2. BASICS OF ENERGY AND ITS VARIOUS FORMS

Syllabus
Basics of Energy and its various forms: Electricity basics - DC & AC currents, Electricity tariff, Load management and Maximum demand control, Power factor.
Thermal basics -Fuels, Thermal energy contents of fuel, Temperature & Pressure, Heat capacity, Sensible and Latent heat, Evaporation, Condensation, Steam, Moist air and Humidity & Heat transfer, Units and conversion.

2.1 Definition

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.

2.2 Various Forms of Energy

There are two types of energy - stored (potential) energy and working (kinetic) energy. For example, the food we eat contains chemical energy, and our body stores this energy until we release it when we work or play.

2.2.1 Potential Energy

Potential energy is stored energy and the energy of position (gravitational). It exists in various forms.

Chemical Energy
Chemical energy is the energy stored in the bonds of atoms and molecules. Biomass, petroleum, natural gas, propane and coal are examples of stored chemical energy.

Nuclear Energy
Nuclear energy is the energy stored in the nucleus of an atom - the energy that holds the nucleus together. The nucleus of a uranium atom is an example of nuclear energy.

Stored Mechanical Energy
Stored mechanical energy is energy stored in objects by the application of a force. Compressed springs and stretched rubber bands are examples of stored mechanical energy.

Gravitational Energy

Gravitational energy is the energy of place or position. Water in a reservoir behind a hydropower dam is an example of gravitational energy. When the water is released to spin the turbines, it becomes motion energy.

2.2.2 Kinetic Energy

Kinetic energy is energy in motion- the motion of waves, electrons, atoms, molecules and substances. It exists in various forms.

Radiant Energy

Radiant energy is electromagnetic energy that travels in transverse waves. Radiant energy includes visible light, x-rays, gamma rays and radio waves. Solar energy is an example of radiant energy.

Thermal Energy

Thermal energy (or heat) is the internal energy in substances- the vibration and movement of atoms and molecules within substances. Geothermal energy is an example of thermal energy.

Motion

The movement of objects or substances from one place to another is motion. Wind and hydropower are examples of motion.

Sound

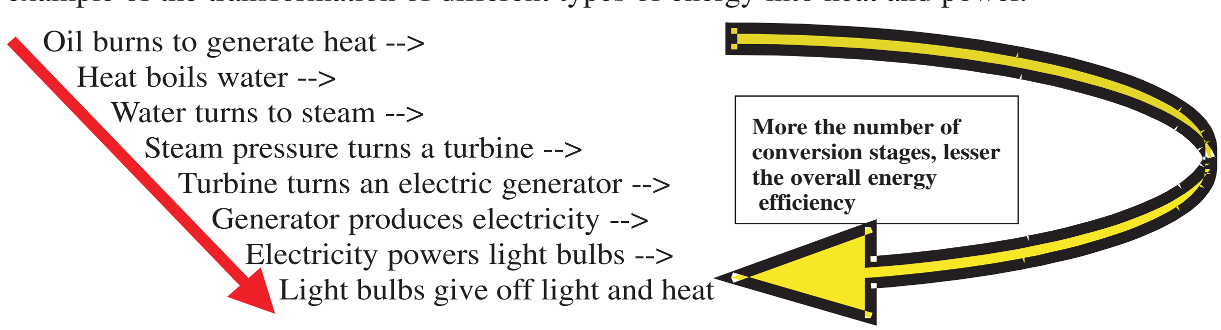
Sound is the movement of energy through substances in longitudinal (compression/rarefaction) waves.

Electrical Energy

Electrical energy is the movement of electrons. Lightning and electricity are examples of electrical energy.

2.2.3 Energy Conversion

Energy is defined as "the ability to do work." In this sense, examples of work include moving something, lifting something, warming something, or lighting something. The following is an example of the transformation of different types of energy into heat and power.



It is difficult to imagine spending an entire day without using energy. We use energy to light our cities and homes, to power machinery in factories, cook our food, play music, and operate our TV.

2.2.4 Grades of Energy

High-Grade Energy

Electrical and chemical energy are high-grade energy, because the energy is concentrated in a small space. Even a small amount of electrical and chemical energy can do a great amount of work. The molecules or particles that store these forms of energy are highly ordered and compact and thus considered as high grade energy. High-grade energy like electricity is better used for high grade applications like melting of metals rather than simply heating of water.

Low-Grade Energy

Heat is low-grade energy. Heat can still be used to do work (example of a heater boiling water), but it rapidly dissipates. The molecules, in which this kind of energy is stored (air and water molecules), are more randomly distributed than the molecules of carbon in a coal. This disordered state of the molecules and the dissipated energy are classified as low-grade energy.

2.3 Electrical Energy Basics

Electric current is divided into two types: Directional Current (DC) and Alternating Current (AC).

Directional (Direct) Current

A non-varying, unidirectional electric current (Example: Current produced by batteries)

Characteristics:

- Direction of the flow of positive and negative charges does not change with time
- Direction of current (direction of flow for positive charges) is constant with time
- Potential difference (voltage) between two points of the circuit does not change polarity with time

Alternating Current

A current which reverses in regularly recurring intervals of time and which has alternately positive and negative values, and occurring a specified number of times per second. (Example: Household electricity produced by generators, Electricity supplied by utilities.)

Characteristics:

- Direction of the current reverses periodically with time
- Voltage (tension) between two points of the circuit changes polarity with time.
- In 50 cycle AC, current reverses direction 100 times a second (two times during onecycle)

Ampere (A)

Current is the rate of flow of charge. The ampere is the basic unit of electric current. It is that current which produces a specified force between two parallel wires, which are 1 metre apart in a vacuum.

Voltage (V)

The volt is the International System of Units (SI) measure of electric potential or electromotive force. A potential of one volt appears across a resistance of one ohm when a current of one ampere flows through that resistance.

1000 V = 1 kiloVolts (kV)

Resistance

$$\text{Resistance} = \frac{\text{Voltage}}{\text{Current}}$$

The unit of resistance is ohm (Ω)

Ohm' Law

Ohm's law states that the current through a conductor is directly proportional to the potential difference across it, provided the temperature and other external conditions remain constant.

Frequency

The supply frequency tells us the cycles at which alternating current changes. The unit of frequency is hertz (Hz :cycles per second).

Kilovolt Ampere (kVA)

It is the product of kilovolts and amperes. This measures the electrical load on a circuit or system. It is also called the apparent power.

$$\text{For a single phase electrical circuit, Apparent power (kVA)} = \frac{\text{Voltage x Amperes}}{1000}$$

$$\text{For a three phase electrical circuit, Apparent power (kVA)} = \frac{\sqrt{3}\text{ x Voltage x Amperes}}{1000}$$

kVAr (Reactive Power)

kVAr is the reactive power. Reactive power is the portion of apparent power that does no work. This type of power must be supplied to all types of magnetic equipment, such as motors, transformers etc. Larger the magnetizing requirement, larger the kVAr.

Kilowatt (kW) (Active Power)

kW is the active power or the work-producing part of apparent power.

$$For\ single\ phase,\ Power\ (kW) = \frac{Voltage\ x\ Amperes\ x\ Power\ factor}{1000}$$

$$For\ Three\ phase,\ Power\ (kW) = \frac{1.732\ x\ Voltage\ x\ Amperes\ x\ Power\ factor}{1000}$$

Power Factor

Power Factor (PF) is the ratio between the active power (kW) and apparent power (kVA).

$$\text{Power Factor } (\text{Cos}\Phi) = \frac{Active\,Power\,(kW)}{Apparent\ Power\,(kVA)}$$

$$= \frac{kW}{\sqrt{(kW)^2 + (kVAr)^2}}$$

$$= 1.0 \text{ (when kVAr = 0)}$$

When current lags the voltage like in inductive loads, it is called lagging power factor and when current leads the voltage like in capacitive loads, it is called leading power factor.

Inductive loads such as induction motors, transformers, discharge lamp, etc. absorb comparatively more lagging reactive power (kVAr) and hence, their power factor is poor. Lower the power factor; electrical network is loaded with more current. It would be advisable to have highest power factor (close to 1) so that network carries only active power which does real work. PF improvement is done by installing capacitors near the load centers, which improve power factor from the point of installation back to the generating station.

Kilowatt-hour (kWh)

Kilowatt-hour is the energy consumed by 1000 Watts in one hour. If 1kW (1000 watts) of a electrical equipment is operated for 1 hour, it would consume 1 kWh of energy (1 unit of electricity).

For a company, it is the amount of electrical units in kWh recorded in the plant over a month for billing purpose. The company is charged / billed based on kWh consumption.

Electricity Tariff

Calculation of electric bill for a company

Electrical utility or power supplying companies charge industrial customers not only based on the amount of energy used (kWh) but also on the peak demand (kVA) for each month.

Contract Demand

Contract demand is the amount of electric power that a customer demands from utility in a specified interval. Unit used is kVA or kW. It is the amount of electric power that the consumer agreed upon with the utility. This would mean that utility has to plan for the specified capacity.

Maximum demand

Maximum demand is the highest average kVA recorded during any one-demand interval within the month. The demand interval is normally 30 minutes, but may vary from utility to utility from 15 minutes to 60 minutes. The demand is measured using a tri-vector meter / digital energy meter.

Prediction of Load

While considering the methods of load prediction, some of the terms used in connection with power supply must be appreciated.

Connected Load - is the nameplate rating (in kW or kVA) of the apparatus installed on a consumer's premises.

Demand Factor - is the ratio of maximum demand to the connected load.

Load Factor - The ratio of average load to maximum load.

$$\text{Load Factor} = \frac{\text{Average Load}}{Maximum\ Load}$$

The load factor can also be defined as the ratio of the energy consumed during a given period to the energy, which would have been used if the maximum load had been maintained throughout that period. For example, load factor for a day (24 hours) will be given by:

$$Load\ \ Factor\ = \frac{Energy\ consumed\ during\ 24\ hours}{Maximum\ load\ recorded\ \ x\ 24\,Hours}$$

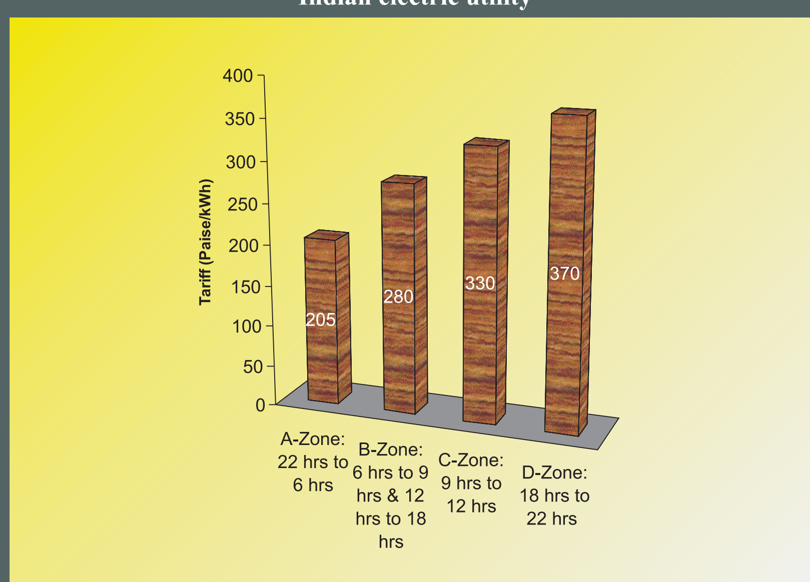
PF Measurement

A power analyzer can measure PF directly, or alternately kWh, kVAh or kVArh readings are recorded from the billing meter installed at the incoming point of supply. The relation kWh / kVAh gives the power factor.

Time of Day (TOD) Tariff

Many electrical utilities like to have flat demand curve to achieve high plant efficiency. They encourage user to draw more power during off-peak hours (say during night time) and less power during peak hours. As per their plan, they offer TOD Tariff, which may be incentives or disincentives. Energy meter will record peak and non-peak consumption separately by timer control. TOD tariff gives opportunity for the user to reduce their billing, as off peak hour tariff charged are quite low in comparison to peak hour tariff.

Figure 2.1 TOD charges for different time zones for one of the Indian electric utility



Three phase AC power measurement

Most of the motive drives such as pumps, compressors, machines etc. operate with 3 phase AC Induction motor. Power consumption can be determined by using the relation.

Power = $\sqrt{3}$ x V x I x CosΦ

Portable power analysers /instruments are available for measuring all electrical parameters.

Example:

A 3-phase AC induction motor (20 kW capacity) is used for pumping operation. Electrical parameter such as current, volt and power factor were measured with power analyzer. Find energy consumption of motor in one hour? (line volts. = 440 V, line current = 25 amps and PF = 0.90).

Energy consumption = *$\sqrt{3}$ x 0.440 (kV) x 25(A) x 0.90(PF) x 1(hour) = 17.15 kWh*

Motor loading calculation

The nameplate details of motor, kW or HP indicate the output parameters of the motor at full load. The voltage, amps and PF refer to the rated input parameters at full load.

Example:

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.

Rated output at full load	= 10 kW
Rated input at full load	= 1.732 x 0.415 x 18.2 x 0.9 = 11.8 kW
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

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

Which applications use single-phase power in an industry?

Single-phase power is mostly used for lighting, fractional HP motors and electric heater applications.

Example :

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 Cos Φ x No of Hours
= 0.230 x 2 x 0.8 x 10 = 3.7 kWh or Units

Example :

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

2.4 Thermal Energy Basics

Temperature and Pressure

Temperature and pressure are measures of the physical state of a substance. They are closely related to the energy contained in the substance. As a result, measurements of temperature and pressure provide a means of determining energy content.

Temperature

It is the degree of hotness or coldness measured on a definite scale. Heat is a form of energy; temperature is a measure of its thermal effects. In other words, temperature is a means of determining sensible heat content of the substance
In the Celsius scale the freezing point of water is 0°C and the boiling point of water is 100°C at atmospheric pressure.

To change temperature given in Fahrenheit (°F) to Celsius (°C)
Start with (°F); subtract 32; multiply by 5; divide by 9; the answer is (°C)

To change temperature given in Celsius (°C) to Fahrenheit (°F)
Start with (°C); multiply by 9; divide by 5; add on 32; the answer is (°F)

$$°C = (°F - 32) \times 5/9$$

Pressure

It is the force per unit area applied to outside of a body. When we heat a gas in a confined space, we create more force; a pressure increase. For example, heating the air inside a balloon will cause the balloon to stretch as the pressure increases.

Pressure, therefore, is also indicative of stored energy. Steam at high pressures contains much more energy than at low pressures.

Heat

Heat is a form of energy, a distinct and measurable property of all matter. The quantity of heat depends on the quantity and type of substance involved.

Unit of Heat

Calorie is the unit for measuring the quantity of heat. It is the quantity of heat, which can raise the temperature of 1 g of water by 1°C.

Calorie is too small a unit for many purposes. Therefore, a bigger unit Kilocalorie (1 Kilocalorie

= 1000 calories) is used to measure heat. 1 kilocalorie can raise the temperature of 1000g (i.e. 1kg) of water by 1°C.

However, nowadays generally joule as the unit of heat energy is used. It is the internationally accepted unit. Its relationship with calorie is as follows:

1 Calorie = 4.187 J

Specific Heat

If the same amount of heat energy is supplied to equal quantities of water and milk, their temperature goes up by different amounts. This property is called the specific heat of a substance and is defined as the quantity of heat required to raise the temperature of 1kg of a substance through 1°C.

The specific heat of water is very high as compared to other common substances; it takes a lot of heat to raise the temperature of water. Also, when water is cooled, it gives out a large quantity of heat.

TABLE 2.1 SPECIFIC HEAT OF SOME COMMON SUBSTANCES

Substance	Specific Heat (Joules / kg °C)
Lead	130
Mercury	140
Brass	380
Copper	390
Iron	470
Glass	670
Aluminium	910
Rubber	1890
Ice	2100
Alcohol	2400
Water	4200

Sensible heat

It is that heat which when added or subtracted results in a change of temperature.

Quantity of Heat

The quantity of heat, Q, supplied to a substance to increase its temperature by t°C depends on

- mass of the substance (m)
- increase in temperature (Δt)
- specific heat of the substance (C_p)

The quantity of heat is given by:

$$Q = \text{mass} \times \text{specific heat} \times \text{increase in temperature}$$
$$Q = m \times C_p \times \Delta t$$

Phase Change

The change of state from the solid state to a liquid state is called fusion. The fixed temperature at which a solid changes into a liquid is called its melting point.

The change of a state from a liquid state to a gas is called vaporization.

Latent heat of fusion

The latent heat of fusion of a substance is the quantity of heat required to convert 1kg solid to liquid state without change of temperature. It is represented by the symbol L. Its unit is Joule per kilogram (J/Kg)

Thus, L (ice) = 336000 J/kg,

Latent Heat of Vaporization

The latent heat of vaporization of a substance is the quantity of heat required to change 1kg of the substance from liquid to vapour state without change of temperature. It is also denoted by the symbol L and its unit is also J/kg. The latent heat of vaporization of water is 22,60,000 J/kg.

When 1 kg of steam at 100°C condenses to form water at 100°C, it gives out 2260 kJ (540 kCals) of heat. Steam gives out more heat than an equal amount of boiling water because of its latent heat.

Latent heat

It is the change in heat content of a substance, when its physical state is changed without a change in temperature.

Super Heat

The heating of vapour, particularly saturated steam to a temperature much higher than the boiling point at the existing pressure. This is done in power plants to improve efficiency and to avoid condensation in the turbine.

Humidity

The moisture content of air is referred to as humidity and may be expressed in two ways: specific humidity and relative humidity.

Specific Humidity

It is the actual weight of water vapour mixed in a kg of dry air.

Humidity Factor

Humidity factor = kg of water per kg of dry air (kg/kg).

Relative Humidity (RH)

It is the measure of degree of saturation of the air at any dry-bulb (DB) temperature. Relative humidity given as a percentage is the actual water content of the air divided by the moisture content of fully saturated air at the existing temperature.

Dew Point

It is the temperature at which condensation of water vapour from the air begins as the temperature of the air-water vapour mixture falls.

Dry bulb Temperature

It is an indication of the sensible heat content of air-water vapour mixtures.

Wet bulb Temperature

It is a measure of total heat content or enthalpy. It is the temperature approached by the dry bulb and the dew point as saturation occurs.

Dew Point Temperature

It is a measure of the latent heat content of air-water vapour mixtures and since latent heat is a function of moisture content, the dew point temperature is determined by the moisture content.

Fuel Density

Density is the ratio of the mass of the fuel to the volume of the fuel at a stated temperature.

Specific gravity of fuel

The density of fuel, relative to water, is called specific gravity. The specific gravity of water is defined as 1. As it is a ratio there are no units. Higher the specific gravity, higher will be the heating values.

Viscosity

The viscosity of a fluid is a measure of its internal resistance to flow. All liquid fuels decrease in viscosity with increasing temperature

Calorific Value

Energy content in an organic matter (Calorific Value) can be measured by burning it and measuring the heat released. This is done by placing a sample of known mass in a bomb calorimeter, a device that is completely sealed and insulated to prevent heat loss. A thermometer is placed inside (but it can be read from the outside) and the increase in temperature after the sample is burnt completely is measured. From this data, energy content in the organic matter can be found out.

The heating value of fuel is the measure of the heat released during the complete combustion of unit weight of fuel. It is expressed as Gross Calorific Value (GCV) or Net Calorific Value (NCV). The difference between GCV and NCV is the heat of vaporization of the moisture and atomic hydrogen (conversion to water vapour) in the fuel. Typical GCV and NCV for heavy fuel oil are 10,500 kcal/kg and 9,800 kcal/kg.

Heat Transfer

Heat will always be transferred from higher temperature to lower temperature independent of the mode. The energy transferred is measured in Joules (kcal or Btu). The rate of energy transfer, more commonly called heat transfer, is measured in Joules/second (kcal/hr or Btu/hr).

Heat is transferred by three primary modes:

- o Conduction (Energy transfer in a solid)
- o Convection (Energy transfer in a fluid)
- o Radiation (Does not need a material to travel through)

Conduction

The conduction of heat takes place, when two bodies are in contact with one another. If one body is at a higher temperature than the other, the motion of the molecules in the hotter body will vibrate the molecules at the point of contact in the cooler body and consequently result in increase in temperature.

The amount of heat transferred by conduction depends upon the temperature difference, the properties of the material involved, the thickness of the material, the surface contact area, and the duration of the transfer.

Good conductors of heat are typically substances that are dense as they have molecules close together. This allows the molecular agitation process to permeate the substance easily. So, metals are good conductors of heat, while gaseous substance, having low densities or widely spaced molecules, are poor conductors of heat. Poor conductors of heat are usually called insulators.

The measure of the ability of a substance to insulate is its thermal resistance. This is commonly referred to as the R-value (RSI in metric). The R-value is generally the inverse of the thermal conductivity, the ability to conduct heat.

Typical units of measure for conductive heat transfer are:

<u>Per unit area (for a given thickness)</u>
Metric (SI) : Watt per square meter (W/m^2)

<u>Overall</u>
Metric (SI) : Watt (W) or kilowatts (kW)

Convection

The transfer of heat by convection involves the movement of a fluid such as a gas or liquid from the hot to the cold portion. There are two types of convection: natural and forced.

In case of natural convection, the fluid in contact with or adjacent to a high temperature body is heated by conduction. As it is heated, it expands, becomes less dense and consequently rises. This begins a fluid motion process in which a circulating current of fluid moves past the heated body, continuously transferring heat away from it.

In the case of forced convection, the movement of the fluid is forced by a fan, pump or other external means. A centralized hot air heating system is a good example of forced convection.

Convection depends on the thermal properties of the fluid as well as surface conditions at the body and other factors that affect the ability of the fluid to flow. With a low conductivity fluid such as air, a rough surface can trap air against the surface reducing the conductive heat transfer and consequently reducing the convective currents.

Units of measure for rate of convective heat transfer are:

Metric (SI) : Watt (W) or kilowatts (kW)

Thermal Radiation

Thermal radiation is a process in which energy is transferred by electromagnetic waves similar to light waves. These waves may be both visible (light) and invisible. A very common example of thermal radiation is a heating element on a heater. When the heater element is first switched on, the radiation is invisible, but you can feel the warmth it radiates. As the element heats, it will glow orange and some of the radiation is now visible. The hotter the element, the brighter it glows and the more radiant energy it emits.

The key processes in the interaction of a substance with thermal radiation are:

Absorption	the process by which radiation enters a body and becomes heat
Transmission	the process by which radiation passes through a body
Reflection	the process by which radiation is neither absorbed or transmitted through the body; rather it bounces off

Objects receive thermal radiation when they are struck by electromagnetic waves, thereby agitating the molecules and atoms. More agitation means more energy and a higher temperature. Energy is transferred to one body from another without contact or transporting medium such as air or water. In fact, thermal radiation heat transfer is the only form of heat transfer possible in a vacuum.

All bodies emit a certain amount of radiation. The amount depends upon the body's temperature and nature of its surface. Some bodies only emit a small amount of radiant energy for their temperature, commonly called low emissivity materials (abbreviated low-E). Low-E windows are used to control the heat radiation in and out of buildings. Windows can be designed to reflect, absorb and transmit different parts of the sun's radiant energy.

The condition of a body's surface will determine the amount of thermal radiation that is absorbed, reflected or re-emitted. Surfaces that are black and rough, such as black iron, will absorb and re-emit almost all the energy that strikes them. Polished and smooth surfaces will not absorb, but reflect, a large part of the incoming radiant energy.

Typical units of measure for rate of radiant heat transfer

Metric (SI) Watt per square meter (W/m^2)

Evaporation

The change by which any substance is converted from a liquid state and carried off as vapour.

Example: People are cooled by evaporation of perspiration from the skin and refrigeration is accomplished by evaporating the liquid refrigerant. Evaporation is a cooling process.

Condensation

The change by which any substance is converted from a gaseous state to liquid state.

Example: Condensation on the other hand is a heating process. As molecules of vapour condense and become liquid, their latent heat of vapourisation evidences itself again as sensible heat, indicated by a rise in temperature. This heating effect of condensation is what causes the considerable rise in atmospheric temperature often noted as fog forms and as rain or snow begins to fall.

Steam

Steam has been a popular mode of conveying energy, since the industrial revolution. The following characteristics of steam make it so popular and useful to the industry:

- High specific heat and latent heat
- High heat transfer coefficient
- Easy to control and distribute
- Cheap and inert

Steam is used for generating power and also used in process industries, such as, sugar, paper, fertilizer, refineries, petrochemicals, chemical, food, synthetic fibre and textiles. In the process industries, the high pressure steam produced in the boiler, is first expanded in a steam turbine for generating power. The extraction or bleed from the turbine, which are generally at low pressure, are used for the process. This method of producing power, by using the steam generated for process in the boiler, is called "Cogeneration."

How to read a Steam Table?

Select the pressure and temperature of the steam at which you want to find the enthalpy. Read the intersection of pressure and temperature for enthalpy (Heat content in the steam)

First law of Thermodynamics

It states that energy may be converted from one form to another, but it is never lost from the system.

Second Law of Thermodynamics

- In any conversion of energy from one form to another, some amount of energy will be dis sipated as heat.
- Thus no energy conversion is 100 % efficient.
- This principle is used in energy equipment efficiency calculations.

Law of Conservation of Matter

- In any physical or chemical change, matter is neither created nor destroyed, but it may be changed from one form to another.
- For example, if a sample of coal were burnt in an enclosed chamber, carbon in coal would end up as CO^2 in the air inside the chamber; In fact, for every carbon atom there would be one carbon dioxide molecule in the combustion products (each of which has one carbon atom). So the carbon atoms would be conserved, and so would every other atom. Thus, no matter would be lost during this conversion of the coal into heat.
- This principle is used in energy and material balance calculations

2.5 Units and Conversions

The energy units are wide and varied. The usage of units varies with country, industry sector, systems such as FPS, CGS, MKS and SI, and also with generations of earlier period using FPS and recent generations using MKS. Even technology/equipment suppliers adopt units that are different from the one being used by the user of that technology/equipment. For example some compressor manufacturers specify output in m^3/min while some specify in cubic feet/minute or even in litres/second. All this cause confusion and hence the need for this chapter on units and conversions.

Energy Units

1 barrel of oil = 42 U.S. gallons (gal) = 0.16 cubic meters (m^3)

1 MW	1,000 kW
1 kW	1,000 Watts
1 kWh	3,412 Btu
1 kWh	1.340 Hp hours
1,000 Btu	0.293 kWh
1 Therm	100,000 Btu (British Thermal Units)
1 Million Btu	293.1 Kilowatt hours
100,000 Btu	1 Therm
1 Watt	3.412 Btu per hour
1 Horsepower	746 Watts or 0.746 Kilo Watts
1 Horsepower hr.	2,545 Btu
1 kJ	0.239005 Kilocalories
1 Calorie	4.187 Joules
1 kcal/Kg	1.8 Btu's/lb.
1 Million Btu	252 Mega calories
1 Btu	252 Calories
1 Btu	1,055 Joules
1 Btu/lb.	2.3260 kJ/kg
1 Btu/lb.	0.5559 Kilocalories/kg

Power (Energy Rate) Equivalents	
1 kilowatt (kW)	1 kilo joule /second (kJ/s)
1 kilowatt (kW)	3413 BTU/hour (Btu/hr.)
1 horsepower (hp)	746 watts (0.746 kW)
1 Ton of refrigeration	12000 Btu/hr.

Pressure:

Gauge pressure is defined relative to the prevailing atmospheric pressure (101.325 kPa at sea level), or as absolute pressure:
Absolute Pressure = Gauge Pressure + Prevailing Atmospheric Pressure

Units of measure of pressure:
Metric (SI) : kilopascals (kPa)
1 pascal (Pa) = 1 Newton/m^2 (N/m^2)

1 physical atmosphere (atm) = 101325 Pa = 760 mm of mercury (mm Hg)
= 14.69 lb-force/in^2 (psi)

1 technical atmosphere (ata) = 1 kilogram-force/cm^2 (kg/cm^2)= 9.806650×10^4 Pa

Power:
1 W = 1 J/s = 0.9478×10^{-3} Btu/s = 3.41214 Btu/hr

Fuel to kWh (Approximate conversion)

Natural gas	M^3 x 10.6	kWh
	Ft^3 x 0.3	kWh
	therms x 29.3	kWh
LPG (propane)	m^3 x 25	kWh
Coal	kg x 8.05	kWh
Coke	kg x 10.0	kWh
Gas oil	litres x 12.5	kWh
Light fuel oil	litres x 12.9	kWh
Medium fuel oil	litres x 13.1	kWh
Heavy fuel oil	litres x 13.3	kWh

Prefixes for units in the International System

Prefix	Symbol	Power	Example	USA/Other
exa	E	10^{18}		quintillion
peta	P	10^{15}	pentagram (Pg)	quadrillion/billiard
tera	T	10^{12}	terawatt (TW)	trillion/billion
giga	G	10^{9}	gigawatt (GW)	billion/milliard
mega	M	10^{6}	megawatt (MW)	million
kilo	k	10^{3}	kilogram (kg)	
hecto	h	10^{2}	hectoliter (hl)	
deka	da	10^{1}	dekagram (dag)	
deci	d	10^{-1}	decimeter (dm)	
centi	c	10^{-2}	centimeter (cm)	
milli	m	10^{-3}	millimeter (mm)	
micro	µ	10^{-6}	micrometer (µm)	
nano	n	10^{-9}	nanosecond (ns)	
pico	p	10^{-12}	picofarad (pf)	
femto	f	10^{-15}	femtogram (fg)	
atto	a	10^{-18}		

Energy

To:	TJ	Gcal	Mtoe	MBtu	GWh
From:	Multiply by:				
TJ	1	238.8	2.388×10^{-5}	947.8	0.2778
Gcal	4.1868×10^{-3}	1	10^{-7}	3.968	1.163×10^{-3}
Mtoe	4.1868×10^{4}	10^{7}	1	3.968×10^{7}	11630
MBtu	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
GWh	3.6	860	8.6×10^{-5}	3412	1

Mass

To:	kg	t	lt	st	lb
From:	multiply by:				
kilogram (kg)	1	0.001	9.84×10^{-4}	1.102×10^{-3}	2.2046
tonne (t)	1000	1	0.984	1.1023	2204.6
long ton (lt)	1016	1.016	1	1.120	2240.0
short ton (st)	907.2	0.9072	0.893	1	2000.0
pound (lb)	0.454	4.54×10^{-4}	4.46×10^{-4}	5.0×10^{-4}	1

Volume

To:	gal U.S.	gal U.K.	bbl	ft^3	l	m^3
From:	multiply by:					
U.S. gallon (gal)	1	0.8327	0.02381	0.1337	3.785	0.0038
U.K. gallon (gal)	1.201	1	0.02859	0.1605	4.546	0.0045
Barrel (bbl)	42.0	34.97	1	5.615	159.0	0.159
Cubic foot (ft^3)	7.48	6.229	0.1781	1	28.3	0.0283
Litre (l)	0.2642	0.220	0.0063	0.0353	1	0.001
Cubic metre (m^3)	264.2	220.0	6.289	35.3147	1000.0	1

QUESTIONS

1.	Discuss one energy conversion activity with various losses occurring stage wise.
2.	The reactive power is represented by (a) kVA (b) kW (c) kVAr (d) PF
3.	A fluorescent tube light consumes 40 W for the tube and 10 W for choke. If the lamp operates for 8 hours a day for 300 days in a year, calculate the total energy cost per annum if the energy cost is Rs.3/- per kWh
4.	Power factor is the ratio of (a) kW / kVA (b) kVA / kW (c) kVA / kVAr (d) kVAr / kV
5.	Define the term load factor.
6.	What do you understand by the term calorific value?
7.	What are the three modes of heat transfer? Explain with examples?
8.	Explain why steam is used commonly in industries?
9.	If an electric heater consumes 4 kWh, what will be the equivalent kilocalories?
10.	Why a cube of ice at $0^{o}C$ is more effective in cooling a drink than the same quantity of water at $0^{o}C$?
11.	10 kg of steam at $100^{o}C$ with latent heat of vapourisation 2260 kJ is cooled to $50^{o}C$. If the specific heat of water is 4200 J/kg^{o}C, find the quantity of heat given out.

REFERENCES

1. Energy Dictionary, Van Nostrand Reinhold Company, New York - V Daniel Hunt.
2. Cleaner Production – Energy Efficiency Manual for GERIAP, UNEP, Bangkok prepared by National Productivity Council

www.eia.doe.gov/kids/btudef.html
www.calculator.org/properties.html
www.katmarsoftware.com