant to condensing temperature, thereby reducing overall specific energy consumption of complete refrigeration system.

CHAPTER 4: Best Operating Practices - Installation of Auto Control Valves (Solenoid Valves) at Various Process Equipment

For each type of dairy product, separate set of section/process equipment and utilities are installed in the plant. Operation of each section/process depends on milk availability and market demand. When plant is operating, there will be variation in load due to variation in the incoming milk to dairy. Milk received will be at peak during morning & evening time, moderate during day time and almost no milk during night time. Each process in the dairy plants will be under CIP for certain amount of time depending on the product it manufactures.

Due to variations in the operation of different processes in the plant, there is variation in chilled water requirement. Maintaining chilled water flow as per final product temperature is very much necessary to maintain product quality as well as lower energy consumption.

Dairy plants have manual control valves at chilled water side in PHE chillers, pasteurizers (in butter milk, curd section) and process equipment. Since control valves are manual, once valves are set with certain percentage of opening, it will remain same throughout the day. Due to variation in process parameters and product flow, temperature of product reaches to minimum when there is low product flow rate and rises up to maximum saturation temperature limit when product flow is at its peak. By allowing temperature of product to go lower than standard required temperature, there will be certain increase in chilled water consumption resulting in increase in compressor power consumption. If temperature of product reach maximum saturation temperature limit, then it will directly affect product quality. In order to avoid both the situations and to keep minimum energy consumption of refrigeration system, it is recommended to install **auto control valve** at each of chillers PHEs, pasteurizers and process equipment **to alter chilled water flow** as per final product temperature.

Pictorial view of Auto Control Valve

The advantages of installing auto control across PHE chillers, pasteurizers PHEs and process equipment is:

- It will control chilled water flow as per final product temperature requirement and completely stop flow of chilled water to non-operating equipment; thereby reducing chilled water pump power consumption.

CHAPTER 5: Best Operating Practices - Installation of Back-Pressure Turbine

All dairy plants have installed boilers to generate steam of required quantity and pressure for process applications in the plant. Dairy plants need steam in various heating applications such as milk pasteurization process and powder plant. All heating process in dairy is through indirect method i.e. there is no direct mixing of steam with any fluid.

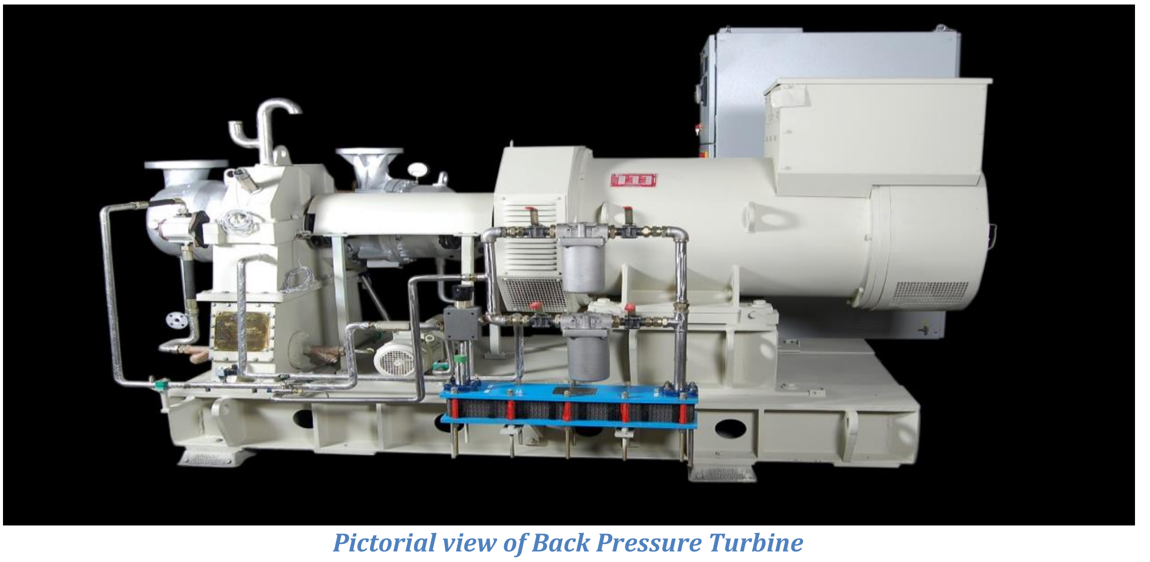
During pasteurization process, milk is heated up to a temperature of greater than 73 °C to kill bacteria. For this purpose, hot water is used at a temperature of around 85 °C. The hot water is generated by using low pressure (LP) steam at 3 kg/cm^2 in hot water Plate Heat Exchanger (PHE).

Other major user of steam in dairy plants is powder plant where steam at around 8 kg/cm^2 is used to heat milk in evaporator columns. In evaporator columns milk is heated with steam under vacuum to remove water content in milk to make powder.

The minimum steam pressure required in dairy is 3 kg/cm^2 for pasteurization process and maximum steam pressure required is around 8 kg/cm^2 for powder plant.

Even though steam pressure required is lesser at user ends, boilers in dairy plants are generating steam at higher pressure (maximum steam pressure of up to 17.5 kg/cm^2). Since steam is generated at higher pressure in boiler compared to user end pressure requirement, pressure is reduced through Pressure Reducing Valves (PRV) as per each user requirement. In PRV, pressure of the steam is reduced to a pre-set limit so as the steam comes out at a lower pressure and will get utilized in the user end process applications. During the process of steam pressure reduction, there is a loss of steam pressure energy in PRV without any use.

In order to utilize steam pressure energy instead of getting wasted in PRV, it is recommended to install back pressure turbine at LP steam header. Passing steam through the turbine instead of PRV will generate electricity and also give the required steam pressure at output as per requirement.



Pictorial view of Back Pressure Turbine

In order to install back pressure turbine, following necessary points needs to be considered for successful installation:

1. Plants need to identify each steam user quantity and pressure requirement. All the steam user which needs steam pressure above 3 kg/cm^2 can be categorized as high pressure user, and all users which needs steam pressure of 3 kg/cm^2 or less can be categorized as low pressure user.

2. It is recommended to install back pressure turbine at low steam pressure user in plant for two major reasons:
    a. Steam consumption of low pressure user is higher compared to high pressure user in dairy - Higher steam flow through turbine will have better electrical power output compared to low steam flow.

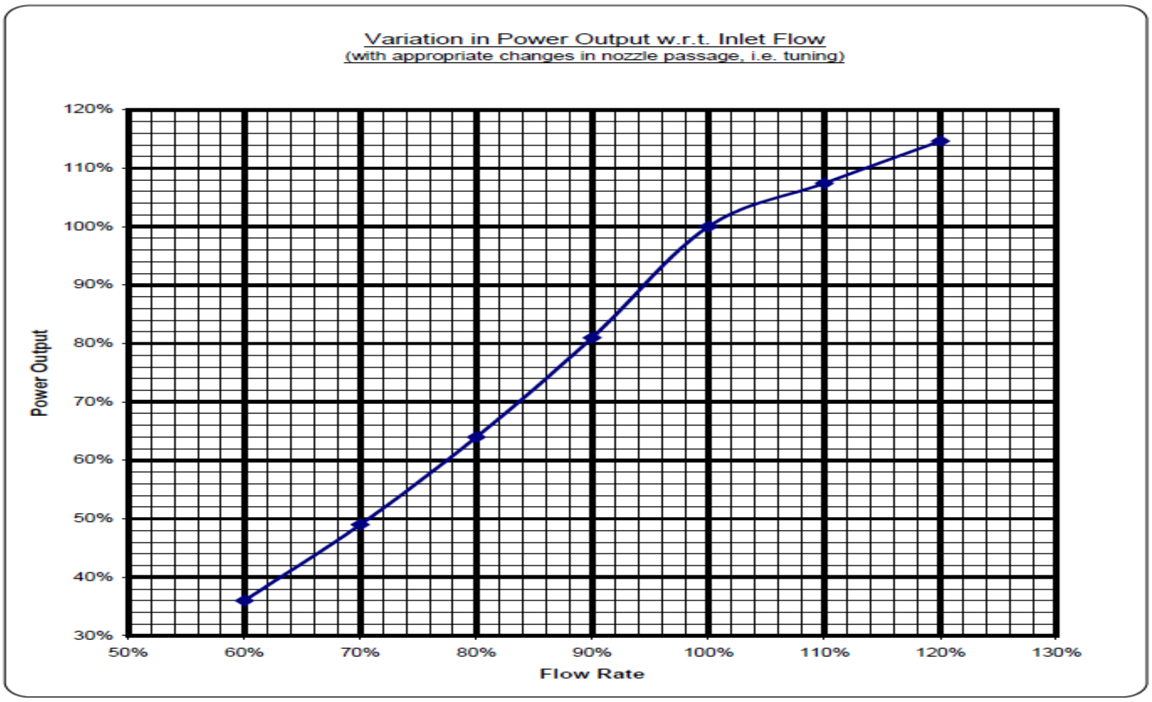
    b. Higher pressure difference between the input and output steam – Higher steam pressure difference between the input and output of turbine will result in better electrical power generation.

3. Plant may need to do minor steam piping changes to accommodate turbine in system and to combine all low pressure user pipe line at one place (Modification may depends on site condition).

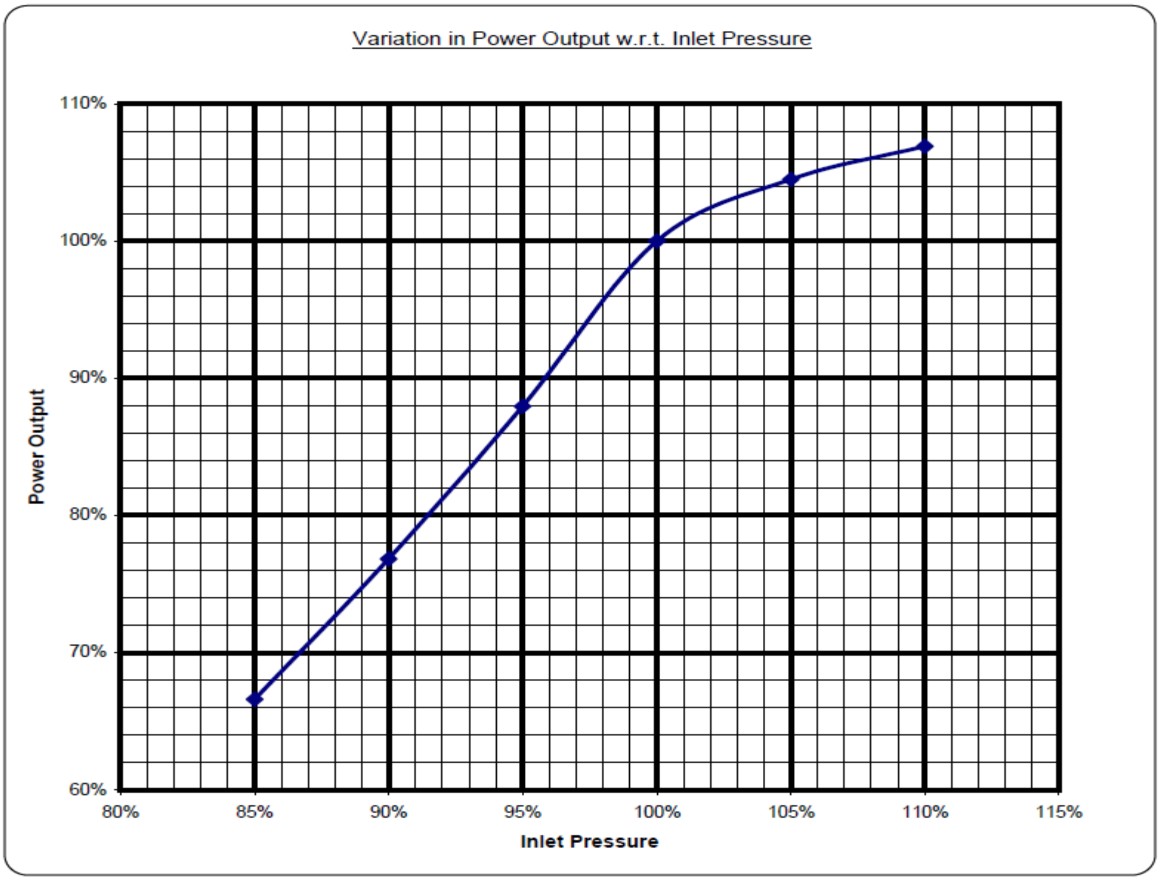
4. Correct quantification of following parameters is necessary:
    a. Steam pressure requirement at the outlet of turbine.
    b. Quantity of steam input and variation in input steam flow rate to turbine (minimum steam flow and maximum steam flow) for successful design of turbine.

After correct quantification of the above mentioned points, plant can calculate exact power generation possibility from turbine and also investment required for the same.

The variation in turbine output power due to variation in inlet steam flow is given in below graph:



The variation in turbine output power due to variation in inlet steam pressure can be seen from below graph:



CHAPTER 6: Best Operating Practices – Waste Heat Recover

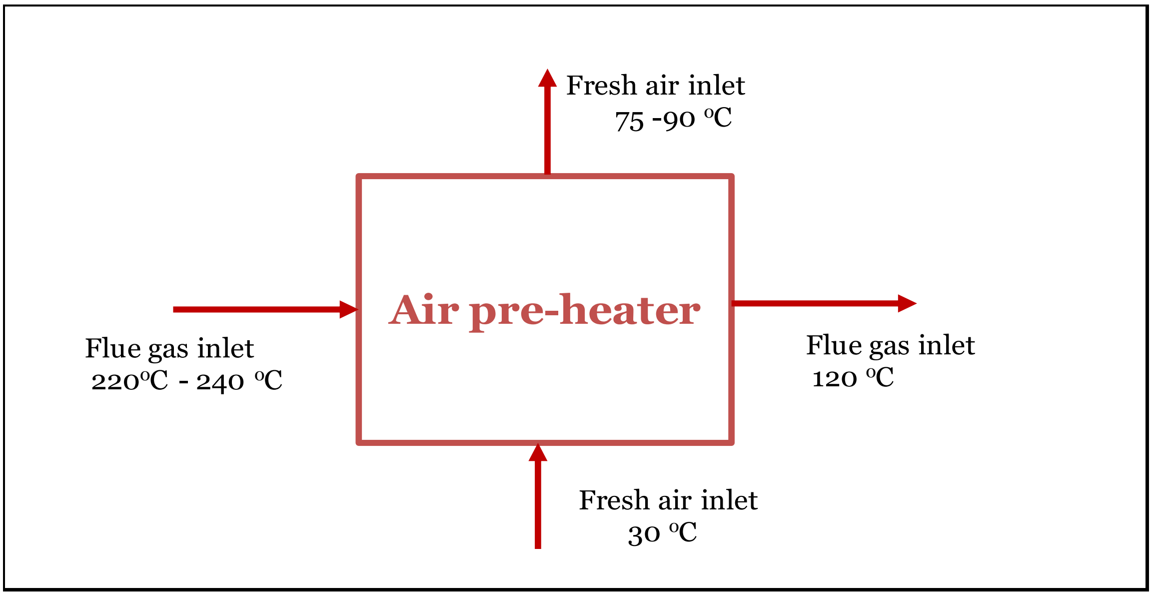
In powder plant, excess amount of liquid milk is converted to milk powder. The conversion of liquid milk to powder is done in two stages. In first stage, milk will be processed through evaporation process, wherein heating of milk takes place in evaporator column under vacuum with use of steam to increase solid contents in milk up to 48 to 50 % by extracting water content from liquid milk.

In second stage, this 48 – 50 % of solid content milk is dried fully to powder form in drier. Drying process of milk starts with pumping the output of evaporator into drier at higher pressure along with hot air at temperature of around 200 ^{0}C.

A hot air generator present in drier generates hot air at temperature of around 200 ^{0}C which is required for drying process by using natural gas as fuel. The hot air drier is having a delivery fan to supply ambient air to hot air generator; and an exhaust fan to suck flue gases out of hot air generator. The flue gas temperature at exhaust of hot air generator is about 220 ^{0}C to 240 ^{0}C.

In general, in dairies the flue gas from hot air generator is wasted without any recovery. High temperature of the flue gas indicates that there is high amount of heat energy present in flue gas.

As the hot air generator intakes ambient air at an average temperature of 30 ^{0}C and heats it up to 200 ^{0}C; it is recommended that instead of using sending ambient air, an air pre heater installed to preheat the ambient air by using hot exhaust flue gases.



A typical air pre-heater system arrangement for preheating ambient air from exhaust flue gases

Air preheater is a shell and tube type of heat exchanger, where fresh air from delivery fan will flow in tube side and flue gas from hot air generator will flow in shell side. Since flue gas is at higher temperature compared to fresh air, there will be heat flow from flue gas to fresh air. As an effect, temperature of the fresh air increases and flue gas temperature decreases.

The advantages of installing air preheaters in drier hot air generator exhaust are:

- Reduction in natural gas consumption since ambient air is getting pre-heated with flue gas waste heat
- Reduces environmental impact since temperature of flue gas from drier hot air generator is reduced through air-preheater.

CHAPTER 7: Best Operating Practices - Compressed Air System

7.1. Rationale

Compressed air is the fourth most used utility after electricity, gas and water as it is extensively used as a source of power for tools, equipment and industrial processes. In general, compressed air systems are not well managed resulting in high-energy losses. Compressed air is highly energy intensive as only 10 to 30% of the electrical energy consumption by an air compressor is usefully converted into compressed air and the balance is lost as unusable heat energy.

It has been observed that the there is still gap between keeping high reliability of compressed air system through maintenance activities and simultaneously reducing energy consumption through adoption of best operating practices for using compressed air system.

7.2. Best operating practices

The following practices can be adopted by industries/SMEs for operating their compressed air system efficiently:

7.2.1. Basic understanding:

- The air compressor motor consumes about 20-40% of the total energy of the motors in many industries.
- For air compressors life cycle, the operating cost on energy is ~84%, ~7% for initial investment and ~9% for maintenance of the air compressor.
- There are three ways for using air compressor efficiently – Reduce the consumption of air, reduce the air pressure and optimize the air compressor.

7.2.2. Reduce the consumption of air

- There are always air leakages (~20%) in the shop floor near to the equipment/application point and/or in the air piping distribution system. Since leakage directly leads to energy loss, it is the highest priority issue for air systems
- Leakage test
  - ✓ Operate compressor at night or holiday, and shut it down when achieving a predetermined pressure value.
  - ✓ When the compressor is shut down, due to the leakage, the pressure will automatically decrease. The amount of leakage can be known by measuring the time (T) taken to decrease the pressure by 1 bar.

Formula

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

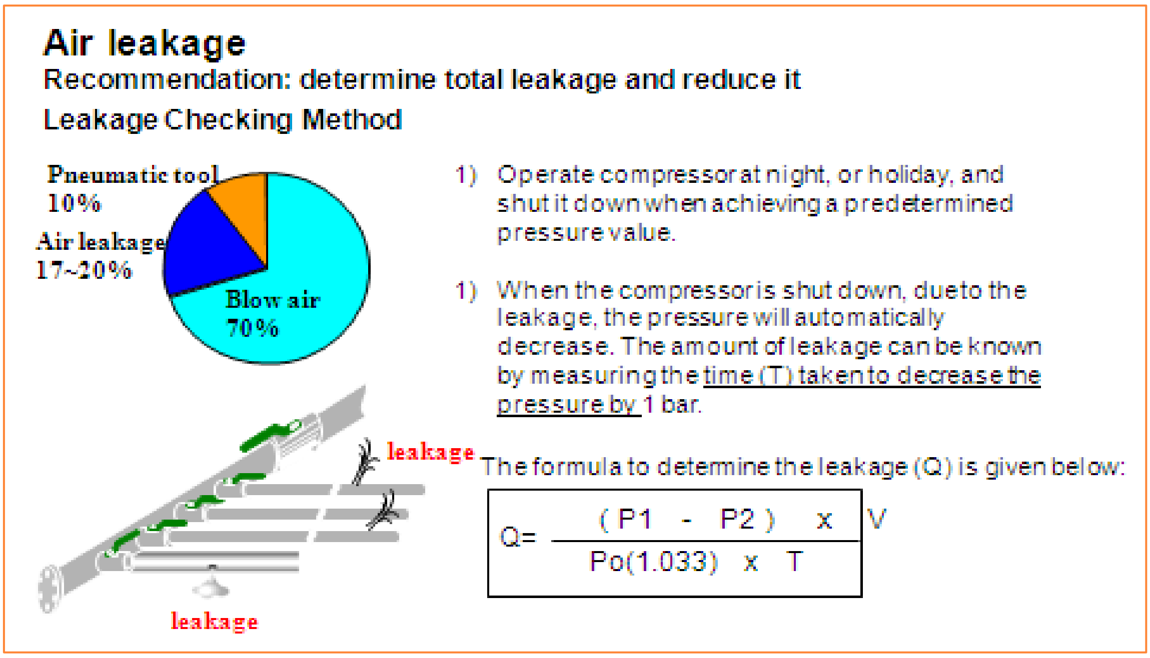
where

Q = Volume of leakage (m^3/min)

P1 = Predetermined pressure (kg/cm^2) (gauge pressure + 1.033kg/cm^2)

P2 = Pressure after leakage (kg/cm^2) (gauge pressure + $1.033 kg/cm^2$)
T = Time taken to reduce pressure from P1 to P2 (min)
Po = Atmospheric air pressure (kg/cm^2)
V = Piping capacity (m^3)

- Recognizing that a leakage occurs from all places is required.
  - ✓ Leakage from coupler
  - ✓ Leakage from pipe
  - ✓ Leakage from internal component of equipment
- For example, use of proper air nozzles for blowing will reduce the air consumption.
- The leakage with a sound is detected by using 'Leak Detector' e.g. Model-AAM-PWLEAK02. However, cautions are required, since there is also the leakage with no sound (silence loss).
- Leakage test can be carried out frequently to check the quantity of air leakages in the plant. The physical verification at joints of hoses, couplers will help to identify the air leakages, even soap solution can be poured at the joints for checking the air leakages.
- Leakage cannot be completely stopped with the one-time measures.
- Continuous monitoring is required.

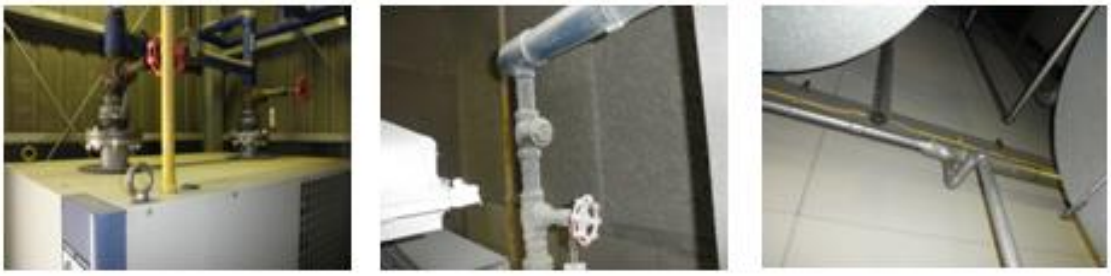


Air leakage

7.2.3. Reduce air pressure and good air piping work

- Pressure Gauges should be installed in the air piping system for regular check of design and operating pressure of pressure gauges. Any fall in pressure in the existing set point of air compressor indicates leakages in the system and such leakage points needs to be identified.

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



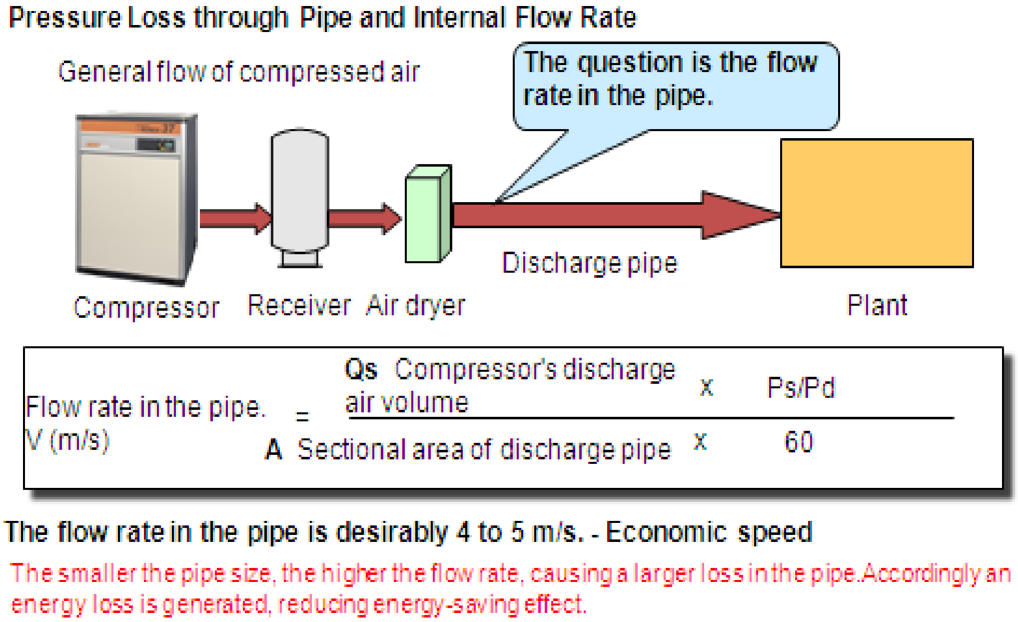
A pipe narrowed immediately after the air dryer. Generates resistance and pressure loss.
A riser pipe. Causes a backward flow of condensate, leading to an increasing number of mechanical troubles.

Contents of Improvement Measures – Examination of Piping Work

- Increase pipe size to reduce pressure loss and important air piping work
  - ✓ Be sure to provide a drain connection for a riser pipe.
  - ✓ Installation to a collecting pipe must be made from above to prevent backflow. (Similarly, branch pipes must be installed from above.)
  - ✓ For a collecting pipe, give an inclination (1/100) from the upstream to the downstream. Attach a drain plug at the end of each pipe.
  - ✓ Buried piping makes it difficult not only to detect air leakage but also to repair
- If there is need for higher pressure for particular application or process, then increase pressure by use of booster compressor instead of increasing set pressure of the entire air compressor system
- Use of hosepipes increases the pressure drop. Piping should not be underground and drain valves should be placed at lower position in pipelines. The filter size should be adequate, so that there is no pressure drop. Higher resistance causes pressure drops and also there is overloading of the air compressors resulting in frequent breakdowns. Piping should be used in looping for reduced pressure drops.

Examples of recommended piping

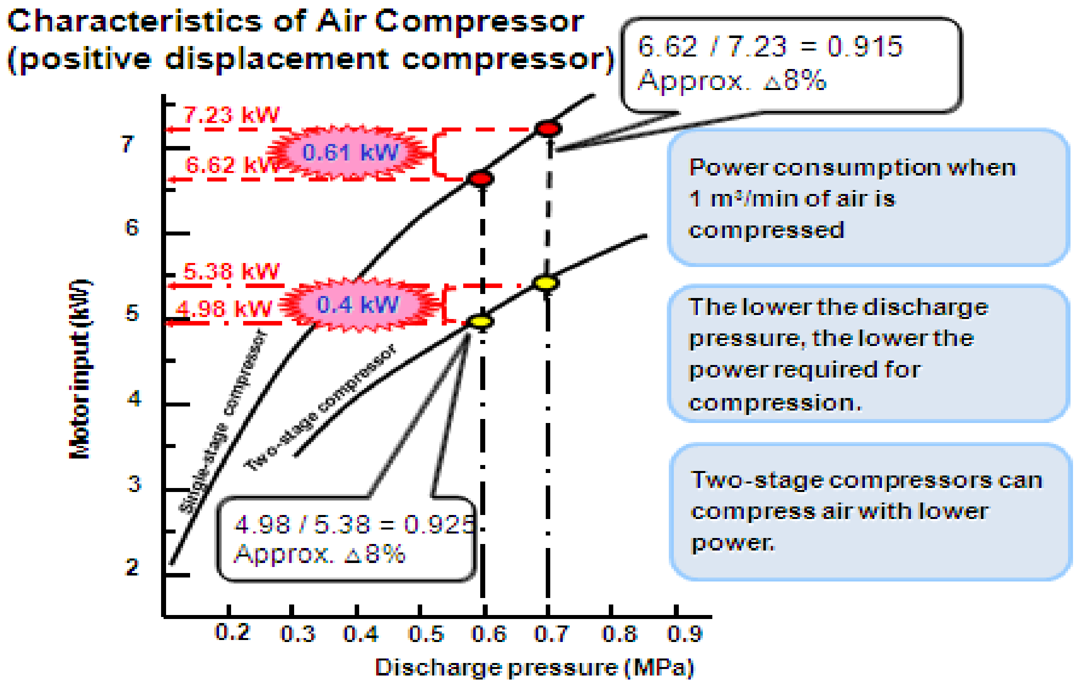
- If adequate and large receiver size is used, there is energy saving about 3%. Proper ventilation of air compressor decreases the surrounding temperature resulting in less stoppage due to over temperature and energy saving with less inlet temperature. For indirect ventilations large size fans are required.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



Pressure loss through pipe and internal flow rate

7.2.4. Optimize the air compressor

- Pressure reduction by 1 bar will give energy saving of 6-8%.
- Air intake into the compressor room and better ventilation. (Pay attention to the gallery design - effective area)
  - ✓ Install the compressor in the direction so that a hermetically closed room or intake of contaminated air (oil, gas, etc.) is avoided.
  - ✓ Prevent the air discharged from the compressor room from being sent back into the room and circulating.
  - ✓ Discharge air in compressor room
  - ✓ Install the fan high on the wall of the compressor room.
  - ✓ When using a rain hood, take resistance into consideration when selecting a ventilating fan.
- Use of inverter type air compressors is important. The continuous air compressor should be used at base load and inverter compressor should be used for variable load with proper pressure setting.
- Multiunit control can be used at the air compressor installations having more than 2 air compressors.



Characteristics of air compressor

7.3. Some important points

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

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

7.4. Environment point in compressed air system

- Replacement of reciprocating air compressor and install low vibration, low noise level air compressors.
- Drain discharge according to the actual drain amount is required in order to efficiently avoid unnecessary damage to the environment and cost associated with generating process of compressed air.

CHAPTER 8: Best Operating Practices - Pumping Systems

8.1. Pumping system description

Most of the pumps in dairy industries are 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. The pump has two main parts such as impeller and diffuser or volute. The impeller is the rotating part that converts pressure energy into the kinetic energy. This kinetic energy of a liquid coming out of an impeller is harnessed by creating a resistance to the flow.

The output power of the pump is called the water horsepower, which is equal to the rate of work done on the fluid, namely

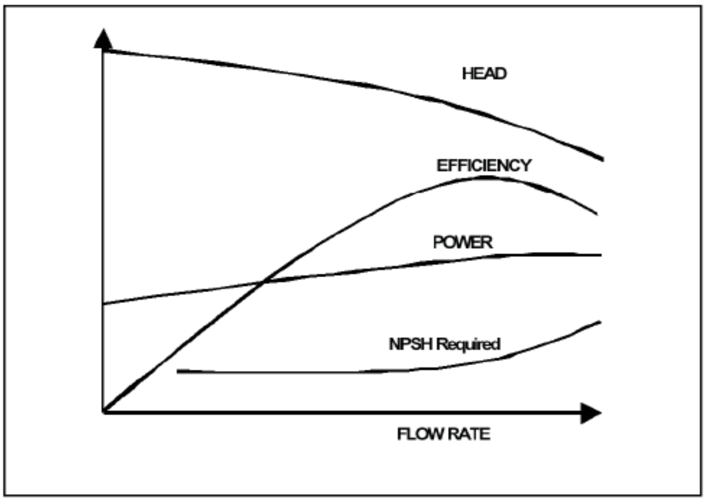
$$P_{out} = Y \times Q \times h_p$$

where, Y is the specific weight of the fluid
Q is the volumetric flow rate
h_p is the energy increase per unit weight, or pump head

8.2. Pump system curves

The pressure (head) that a pump will develop is in direct relationship to the impeller diameter, the number of impellers, the size of impeller eye, and shaft speed. Capacity is determined by the exit width of the impeller. The head and capacity are the main factors, which affect the horsepower size of the motor to be used. The more the quantity of water to be pumped, the more energy is required.

A centrifugal pump is not positive acting; it will not pump the same volume always. The greater the depth of the water, the lesser is the flow from the pump. Also, when it pumps against increasing pressure, the less it will pump. For these reasons it is important to select a centrifugal pump that is designed to do a particular job.



System

Pump performance curves

Hydraulic power, pump shaft power and electrical input power

$$\text{Hydraulic power } P_h = \frac{Q\ (m^3/s) \times \text{Total head}, h_d - h_s\ (m) \times \rho\ (kg/m^3) \times g\ (m/s^2)}{1000}$$

Where h_d - discharge head,

h_s- suction head,

ρ- density of the fluid,

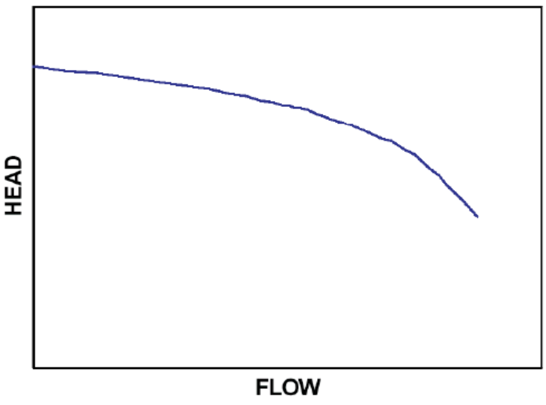
g- acceleration due to gravity

$$\text{Pump shaft power}, P_s = \frac{\text{Hydraulic power}, P_h}{\text{Pump efficiency}, \eta_{pump}}$$

$$\text{Electrical input power} = \frac{\text{Pump shaft power}, P_s}{\text{Pump efficiency}, \eta_{pump}}$$

8.2.1. Pump curves and pump operating point

The performance of a pump can be expressed graphically as head against flow rate. The centrifugal pump has a curve where the head falls gradually with increasing flow.

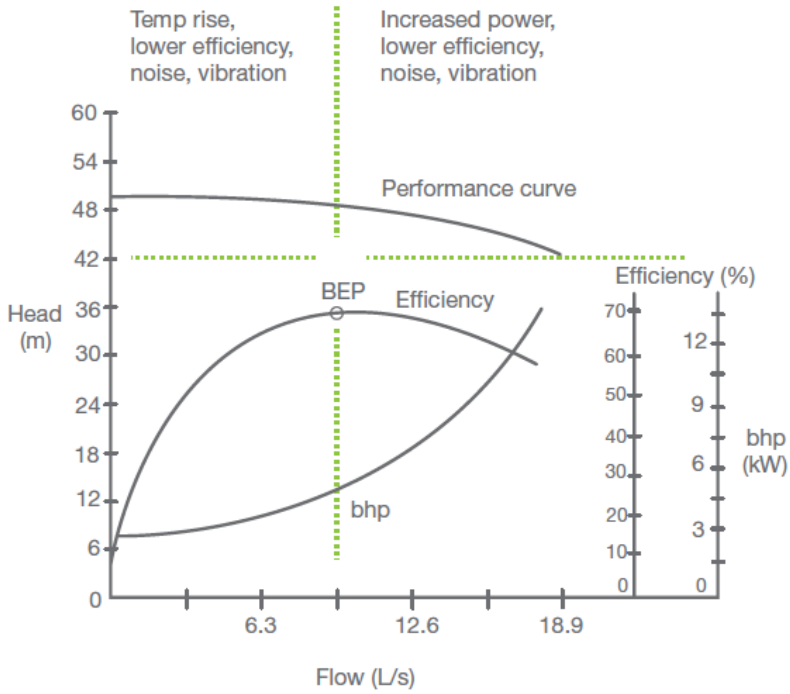


Pump curve

8.2.2. Pump operating point

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

The performance of a pump is typically described by a graph plotting the pressure generated by the pump (measured in terms of head) against flow rate.



Pump operating point

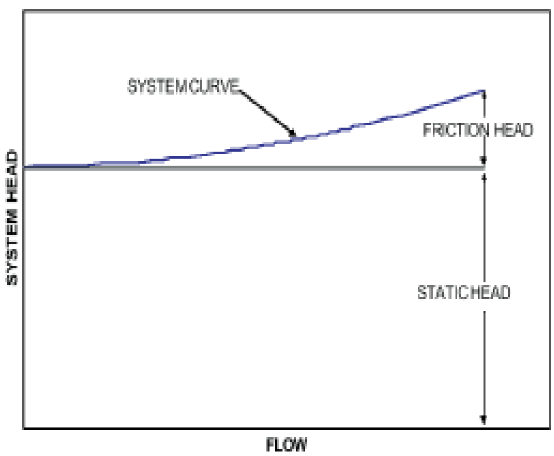
If the actual system curve is different in reality to that calculated, the pump will operate at a flow and head different to that expected.

8.3. System characteristics

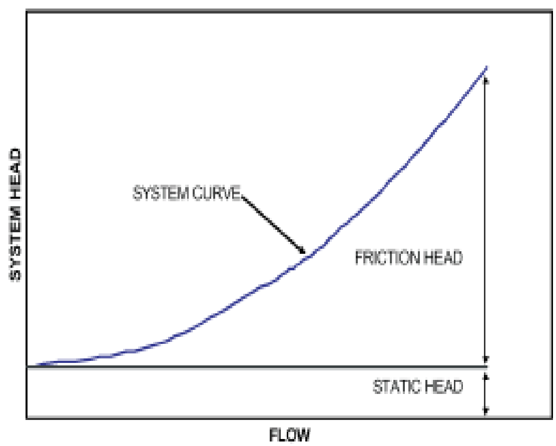
In a pumping system, the objective, in most cases, is either to transfer a liquid from a required destination (e.g. filling a high level reservoir) or to circulate liquid around (e.g. as a means of heat transfer in heat exchanger).

A pressure is needed to make the liquid flow at the required rate and this must overcome head losses in the system. Losses are of two types: static and friction head.

Static head is simply the difference in height of the supply and destination reservoirs Static head is independent of flow. Friction head (sometimes called dynamic head loss) is the friction loss, on the liquid being moved, in pipes, valves and equipment in the system. Most systems have a combination of static and friction head. The two types of losses are shown in below figure:



System with high static head



System with low static head

Static head is a characteristic of the specific installation and reducing this head wherever possible, generally helps both the cost of the installation and the cost of pumping the liquid. Friction head losses must be minimized to reduce pumping cost, but after eliminating unnecessary pipefittings and length. Further reduction in friction head will require larger diameter pipe, which adds to installation cost.

8.4. Indication that pump is oversized

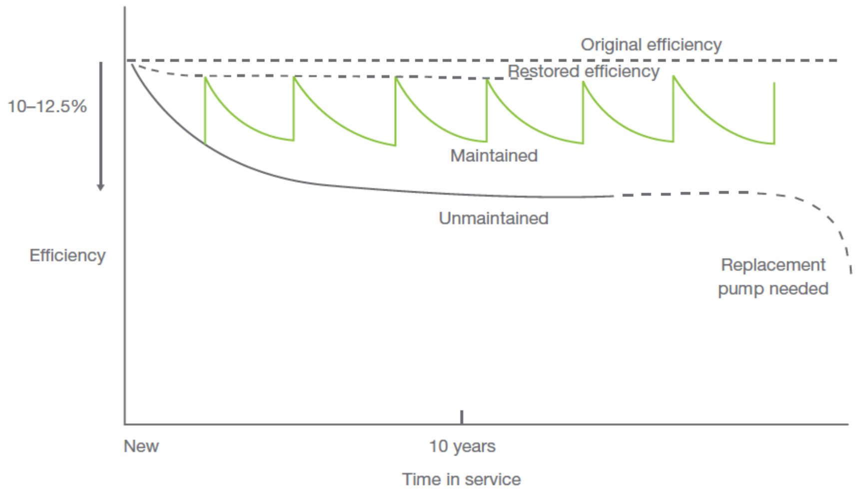
Following table enlists the characteristics of an oversized pump and its reasoning;

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

8.5. Pump wear and maintenance

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

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



Average wear trends for maintained and unmaintained pumps

8.6. Common problems and measures to improve efficiency

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

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

8.7. Best operating practices summary

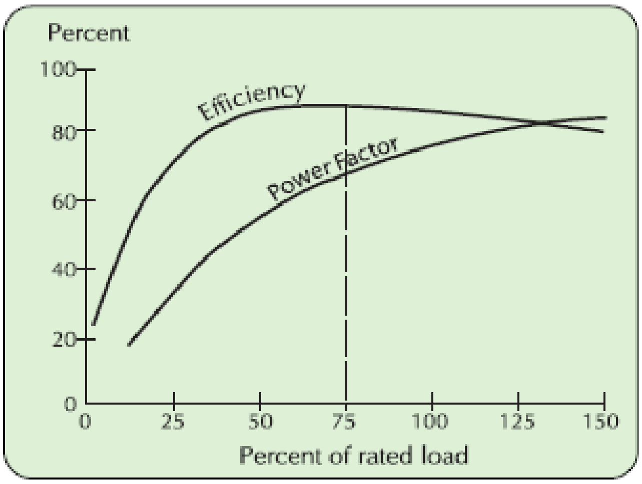
- Ensure adequate NPSH at site during installation.
- Ensure availability of basic instruments at pumps like pressure gauges, flow meters.
- Operate pumps near best efficiency point.
- Modify pumping system and pumps losses to minimize throttling.
- Adapt to wide load variation with variable speed drives or sequence control of multiple units.
- Stop running multiple pumps -add an auto-start for an on-line spare or add a booster pump in the problem area.
- Use booster pumps for small loads requiring higher pressures.
- Increase fluid temperature to reduce pumping rates in case of heat exchangers.
- Repair seals and packing to minimize water loss by dripping
- Balance the system flows and reduce pump power requirements
- Avoid pumping head with a free return (gravity): Use siphone effect to advantage
- Conduct water balance consumption

- Avoid cooling water re-circulation in DG sets, air compressors, refrigeration systems, cooling towers feed water pumps, condenser pumps and process pumps.
- In multiple pump operations, carefully the operation of pumps to avoid throttling
- Provide booster pumps for few areas of higher head
- Replace od pumps by energy efficient pumps
- In case of over designed pump, provide variable speed drive, or downsize/replace impeller or replace with correct sized pump for efficient operation
- Optimize number of stages in multi-stage pump in case of head margins
- Reduce system resistance by pressure drop assessment and pipe size optimization

CHAPTER 9: Best Operating Practices - Motors

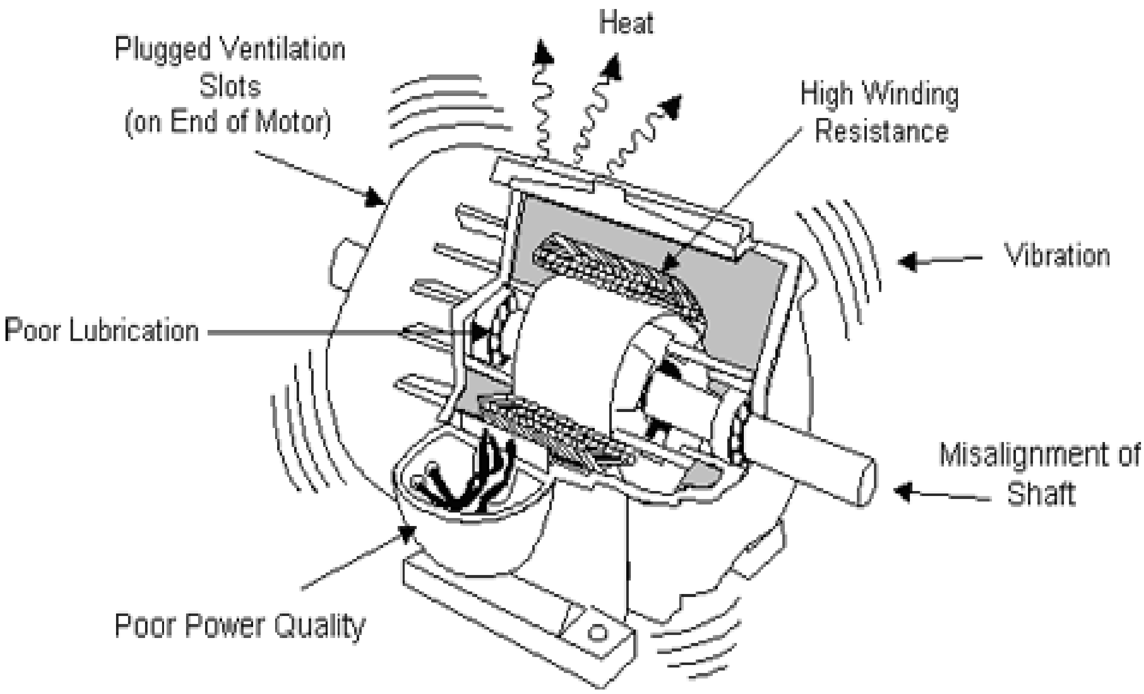
9.1. Motors description

Electrical motors are the principal source of motive power in any plant. Machine tools, auxiliary equipment and other utilities come equipped with one or more electric motors. A machine tool can have several electric motors other than the main spindle motor. These are used for allied operations. Motors are generally efficient, but their efficiency and performance depends on the motor load. Figure shows the variation in efficiency and power factor vis-à-vis the total load, for a typical motor.



Motor efficiency / power factor vs load curve

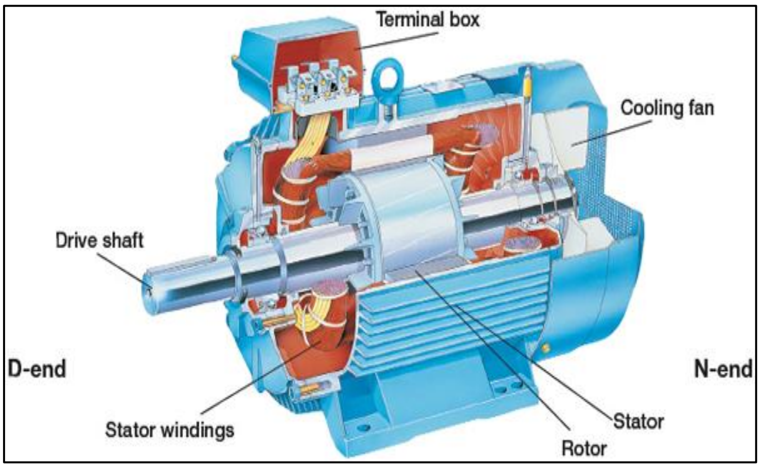
Since there are different types of motors in a dairy plant, it is very important to maintain them and adopt proper operating practices. As they run for years, motors can become less efficient because of wear, breakdown of lubricants, and mis-alignment. Good motor-maintenance practice helps avoid or postpone these problems. A lack of maintenance can reduce a motor's energy efficiency and increase unplanned downtime. Scheduled maintenance is the best way to keep the motors operating efficiently and reliably.



Operational problems of a motor

9.2. Types of motors

➲ Induction motors

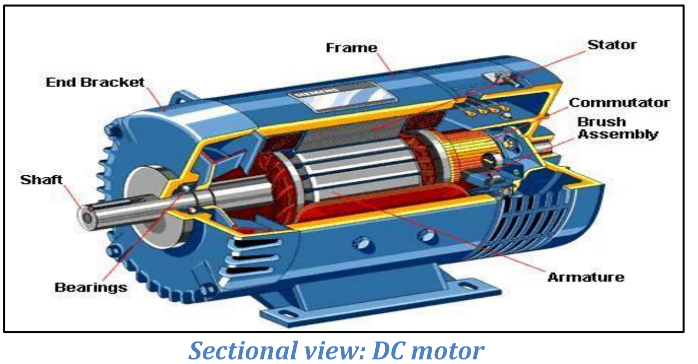


Sectional view: induction motor

Induction motors are the most commonly used prime mover for various equipment in industrial applications. In induction motors, the induced magnetic field of the stator winding induces a current in the rotor. This induced rotor current produces a second magnetic field, which tries to oppose the stator magnetic field, and this causes the rotor to rotate. The 3-phase squirrel cage motor is the workhorse of industry; it is rugged and reliable, and is by far the most common motor type used in industry. These motors drive pumps, blowers and fans, compressors, conveyers and production lines. The 3-phase induction motor has three windings each connected to a separate phase of the power supply.

➲ Direct-Current motors

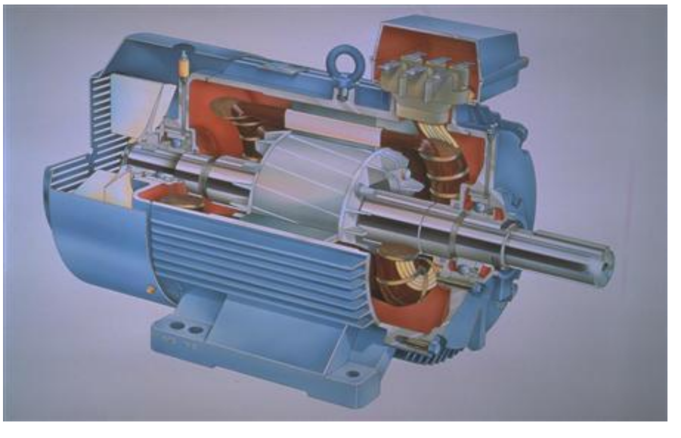
Direct-Current (DC) motors, as the name implies, use direct-unidirectional current. Direct current motors are used in special applications - where high starting torque or smooth acceleration over a broad speed range is required.



Sectional view: DC motor

➲ Synchronous motors

Synchronous Motor is called so because the speed of the rotor of this motor is same as the rotating magnetic field. It is basically a fixed speed motor because it has only one speed, which is synchronous speed and therefore no intermediate speed is there; or in other words it is in synchronism with the supply frequency. Alternating Current (AC) power is fed to the stator of the synchronous motor. The rotor is fed by DC from a separate source. AC power is fed to the stator of the synchronous motor. The rotor is fed by Direct Current (DC) from a separate source. The rotor magnetic field locks onto the stator rotating magnetic field and rotates at the same speed. The speed of the rotor is a function of the supply frequency and the number of magnetic poles in the stator. While induction motors rotate with a slip, i.e., Revolutions Per Minute (rpm) is less than the synchronous speed; the synchronous motor rotate with no slip, i.e., the rpm is same as the synchronous speed governed by supply frequency and number of poles. The slip energy is provided by the D.C. excitation power.


Synchronous motor

9.3. Best operating practices for motors

BOP 1: Replace motors, rather than rewind, when appropriate

Motors are generally repaired more than once, with a typical loss of nearly 2 % in efficiency at each rewind. These motors are generally less efficient than their nominal ratings, and must be replaced appropriately. 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 repair them.

BOP 2: Use appropriately sized motors for replacement

- Many motors are oversized for their applications, resulting in poor motor efficiency and excessive energy use. Always use motors sized according to the requirement of the load. It is good practice to operate motors between 75 -100 % of their full load rating because motors run most efficiently near their designed power rating.
- When replacing motors, always buy energy efficient motors instead of conventional motors. The cost of energy consumed by a conventional motor during its life is far greater than the incremental cost of the energy efficient motor.

BOP 3: Ensure voltage balance across motor terminals

A properly balanced voltage supply is essential for a motor to reach its rated performance. An unbalanced three-phase voltage affects a motor's current, speed, torque, and temperature rise. Equal loads on all three phases of electric service help in assuring a voltage balance while minimizing voltage losses. The options that can be exercised to minimize voltage unbalance include:

- Balancing any single phase loads equally among all the three phases
- Segregating any single phase loads which disturb the load balance and feed them from a separate line / transformer

BOP 4: Reducing under-loading

Probably the most common practice contributing to sub-optimal motor efficiency is that of under-loading. Under-loading results in lower efficiency and power factor, and higher-than-necessary first cost for the motor and related control equipment.

- Carefully evaluate the load that would determine the capacity of the motor to be selected.
- For motors, which consistently operate at loads below 40% of rated capacity, an inexpensive and effective measure might be to operate in star mode. A change from the standard delta operation to star operation involves re-configuring the wiring of the three phases of power input at the terminal box
- Motor operation in the star mode is possible only for applications where the torque-to-speed requirement is lower at reduced load.
- For applications with high initial torque and low running torque needs, Del-Star starters are also available in market, which help in load following derating of electric motors after initial start-up.

BOP 5: Regular up-keep

Properly selected and installed motors can operate for many years with minimal maintenance. Nonetheless, regular care will extend their life and maximize their energy efficiency. A list of such practices and measures is presented below:

- Clean motor surfaces and ventilation openings periodically. Heavy accumulations of dust and lint will result in overheating and premature motor failure.
- Properly lubricate moving parts to avoid unnecessary wear. Be sure to apply appropriate types and quantities of lubricant. Applying too little or too much can harm motor components.
- Check motor for over-heating and abnormal noises/sounds, sparking and ensure proper bedding of brushes.
- Tighten belts and pulleys to eliminate transmission losses.

BOP 6: Install variable frequency drives

Motors frequently drive variable loads such as pumps, hydraulic systems and fans. In these applications, the motors' efficiency is often poor because they are operated at low loads. It is appropriate to use a Variable Frequency Drive (VFD) with the motor.

Use of VFDs

BOP 7: Install capacitor banks

Induction motors are characterized by power factors less than unity, leading to lower overall efficiency (and higher overall operating cost) associated with a plant's electrical system.

- Install capacitors banks across motors with a high rating to reduce the distribution losses.
- Capacitors connected in parallel (shunted) with the motor are typically used to improve the power factor.
- The size of capacitor required for a particular motor depends upon the no-load reactive kVA (kVAR) drawn by the motor, which can be determined only from no-load testing of the motor. In general, the capacitor is selected to not exceed 90 % of the no-load kVAR of the motor. (Higher capacitors could result in over-voltages and motor burnouts).

9.4. Do's and Don'ts in motor operations

The common do's and don'ts with regards to operation of a motor are summarized in table below:

Summary of best operating practices for efficient operation of motors

Do's	Don'ts
• Properly sized to the load for optimum efficiency.	• Avoid mis-alignment in motor
• Use energy-efficient motors where economical.	• Avoid under-voltage and over-voltage conditions
• Use synchronous motors to improve power factor	• Replace, rather than rewind, motors when appropriate
• Provide proper ventilation	• Avoid slippage due to belt tension
• Demand efficiency restoration after motor rewinding.	• Eliminate variable-pitch pulleys.
• Use flat belts as alternatives to v-belts.	• Eliminate eddy current couplings.
• Balance the three-phase power supply.	• Do not run motors when not in use.

CHAPTER 10: Best Operating Practices - Lighting

10.1. Categorization

Lighting system provides light for practical use and to make things visible and clear enough inside and outside factories. In industries/SMEs, lighting includes both day-lighting and artificial light source. Proper lighting fixture selection, layout and control not only enhance lighting effect but also reduce energy consumption by lighting fixtures.

Based on construction and operating characteristics, lights are basically categorized into 3 types: incandescent, florescent and high intensity discharge lamps (HID). Further, depending on the place of use, lights can be broadly classified for indoor and outdoor use.

10.1.1. Indoor lighting

- Most common types are incandescent lamp, fluorescent tube light (FTL), compact fluorescent lamp (CFL), high pressure mercury/sodium vapour lamp (HPMV/HPSV) and metal halide lamps. Now a days, light emitting diode lamp (LED) are also being used and gaining popularity however light/brightness is an issue with LED as it may create glare and negative on occupant/user.
- Uniformity of illuminance is one of the important factors that must be considered during the initial planning stage and/or for modifying existing lighting scheme. Uniformity of illuminance is achieved by proper spacing between the centres of each luminaire/fixture of particular type, size and lux levels.

10.1.2. Outdoor lighting

- Commonly HID lamps are high pressure mercury/sodium vapour lamp (HPMV/HPSV), low pressure sodium vapour lamp (LPSV), halogen lamps and metal halide lamps.
- Recently light emitting diode lamp (LED) and magnetic induction lamps are gaining popularity due to long life and higher energy efficiency.

10.2. Fixture selection and sizing

10.2.1. Low-bay and High-bay lights fixtures

- Low bay light fixture is typically used with ceiling heights 20’ or less. High bay light fixtures are typically used for heights between 20’ to 45’.
- Low bay light usually features some type of diffuser on the bottom of the light to spread the light in a manner reflective of the lower ceiling height. High bay lights typically have an aluminum reflector which allows a beam of light to reflect downwards to the floor area. Other types of high bay lights have a prismatic reflector which illuminates shelving, etc. from the floor to the ceiling.
- Irrespective of low bay or high bay lighting, metal halide type lighting allows users to illuminate large areas with very few lights, making it the energy savings choice for buildings of all sizes.

10.2.2. Flood light fixtures

- Floodlights fixtures with reflectors are used to illuminate a wide area like roads, car parking, playground etc.
- Parabolic aluminized reflector light fixtures are used when a substantial amount of flat lighting is required for a scene.

10.2.3. Luminaire efficiency

- The efficiency of a luminaire is the ratio of luminaire lumen output to the lamp lumen output. Mirror optics of a luminaire and louvers decides the luminaire efficiency along with the improved visual comfort and glare control.
- Lighting simulation tools can be used to choose which luminaire will suit best the required application by analyzing the lighting distribution and glare index.

10.3. Layout

- In order to design a luminaire layout that best meets the illuminance level and uniformity requirements of the job, two types of information are generally needed: average illuminance level and illuminance level at given point.
- Every luminaire/fixture will have recommended space to height ratio (SHR), it is better to choose luminaires with larger SHR, this can reduce the number of fittings and connected lighting load.
- Lighting layout at corners of room is undesirable hence lights layout at distance from all four corners is desirable in a room.

Area	Recommended Lux level	Average lux level in foundry
Corridors and walkway	40	5 – 20
Change rooms, storage	80	25 – 55
Mould and core preparation	160	45 – 85
Melting shop floor	240	105 – 165
Office work space	250	185 – 305
Laboratory	500	215 – 245
Inspection area	1500	255 – 365

10.4. Maintenance of fixtures

- Light levels decrease over time because of aging lamps and dirt on fixtures, lamps and room surfaces. Together, these factors can reduce illumination by 50 percent or more, while lights continue drawing full power.
- Regular maintenance is essential to ensure that facilities receive the desired quantity and quality of light, as well as energy efficiency, from their lighting systems. Periodic maintenance can produce a range of benefits, including a brighter and cleaner workplace, a higher level of safety, and enhanced productivity.

- The basic maintenance includes cleaning of lamps and fixtures, cleaning and re-painting interiors and re-lamping. Keep light-reflecting surfaces and lenses clean in order to maintain designed light levels.
- Workers should take care not to touch the envelope of halogen bulbs because doing so leaves skin oils on the glass surface. As these bulbs heat and cool, the oils cause uneven stress, leading to glass cracking and shorter lamp life.
- Tips for cleaning fixtures:
  - Clean lighting fixtures whenever lamps are replaced. In areas where doors allow outside air or filtering is not adequate, clean at least twice a year.
  - Wipe plastic lenses with damp, not dry cloth (a mild detergent may be needed). Small cell louver panels, including parabolic wedge louvers, should be removed and dipped in mild detergent solution, then air-dried.
  - Do not wipe luminaire or lamps while fixture is energized.
- Line voltage should be checked at the fixture and compared with the ballast rating to be sure it is within the prescribed limits, so as to prevent lamps premature failure due to flickering caused by voltage fluctuation, hence if voltage controllers/stabilizers are present then its maintenance should also be done periodically.
- Replacement of old conventional magnetic ballast with new electronic ballast also reduces maintenance part of ballast repairing.
- To avoid damage to ballasts, lamps are replaced when it ceases operation unexpectedly, failed to light up after turning it on.
- Lamps should be replaced when they reach 70%-80% of their rated life.
- Bulbs should be replaced not only when they break, but on a schedule according to how the brightness of the lamp decays over time. Some bulbs lose over a third of their initial brightness over a few years.

10.5. Control Strategies

10.5.1. Localized switching

Localized switching is preferred in large spaces. By using localized switching it is possible to turn off artificial lighting in specific areas, while still operating it in other areas where it is required, a situation which is impossible if the lighting for an entire space is controlled from a single switch.

10.5.2. Occupancy sensors

Occupancy Sensors

Occupancy–linked control can be achieved using infra-red, acoustic, ultrasonic /microwave sensors, which detect either movement/noise in room spaces. These sensors switch-on lighting when occupancy is detected, and switch-off again, when no occupancy movement is detected for a set time period. They are designed to override manual switches and to prevent a situation where lighting is left on in unoccupied spaces. With this type of system it is important to incorporate a built–in time delay, since occupants often remain still or quiet for short periods and do not appreciate being plunged into darkness if not constantly moving around.

10.5.3. Photocells

These measure the amount of natural light available and suitable for both indoor and outdoor (Street lights) applications. When the available light falls below a specified level, a control unit switches the lights on (or adjusts a driver to provide more light).

Photocells can be programmed so that lights do not flip on and off on partially cloudy days.

10.5.4. Time based Control

Timed–turnoff switches are the least expensive type of automatic lighting control. Electronic timer switch provides a choice of time intervals, which can be selected by adjusting knob located behind the faceplate. Most timer models allow occupants to turn off lights manually; some models allow occupants to keep on, overriding the timer. Timed-turnoff switches are available with a wide range of time spans. The choice of time span is a compromise. Shorter time spans waste less energy but increases the probability that the lights will turn off while someone is in the space.

10.5.5. Dimming technologies

It include common manual dimming switches as well as more sophisticated technology that automatically reduce light output according to the availability of daylight or other ambient light. While dimming of incandescent lamps is common, dimming of fluorescent fixtures can only be accomplished if they have ballasts designed especially for dimming applications.

10.5.6. Day lighting controls

It adjusts light output levels from fixtures in perimeter areas next to windows or under skylights in response to natural outdoor light entering the building. Day lighting controls are available in continuous dimming and stepped reduction models.

10.5.7. Automated lighting management systems

It provides centralized computer control of lighting systems.

10.6. Efficiency improvement

10.6.1. Use of daylights

Glass strips, running continuously across the breadth of the roof at regular intervals, can provide uniform lighting on industrial shop floors and storage bays, also maximum usage of daylights should be done in industries /factories by using transparent/translucent roofing sheets so as to minimize usage of electrical lighting in daytime.

10.6.2. Lighting voltage transformer/controller

Higher and frequent voltage variation leads to increased energy consumption by lighting loads, lamp lumen depreciation and also reduces the life of lamps.

Lighting voltage controller

It is always recommended to maintain single phase voltage between 210 – 215 V exclusively for lighting circuit for better and optimum performance of luminaries.

It is recommended that the plant should install lighting transformers to separate the lighting load from other plant load and process load. In areas where lighting transformers may not be feasible, energy savers or voltage reduction devices may be installed in the outgoing circuit. This is likely to improve the power factor as well as increase the reliability of the lighting infrastructure.

The reduction of voltage to these levels does not impair the ability of discharge lamps to strike, though an insignificant reduction in lumen output takes place. Usage of lower voltage leads to an increase in the operating power factor as well as the life of luminaries, which is confirmed by lower failure rates.

10.6.3. Occupancy sensors based control

In most of the offices and factories it is observed that the lighting in the most of the areas is ON during the non-use period as well.

To avoid the idle running of the lighting system, it is recommended to retrofit the occupancy sensors by identifying such areas to save energy.

10.6.4. Lighting dimmer control

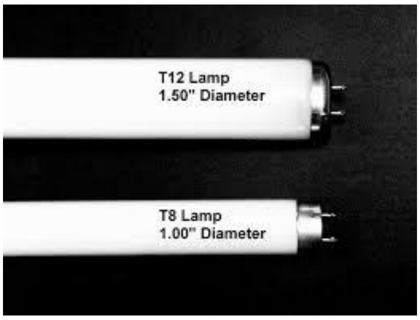
Use of dimmer control in parking areas will reduce the substantial energy consumption as most of the time parking area is non-occupied space once shifts in the evening starts.

Lighting dimmer control

10.6.5. Replacement of existing lights with energy efficient lighting

- Replace T12 (52 watts)/T8 (40 watts) with FTL T5 (30 watts) or LED tube light(20 watts)
- Replace CFLs with LED lamps with good lumens
- Replace of metal halide lamps of (250W) with magnetic induction flood lamp of (150 W)
- Replace of HPMV lamps of (400W) with high bay magnetic induction lamp of (250W)

Photographs of these replacements are provided below.

Existing	**Replacement**
 T12 and T8 FTL	 T5 FTL
 CFL	 LED
 Metal Halide flood lamp	 Magnetic Induction Flood Lamp
 High bay HPMV lamp	 High bay Magnetic induction lamp

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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Details of GEF projects on energy efficiency being implemented by BEE can be found on www.indiasavesenergy.in