MODULE I

1.1 Introduction

Energy is one of the major inputs for the economic development of any country. In the case of the developing countries, the energy sector assumes a critical importance in view of the ever increasing energy needs requiring huge investments to meetthem.

Energy is the ability to do work and work is the transfer of energy from one form to another. In practical terms, energy is what we use to manipulate the world around us, whether by exciting our muscles, by using electricity, or by using mechanical devices such as automobiles. Energy comes in different forms - heat (thermal), light (radiant), mechanical, electrical, chemical, and nuclear energy.

Energy can be classified into several types based on the following criteria:

- Primary and Secondaryenergy
- Commercial and Non commercialenergy
- Renewable and Non-Renewableenergy

1.1.1 Primary and SecondaryEnergy

Primary energy sources are those that are either found or stored in nature. Common primary energy sources are coal, oil, natural gas, and biomass (such as wood). Other primary energy sources available include nuclear energy from radioactive substances, thermal energy stored in earth's interior, and potential energy due to earth's gravity. The major primary and secondary energy sources are shown in Figure 1.1

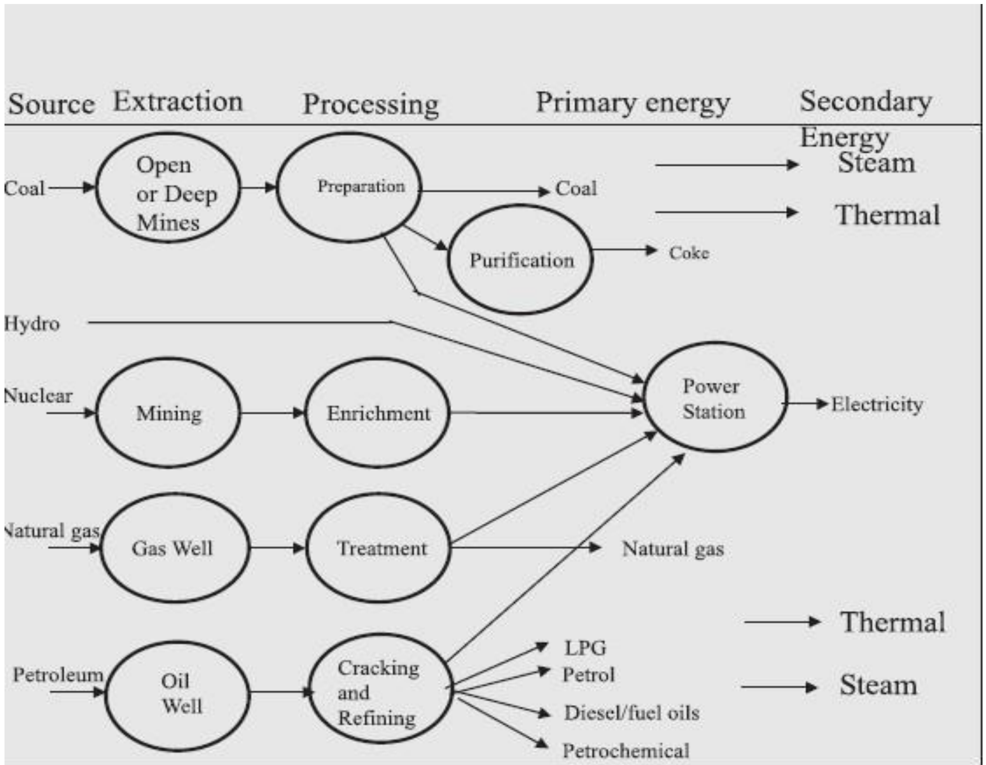


Figure 1.1 Major Primary and Secondary Sources

Primary energy sources are mostly converted in industrial utilities into secondary energy sources; for example coal, oil or gas converted into steam and electricity. Primary energy can also be used directly. Some energy sources have non-energy uses, for example coal or natural gas can beused as a feedstock in fertilizerplants.

1.1.2 Commercial Energy and Non CommercialEnergy

Commercial Energy

The energy sources that are available in the market for a definite price are known as commercial energy. By far the most important forms of commercial energy are electricity, coal and refined petroleum products. Commercial energy forms the basis of industrial, agricultural, transport and commercial development in the modern world. In the industrialized countries, commercialized fuels are predominant source not only for economic production, but also for many household tasks of generalpopulation.

Examples: Electricity, lignite, coal, oil, natural gas etc.

Non-Commercial Energy

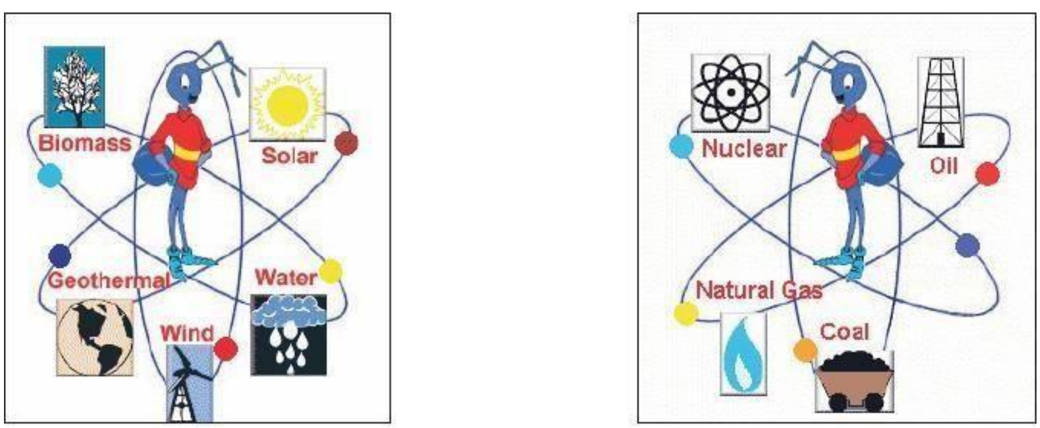
The energy sources that are not available in the commercial market for a price are classified as non-commercial energy. Non-commercial energy sources include fuels such as firewood, cattle dung and agricultural wastes, which are traditionally gathered, and not bought at a price used especially in rural households. These are also called traditional fuels. Non- commercial energy is often ignored in energy accounting.

Example: Firewood, agro waste in rural areas; solar energy for water heating, electricity generation, for drying grain, fish and fruits; animal power for transport, threshing, lifting water for irrigation, crushing sugarcane; wind energy for lifting water and electricity generation.

1.1.3 Renewable and Non-RenewableEnergy

Renewable energy is energy obtained from sources that are essentially inexhaustible. Examples of renewable resources include wind power, solar power, geothermal energy, tidal power and hydroelectric power (See Figure 1.2). The most important feature of renewable energy is that it can be harnessed without the release of harmful pollutants.

Non-renewable energy is the conventional fossil fuels such as coal, oil and gas, which are likely to deplete with time.



Renewable Non-Renewable

Figure 1.2 Renewable and Non-Renewable Energy

1.2 Energy and Power

1.2.1 Energy

Energy is the ability to do a work. Its unit is Joule (J)

Energy = force * Distance

1.2.2 Power

Power is defined as the rate of doing work. Its unit is watt (W)

1.2.3 Relation Between Energy andPower

Energy = Power * Time

Example 1.1

A portable machine requires a force of 200N to move it. How much work is done if the machine is moved 20m and what average power is utilized if the movement takes 25s?

Solution

Work done = force * distance

= 200N * 20m

= 4000 Nm or 4 kJ

Power = work done / time taken = 4000 J / 25 s = 160 J/s = 160 W

1.3 Present and Past Scenario of Primary Energy Resources In TheWorld

1.3.1 Coal

Coal is the most abundant fossil fuel in the world. Coal reserves are available in almost every country in the world. The largest coal reserves are available in the USA followed by Russia, China, Australia and India. The global coal reserve was estimated to be **891.531 billion tones by the end of 2013**. But by the end of **2003, it was estimated to be 984.453 billiontones**.

1.3.2 Crude Oil

The global proven crude oil reserve was estimated to be **1687 billion barrels by the end of 2013**. But by the end of **2003, it was estimated to be 1147 billion barrels**. Almost 48% of proven oil reserves are in the Middle East countries. Saudi Arabia has the largest share of the reserve with 15.8% followed by Russia and USA.

1.3.3 NaturalGas

Natural gas is a gaseous fossil fuel consisting primarily of methane but also includes small quantities of ethane, propane, butane and pentane. Before natural gas can be used as a fuel, it undergoes extensive processing for removing almost all constituents except methane. Natural gas resources are large but they are highly concentrated in few countries. Iran has largest share (18.2%) followed by Russia (16.8%) and Qatar (13.3%). India has only about 0.7% of global natural reserves. The global proven natural gas reserve was estimated to be **176 trillion cubic meters by the end of 2003**. But by the end of 2013**, it was estimated to be 186 trillion cubicmeters**.

1.4 National Energy ConsumptionData

The primary energy consumption of some of the countries are given in table. It is seen that India's primary energy consumption is only 4.7% of the world (USA-18%, China-22%).

Table-1.7 Primary Energy consumption at the end of 2013								
	Million tonnes of oil equivalent (Mtoe)							% of Share
Country	**Oil**	**Natural gas**	**Coal**	**Nuclear Energy**	**Hydro-Power**	**Renewable Energy**	**Total**	
China	507.4	145.5	1925.3	25	206.3	42.9	2852.4	22.4
US	831.0	671.0	455.7	187.9	61.5	58.6	2265.8	17.8
Russia	153.1	372.1	93.5	39.1	41	0.1	699	5.5
India	175.2	46.3	324.3	7.5	29.8	11.7	595.0	4.7
Japan	208.9	105.2	128.6	3.3	18.6	9.4	474.0	3.7
Germany	112.1	75.3	81.3	22.0	4.6	29.7	325.0	2.6
Others	2197.4	1198.3	818	278.4	494	126.9	5519.2	43.3
World	**4185.1**	**3030.4**	**3826.7**	**563.2**	**855.8**	**279.3**	**12730.4**	**100**

Source: BP Statistical Review of World Energy, June 2014

	4.18%	1.52%	8.47%	1.33%	3.48%	4.18%	**4.7%**

1.5 Environmental Aspects Associated with energyutilization

The usage of energy resources in industry leads to environmental damages by polluting the atmosphere. Few of examples of air pollution are sulphur dioxide (SO2), nitrous oxide (NOX) andcarbon monoxide (CO) emissions from boilers and furnaces, chloro-fluro carbons (CFC) emissions from refrigerants use, etc. In chemical and fertilizers industries, toxic gases are released. Cement plants and power plants spew out particulatematter.

1.5.1 AirPollution

In both developed and rapidly industrializing countries, the major historic air pollution problem has typically been high levels of smoke and SO2 arising from the combustion of sulphur-containing fossil fuels such as coal for domestic and industrial purposes.

In both developed and developing countries, the major threat to clean air is now posed by traffic emissions. Petrol- and diesel-engined motor vehicles emit a wide variety of pollutants, principallycarbonmonoxide(CO),oxidesofnitrogen(NOx),volatileorganiccompounds(VOCs)and particulates, which have an increasing impact on urban air quality.

In addition, photochemical reactions resulting from the action of sunlight on NO_2 and VOCs from vehicles leads to the formation of ozone, a secondary long-range pollutant, which impacts in rural areas often far from the original emission site. Acid rain is another long-range pollutant influenced by vehicle NO_xemissions.

The principle pollutants produced by industrial, domestic and traffic sources are sulphur dioxide, nitrogen oxides, particulate matter, carbon monoxide, ozone, hydrocarbons, benzene, 1,3-butadiene, toxic organic micro pollutants, lead and heavy metals

1.5.2 Climate Change

Human activities, particularly the combustion of fossil fuels, have made the blanket of greenhouse gases (water vapour, carbon dioxide, methane, ozone etc.) around the earth thicker. The resulting increase in global temperature is altering the complex web of systems that allow life to thrive on earth such as rainfall, wind patterns, ocean currents and distribution of plant and animal species.

1.5.3 Greenhouse Effect and CarbonCycle

Life on earth is made possible by energy from the sun, which arrives mainly in the form of visible light. About 30 percent of the sunlight is scattered back into space by outer atmosphere and the balance 70 percent reaches the earth's surface, which reflects it in form of infrared radiation. The escape of slow moving infrared radiation is delayed by the green house gases. A thicker blanket of greenhouse gases traps more infrared radiation and increase the earth'stemperature

Carbon dioxide is responsible for 60 percent of the "enhanced greenhouse effect". Humans are burning coal, oil and natural gas at a rate that is much faster than the rate at which these fossil fuels were created. This is releasing the carbon stored in the fuels into the atmosphere and upsetting the carbon cycle (a precise balanced system by which carbon is exchanged between the air, the oceans and land vegetation taking place over millions of years). Currently, carbon dioxide levels in the atmospheric are rising by over 10 percent every 20 years.

The effects of increase in the earth's temperature are as follows:

- **Severe Storms andFlooding**
- **FoodShortages**
- **Reduced Freshwatersupply**
- **Loss ofBiodiversity**
- **IncreasedDiseases**

1.5.4 AcidRain

Acid rain is caused by release of SOX and NOX from combustion of fossil fuels, which then mix with water vapour in atmosphere to form sulphuric and nitric acids respectively.

The effects of acid rain are as follows:

- Acidification of lakes, streams, andsoils
- Direct and indirect effects (release of metals, For example: Aluminum which washesaway plantnutrients)
- Killing of wildlife (trees, crops, aquatic plants, andanimals)
- Decay of building materials and paints, statues, andsculptures
- Health problems (respiratory, burning- skin andeyes)

1.6 Energy Auditing

As per the Energy Conservation Act, 2001, Energy Audit is defined as "***the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energyconsumption***".

The objective of Energy Management is to achieve and maintain optimum energy procurement and utilization, throughout the organization and:

To minimize energy costs / waste without affecting production & quality
To minimize environmental effects.

1.7 Energy Audit:Needs

In any industry, the three top operating expenses are often found to be energy (both electrical and thermal), labour and materials. If one were to relate to the manageability of the cost or potential cost savings in each of the above components, energy would invariablyemerge as a top ranker, and thus energy management function constitutes a strategic area for cost reduction. Energy Audit will help to understand more about the ways energy and fuel are used in any industry, and help in identifying the areas where waste can occur and where scope for improvementexists.

The Energy Audit would give a positive orientation to the energy cost reduction, preventive maintenance and quality control programmes which are vital for production and utility activities. Such an audit programme will help to keep focus on variations which occur in the energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment etc.

In general, Energy Audit is the translation of conservation ideas into realities, by lending technically feasible solutions with economic and other organizational considerations within a specified time frame.

The primary objective of Energy Audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs. Energy Audit provides a " bench-mark" (Reference point) for managing energy in the organization and also provides the basis for planning a more effective use of energy throughout the organization.

1.8 Energy Audit: Types

Type of Energy Audit

The type of Energy Audit to be performed depends on:

.Function and type of industry

.Depth to which final audit is needed, and
.Potential and magnitude of cost reduction desired

Thus Energy Audit can be classified into the following two types.

i) PreliminaryAudit

ii) DetailedAudit

Preliminary Energy Audit Methodology

Preliminary energy audit is a relatively quick exercise to:

- Establish energy consumption in theorganization
- Estimate the scope forsaving
- Identify the most likely (and the easiest areas forattention
- Identify immediate (especially no-/low-cost) improvements/savings
- Set a 'referencepoint'
- Identify areas for more detailedstudy/measurement
- Preliminary energy audit uses existing, or easily obtaineddata

Detailed Energy Audit Methodology

A comprehensive audit provides a detailed energy project implementation plan for a facility, since it evaluates all major energy using systems.

This type of audit offers the most accurate estimate of energy savings and cost. It considers the interactive effects of all projects, accounts for the energy use of all major equipment, and includes detailed energy cost saving calculations and project cost.

In a comprehensive audit, one of the key elements is the energy balance. This is based on an inventory of energy using systems, assumptions of current operating conditions and calculations of energy use. This estimated use is then compared to utility billcharges.

Detailed energy auditing is carried out in three phases: Phase I, II and III.

Phase I - Pre AuditPhase

Phase II - Audit Phase

Phase III - Post Audit Phase

Phase I -Pre Audit Phase Activities

A structured methodology to carry out an energy audit is necessary for efficient working. An initial study of the site should always be carried out, as the planning of the procedures necessary for an audit is most important.

Initial Site Visit and Preparation Required for Detailed Auditing

An initial site visit may take one day and gives the Energy Auditor/Engineer an opportunity to meet the personnel concerned, to familiarize him with the site and to assess the procedures necessary to carry out the energy audit.

During the initial site visit the Energy Auditor/Engineer should carry out the following actions: -

- Discuss with the site's senior management the aims of the energyaudit.
- Discuss economic guidelines associated with the recommendations of theaudit.
- Analyze the major energy consumption data with the relevantpersonnel.
- Obtain site drawings where available - building layout, steam distribution, compressed air distribution, electricity distributionetc.
- Tour the site accompanied byengineering/production

The main aims of this visit are: -

- To finalize Energy Auditteam
- To identify the main energy consuming areas/plant items to be surveyed during theaudit.
- To identify any existing instrumentation/ additional meteringrequired.
- To decide whether any meters will have to be installed prior to the audit eg.kWh, steam, oil or gasmeters.

- To identify the instrumentation required for carrying out theaudit.
- To plan with timeframe
- To collect macro data on plant energy resources, major energy consumingcenters
- To create awareness through meetings/programme

<u>Phase II- Detailed Energy Audit Activities</u>

Depending on the nature and complexity of the site, a comprehensive audit can take from several weeks to several months to complete. Detailed studies to establish, and investigate, energy and material balances for specific plant departments or items of process equipment are carried out. Whenever possible, checks of plant operations are carried out over extended periods of time, at nights and at weekends as well as during normal daytime working hours, to ensure that nothing is overlooked.

The audit report will include a description of energy inputs and product outputs by major department or by major processing function, and will evaluate the efficiency of each step of the manufacturing process. Means of improving these efficiencies will be listed, and at least a preliminary assessment of the cost of the improvements will be made to indicate the expected pay- back on any capital investment needed. The audit report should conclude with specific recommendations for detailed engineering studies and feasibility analyses, which must then be per- formed to justify the implementation of those conservation measures that require investments.

The information to be collected during the detailed audit includes: -

1. Energy consumption by type of energy, by department, by major items of process equipment, byend-use
2. Material balance data (raw materials, intermediate and final products, recycled materials, use of scrap or waste products, production of by-products for re-use in other industries,etc.)
3. Energy cost and tariffdata
4. Process and material flowdiagrams

5. Generation and distribution of site services (eg. compressed air,steam).
6. Sources of energy supply (e.g. electricity from the grid orself-generation)
7. Potential for fuel substitution, process modifications, and the use of co-generation systems (combined heat and powergeneration).
8. EnergyManagementproceduresandenergyawarenesstrainingprogramswithinthe establishment

1.9 Energy Audit-Methodology

A comprehensive ten-step methodology for conduct of Energy Audit at field level is presented below. Energy Manager and Energy Auditor may follow these steps to start with and add/change as per their needs and industry types.

Ten Steps Methodology for Detailed Energy Audit

Step No	PLAN OF ACTION	PURPOSE / RESULTS
	Phase I – Pre Audit Phase	
Step 1	• Plan and organise • Walk through Audit • Informal Interview with Energy Manager, Production / Plant Manager	• Resource planning, Establish/organize a Energy audit team • Organize Instruments & time frame • Macro Data collection (suitable to type of industry.) • Familiarization of process/plant activities • First hand observation & Assessment of current level operation and practices
Step 2	• Conduct of brief meeting / awareness programme with all divisional heads and persons concerned (2-3 hrs.)	• Building up cooperation • Issue questionnaire for each department • Orientation, awareness creation
	Phase II – Audit Phase	
Step 3	• Primary data gathering, Process Flow Diagram, & Energy Utility Diagram	• Historic data analysis, Baseline data collection • Prepare process flow charts • All service utilities system diagram (Example: Single line power distribution diagram, water, compressed air & steam distribution. • Design, operating data and schedule of operation • Annual Energy Bill and energy consumption pattern (Refer manual, log sheet, name plate, interview)
Step 4	• Conduct survey and monitoring	• Measurements : Motor survey, Insulation, and Lighting survey with portable instruments for collection of more and accurate data. Confirm and compare operating data with design data.
Step 5	• Conduct of detailed trials /experiments for selected energy guzzlers	• Trials/Experiments: - 24 hours power monitoring (MD, PF, kWh etc.). - Load variations trends in pumps, fan compressors etc.

		- Boiler/Efficiency trials for (4 – 8 hours) - Furnace Efficiency trials Equipments Performance experiments etc
Step6	• Analysis of energy use	• Energy and Material balance & energy loss/waste analysis
Step 7	• Identification and development of Energy Conservation (ENCON) opportunities	• Identification & Consolidation ENCON measures • Conceive, develop, and refine ideas • Review the previous ideas suggested by unit personal • Review the previous ideas suggested by energy audit if any • Use brainstorming and value analysis techniques • Contact vendors for new/efficient technology
Step 8	• Cost benefit analysis	• Assess technical feasibility, economic viability and prioritization of ENCON options for implementation • Select the most promising projects • Prioritise by low, medium, long term measures
Step9	• Reporting & Presentation to the Top Management	• Documentation, Report Presentation to the top Management.
	Phase III –Post Audit phase	
Step10	• Implementation and Follow-up	Assist and Implement ENCON recommendation measures and Monitor the performance • Action plan, Schedule for implementation • Follow-up and periodic review

1.10 Barriers to Energy Conservation

Traditional energy prices are understated because they do not include the health, social, and environmental costs of using fuels. For example, gasoline prices do not take into account the costs associated with military requirements to protect access to oil sources, global warming, acid rain, and adverse health effects. This is an institutional barrier to increasing energy efficiency. Some of the key barriers to achieving increased efficiency are listed below.

1.10.1 Lack of Objective ConsumerInformation

Efficiency claims in the market place are often made by competing manufacturers, without an objective third party to evaluate the actual efficiency claims.

1.10.2 Failure of Consumers to Make Optimal Energy-EfficiencyDecisions

Consumers often choose the least expensive appliance, rather than the appliance that will save them money over the long term; consumers are also often confused about efficiency ratings and efficiency improvements.

1.10.3 Replacement Market Decisions Based on Availability Rather ThanEfficiency

Decisions concerning replacement of worn out or broken equipment are made without energy efficiency as a high priority. Usually, the primary concern for the consumer is restoring service as quickly as possible. This requires buying whatever equipment the plumbing or heating contractor may have on hand.

1.10.4 Energy Prices do not take into Accountthe Full Environmental or SocietalCosts

External costs associated with public health, energy production, global warming, acid rain, air pollution, energy security, or reliability of supply are usually ignored.

1.10.5 Competition for Capital to Make Energy-EfficiencyInvestments

Energy-efficiency investments in the commercial and industrial sectors often must compete with other business investments; therefore, efficiency investments with a payback of more than 3 years are avoided.

1.10.6 The Separation of Building Ownership from Utility BillResponsibility

Renters will rarely make energy-efficiency investments in buildings that they do not own, especially when the utilities are included in the rent.

1.10.7 Commercial Buildings and Retail Space are Usually Built on Speculation with Low First-Cost aPriority

The building's long-term operation cost, which is usually paid by the tenant(s) rather than the owner, is not important to thespeculator/builder.

1.11 Role of EnergyManagers

"The tasks of energy manger are setting goals, tracking progress, and promoting the energy management program. An Energy Manager helps an organization achieve its goals by establishing energy performance as a core value."

The Energy Manager is not always an expert in energy and technical systems. Successful Energy Manager understands how energy management helps the organization achieve its financial and environmental goals and objectives. Depending on the size of the organization, the Energy Manager role can be a full-time position or an addition to other responsibilities.

Energy Manager: Responsibilities and Duties to be Assigned Under The Energy Conservation Act, 2001.

Responsibilities

- Prepare an annual activity plan and present to management concerning financially attractive investments to reduce energycosts

- Establish an energy conservation cell within the firm with management's consent about themandate and task of thecell.

- Initiate activities to improve monitoring and process control to reduce energycosts.

- Analyze equipment performance with respect to energyefficiency

- Ensure proper functioning and calibration of instrumentation required to assess level ofenergy consumption directly orindirectly.

- Prepare information material and conduct internal workshops about the topic for otherstaff.

- Improve disaggregating of energy consumption data down to shop level or profit center of afirm.

- Establish a methodology how to accurately calculate the specific energy consumption ofvarious products/services or activity of thefirm.

- Develop and manage training programme for energy efficiency at operatinglevels.

- Co-ordinate nomination of management personnel to externalprograms.

• Create knowledge bank on sectoral, national and inter-national development on energy efficiency technology and management system and informationdenomination

• Develop integrated system of energy efficiency and environmental upgradation.

• Co-ordinate implementation of energy audit/efficiency improvement projects through external agencies.

• Establish and/or participate in information exchange with other energy managers of the same sector throughassociation

Duties

• Report to BEE and State level Designated Agency once a year the information with regard tothe energy consumed and action taken on the recommendation of the accredited energy auditor, as per BEEFormat.

• Establish an improved data recording, collection and analysis system to keep track of energy consumption.

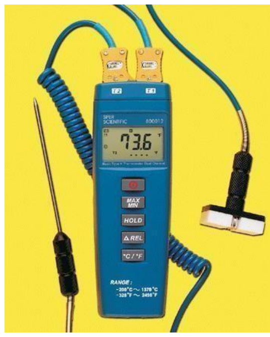
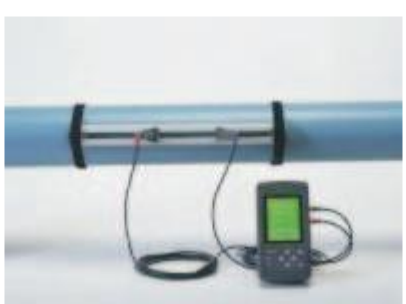
• Provide support to Accredited Energy Audit Firm retained by the company for the conduct of energy audit

• Provide information to BEE as demanded in the Act, and with respect to the tasks given by a mandate, and the jobdescription.

• Prepare a scheme for efficient use of energy and its conservation and implement such scheme keeping in view of the economic stability of the investment in such form and manner as may be provided in the regulations of the Energy ConservationAct.

1.12 Energy AuditInstruments

 	**Electrical Measuring Instruments:** These are instruments for measuring major electrical parameters such as kVA, kW, PF, Hertz, kVAr, Amps and Volts. In addition some of these instruments also measure harmonics. These instruments are applied on-line i.eon running motors without any need to stop the motor. Instant measurements can be taken with hand-held meters, while more advanced ones facilitates cumulative readings with print outs at specified intervals.
	**Combustion analyzer:** This instrument has in-built chemical cells whichmeasurevariousgasessuchasO_2,CO, NO_X andSO_X.
	**Fuel Efficiency Monitor:** This measures oxygen and temperature ofthe flue gas. Calorific values of common fuels are fed into the microprocessor which calcu-lates the combustionefficiency.
	**Fyrite:** A hand bellow pump draws the flue gas sample into the solution inside the fyrite. A chemical reaction changes the liquid volume revealing the amount of gas. A separatefyritecan be used for O_2 and CO_2measurement.

	**Contact thermometer:** These are thermocouples which measuresfor example flue gas, hot air, hot water temperatures by insertion of probe into thestream. For surface temperature, a leaf type probe is used with the same instrument.
	**Infrared Thermometer:** This is a non-contact type measurement which when directed at a heat source directly gives the temperature read out. This instrument is useful for measuring hot spots in furnaces, surface temperatures etc.
	**Pitot Tube and manometer:** Air velocity in ducts can be measured using a pitot tube and inclined manometer for further calculation offlows.
	**Water flow meter:** This non-contact flow measuring device using Doppler effect / Ultra sonic principle. There is a transmitter and receiver which are positioned on opposite sides of the pipe. The meter directly gives the flow. Water and other fluid flows can be easily measured with this meter.

<table>
<tr>
<td>

Tachometer</td>
<td>
Stroboscope</td>
<td>Speed Measurements:
Inanyauditexercisespeedmeasurementsare critical as thaymay change with frequency, belt slip and loading.

A simple tachometer is a contact type instrument which can be used where direct access is possible.

More sophisticated and safer ones are non contact instruments such as stroboscopes.</td>
</tr>
<tr>
<td colspan="2"></td>
<td>Leak Detectors:
Ultrasonic instruments are available which can be used to detect leaks of compressed air and other gases which are normally not possible to detect with human abilities.</td>
</tr>
<tr>
<td colspan="2"></td>
<td>Lux meters:
Illumination levels are measured with a lux meter. It consists of a photo cell which senses the light output, converts to electrical impulses which are calibrated as lux.</td>
</tr>
</table>

MODULE-II

2.1 Electricity Billing - HTSupply

The electricity billing by utilities for medium & large enterprises, in High Tension (HT) category, is often done on two-part tariff structure, i.e. one part for capacity (or demand) drawn and the second part for actual energy drawn during the billing cycle. Capacity or demand is in kVA (apparent power) or kW terms. The reactive energy (i.e.) kVArh drawn by the service is also recorded and billed for in some utilities, because this would affect the load on theutility.

Accordingly, utility charges for maximum demand, active energy and reactive power drawn (as reflected by the power factor) in its billing structure. In addition, other fixed and variable expenses are also levied.

2.2 The Tariff Structure of HT ElectricityBilling

The tariff structure of HT supply generally includes the following components:

a) Maximum demandCharges

These charges relate to maximum demand registered during month/billing period and corresponding rate of utility.

b) EnergyCharges

These charges relate to energy (kilowatt hours) consumed during month / billing period and corresponding rates, often levied in slabs of use rates. Some utilities now charge on the basis of apparent energy (kVAh), which is a vector sum of kWh and kVArh.

c) Powerfactor

Power factor penalty or bonus rates, as levied by most utilities, are to contain reactive power drawn from grid.

d) Fuelcost

Fuel cost adjustment charges as levied by some utilities are to adjust the increasing fuel expenses over a base reference value.

e) Electricity dutycharges

Electricity duty charges levied w.r.t units consumed.

f) Meterrentals

g) Lighting and fan powerconsumption

Lighting and fan power consumption is often at higher rates, levied sometimes on slab basis or on actual metering basis.

h) Time Of Day(TOD)

Time Of Day (TOD) rates like peak and non-peak hours are also prevalent in tariff structure provisions of some utilities.

i) Penalty for exceeding contractdemand

2.3 Electricity Billing - LTSupply

The electricity billing by utilities for LT category, is often done on one-part tariff structure, i.e. billing is done for actual energy drawn during the billing cycle.

2.4 The Tariff Structure of LT ElectricityBilling

The tariff structure of LT supply generally includes the following components:

a) EnergyCharges

These charges relate to energy (kilowatt hours) consumed during month / billing period and corresponding rates, often levied in slabs of use rates. Some utilities now charge on the basis of apparent energy (kVAh), which is a vector sum of kWh and kVArh.

b)Meterrentals

c) Surcharge if metering is at LT side in some of theutilities

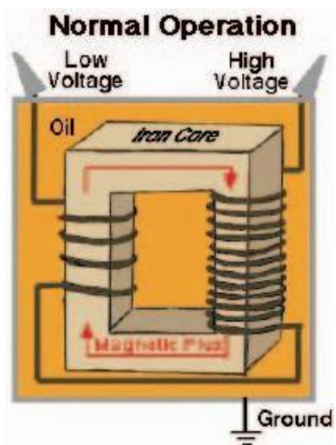
2.5 Transformers

A transformer can accept energy at one voltage and deliver it at another voltage. This permits electrical energy to be generated at relatively low voltages and transmitted at high voltages and low currents, thus reducing line losses and voltage drop (see Figure 2.1).

Figure 2.1 View of a Transformer

Transformers consist of two or more coils that are electrically insulated, but magnetically linked. The primary coil is connected to the power source and the secondary coil connects to the load.Theturn'sratioistheratiobetweenthenumberofturns onthesecondarytotheturns onthe primary (See Figure2.2).

Figure 2.2 Transformer Coil



The secondary voltage is equal to the primary voltage times the turn's ratio. Ampere-turns are calculated by multiplying the current in the coil times the number of turns. Primary ampere-turns are equal to secondary ampere-turns. Voltage regulation of a transformer is the percent increase in voltage from full load to no load.

2.5.1 Types ofTransformers

Transformers are classified as two categories: power transformers and distribution transformers.

Power transformers are used in transmission network of higher voltages, deployed for step-up and step down transformer application (400 kV, 200 kV, 110 kV, 66 kV, 33kV)

Distribution transformers are used for lower voltage distribution networks as a means to end user connectivity. (11kV, 6.6 kV, 3.3 kV, 440V,230V)

2.5.2 Rating ofTransformer

Rating of the transformer is calculated based on the connected load and applying the diversity factor on the connected load, applicable to the particular industry and arrive at the kVA rating of the Transformer. Diversity factor is defined as the ratio of overall maximum demand of the plant to the sum of individual maximum demand of various equipments. Diversity factor varies from industry to industry and depends on various factors such as individual loads, load factor and future expansion needs of the plant. Diversity factor will always be less than one.

2.5.3 Location ofTransformer

Location of the transformer is very important as far as distribution loss is concerned. Transformer receives HT voltage from the grid and steps it down to the required voltage. Transformers should be placed close to the load centre, considering other features like optimization needs for centralized control, operational flexibility etc. This will bring down the distribution loss in cables.

2.5.4 Transformer Losses andEfficiency

The efficiency varies anywhere between 96 to 99 percent. The efficiency of the transformers not only depends on the design, but also, on the effective operatingload.

Transformer losses consist of two parts: No-load loss and Load loss

1. No-load loss (also called core loss) is the power consumed to sustain the magnetic field in the transformer's steel core. Core loss occurs whenever the transformer is energized; core loss does not vary with load. Core losses are caused by two factors: hysteresis and eddy current losses. Hysteresis loss is that energy lost by reversing the magnetic fieldin

the core as the magnetizing AC rises and falls and reverses direction. Eddy current loss is a result of induced currents circulating in the core.

2. Load loss (also called copper loss) is associated with full-load current flow in the transformer windings. Copper loss is power lost in the primary and secondary windings of a transformer due to the ohmic resistance of the windings. Copper loss varies with thesquare of the load current. ($P = I^2R$).

2.6 Power Factor Improvement andBenefits

2.6.1 Power factorBasics

In all industrial electrical distribution systems, the major loads are resistive and inductive. Resistive loads are incandescent lighting and resistance heating. In case of pure resistive loads, the voltage (V), current (I), resistance (R) relations are linearly related, i.e.

$V = I x R$ and Power (kW) $= V x I$

Typical inductive loads are A.C. Motors, induction furnaces, transformers and ballast- type lighting. Inductive loads require two kinds of power: a) active (or working) power to perform the work and b) reactive power to create and maintain electro-magnetic fields.

Active power is measured in kW (Kilo Watts). Reactive power is measured in kVAr (Kilo Volt-Amperes Reactive).

The vector sum of the active power and reactive power make up the total (or apparent) power used. This is the power generated by the SEBs for the user to perform a given amount of work. Total Power is measured in kVA (Kilo Volts-Amperes) (See Figure 2.3).

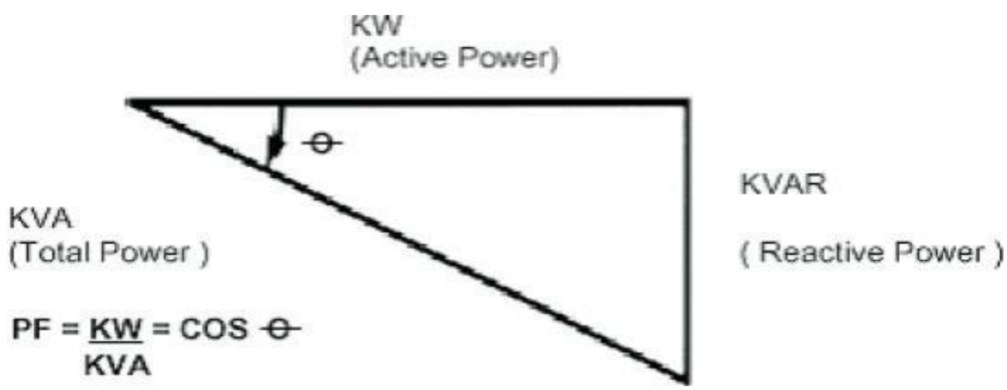


Fig 2.3 Power Triangle

The active power (shaft power required or true power required) in kW and the reactive power required (kVAr) are 90° apart vectorically in a pure inductive circuit i.e., reactive power kVAr lagging the active kW. The vector sum of the two is called the apparent power or kVA, as illustrated above and the kVA reflects the actual electrical load on distribution system.

The ratio of kW to kVA is called the power factor, which is always less than or equal to unity. Theoretically, when electric utilities supply power, if all loads have unity power factor, maximum power can be transferred for the same distribution system capacity. However, as the loads are inductive in nature, with the power factor ranging from 0.2 to 0.9, the electrical distribution network is stressed for capacity at low power factors.

2.6.2 Improving PowerFactor

The solution to improve the power factor is to add power factor correction capacitors to the plant power distribution system. They act as reactive power generators, and provide the needed reactive power to accomplish kW of work. This reduces the amount of reactive power, and thus total power, generated by the utilities.

2.6.3 The advantages of PF improvement by capacitoraddition

- Reactive component of the network is reduced and so also the total current in the system from the sourceend.
- I^2R powerlossesare reducedinthesystembecauseofreductionincurrent.
- Voltage level at the load end isincreased.
- kVA loading on the source generators as also on the transformers and lines up to the capacitors reduces giving capacity relief. A high power factor can help in utilizingthe full capacity of your electricalsystem.

2.6.4 Cost benefits of PFimprovement

While costs of PF improvement are in terms of investment needs for capacitor addition the benefits to be quantified for feasibility analysis are:

- Reduced kVA (Maximum demand) charges in utilitybill
- Reduced distribution losses (KWH) within the plantnetwork
- Better voltage at motor terminals and improved performance ofmotors

- A high power factor eliminates penalty charges imposed when operating with alow powerfactor
- Investment on system facilities such as transformers, cables, switchgears etcfor delivering load isreduced.

2.6.5 Direct relation for capacitorsizing

$$\text{kVAr Rating} = \text{kW} [\tan \Phi 1 - \tan \Phi 2]$$

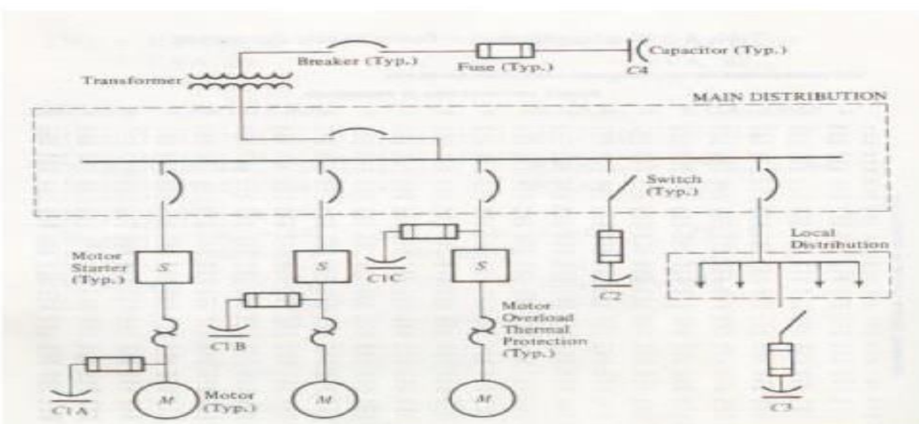
Where kVAr rating is the size of the capacitor needed, kW is the average power drawn, tan ϕ1 is the trigonometric ratio for the present power factor, and tan ϕ_2 is the trigonometric ratio for the desiredPF.

Φ_1 = Existing ($\text{Cos}_{-1}\text{PF}_1$) and Φ_2 = Improved ($\text{Cos}_{-1}\text{PF}_2$)

2.6.6 Location ofCapacitors

The primary purpose of capacitors is to reduce the maximum demand. Additional benefits are derived by capacitor location. The Figure 2.3 indicates typical capacitor locations. Maximum benefit of capacitors is derived by locating them as close as possible to the load. At this location, its kVAr are confined to the smallest possible segment, decreasing the load current. This, in turn, will reduce power losses of the system substantially. Power losses are proportional to the square of the current. When power losses are reduced, voltage at the motor increases; thus, motor performance alsoincreases.

Fig 2.4 Power Distribution Diagram Illustrating Capacitor Locations



Locations C1A, C1B and C1C of Figure 1.9 indicate three different arrangements at the load. Note that in all three locations extra switches are not required, since the capacitor is either switched with the motor starter or the breaker before the starter. Case C1A is recommended for new installation, since the maximum benefit is derived and the size of the motor thermal protector is reduced. In Case C1B, as in Case C1A, the capacitor is energized only when the motor is in operation. Case C1B is recommended in cases where the installation already existsand the thermal protector does not need to be re-sized. In position C1C, the capacitor is permanently connected to the circuit but does not require a separate switch, since capacitor can be disconnected by the breaker before thestarter.

It should be noted that the rating of the capacitor should not be greater than the no-load magnetizing kVAr of the motor. If this condition exists, damaging over voltage or transient torques can occur. This is why most motor manufacturers specify maximum capacitor ratings to be applied to specific motors.

The next preference for capacitor locations as illustrated by Figure 1.9 is at locations C2 and C3. In these locations, a breaker or switch will be required. Location C4 requires a high voltage breaker. The advantage of locating capacitors at power centres or feeders is that they can be grouped together. When several motors are running intermittently, the capacitors are permitted to be on line all the time, reducing the total power regardless ofload.

From energy efficiency point of view, capacitor location at receiving substation only helps the utility in loss reduction. Locating capacitors at tail end will help to reduce loss reduction within the plants distribution network as well and directly benefit the user by reduced consumption. Reduction in the distribution loss % in kWh when tail end power factor is raised from PF1 to a new power factor PF2, will be proportionalto

$$\left[1 - (PF_1 / PF_2)^2\right] x100$$

2.7 Harmonics

In any alternating current network, flow of current depends upon the voltage applied and the impedance (resistance to AC) provided by elements like resistances, reactances of inductive and capacitive nature. As the value of impedance in above devices is constant, they are called linear whereby the voltage and current relation is of linear nature.

Howeverin real life situation, various devices like diodes, silicon controlled rectifiers, PWM systems, thyristors, voltage & current chopping saturated core reactors, induction & arc furnaces are also deployed for various requirements and due to their varying impedance characteristic, these NON LINEAR devices cause distortion in voltage and current waveforms which is of increasing concern in recent times. Harmonics occurs as spikes at intervals which are multiples of the mains (supply) frequency and these distort the pure sine wave form of the supply voltage &current.

Harmonics are multiples of the fundamental frequency of an electrical power system. If, for example, the fundamental frequency is 50 Hz, then the 5th harmonic is five times that frequency, or 250 Hz. Likewise, the 7th harmonic is seven times the fundamental or 350 Hz, and so on for higher orderharmonics.

Harmonics can be discussed in terms of current or voltage. A 5th harmonic current is simply a current flowing at 250 Hz on a 50 Hz system. The 5th harmonic current flowing through the system impedance creates a 5th harmonic voltage. Total Harmonic Distortion (THD) expresses the amount of harmonics. The following is the formula for calculating the THD for current:

$$THD_{current} = \sqrt{\sum_{n=2}^{n=n}\left(\frac{I_n}{I_1}\right)^2} \times 100$$

Then…

$$I_{THD} = \sqrt{\left[\left(\frac{50}{250}\right)^2 + \left(\frac{35}{250}\right)^2\right]} x100 \; = \; 24\%$$

When harmonic currents flow in a power system, they are known as “poor power quality” or “dirty power”. Other causes of poor power quality include transients such as voltage spikes, surges, sags, and ringing. Because they repeat every cycle, harmonics are regarded as a steady-state cause of poor power quality.

When expressed as a percentage of fundamental voltage THD is given by,

$$THD_{voltage} = \sqrt{\sum_{n=2}^{n=n}\left(\frac{V_n}{V_1}\right)^2} \times 100$$

where V_1 is the fundamental frequency voltage and V_n is n^{th} harmonic voltage component.

2.7.1 Major Causes OfHarmonics

Devices that draw non-sinusoidal currents when a sinusoidal voltage is applied create harmonics. Frequently these are devices that convert AC to DC. Some of these devices are listed below:

- Electronic Switching PowerConverters
- Computers, Uninterruptible power supplies (UPS), Solid-staterectifiers
- Electronic process control equipment, PLC's,etc
- Electronic lighting ballasts, including light dimmer

Reduced voltage motorcontrollers

Arcing Devices

- Discharge lighting, e.g. Fluorescent, Sodium and Mercuryvapor
- Arc furnaces, Welding equipment, Electrical tractionsystem

Ferromagnetic Devices

- Transformers operating near saturationlevel
- Magnetic ballasts (Saturated Ironcore)
- Induction heating equipment, Chokes,Motors

Appliances

- TV sets, air conditioners, washing machines, microwaveovens
- Fax machines, photocopiers,printers

These devices use power electronics like SCRs, diodes, and thyristors, which are a growing percentage of the load in industrial power systems. The majority use a 6-pulse converter. Most loads which produce harmonics, do so as a steady-state phenomenon. A snapshot reading of an operating load that is suspected to be non-linear can determine if it is producing harmonics. Normally each load would manifest a specific harmonicspectrum.

Many problems can arise from harmonic currents in a power system. Some problems are easy to detect; others exist and persist because harmonics are not suspected. Higher RMS current and voltage in the system are caused by harmonic currents, which can result in any of the problems listed below:

1. Blinking of Incandescent Lights - TransformerSaturation
2. Capacitor Failure - HarmonicResonance
3. Circuit Breakers Tripping - Inductive Heating andOverload
4. Conductor Failure - InductiveHeating
5. Electronic Equipment Shutting down - VoltageDistortion
6. Flickering of Fluorescent Lights - TransformerSaturation
7. Fuses Blowing for No Apparent Reason - Inductive Heating andOverload
8. Motor Failures (overheating) - VoltageDrop
9. Neutral Conductor and Terminal Failures - Additive TriplenCurrents
10. Electromagnetic Load Failures - InductiveHeating
11. Overheating of Metal Enclosures - InductiveHeating
12. Power Interference on Voice Communication - HarmonicNoise
13. Transformer Failures - InductiveHeating

2.7.2 OvercomingHarmonics

Tuned Harmonic filters consisting of a capacitor bank and reactor in series are designed and adopted for suppressing harmonics, by providing low impedance path for harmonic component.

The Harmonic filters connected suitably near the equipment generating harmonics help to reduce THD to acceptable limits. In present Indian context where no Electro Magnetic Compatibility regulations exist as a application of Harmonic filters is very relevant for industries having diesel power generation sets and co-generation units.

2.8 ElectricMotors

Motors convert electrical energy into mechanical energy by the interaction between the magnetic fields set up in the stator and rotor windings. Industrial electric motors can be broadly classified as induction motors, direct current motors or synchronous motors. All motor types have the same four operating components: stator (stationary windings), rotor (rotating windings), bearings, and frame (enclosure).

2.9 Electric MotorTypes

2.9.1 InductionMotors

Induction motors are the most commonly used prime mover for various equipments 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, andis 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 powersupply.

2.9.2 Direct-CurrentMotors

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

2.9.3 Synchronous Motors

AC power is fed to the stator of the synchronous motor. The rotor is fed by 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., 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.

2.10 Losses in InductionMotors

2.10.1 StatorandRotorI^2RLosses

These losses are major losses and typically account for 55% to 60% of the total losses. I^2R losses are heating losses resulting from current passing through stator and rotor conductors. I^2R losses are the function of a conductor resistance, the square of current. Resistance of conductor is a function of conductor material, length and cross sectional area. The suitable selection of copper conductor size will reduce the resistance. Reducing the motor current is most readily accomplished by decreasing the magnetizing component of current. This involves lowering the operating flux density and possible shortening of air gap. Rotor I^2R losses are a function of the rotor conductors (usually aluminium) and the rotor slip. Utilisation of copper conductors will reduce the winding resistance. Motor operation closer to synchronous speed will also reduce rotorlosses.

2.10.2 Core Losses

Core losses are those found in the stator-rotor magnetic steel and are due to hysterisis effect and eddy current effect during 50 Hz magnetization of the core material. These losses are independent of load and account for 20 – 25 % of the total losses.

The hysterisis losses which are a function of flux density, are be reduced by utilizing low loss grade of silicon steel laminations. The reduction of flux density is achieved by suitable increase in the core length of stator and rotor. Eddy current losses are generated by circulating current within the core steel laminations. These are reduced by using thinner laminations.

2.10.3 Friction and WindageLosses

Friction and windage losses results from bearing friction, windage and circulating air through the motor and account for 8 – 12 % of total losses. These losses are independent of load. The reduction in heat generated by stator and rotor losses permit the use of smaller fan. The windage losses also reduce with the diameter of fan leading to reduction in windage losses.

2.10.4 StrayLoad-Losses

These losses vary according to square of the load current and are caused by leakage flux induced by load currents in the laminations and account for 4 to 5 % of total losses. These losses are reduced by careful selection of slot numbers, tooth/slot geometry and air gap.

2.11 MotorEfficiency

Two important attributes relating to efficiency of electricity use by A.C. Induction motors are efficiency (η), defined as the ratio of the mechanical energy delivered at the rotating shaft to the electrical energy input at its terminals, and power factor (PF). Motors, like other inductive loads, are characterized by power factors less than one. As a result, the total current draw needed to deliver the same real power is higher than for a load characterized by a higher PF. An important effect of operating with a PF less than one is that resistance losses in wiring upstream of the motor will be higher, since these are proportional to the square of the current. Thus, both a high value for η and a PF close to unity are desired for efficient overall operation in a plant.

Squirrel cage motors are normally more efficient than slip-ring motors, and higher-speed motors are normally more efficient than lower-speed motors. Efficiency is also a function of motor temperature. Totally-enclosed, fan-cooled (TEFC) motors are more efficient than screen protected, drip-proof (SPDP) motors. Also, as with most equipment, motor efficiency increases with the rated capacity.

2.12 Energy-EfficientMotors

Energy-efficient motors (EEM) are the ones in which, design improvements are incorporated specifically to increase operating efficiency over motors of standard design. Design improvements focus on reducing intrinsic motor losses. Improvements include the use of lower-loss silicon steel, a longer core (to increase active material), thicker wires (to reduce resistance), thinner laminations, smaller air gap between stator and rotor, copper instead of aluminum bars in the rotor, superior bearings and a smaller fan, etc.

Energy-efficient motors now available in India operate with efficiencies that are typically 3 to 4 percentage points higher than standard motors. In keeping with the stipulations of the BIS, energy-efficient motors are designed to operate without loss in efficiency at loads between 75 % and 100 % of rated capacity. This may result in major benefits in varying load applications. The power factor is about the same or may be higher than for standard motors. Furthermore, energy-efficient motors have lower operating temperatures and noise levels, greater ability to accelerate higher-inertia loads, and are less affected by supply voltage fluctuations.

2.13 Factors Affecting Energy Efficiency & Minimizing Motor Lossesin Operation

Motor performance is affected considerably by the quality of input power, that is the actual volts and frequency available at motor terminals vis-à-vis rated values as well as voltage and frequency variations and voltage unbalance across the three phases. Motors in India must comply with standards set by the Bureau of Indian Standards (BIS) for tolerance to variations in input power quality. The BIS standards specify that a motor should be capable of delivering its rated output with a voltage variation of +/- 6 % and frequency variation of +/- 3 %. Fluctuations much larger than these are quite common in utility-supplied electricity in India. Voltage fluctuations can have detrimental impacts on motor performance.

Voltage unbalance, the condition where the voltages in the three phases are not equal, can be still more detrimental to motor performance and motor life. Unbalance typically occurs as a result of supplying single-phase loads disproportionately from one of the phases. It can also result from the use of different sizes of cables in the distributionsystem.

Example2.1:

A three phase,10 kW motor has the name plate details as 415 V, 18.2 amps and 0.9 PF. Actual input measurement shows 415 V, 12 amps and 0.7 PF which was measured with power analyzer during motor running. Determine the motor loading?

Rated output at full load = 10 kW

Rated input at full load = $\sqrt{3} \times V \times I \times \cos\Phi$ = 1.732 x 0.415 x 18.2 x 0.9 = 11.8kW

The rated efficiency of motor at full load = (10 x 100) / 11.8 = 85%

Measured (Actual) input power = 1.732x 0.415 x 12x 0.7 = 6.0 kW

$$Motor\ loading\ \% = \frac{Measured\ kW}{Rated\ kW}\ x\ 100 = \frac{6.0}{11.8}\ x\ 100 = 51.2\ \%$$

Example 2.2:

A 400 Watt mercury vapor lamp was switched on for 10 hours per day. The supply volt is 230 V. Find the power consumption per day? (Volt = 230 V, Current = 2 amps, PF = 0.8)

Electricity consumption (kWh) = V x I x CosΦ x No of Hours

= 0.230 x 2 x 0.8 x 10 = 3.7 kWh or Units

Example 2.3:

An electric heater of 230 V, 5 kW rating is used for hot water generation in an industry. Find electricity consumption per hour (a) at the rated voltage (b) at 200 V.

(a) Electricity consumption (kWh) at rated voltage = 5 kW x 1 hour = 5kWh.

(b) Electricity consumption at 200 V (kWh) = (200 / 230)2 x 5 kW x 1 hour = 3.78kWh.

Example2.4 :

The utility bill shows an average power factor of 0.72 with an average KW of 627. How much kVAr is required to improve the power factor to .95 ?

Using formula

Cos* Φ *1 = 0.72 , tan* Φ *1 =0.963

Cos* Φ *2 = 0.95 , tan* Φ *2 =0.329

kVAr required = P (tan $Φ_1$ - tan $Φ_2$)

= 627 (0.964 –0.329)

= 398 kVAr

2.14 Motor EfficiencyComputation

Example 2.5:

Motor Specifications

Rated power = 34 kW/45 HP
Voltage = 415 Volt
Current = 57 Amps
Speed = 1475 rpm
Insulation class = F
Frame = LD 200 L
Connection = Delta

No load test Data

Voltage, V = 415 Volts
Current, I = 16.1 Amps
Frequency, F = 50 Hz
Stator phase resistance at 30°C = 0.264 Ohms
No load power, Pnl = 1063.74 Watts

a) Calculate iron plus friction and windage losses

b) Calculate stator resistance at 120°C

$$R_2 = R_1 \times \frac{235 + t_2}{235 + t_1}$$

c) Calculate stator copper losses at operating temperature of resistance at 120°C

d) Calculate full load slip(s) and rotor input assuming rotor losses are slip times rotor input.

e) Determine the motor input assuming that stray losses are 0.5 % of the motor rated power

f) Calculate motor full load efficiency and full load power factor

Solution

a) Let Iron plus friction and windage loss, P_i + fw

No load power, P_{nl} = 1063.74 Watts

Stator Copper loss, P st-30°C (Pst.cu)

$= 3 \times (16.1 / \sqrt{3})^2 \times 0.264$

= 68.43 Watts

$P_i + fw = P_{nl} - Pst.cu$

= 1063.74 – 68.43

= 995.3 W

b) Stator Resistance at 120°C,

$$R_{120°C} = 0.264 \times \frac{120 + 235}{30 + 235}$$

= 0.354 ohms per phase

c) Stator copper losses at full load, Pst.cu 120°C

$= 3 \times (57 / \sqrt{3})^2 \times 0.354$

= 1150.1 Watts

d) Full load slip

S = (1500 – 1475) / 1500

= 0.0167

Rotor input, Pr = P_{output}/ (1-S)
= 34000 / (1-0.0167)
= 34577.4 Watts

e) Motor full load input power, P input

$= P_r + Pst.cu\ 120°C + (P_i + fw) + P_{stray}$

$= 34577.4 + 1150.1 + 995.3 + (0.005^* \times 34000)$

= 36892.8 Watts

*where, stray losses = 0.5% of rated output (assumed)

f) Motor efficiency at full load

$$\text{Efficiency} = \frac{P_{output}}{P_{input}} \times 100$$

$$= \frac{34000}{36892.8} \times 100$$

= 92.2 %

2.15 Lighting

Lighting is provided in industries, commercial buildings, indoor and outdoor for providing comfortable working environment.

Lighting is an area, which provides a major scope to achieve energy efficiency at the design stage, by incorporation of modern energy efficient lamps, luminaires and gears, apart from good operational practices.

2.16 Lumen

It is a unit of light flow or luminous flux. The lumen rating of a lamp is a measure of the total light output of the lamp. The most common measurement of light output (or luminous flux) is the lumen. Light sources are labeled with an output rating in lumens.

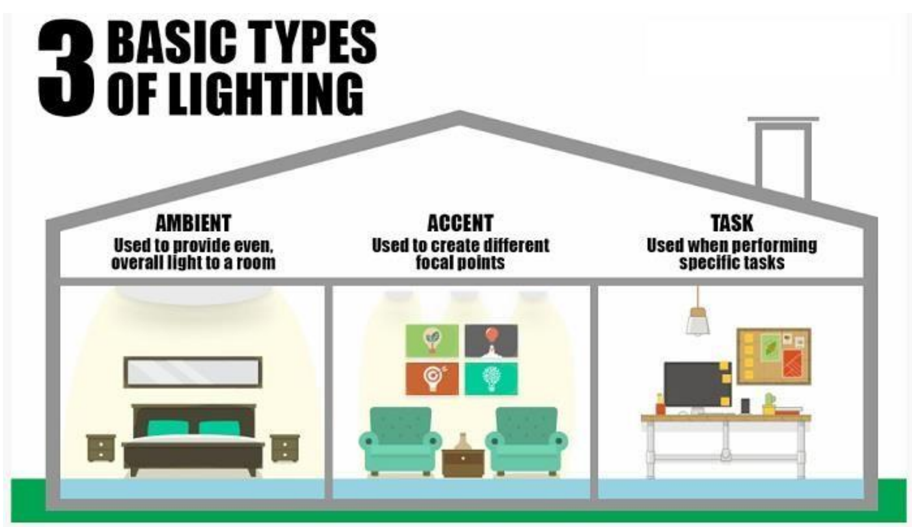
2.17 Lux

It is the metric unit of measure for illuminance of a surface. One lux is equal to one lumen per square meter.

2.18 Lamp CircuitEfficacy

It is the amount of light (lumens) emitted by a lamp for each watt of power consumed by the lamp circuit, i.e. including control gear losses. This is a more meaningful measure for those lamps that require control gear. Unit: lumens per circuit watt(lm/W).

2.19 Types ofLightings



2.19.1 Ambient IndoorLighting

General or ambient lighting is intended to light up a room in its entirety, to provide a uniform level of illumination throughout the space, independently of other lighting sources.

Moreover, its purpose is to ensure safe and easy traffic, as well as to create an overview of the room. The ambient light ‘bounces’ off the walls to illuminate as much space as possible.

Types of fixtures that can provide general ambient indoor lighting:

- Chandelier
- Ceiling mountedfixture
- Wall-mountedfixture
- Traditional recessed fixtures and/or LEDDownlights
- Tracklight
- Floor lamp
- Tablelamp

2.19.2 Ambient OutdoorLighting

Outdoor lighting is usually installed in order to ensure visibility and increase security around a building. It is also recommended to light up the exterior of the building, entrances and stairs to reduce and perhaps eliminate the risk of injury that can occur when entering and leaving the building.

Types of fixtures that provide ambient outdoor lighting:

- Spotlight
- Hangingfixture
- Garage and canopylighting
- Postlantern

- Walllighting
- Recessed fixture used in overhangingstructures

2.19.3 TaskLighting

Task lighting sheds light on the tasks a person carries out in a given space such as reading, cooking, computer work, for which a brighter light is required in a smaller focal point of the room.

For a more pleasant lighting, it is often best to avoid harsh lights or lighting that casts troublesome shadows. It is also practical to install a single switch for focal lighting, independent from the room's overall lighting switch.

Types of Fixtures that Provide Task Lighting:

- Directional gimbal recessed fixture ordownlight
- Pendantlighting
- Slim line bar andundercabinet
- Tape andextrusion
- Portable or desklamp

2.19.4 AccentLighting

Accent lighting is used mainly to focus on a specific point of interest or to achieve a desired effect. This type of lighting gives the impression of a larger room; it is more frequently used to highlight an architectural feature, a plant (in outdoor layout), a sculpture, or a collection ofobjects.

As a general rule, effective accent lighting requires the installation of three times more light on the focal point than ambient lighting generally provides.

Types of Fixtures that Provide Accent Lighting:

- Tracklight

- Slim line bar andundercabinet
- Tape andextrusion
- Directional recessed fixture or downlight
- Wall-mountedfixtures

2.20 LEDLighting

The LEDs have the following merits over the filament lamps.

- Lesser power consumption (Less than 1W/lamp)
- Withstand high voltage fluctuation in the powersupply.
- Longer operating life (more than 1,00,000hours)

2.21 Encon Measures inLighting

- Install energy efficient fluorescent lamps in place of "Conventional" fluorescentlamps.
- Install Compact Fluorescent Lamps (CFL's) in place of incandescent lamps.**CFL's are highly suitable for places such as Living rooms, Hotel lounges, Bars, Restaurants, Pathways, Building entrances, Corridors,etc.**
- Install metal halide lamps in place of mercury / sodium vapourlamps.**These lamps are highly suitable for applications such as assembly line, inspection areas, painting shops,etc.**
- Install High Pressure Sodium Vapour(HPSV) lamps for applications **where colour rendering is not critical such as street lighting, yard lighting,etc.**
- Install LED panel indicator lamps in place of filament lamps. **These lamps are suitable in industries for monitoring, fault indication, signaling,etc.**
- Grouping of lighting system, to provide greater flexibility in lightingcontrol**.**
- Install microprocessor based controllers. **Advanced lighting control system uses movement detectors or lighting sensors, to feed signals to thecontrollers.**

- Ensure optimum usage of daylighting.
- Installation of "exclusive" transformer for lighting. **This provides a better voltage regulation for the lighting. This will reduce the voltage related problems, which in turn increases the efficiency of the lightingsystem.**
- Installat servo stabilizer for lighting feeder for improving lightingefficiency
- Installation of high frequency (HF) electronic ballasts in place of conventionalballasts

MODULE III

3.1 Stoichiometry

Stoichiometry is the study of the relationship between relative amounts of substanc es. Theformula of a compound provides information about the relative amount of each element
present in either one molecule of the compound or one mole of the compound. For example, one molecule of $CaCl_2$ contains 1 mol Ca^{2+} ions and 2 mol Cl^- ions.

Stoichiometry can be used to determine the chemical formula of a compound by studying the relative amounts of elements present or can be used to study the relative amounts of compounds that are consumed and produced during a chemical reaction

3.2 Efficiency computation ofBoilers

Efficiency testing helps us to find out how far the boiler efficiency drifts away from the best efficiency. Any observed abnormal deviations could therefore be investigated to pinpoint the problem area for necessary corrective action. Hence it is necessary to find out the current level of efficiency for performance evaluation, which is a pre requisite for energy conservation action inindustry.

Most standards for computation of boiler efficiency, including IS 8753 and BS845 are designed for spot measurement of boiler efficiency. Basically Boiler efficiency can be tested by the following methods:

1) **The Direct Method:** Where the energy gain of the working fluid (water and steam) is compared with the energy content of the boilerfuel.
2) **The Indirect Method:** Where the efficiency is the difference between the losses and the energyinput.

3.2.1 he Direct MethodTesting

This is also known as 'input-output method' due to the fact that it needs only the useful output (steam) and the heat input (i.e. fuel) for evaluating the efficiency. This efficiency can be evaluated using theformula:

$$Boiler\ Efficiency = \frac{Heat\ Output}{Heat\ Input} \times 100$$

$$Boiler\ Efficiency = \frac{\text{Steam flow rate x (steam enthalpy} - \text{feed water enthalpy)}}{\text{Fuel firing rate x Gross calorific value}}\ x\,100$$

Example3.1

Water consumption and coal consumption were measured in a coal-fired boiler at hourly intervals. Weighed quantities of coal were fed to the boiler during the trial period. Simultaneously water level difference was noted to calculate steam generation during the trial period. Blow down was avoided during the test. The measured data is givenbelow.

Type of boiler: Coal fired Boiler

Heat output data

Quantity of steam generated (output)	:	8 TPH
Steam pressure / temperature	:	10 kg/cm^2(g)/ 180°C
Enthalpy of steam(dry & Saturated) at 10 kg/cm^2(g) pressure	:	665 kCal/kg
Feed water temperature	:	85°C
Enthalpy of feed water	:	85 kCal/kg

Heat input data

Quantity of coal consumed (Input)	:	1.6 TPH
GCV of coal	:	4000 kCal/kg

Calculation

Boiler efficiency (η): $= \frac{Q \times (H - h) \times 100}{(q \times GCV)}$

Where **Q** = Quantity of steam generated per hour (kg/hr)

q = Quantity of fuel used per hour (kg/hr)

GCV = Gross calorific value of the fuel (kCal/kg)

H = Enthalpy of steam (kCal/kg)

h = Enthalpy of feed water (kCal/kg)

Boiler efficiency (η) $= \frac{8\ TPH \times 1000 kg/T \times (665 - 85) \times 100}{1.6\ TPH \times 1000 kg/T \times 4000\ kCal/kg}$

= **72.5%**

3.2.1.1 Merits and Demerits of DirectMethod

Merits

- Plant people can evaluate quickly the efficiency ofboilers
- Requires few parameters forcomputation
- Needs few instruments formonitoring

Demerits

- Does not give clues to the operator as to why efficiency of system islower
- Does not calculate various losses accountable for various efficiencylevels
- Evaporation ratio and efficiency may mislead, if the steam is highly wet due to watercarryover

3.3 Energy Conservation Opportunities inBoilers

1. StackTemperature

The stack temperature (Temperature used to remove water vapor in the exhaust condenses on the stack walls) should be as low as possible. An estimated 1% efficiency loss occurs with every 22 °C increase in stack temperature.

2. Feed Water Preheating using Economizer

Feed Water Preheating using economizer would reduce the exit temperature to 65 °C, thereby increasing thermal efficiency by 5%.

3. Combustion AirPreheat

Combustion air preheating is an alternative to feed water pre-heating. In order to improve thermal efficiency by 1%, the combustion air temperature must be raised by 20 °C using pre-heater.

4. Incomplete Combustion

Incomplete combustion can arise from a shortage of air or surplus of fuel or poor distribution of fuel. It is usually obvious from the colour or smoke, and must be corrected immediately.

5. Excess AirControl

Controlling excess air to an optimum level always results in reduction in flue gas losses; for every 1% reduction in excess air there is approximately 0.6% rise in efficiency.

6. Radiation and Convection HeatLoss

Repairing or augmenting insulation can reduce heat loss through boiler walls and piping.

7. Automatic Blow downControl

Uncontrolled continuous blow down is very wasteful. Automatic blow down controls can be installed that sense and respond to boiler water conductivity and pH. A 10% blow downin a15 kg/cm^2 boilerresultsin3%efficiencyloss.

8. Reduction of Scaling and SootLosses

In oil and coal-fired boilers, soot buildup on tubes acts as an insulator against heat transfer. Any such deposits should be removed on a regular basis. It is estimated that 3 mm of soot can cause an increase in fuel consumption by 2.5% due to increased flue gas temperatures. Periodic off-line cleaning of radiant furnace surfaces, boiler tube banks, economizers and air heaters may be necessary to remove stubborn deposits.

9. Variable Speed Control for Fans, Blowers andPumps

The possibility of replacing the dampers by a VSD should be improve the system efficiency.

10. Effect of Boiler Loading onEfficiency

The maximum efficiency of the boiler does not occur at full load, but at about two-thirds of the full load.

12. Proper BoilerScheduling

Operate a fewer number of boilers at higher loads, than to operate a large number at low loads.

13. BoilerReplacement

The potential savings from replacing a boiler depend on the anticipated change in overall efficiency. A change in a boiler can be financially attractive if the existing boiler is :

- old andinefficient
- not capable of firing cheaper substitutionfuel
- over or under-sized for presentrequirements
- not designed for ideal loadingconditions

3.4 Efficiency computation ofFurnaces

A furnace is an equipment to melt metals for casting or heat materials for change of shape (rolling, forging etc) or change of properties (heat treatment).

The efficiency of furnace can be judged by measuring the amount of fuel needed per unit weight of material.

$$\text{Thermal efficiency of the furnace} = \frac{\text{Heat in the stock}}{\text{Heat in the fuel consumed for heating the stock}}$$

The quantity of heat to be imparted (Q) to the stock can be found from

$$\mathbf{Q = m \times Cp\ (t_1 - t_2)}$$

Where

Q = Quantity of heat of stock in kCal

m = Weight of the stock in kg

Cp = Mean specific heat of stock in

kCal/kg°Ct_1 = Final temperature of stock

desired, °C

t_2 = Initial temperature of the stock before it enters the furnace, °C

Example 3.2

An oil-fired reheating furnace has an operating temperature of around 1340°C. Average fuel consumption is 400 litres/hour. The flue gas exit temperature is 750 °C after air pre-heater. Air is preheated from ambient temperature of 40 °C to 190 °C through an air pre-heater. The furnace has 460 mm thick wall (x) on the billet extraction outlet side, which is 1 m high (D) and 1 m wide. The other data are as given below. Find out the efficiency of the furnace by directmethod.

Exit fluegastemperature = 750°C

Ambient temperature = 40°C

Preheatedairtemperature = 190°C

Specific gravityofoil =0.92

Average fuel oil consumption = 400 Litres / hr

= 400 × 0.92 =368 kg/hr

Calorific valueofoil = 10000 kCal/kg

Average O2 percentage in flue gas = 12%

Weightofstock = 6000 kg/hr

Specific heatofBillet = 0.12kCal/kg/°C

Average surface temperature of heating + soaking zone = 122 °C

Average surface temperature of area other than heating and soaking zone = 80 °C

Area of heating + soaking zone = 70.18 m2

Area other than heating and soaking zone = 12.6 m2

Solution:

Heatinput = 400 litres /hr
= 368 kg/hr

Heat output = m × Cp ×ΔT
= 6000 kg × 0.12 × (1340 – 40)
= 936000 kCal

Efficiency $= 936000 \times 100 / (368 \times 10000)$

= 25.43 %
= 25% (app)
Losses = 75% (app)

3.5 Energy Conservation measures inFurnaces

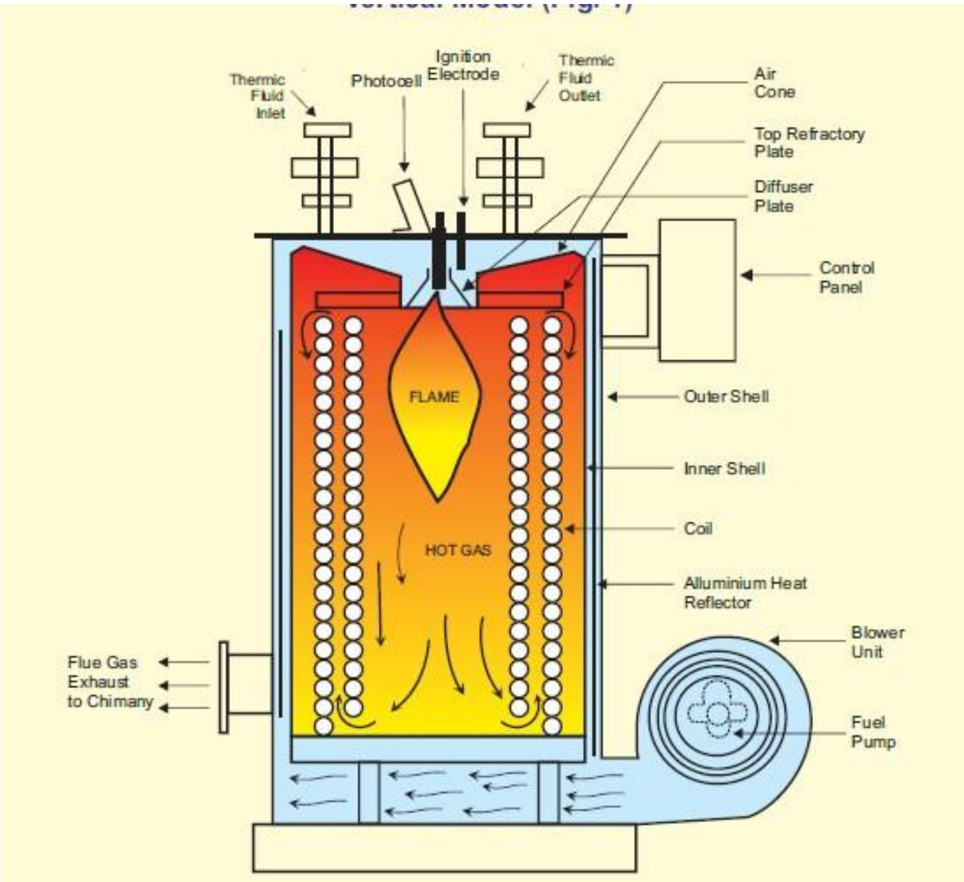
1) Complete combustion with minimum excessair
2) Correct heatdistribution
3) Operate furnace at the desiredtemperature
4) Reduce heat losses from furnaceopenings
5) Maintain correct amount of furnacedraught
6) Optimum capacity utilization of furnace will give maximum thermal efficiency
7) Waste heat recovery from the flue gases improves systemefficiency
8) Minimum refractorylosses

   The appropriate choice of refractory and insulation materials goes a long way in achieving fairly high fuel savings in industrialfurnaces
9) Use of Ceramic Coatings in furnace chamber promotes rapid and efficient transfer of heat, thereby extended life ofrefractories.

3.6 Thermic FluidHeaters

Thermic Fluid is used as a heat transfer mechanism in some industrial process and heating applications. Thermic Fluid may be a vegetable or mineral based oil and the oil may beraised to a high temperature without the need for any pressurization. The relatively high flow and return temperatures may limit the potential for flue gas heat recovery unless some other system can absorb this heat usefully. Careful design and selection isrequired to achieve best energyefficiency.

Thermic fluid heaters are used just to heat the water, not necessarily producing steam. Water is heated by passing hot thermic fluid in tubes submerged in water. This arrangement is similar to the fire-tube boiler .



The combustion air enters through the fan inlet, travels upwards through the space between the inner shell & the outer shell, gets pre-heated & enters the top mounted burner Hot flue gases travel down the full length of the vessel creating the first (radiant) pass The flue gases then travel upwards through the space between the inner coil & the outer coil creating the second (convection) pass The third (convection) pass is downwards through the space between the outer coil & the inner shell to the flue gasoutlet.

3.7 Steam: Concept, Properties &Usage

Steam has been a popular mode of conveying energy since the industrial revolution. Steam is used for generating power and alsoused in process industries such as sugar, paper, fertilizer, refineries, petrochemicals, chemical, food, synthetic fiber andtextiles.

The following characteristics of steam make it so popular and useful to the industry:

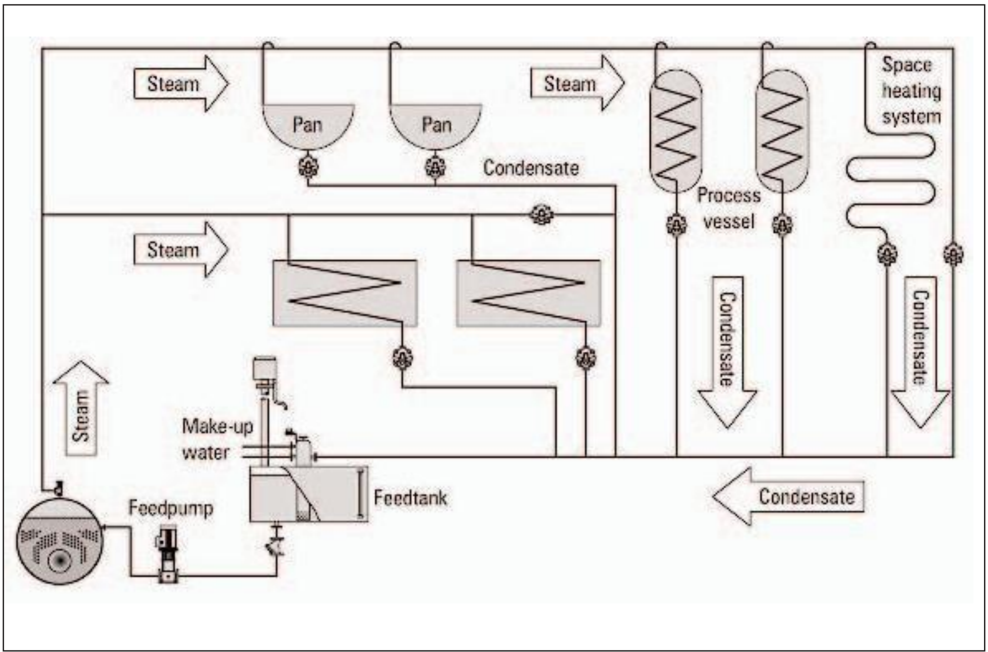
- Highest specific heat and latentheat
- Highest heat transfercoefficient
- Easy to control anddistribute
- Cheap andinert

Water can exist in the form of solid (ice), liquid (water) and gas (steam) respectively. If heat energy is added to water, its temperature rises until a value is reached at which the water can no longer exist as a liquid. We call this the "saturation" point and with any further addition of energy, some of the water will boil off as steam. This evaporation requires relatively large amounts of energy, and while it is being added, the water and the steam released are both at the same temperature. Equally, if steam is made to release the energy that was added to evaporate it, then the steam will condense and water at same temperature will beformed.

3.8 SteamDistribution

The steam distribution system is the essential link between the steam generator and the steam user. Whatever the source, an efficient steam distribution system is essential if steam of the right quality and pressure is to be supplied, in the right quantity, to the steam using equipment. Installation and maintenance of the steam system are important issues, and must be considered at the design stage.

Figure 3.2 Steam Distribution System



As steam condenses in a process, flow is induced in the supply pipe. Condensate has a very small volume compared to the steam, and this causes a pressure drop, which causes the steam to flow through the pipes. The steam generated in the boiler must be conveyed through pipe work to the point where its heat energy is required. Initially there will be one or more main pipes, or 'steam mains', which carry steam from the boiler in the general direction of the steam using plant. Smaller branch pipes can then carry the steam to the individual pieces of equip- ment. A typical steam distribution system is shown in Figure 3.2.

3.9 SteamTraps

The purpose of installing the steam traps is to obtain fast heating of the product and equipment by keeping the steam lines and equipment free of condensate, air and non-condensable gases. A steam trap is a valve device that discharges condensate and air from the line or piece of equipment without discharging thesteam.

The three important functions of steam traps are:

- To discharge condensate as soon as it isformed.
- Not to allow steam toescape.

- To be capable of discharging air and other incondensiblegases.

3.9.1 Types of Stem Traps

There are three basic types of steam trap into which all variations fall, all three are classified by International Standard ISO 6704:1982.

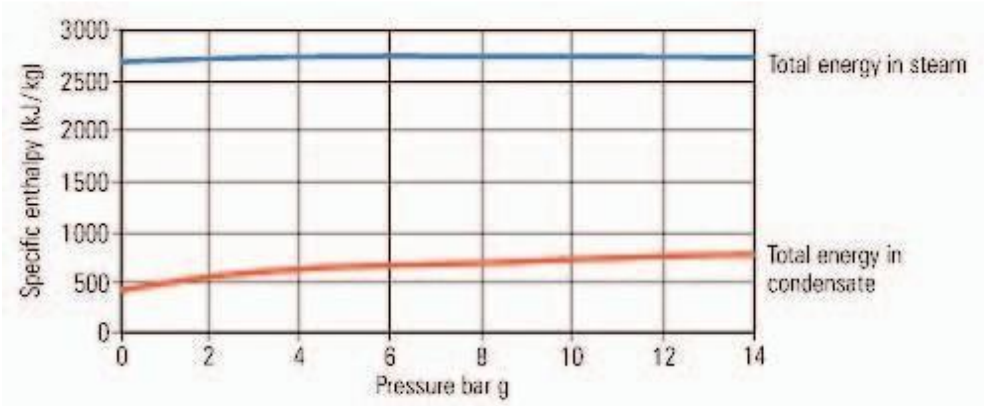
Thermostatic (operated by changes in fluid temperature) - The temperature of saturated steam is determined by its pressure. In the steam space, steam gives up its enthalpy of evaporation (heat), producing condensate at steam temperature. As a result of any further heat loss, the temperature of the condensate will fall. A thermostatic trap will pass condensate when this lower temperature is sensed. As steam reaches the trap, the temperature increases and the trap closes.

Mechanical (operated by changes in fluid density) - This range of steam traps operates by sensing the difference in density between steam and condensate. These steam traps include 'ball float traps' and 'inverted bucket traps'. In the 'ball float trap', the ball rises in the presence of condensate, opening a valve which passes the denser condensate. With the 'inverted bucket trap', the inverted bucket floats when steam reaches the trap and rises to shut the valve. Both are essentially 'mechanical' in their method ofoperation.

Thermodynamic (operated by changes in fluid dynamics) - Thermodynamic steam traps rely partly on the formation of flash steam from condensate. This group includes 'thermodynamic', 'disc', 'impulse' and 'labyrinth' steam traps.

3.10 CondensateRecovery

Figure 3.3 Heat Content of Steam and Condensate at the Same Pressure



The steam condenses after giving off its latent heat in the heating coil or the jacket of the process equipment. A sizable portion (about 25%) of the total heat in the steam leaves the process equipment as hot water. Figure 3.3 compares the amount of energy in a kilogram of steam and condensate at the same pressure. The percentage of energy in condensate to that in steam can vary from 18% at 1 bar g to 30% at 14 bar g; clearly the liquid condensate is worth reclaiming. If this water is returned to the boiler house, it will reduce the fuel requirements of the boiler. For every 60°C rise in the feed water temperature, there will be approximately 1% saving of fuel in theboiler.

3.10.1 Benefits of CondensateRecovery

- Water charges arereduced.
- Effluent charges and possible cooling costs arereduced.
- Fuel costs arereduced.
- More steam can be produced from theboiler.
- Boiler blowdown is reduced - less energy is lost from theboiler.
- Chemical treatment of raw make-up water isreduced.

3.11 Flash SteamRecovery

Flash steam is produced when condensate at a high pressure is released to a lower pressure and can be used for low pressure heating.

The higher the steam pressure and lower the flash steam pressure the greater the quantity of flash steam that can be generated. In many cases, flash steam from high pressure equipments is made use of directly on the low pressure equipments to reduce use of steam through pressure reducing valves.

The flash steam quantity can be calculated by the following formula with the help of a steam table:

Flash steam available % = (S1 –S2) / L2

Where: S_1 is the sensible heat of higher pressurecondensate.

S_2 is the sensible heat of the steam at lower pressure (at which it has been flashed). L_2 is the latent heat of flash steam (at lower pressure).

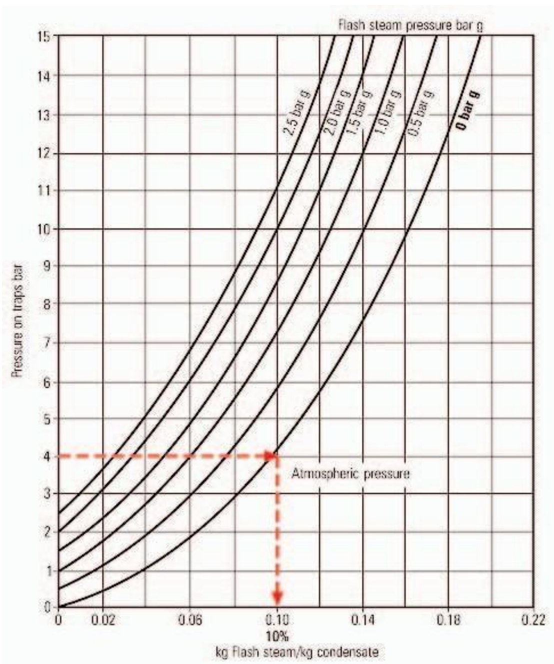


Figure 3.4 Quantity of Flash Steam Graph

Flash steam can be used on low pressure applications like direct injection and can replace an equal quantity of live steam that would be otherwise required. The demand for flash steam should exceed its supply, so that there is no build up of pressure in the flash vessel and the consequent loss of steam through the safety valve. Generally, the simplest method of using flash steam is to flash from a machine/equipment at a higher pressure to a machine/equipment at a lower pressure, thereby augmenting steam supply to the low pressure equipment.

In general, a flash system should run at the lowest possible pressure so that the maximum amount of flash is available and the backpressure on the high pressure systems is kept as low aspossible.

Flash steam from the condensate can be separated in an equipment called the 'flash vessel'. This is a vertical vessel as shown in the Figure 3.5. The diameter of the vessel is such that a considerable drop in velocity allows the condensate to fall to the bottom of the vessel from where it is drained out by a steam trap preferably a float trap. Flash steam itself rises to leave the vessel at the top. The height of the vessel should be sufficient enoughto avoid water being carried over in the flashsteam.

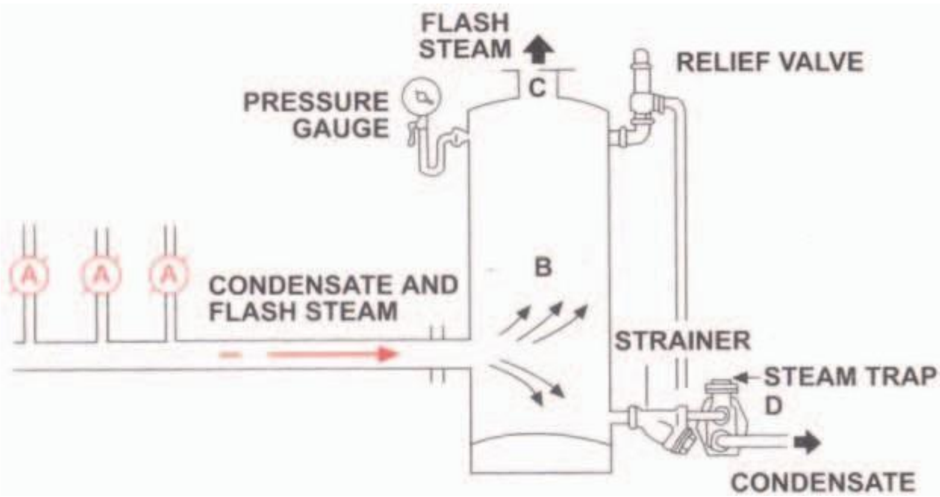


Figure 3.5 Flash Steam Recovery

The condensate from the traps (A) along with some flash steam generated passes through vessel (B). The flash steam is let out through (C) and the residual condensate from (B) goes out through the steam trap (D). The flash vessel is usually fitted with a 'pressure gauge' to know the quality of flash steam leaving the vessel. A 'safety valve' is also provided to vent out the steam in case of high pressure build up in the vessel.

MODULE-IV

4.1 Energy Efficiency / Saving Measures inPumps

$$\text{Pump efficiency} = \frac{\text{Hydraulic power, } P_h}{\text{Power input to the pump shaft}} \times 100$$

Where,

Hydraulic power $P_h(kW) = Q \times (h_d - h_s) \times \rho \times g / 1000$

Q = Volume flow rate (m^3 / s), ρ = density of the fluid (kg/m^3), g = acceleration due to gravity (m/s^2), $(h_d - h_s)$ = Total head in metres

- Ensure adequate NPSH at site ofinstallation

- Ensure availability of basic instruments at pumps like pressure gauges, flowmeters.

- Operate pumps near best efficiencypoint.

- Modify pumping system and pumps losses to minimizethrottling.

- Adapt to wide load variation with variable speed drives or sequenced control of multipleunits.

- Stop running multiple pumps - add an auto-start for an on-line spare or add a booster pump in the problemarea.

- Use booster pumps for small loads requiring higherpressures.

- Increase fluid temperature differentials to reduce pumping rates in case of heatexchangers.

- Repair seals and packing to minimize water loss bydripping.

- Balance the system to minimize flows and reduce pump powerrequirements.

- Avoid pumping head with a free-fall return (gravity); Use siphon effect toadvantage:

- Conduct water balance to minimize waterconsumption

- Avoid cooling water re-circulation in DG sets, air compressors, refrigeration systems, cooling towers feed water pumps, condenser pumps and processpumps.

- In multiple pump operations, carefully combine the operation of pumps to avoidthrottling
- Provide booster pump for few areas of higherhead

- Replace old pumps by energy efficientpumps

- In the case of over designed pump, provide variable speed drive, or downsize / replace impeller or replace with correct sized pump for efficientoperation.

- Optimize number of stages in multi-stage pump in case of headmargins

- Reduce system resistance by pressure drop assessment and pipe sizeoptimization.

4.2 Energy Efficiency / Saving Measures in Fans &Blowers

1. Minimizing excess air level in combustion systems to reduce FD fan and ID fanload.
2. Minimizing air in-leaks in hot flue gas path to reduce ID fan load, especially in case of kilns, boiler plants, furnaces, etc. Cold air in-leaks increase ID fan load tremendously, due to density increase of flue gases and in-fact choke up the capacity of fan, resulting as a bottleneck for boiler / furnaceitself.

3. In-leaks / out-leaks in air conditioning systems also have a major impact on energy Efficiency and fan power consumption and need to beminimized.

The findings of performance assessment trials will automatically indicate potential areas for improvement, which could be one or a more of the following:

1. Change of impeller by a high efficiency impeller along withcone.
2. Change of fan assembly as a whole, by a higher efficiencyfan
3. Impeller de-rating (by a smaller diaimpeller)
4. Change of metallic / Glass reinforced Plastic (GRP) impeller by the more energy Efficient hollow FRP impeller with aerofoil design, in case of axial flow fans, where significant savings have beenreported
5. Fan speed reduction by pulley dia modifications forderating
6. Option of two speed motors or variable speed drives for variable dutyconditions
7. Option of energy efficient flat belts, or, cogged raw edged V belts, in place of conventional V belt systems, for reducing transmissionlosses.
8. Adopting inlet guide vanes in place of discharge dampercontrol
9. Minimizing system resistance and pressure drops by improvements in ductsystem

4.3 Energy Efficiency / Saving Measures in Compressed AirSystem

• Ensure air intake to compressor is not warm and humid by locating compressors in well ventilated area or by drawing cold air from outside. Every 4°C rise in air inlet temperature will increase power consumption by 1percent.

• Clean air-inlet filters regularly. Compressor efficiency will be reduced by 2 percent for every 250 mm WC pressure drop across thefilter.

• Keep compressor valves in good condition by removing and inspecting once every six months. Worn-out valves can reduce compressor efficiency by as much as 50percent.

• Install manometers across the filter and monitor the pressure drop as a guide to replacement of element.

• Minimize low-load compressor operation; if air demand is less than 50 percent of compressor capacity, consider change over to a smaller compressor or reduce compressor speed appropriately (by reducing motor pulley size) in case of belt drivencompressors.

• Consider the use of regenerative air dryers, which uses the heat of compressed air to remove moisture.

• Fouled inter-coolers reduce compressor efficiency and cause more water condensation in air receivers and distribution lines resulting in increased corrosion. Periodic cleaning of intercoolers must beensured.

• Compressor free air delivery test (FAD) must be done periodically to check the present operating capacity against its design capacity and corrective steps must be taken ifrequired.

• If more than one compressor is feeding to a common header, compressors must be operated in such a way that only one small compressor should handle the load variations whereas other compressors will operate at full load.

• The possibility of heat recovery from hot compressed air to generate hot air or water for process application must be economically analyzed in case of largecompressors.

• Consideration should be given to two-stage or multistage compressor as it consumes less power for the same air output than a single stagecompressor.

• If pressure requirements for processes are widely different (e.g. 3 bar to 7 bar), it is advisable to have two separate compressed airsystems.

• Reduce compressor delivery pressure, wherever possible, to saveenergy.

• Provide extra air receivers at points of high cyclic-air demand which permits operation without extra compressorcapacity.

• Retrofit with variable speed drives in big compressors, say over 100 kW, to eliminatethe `unloaded' running condition altogether.

• Keep the minimum possible range between load and unload pressuresettings.

• Automatic timer controlled drain traps wastes compressed air every time the valve opens. So frequency of drainage should beoptimized.

• Check air compressor logs regularly for abnormal readings, especially motor current cooling water flow and temperature, inter-stage and discharge pressures and temperatures and compressor load-cycle.

• Compressed air leakage of 40 – 50 percent is not uncommon. Carry out periodic leak tests to estimate the quantity ofleakage.

• Install equipment interlocked solenoid cut-off valves in the air system so that air supply to a machine can be switched off when not inuse.

• Present energy prices justify liberal designs of pipeline sizes to reduce pressuredrops.

• Compressed air piping layout should be made preferably as a ring main to provide desired pressures for allusers.

• A smaller dedicated compressor can be installed at load point, located far off from the central compressor house, instead of supplying air through lengthypipelines.

• All pneumatic equipment should be properly lubricated, which will reduce friction, prevent wear of seals and other rubber parts thus preventing energy wastage due to excessive air consumption or leakage.

• Misuse of compressed air such as for body cleaning, agitation, general floor cleaning, and other similar applications must be discouraged in order to save compressed air andenergy.

• Pneumatic equipment should not be operated above the recommended operating pressure as this not only wastes energy bus can also lead to excessive wear of equipment's components which leads to further energywastage.

• Pneumatic transport can be replaced by mechanical system as the former consumed about 8 times more energy. Highest possibility of energy savings is by reducing compressed airuse.

• Pneumatic tools such as drill and grinders consume about 20 times more energy than motor driven tools. Hence they have to be used efficiently. Wherever possible, they should be replaced with electrically operatedtools.

• Where possible welding is a good practice and should be preferred over threadedconnections.

• On account of high pressure drop, ball or plug or gate valves are preferable over globe valves in compressed airlines.

4 .4 Energy Efficiency / Saving Measures in Refrigeration System

a) Cold Insulation

Insulate all cold lines / vessels using economic insulation thickness to minimize heat gains; and choose appropriate (correct) insulation.

b) BuildingEnvelope

Optimize air conditioning volumes by measures such as use of false ceiling and segregation of critical areas for air conditioning by air curtains.

c) Building Heat LoadsMinimization

Minimize the air conditioning loads by measures such as roof cooling, roof painting, efficient lighting, pre-cooling of fresh air by air- to-air heat exchangers, variable volume air system, optimal Thermo static setting of temperature of air conditioned spaces, sun film applications, etc.

e) Process Heat LoadsMinimization

Minimize process heat loads in terms of TR capacity as well as refrigeration level, i.e., temperature required, by way of:

i) Flowoptimization

ii) Heat transfer area increase to accept higher temperaturecoolant

iii) Avoiding wastages like heat gains, loss of chilled water, idleflows.

iv) Frequent cleaning / de-scaling of all heatexchangers

f) At the Refrigeration A/C PlantArea

i) Ensure regular maintenance of all A/C plant components as per manufacturerguidelines.

ii) Ensure adequate quantity of chilled water and cooling water flows, avoid bypass flows by closing valves of idleequipment.

iii) Minimize part load operations by matching loads and plant capacity on line; adopt variable speed drives for varying processload.

iv) Make efforts to continuously optimize condenser and evaporator parametersfor minimizing specific energy consumption and maximizingcapacity.

v) Adopt VAR system where economics permit as a non-CFCsolution.

4.5 Energy Efficiency / Saving Measures in A/C

- Ensure air intake to compressor is not warm and humid by locating compressors in well ventilated area or by drawing cold air from outside. Every 4°C rise in air inlet temperature will increase power consumption by 1percent.

- Clean air-inlet filters regularly. Compressor efficiency will be reduced by 2 percent for every 250 mm WC pressure drop across thefilter.

- Keep compressor valves in good condition by removing and inspecting once every six months. Worn-out valves can reduce compressor efficiency by as much as 50percent.

- Install manometers across the filter and monitor the pressure drop as a guide to replacement ofelement.

- Minimize low-load compressor operation; if air demand is less than 50 percent of compressor capacity, consider change over to a smaller compressor or reduce compressor speed appropriately (by reducing motor pulley size) in case of belt drivencompressors.

- Consider the use of regenerative air dryers, which uses the heat of compressed air to remove moisture.

- Fouled inter-coolers reduce compressor efficiency and cause more water condensation in air receivers and distribution lines resulting in increased corrosion. Periodic cleaning of intercoolers must beensured.

- Compressor free air delivery test (FAD) must be done periodically to check the present operating capacity against its design capacity and corrective steps must be taken ifrequired.

- If more than one compressor is feeding to a common header, compressors must be operated in such a way that only one small compressor should handle the load variations whereas other compressors will operate at fullload.

- The possibility of heat recovery from hot compressed air to generate hot air or water for process application must be economically analyzed in case of largecompressors.

- Consideration should be given to two-stage or multistage compressor as it consumes lesspower for the same air output than a single stagecompressor.

- If pressure requirements for processes are widely different (e.g. 3 bar to 7 bar), it is advisable to have two separate compressed air systems.

- Reduce compressor delivery pressure, wherever possible, to saveenergy.

- Provide extra air receivers at points of high cyclic-air demand which permits operation without extra compressorcapacity.

- Retrofit with variable speed drives in big compressors, say over 100 kW, to eliminatethe `unloaded' running condition altogether.

- Keep the minimum possible range between load and unload pressuresettings.

- Automatic timer controlled drain traps wastes compressed air every time the valve opens. So frequency of drainage should beoptimized.

- Check air compressor logs regularly for abnormal readings, especially motor current cooling water flow and temperature, inter-stage and discharge pressures and temperatures and compressorload-cycle.

- Compressed air leakage of 40 – 50 percent is not uncommon. Carry out periodic leak tests to estimate the quantity ofleakage.

- Install equipment interlocked solenoid cut-off valves in the air system so that air supply to a machine can be switched off when not inuse.

- Present energy prices justify liberal designs of pipeline sizes to reduce pressuredrops.

- Compressed air piping layout should be made preferably as a ring main to provide desired pressures for allusers.

- A smaller dedicated compressor can be installed at load point, located far off from the central compressor house, instead of supplying air through lengthypipelines.

- All pneumatic equipment should be properly lubricated, which will reduce friction, prevent wear of seals and other rubber parts thus preventing energy wastage due to excessive air consumption orleakage.

- Misuse of compressed air such as for body cleaning, agitation, general floor cleaning, and other similar applications must be discouraged in order to save compressed air andenergy.

- Pneumatic equipment should not be operated above the recommended operating pressure as this not only wastes energy bus can also lead to excessive wear of equipment's components which leads to further energywastage.

- Pneumatic transport can be replaced by mechanical system as the former consumed about 8 times more energy. Highest possibility of energy savings is by reducing compressed airuse.

- Pneumatic tools such as drill and grinders consume about 20 times more energy than motordriven tools. Hence they have to be used efficiently. Wherever possible, they should be replaced with electrically operatedtools.

- Where possible welding is a good practice and should be preferred over threaded connections.
- On account of high pressure drop, ball or plug or gate valves are preferable over globe valves in compressed airlines.

4.6 Energy Saving Opportunities in CoolingTowers

- Follow manufacturer's recommended clearances around cooling towers and relocate or modify structures that interfere with the air intake orexhaust.
- Optimize cooling tower fan blade angle on a seasonal and/or loadbasis.
- Correct excessive and/or uneven fan blade tip clearance and poor fanbalance.
- On old counter-flow cooling towers, replace old spray type nozzles with new square spray ABS practically non-cloggingnozzles.
- Replace splash bars with self-extinguishing PVC cellular filmfill.
- Install new nozzles to obtain a more uniform waterpattern
- Periodically clean plugged cooling tower distributionnozzles.
- Balance flow to cooling tower hot waterbasins.
- Cover hot water basins to minimize algae growth that contributes tofouling.
- Optimize blow down flow rate, as per COClimit.
- Replace slat type drift eliminators with low pressure drop, self extinguishing, PVC cellular units.

- Restrict flows through large loads to designvalues.

- Segregate high heat loads like furnaces, air compressors, DG sets, and isolate cooling towers for sensitive applications like A/C plants, condensers of captive power plant etc. A 1°C cooling water temperature increase may increase A/C compressor kW by 2.7%. A 1°C drop in cooling water temperature can give a heat rate saving of kCal/kWh in a thermal powerplant.

- Monitor L/G ratio, CW flow rates w.r.t. design as well as seasonal variations. It would help to increase water load during summer and times when approachis high and increase air flow during monsoon times and when approach isnarrow.

- Monitor approach, effectiveness and cooling capacity for continuous optimization efforts, as per seasonal variations as well as load side variations.

- Consider COC improvement measures for water savings.

- Consider energy efficient FRP blade adoption for fan energysavings.

- Consider possible improvements on CW pumps with respect to efficiencyimprovement.

- Control cooling tower fans based on leaving water temperatures especially in case of small units.
- Optimize process CW flow requirements, to save on pumping energy, cooling load, evaporation losses (directly proportional to circulation rate) and blow downlosses.

4.7 Energy Saving Measures in DGSet

a) Ensure steady load conditions on the DG set, and provide cold, dust free air at intake (use of air washers for large sets, in case of dry, hot weather, can beconsidered).

b) Improve airfiltration.

c) Ensure fuel oil storage, handling and preparation as per manufacturers'guidelines/oil companydata.

d) Consider fuel oil additives in case they benefit fuel oil properties for DG setusage.

e) Calibrate fuel injection pumpsfrequently.

f) Ensure compliance with maintenancechecklist.

g) Ensure steady load conditions, avoiding fluctuations, imbalance in phases, harmonic loads.

h) In case of a base load operation, consider waste heat recovery system adoption for steam generation or refrigeration chiller unit incorporation. Even the Jacket Cooling Water is amenable for heat recovery, vapour absorption systemadoption.

i) In terms of fuel cost economy, consider partial use of biomass gas for generation. Ensure tar removal from the gas for improving availability of the engine in the long run.

j) Consider parallel operation among the DG sets for improved loading and fuel economy therefore.

k) Carryout regular field trials to monitor DG set performance, and maintenance planning as perrequirements.

MODULE V

5.1 Definition & Objectives of EnergyManagement

The fundamental goal of energy management is to produce goods and provide services with the least cost and least environmental effect.

As per the Energy Conservation Act, 2001, Energy Audit is defined as "***the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energyconsumption***".

The objective of Energy Management is to achieve and maintain optimum energy procurement and utilization, throughout the organization and:

- To minimize energy costs / waste without affecting production &quality
- To minimize environmentaleffects.

5.2 Energy Audit:Needs

In any industry, the three top operating expenses are often found to be energy (both electrical and thermal), labour and materials. If one were to relate to the manageability of the cost or potential cost savings in each of the above components, energy would invariably emerge as a top ranker, and thus energy management function constitutes a strategic area for cost reduction. Energy Audit will help to understand more about the ways energy and fuel are used in any industry, and help in identifying the areas where waste can occur and where scope for improvementexists.

TheEnergyAuditwould giveapositiveorientationtotheenergycostreduction, preventive maintenance and quality control programmes which are vital for production and utility activities. Such an audit programme will help to keep focus on variations which occur in the energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipmentetc.

In general, Energy Audit is the translation of conservation ideas into realities, by lending technically feasible solutions with economic and other organizational considerations within a specified time frame.

The primary objective of Energy Audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs. Energy Audit provides a " bench-mark" (Reference point) for managing energy in the organization and also provides the basis for planning a more effective use of energy throughout the organization.

5.3 Energy Audit:Types

Type of Energy Audit

The type of Energy Audit to be performed depends on:

- Function and type ofindustry
- Depth to which final audit is needed,and

- Potential and magnitude of cost reductiondesired

Thus Energy Audit can be classified into the following two types.

i) PreliminaryAudit

ii) DetailedAudit

5.3.1 Preliminary Energy AuditMethodology

Preliminary energy audit is a relatively quick exercise to:

- Establish energy consumption in theorganization
- Estimate the scope forsaving
- Identify the most likely (and the easiest areas forattention
- Identify immediate (especially no-/low-cost) improvements/savings
- Set a 'referencepoint'
- Identify areas for more detailedstudy/measurement
- Preliminary energy audit uses existing, or easily obtaineddata

5.3.2 Detailed Energy AuditMethodology

A comprehensive audit provides a detailed energy project implementation plan for a facility, since it evaluates all major energy using systems.

This type of audit offers the most accurate estimate of energy savings and cost. It considers the interactive effects of all projects, accounts for the energy use of all major equipment, and includes detailed energy cost saving calculations and project cost.

In a comprehensive audit, one of the key elements is the energy balance. This is based on an inventory of energy using systems, assumptions of current operating conditions and calculations of energy use. This estimated use is then compared to utility billcharges.

Detailed energy auditing is carried out in three phases: Phase I, II and III.

Phase I - Pre AuditPhase

Phase II - Audit Phase

Phase III - Post AuditPhase

Phase I -Pre Audit Phase Activities

A structured methodology to carry out an energy audit is necessary for efficient working. An initial study of the site should always be carried out, as the planning of the procedures necessary for an audit is most important.

Initial Site Visit and Preparation Required for Detailed Auditing

An initial site visit may take one day and gives the Energy Auditor/Engineer an opportunity to meet the personnel concerned, to familiarize him with the site and to assess the procedures necessary to carry out the energy audit.

During the initial site visit the Energy Auditor/Engineer should carry out the following actions: -

- Discuss with the site's senior management the aims of the energyaudit.
- Discuss economic guidelines associated with the recommendations of theaudit.
- Analyze the major energy consumption data with the relevantpersonnel.
- Obtain site drawings where available - building layout, steam distribution, compressed air distribution, electricity distributionetc.
- Tour the site accompanied byengineering/production

The main aims of this visit are: -

- To finalize Energy Auditteam
- To identify the main energy consuming areas/plant items to be surveyed during theaudit.
- To identify any existing instrumentation/ additional meteringrequired.
- To decide whether any meters will have to be installed prior to the audit eg.kWh, steam, oil or gasmeters.
- To identify the instrumentation required for carrying out theaudit.
- To plan with timeframe
- To collect macro data on plant energy resources, major energy consumingcenters
- To create awareness through meetings/programme

Phase II- Detailed Energy Audit Activities

Depending on the nature and complexity of the site, a comprehensive audit can take from several weeks to several months to complete. Detailed studies to establish, and investigate, energy and material balances for specific plant departments or items of process equipment are carried out. Whenever possible, checks of plant operations are carried out over extended periods of time, at nights and at weekends as well as during normal daytime working hours, to ensure that nothing is overlooked.

The audit report will include a description of energy inputs and product outputs by major department or by major processing function, and will evaluate the efficiency of each step of the manufacturing process. Means of improving these efficiencies will be listed, and at least a preliminary assessment of the cost of the improvements will be made to indicate the expected pay- back on any capital investment needed. The audit report should conclude with specific recommendations for detailed engineering studies and feasibility analyses, which must then be per- formed to justify the implementation of those conservation measures that require investments.

The information to be collected during the detailed audit includes: -

1. Energy consumption by type of energy, by department, by major items of process equipment, byend-use
2. Material balance data (raw materials, intermediate and final products, recycled materials, use of scrap or waste products, production of by-products for re-use in other industries,etc.)
3. Energy cost and tariffdata
4. Process and material flowdiagrams
5. Generation and distribution of site services (eg. compressed air,steam).
6. Sources of energy supply (e.g. electricity from the grid orself-generation)
7. Potential for fuel substitution, process modifications, and the use of co-generation systems (combined heat and powergeneration).
8. Energy Management procedures and energy awareness training programs within the establishment

5.4 Energy Audit ReportingFormat

After successfully carried out energy audit energy manager/energy auditor should report to the top management for effective communication and implementation. A typical energy audit reporting contents and format are given below. The following format is applicable for most of the industries. However the format can be suitably modified for specific requirement applicable for a particular type of industry.

Report on

DETAILED ENERGY AUDIT

TABLE OF CONTENTS

i. **Acknowledgement**

ii. **Executive Summary**

Energy Audit Options at a glance & Recommendations

1.0 Introduction about the plant

1.1 General Plant details and descriptions

1.2 Energy Audit Team

1.3 Component of production cost (Raw materials, energy, chemicals, manpower, overhead, others)

1.4 Major Energy use and Areas

2.0 Production Process Description

2.1 Brief description of manufacturing process

2.2 Process flow diagram and Major Unit operations

2.3 Major Raw material Inputs, Quantity and Costs

3.0 Energy and Utility System Description

3.1 List of Utilities

3.2 Brief Description of each utility

3.2.1 Electricity
3.2.2 Steam
3.2.3 Water
3.2.4 Compressed air
3.2.5 Chilled water
3.2.6 Cooling water

4.0 Detailed Process flow diagram and Energy& Material balance

4.1 Flow chart showing flow rate, temperature, pressures of all input-output streams

4.2 Water balance for entire industry

5.0 Energy efficiency in utility and process systems

5.1 Specific Energy consumption

5.2 Boiler efficiency assessment

5.3 Thermic Fluid Heater performance assessment

5.4 Furnace efficiency Analysis

5.5 Cooling water system performance assessment

5.6 DG set performance assessment

5.7 Refrigeration system performance

5.8 Compressed air system performance

5.9 Electric motor load analysis

5.10 Lighting system

6.0 Energy Conservation Options & Recommendations

6.1 List of options in terms of No cost/ Low Cost, Medium cost and high investment Cost, Annual Energy & Cost savings, and payback

6.2 Implementation plan for energy saving measures/Projects

ANNEXURE

A1. List of Energy Audit Worksheets

A2. List of instruments

A3. List of Vendors and Other Technical details

5.5 Understanding EnergyCosts

Understanding energy cost is vital factor for awareness creation and saving calculation. In many industries sufficient meters may not be available to measure all the energy used. In such cases, invoices for fuels and electricity will be useful. The annual company balance sheet is the other sources where fuel cost and power are given with production related information.

Energy invoices can be used for the following purposes:

- They provide a record of energy purchased in a given year, which gives a base-line for futurereference
- Energy invoices may indicate the potential for savings when related to production requirements or to air conditioning requirements/space heatingetc.
- When electricity is purchased on the basis of maximum demandtariff
- They can suggest where savings are most likely to bemade.
- In later years invoices can be used to quantify the energy and cost savings made through energy conservationmeasures

5.5.1 FuelCosts

A wide variety of fuels are available for thermal energy supply. Few are listed below:

- Fueloil
- Low Sulphur Heavy Stock(LSHS)
- Light Diesel Oil(LDO)
- Liquefied Petroleum Gas(LPG)
- COAL
- LIGNITE
- WOODETC.

Understanding fuel cost is fairly simple and it is purchased in Tons or Kiloliters. Availability, cost and quality are the main three factors that should be considered while purchasing. The following factors should be taken into account during procurement of fuels for energy efficiency andeconomics.

- Price at source, transport charge, type oftransport
- Quality of fuel (contaminations, moistureetc)
- Energy content (calorificvalue)

5.5.2 PowerCosts

Electricity price in India not only varies from State to State, but also city to city and consumer to consumer though it does the same work everywhere. Many factors are involved in deciding final cost of purchased electricity such as:

- Maximum demand charges,kVA
- Energy Charges,kWh
- TOD Charges, Peak/Non-peakperiod
- Power factor Charge,P.F
- Other incentives and penalties applied from time totime
- High tension tariff and low tension tariff ratechanges
- Slab rate cost and itsvariation
- Typeoftariffclauseandrateforvariouscategories suchascommercial,residential, industrial, Government, agricultural,etc.
- Tariff rate for developed and underdevelopedarea/States
- Tax holiday for newprojects

5.6 Benchmarking and EnergyPerformance

Benchmarking of energy consumption internally (historical / trend analysis) and externally (across similar industries) are two powerful tools for performance assessment and logical evolution of avenues for improvement. Historical data well documented helps to bring out energy consumption and cost trends month-wise / day-wise. Trend analysis of energy consumption, cost, relevant production features, specific energy consumption, help to understand effects of capacity utilization on energy use efficiency and costs on a broader scale.

External benchmarking relates to inter-unit comparison across a group of similar units. However, it would be important to ascertain similarities, as otherwise findings can be grossly misleading.

Few comparative factors, which need to be looked into while benchmarking externally are:

- Scale ofoperation
- Vintage oftechnology
- Raw material specifications andquality
- Product specifications and quality

Benchmarking energy performancepermits

- Quantification of fixed and variable energy consumption trends vis-à-vis production levels
- Comparison of the industry energy performance with respect to various production levels (capacityutilization)
- Identification of best practices (based on the external benchmarkingdata)
- Scope and margin available for energy consumption and costreduction
- Basis for monitoring and target setting exercises.

The benchmark parameters canbe:

- Gross productionrelated

  e.g. kWh/MT clinker or cement produced (cement plant)

  e.g. kWh/kg yarn produced (Textile unit)

  e.g. kWh/MT, kCal/kg, paper produced (Paper plant)

  e.g. kCal/kWh Power produced (Heat rate of a power plant)

  e.g. Million kilocals/MT Urea or Ammonia (Fertilizer plant)

  e.g. kWh/MT of liquid metal output (in a foundry)

- Equipment / utilityrelated

  e.g. kW/ton of refrigeration (on Air conditioning plant)

  e.g. % thermal efficiency of a boiler plant

  e.g. % cooling tower effectiveness in a cooling tower

  e.g. kWh/NM^3 of compressed air generated

  e.g. kWh /litre in a diesel power generation plant.

5.7 Energy Performance

The energy performance is the percentage of energy saved at the current rate of use compared to the reference year rate of use. The greater the improvement, the higher the number will be.

$$\text{Plant energy performance} = \frac{\text{Reference year's energy- Current year'senergy}}{\text{Reference year'senergy}} \times 100$$

5.8 Matching Energy Usage toRequirement

Mismatch between equipment capacity and user requirement often leads toinefficiencies due to part load operations, wastages etc. Worst case design,is a designer's characteristic, while optimization is the energy manager's mandate and many situations present themselves towards an exercise involving graceful matching of energy equipment capacity to end-use needs. Some examplesbeing:

- Eliminate throttling of a pump by impeller trimming, resizing pump, installing variable speeddrives
- Eliminate damper operations in fans by impeller trimming, installing variable speed drives, pulley diameter modification for belt drives, fan resizing for betterefficiency.
- Moderation of chilled water temperature for process chillingneeds
- Recovery of energy lost in control valve pressure drops by back pressure/turbine adoption
- Adoption of task lighting in place of less effective arealighting

5.9 Maximizing SystemEfficiency

Once the energy usage and sources are matched properly, the next step is to operate the equipment efficiently through best practices in operation and maintenance as well as judicious technology adoption. Some illustrations in this context are:

- Eliminate steam leakages by trapimprovements
- Maximize condensaterecovery
- Adopt combustion controls for maximizing combustionefficiency
- Replace pumps, fans, air compressors, refrigeration compressors, boilers, furnaces, heaters and other energy consuming equipment, wherever significant energy efficiency marginsexist.

5.10 Optimizing the Input EnergyRequirements

Consequent upon fine-tuning the energy use practices, attention is accorded to considerations for minimizing energy input requirements. The range of measures could include:

- Shuffling of compressors to matchneeds.
- Periodic review of insulationthickness
- Identify potential for heat exchanger networking and processintegration.
- Optimisation of transformer operation with respect toload.

5.11 Fuel and EnergySubstitution

Substituting existing fossil fuel with more efficient and less cost/less polluting fuels such as natural gas, biogas and locally available agro-residues. Fuel substitution has taken place in all the major sectors of the Indian economy. Kerosene and Liquefied Petroleum Gas (LPG) have substituted soft coke in residential use.

Few examples of fuel substitution

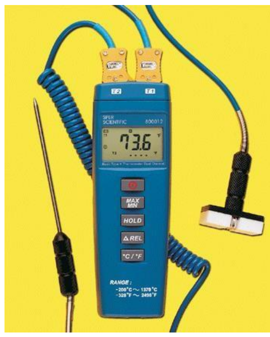
- Natural gas is increasingly the fuel of choice as fuel and feedstock in the fertilizer, petro chemicals, power and sponge ironindustries.
- Replacement of coal by coconut shells, rice husketc.
- Replacement of LDO by LSHS

Few examples of energysubstitution

- Replacement of electric heaters by steamheaters
- Replacement of steam based hot water by solarsystems

5.12 Energy AuditInstruments

 	**Electrical Measuring Instruments:** These are instruments for measuring major electrical parameters such as kVA, kW, PF, Hertz, kVAr, Amps and Volts. In addition some of these instruments also measure harmonics. These instruments are applied on-line i.eon running motors without any need to stop the motor. Instant measurements can be taken with hand-held meters, while more advanced ones facilitates cumulative readings with print outs at specified intervals.
	**Combustion analyzer:** This instrument has in-built chemical cells whichmeasurevariousgasessuchasO_2,CO, NO_X andSO_X.
	**Fuel Efficiency Monitor:** Thismeasuresoxygenandtemperatureofthe flue gas. Calorific values of common fuels are fed into the microprocessor which calcu-lates the combustionefficiency.
	**Fyrite:** A hand bellow pump draws the flue gas sample into the solution inside the fyrite. A chemical reaction changes the liquid volume revealingtheamountofgas.Aseparatefyritecan be used for O_2 and CO_2measurement.

	**Contact thermometer:** These are thermocouples which measuresfor example flue gas, hot air, hot water temperatures by insertion of probe into thestream. For surface temperature, a leaf type probe is used with the same instrument.
	**Infrared Thermometer:** This is a non-contact type measurement which when directed at a heat source directly gives the temperature read out. This instrumentis useful for measuring hot spots in furnaces, surface temperatures etc.
	**Pitot Tube and manometer:** Air velocity in ducts can be measured using a pitot tube and inclined manometer for further calculation offlows.
	**Water flow meter:** This non-contact flow measuring device using Doppler effect / Ultra sonic principle. There is a transmitter and receiver which are positioned on opposite sides of the pipe. The meter directly gives the flow. Water andother fluid flows can be easily measured with this meter.

<table>
<tr>
<td>

Tachometer</td>
<td>
Stroboscope</td>
<td>Speed Measurements:
Inanyauditexercisespeedmeasurementsare critical as thay may change with frequency, belt slip andloading.

A simple tachometer is a contact type instrument which can be used where direct access is possible.

More sophisticated and safer ones are non contact instruments such as stroboscopes.</td>
</tr>
<tr>
<td colspan="2"></td>
<td>Leak Detectors:
Ultrasonic instruments are available which can be used to detect leaks of compressed air and other gases which are normally not possible to detect with human abilities.</td>
</tr>
<tr>
<td colspan="2"></td>
<td>Lux meters:
Illumination levels are measured with a lux meter. It consists of a photo cell which senses the light output, converts to electrical impulses which are calibrated as lux.</td>
</tr>
</table>

MODULE-VI

6.1 EnergyEconomics

In the process of energy management, at some stage, investment would be required for reducing the energy consumption of a process or utility. Investment would be required for modifications/retrofitting and for incorporating new technology. It would be prudent to adopt a systematic approach for merit rating of the different investment options vis-à-vis the anticipated savings.

It is essential to identify the benefits of the proposed measure with reference to not only energy savings but also other associated benefits such as increased productivity, improved product quality etc.

The cost involved in the proposed measure should be captured in totality viz.

- Direct projectcost
- Additional operations and maintenancecost
- Training of personnel on new technologyetc.

Based on the above, the energy economics can be carried out by the energy management team. Energy manager has to identify how cost savings arising from energy management could be redeployed within his organization to the maximum effect. To do this, he has towork out how benefits of increased energy efficiency can be best sold to top managementas,

- Reducing operating /production costs
- Increasing employee comfort andwell-being
- Improving cost-effectiveness and/orprofits
- Protecting under-funded coreactivities
- Enhancing the quality of service or customer caredelivered
- Protecting theenvironment

6.2 Cost-Benefit Analysis

Within any organization there are many worthy causes, each of which requires funding and it is the job of senior management to invest in capital where it is going to obtain thegreatest return. In order to make a decision about any course of action, management needs to be able to appraise all the costs involved in a project and determine the potential benefits.

This however, is not quite as simple as it might first appear. The capital value of plant or equipment usually decreases with time and it often requires more maintenance as it gets older. If money is borrowed from a bank to finance a project, then interest will have to be paid on the loan. Inflation too will influence the value of any future energy savings that might be achieved. It is therefore important that the cost-benefit analysis allows for all these factors, with the aim of determining which investments should be undertaken, and of optimizing the benefits achieved. To this end a number of accounting and financial appraisal techniques have been developed which help energy managers and auditors make correct and objectivedecisions.

When appraising the cost-benefit involved in a project it is important to understand the difference between fixed and variable costs. Variable costs are those which vary directly with the output of a particular plant or production process, such as fuel costs. Fixed costs are those costs, which are not dependent on plant or process output, such as site-rent and insurance. The total cost of any project is therefore the sum of the fixed and variablecosts.

6.3 Discount Rate or Rate ofReturn

The rate of return is the amount you receive after the cost of an initial investment, calculatedin the form of a percentage. The percentage can be reflected as a positive, which is considered a gain or profit. When the percentage is negative, it reflects a loss. This information is very useful in determining whether or not the initial investment you made was a goodone.

6.3.1 The Rate of Return Formula

There are two major numbers needed to calculate the rate of return:

Current value = the current value of the item.

Original value = the price at which you purchased the item.

Then, apply these values to the

Rate of return formula = ((Current value - original value) / original value) x 100

Example 6.1

Let's say that in 2002 you purchased a home for Rs 2,000,000. In the next few years, homes in your neighborhood have been selling well due to the new shopping plaza a couple of miles away, which increased the market value of your home. So in 2007, you decided to downsize and sell your home. Based on the current market value during this time, you were able to sell your home for Rs 2,500,000. Using the formula, let's calculate the rate of return on your investment:

Current value = 2500,000

Original value = 2,000,000

Then

rate of return formula = ((Current value - original value) / original value) x 100 =

rateofreturn = ((2,500,000 – 2,000,000)/ 2,000,000) *100

= 25%

Here the positive percentage indicates the business is profitable.

6.4 Simple Pay-BackPeriod

Simple Payback Period (SPP) is defined as the time (number of years) required to recovering the initial investment (First Cost), considering only the Net Annual Saving:

The simple payback period is usually calculated as follows:

$$Simple\ payback\ period = \frac{First\ cost}{Yearly\,benefits - Yearly\,costs}$$

6.4.1 Advantages

A widely used investment criterion, the payback period seems to offer the following advantages:

- It is simple, both in concept and application. Obviously a shorter payback generally indicates a more attractive investment. It does not use tedious calculations.
- It favours projects, which generate substantial cash inflows inearlier years, and discriminates against projects, which bring substantial cash inflows in later years but not in earlier years.

6.4.2 Limitations

- It fails to consider the time value ofmoney
- It ignores cash flows beyond the paybackperiod.

Example 6.2

A new small cogeneration plant installation is expected to reduce a company's annual energy bill by Rs.4,86,000. If the capital cost of the new boiler installation is Rs.22,20,000 and the annual maintenance and operating costs are Rs. 42,000, the expected payback period for the project can be worked out as.

Solution

PB = 22,20,000 / (4,86,000 – 42,000) = 5.0 years

6.5 Internal Rate ofReturn

This method calculates the rate of return that the investment is expected to yield. The internal rate of return (IRR) method expresses each investment alternative in terms of a rate of return (a compound interest rate). The expected rate of return is the interest rate for which total discounted benefits become just equal to total discounted costs (i.e net present benefits or net annual benefits are equal to zero, or for which the benefit / cost ratio equals one). The criterion for selection among alternatives is to choose the investment with the highest rate of return.

The rate of return is usually calculated by a process of trial and error, whereby the net cash flow is computed for various discount rates until its value is reduced to zero.

The internal rate of return (IRR) of a project is the discount rate, which makes its net present value (NPV) equal to zero. It is the discount rate in the equation:

$$0 = \frac{CF_0}{(1+\kappa)^0} + \frac{CF_1}{(1+\kappa)^1} + \ldots\ldots + \frac{CF_n}{(1+\kappa)^n} = \sum_{t=0}^{n} \frac{CF_t}{(1+\kappa)^t}$$

where CFt = cash flow at the end of year "t"

k = discount rate

n = life of the project.

6.6 Net PresentValue

The net *present value* method calculates the *present value* of all the yearly cash flows(i.e. capital costs and net savings) incurred or accrued throughout the life of a project, and summatesthem.

The net present value (NPV) of a project is equal to the sum of the present values ofall the cash flows associated with it.Symbolically,

$$NPV = \frac{CF_0}{(1+\kappa)^0} + \frac{CF_1}{(1+\kappa)^1} + \cdots + \frac{CF_n}{(1+\kappa)^n} = \sum_{t=0}^{n} \frac{CF_t}{(1+\kappa)^t}$$

Where NPV = Net Present Value

CFt = Cash flow occurring at the end of year 't' (t=0,1,….n)

n = life of the project

k = Discount rate

The discount rate (k) employed for evaluating the present value of the expected future cash flows should reflect the risk of the project.

6.6.1 Advantages

The net present value criterion has considerable merits.

- It takes into account the time value ofmoney.
- It considers the cash flow stream in its projectlife.

6.7 Life Cycle Costing(LCC)

Life cycle costing, or whole-life costing, is the process of estimating how much money you will spend on an asset over the course of its useful life. Whole-life costing covers an asset's costs from the time you purchase it to the time you get rid of it including the costs of acquisition, maintenance, repair, replacement, energy, and any other monetary costs (less any income amounts, such as salvage value) that are affected by the investment decision. The time value of money must be taken into account for all amounts, and the amounts must be considered over the relevant period.

To calculate an asset's life cycle cost, estimate the following expenses:

1. Purchase
2. Installation
3. Operating
4. Maintenance
5. Financing (exampleinterest…)
6. Depreciation
7. Disposal

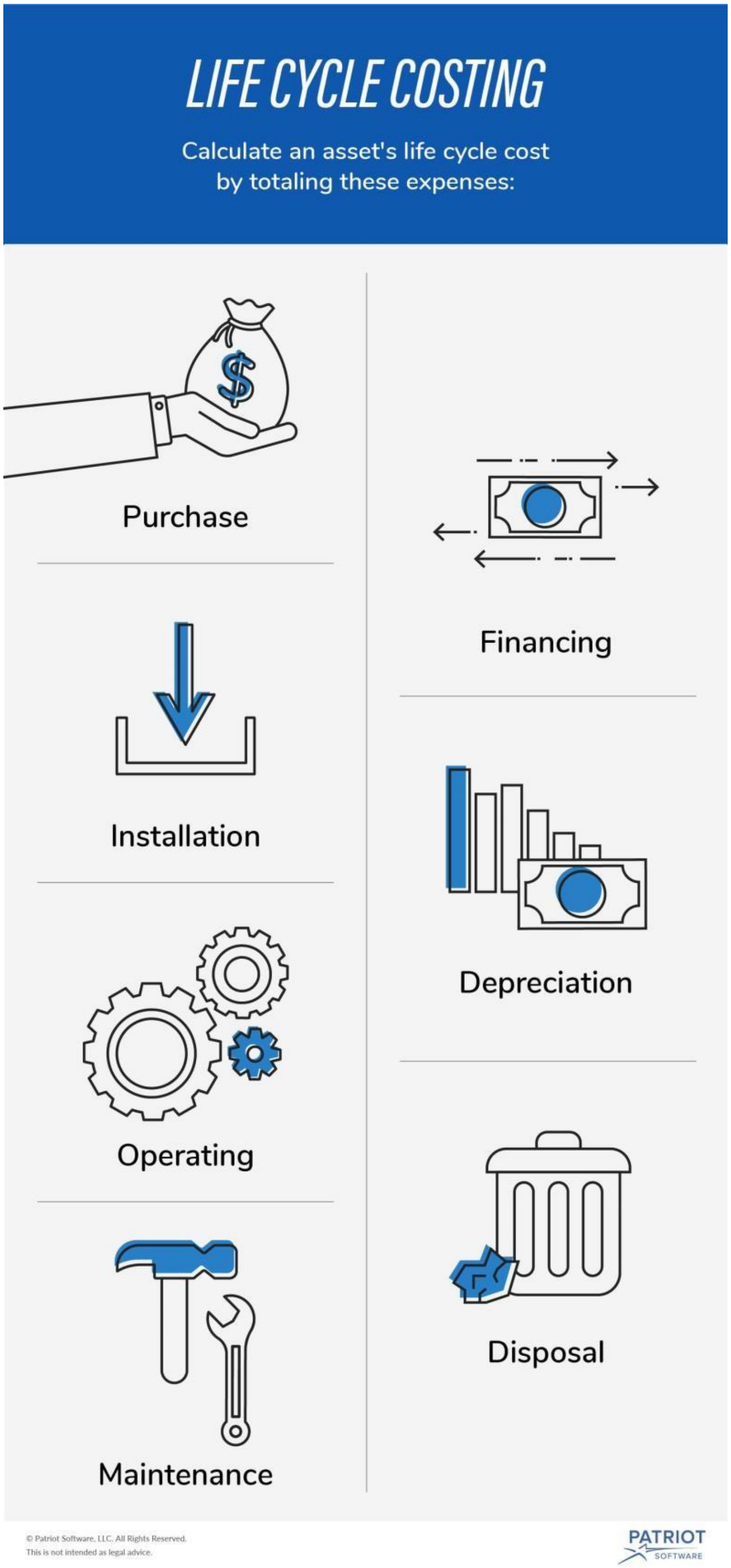


Figure 6.1 Stages of LCC

6.8 ESCO (Energy Saving Company)Concept

ESCOs are usually companies that provide a complete energy project service, from assessment to design to construction or installation, along with engineering and project management services, and financing. In one way or another, the contract involves the capitalization of all ofthe services and goods purchased, and repayment out of the energy savings that result from the project.

In performance contracting, an end-user (such as an industry, institution, or utility) seeking to improve its energy efficiency, contracts with ESCO for energy efficiency services and financing.

In some contracts, the ESCOs provide a guarantee for the savings that will be realized, andabsorbs the cost if real savings fall short of this level. Typically, there will be a risk management cost involved in the contract in these situations. Insurance is sometimes attached, at a cost, to protect the ESCO in the event of a savings shortfall.

Energy efficiency projects generate incremental cost savings as opposed to incremental revenues from the sale of outputs. The energy cost savings can be turned into incremental cash flows to the lender or ESCO based on the commitment of the energy user (and in some cases, a utility) to pay for the savings.

ESCOs are not “bankers” in the narrow sense. Their strength is in putting together a package of services that can provide guaranteed and measurable energy savings that serve as the basis for guaranteed cost savings. But, the energy savings must be measurable. The figure shows ESCos role.

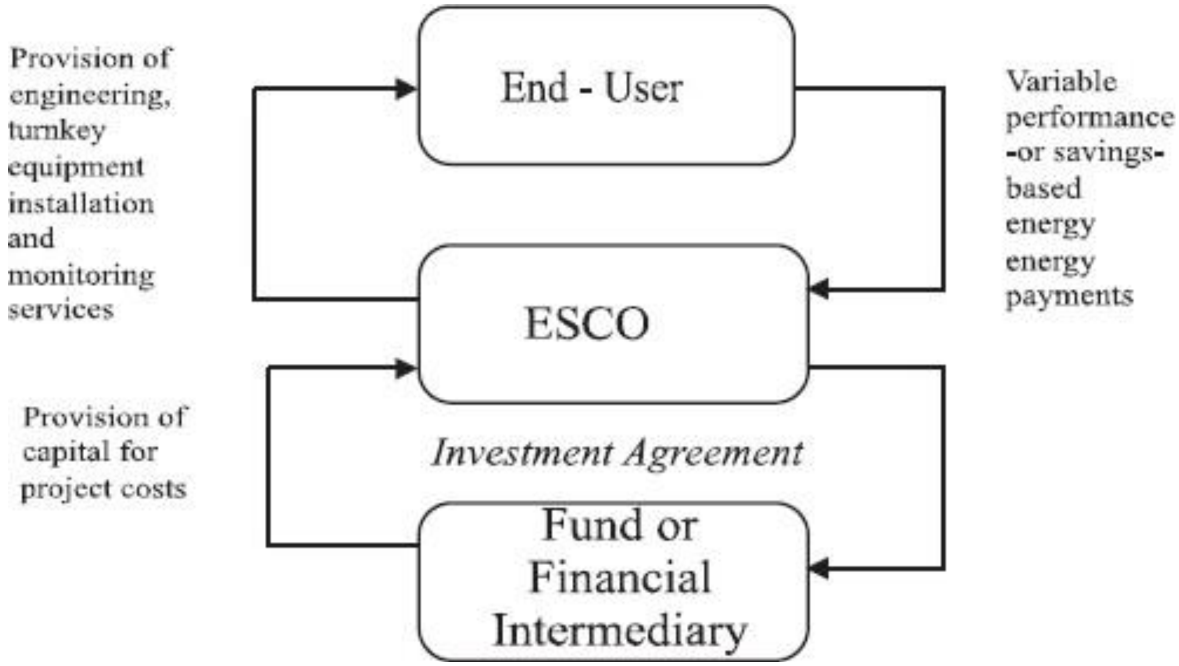


Figure 6.2 Role of ESCO