

BEYOND

SMART CITIES

ENERGY SAVINGS PERFORMANCE AND
MEASUREMENT & VERIFICATION
ONLINE TRAINING COURSE

KRISHNAJI PAWAR, LEED AP BD+C, GSAS CGP, ISO 14001:2015, GCP
ENERGY SPECIALIST CURRICULUM

ENERGY EFFICIENCY SPECIALIST
BEYOND SMART CITIES



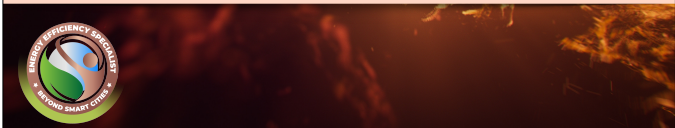
BEYOND

SMART CITIES

THERMAL ENERGY BASICS - HEAT TRANSFER
FOR ENERGY PROFESSIONALS

KRISHNAJI PAWAR, LEED AP BD+C, GSAS CGP, ISO 14001:2015, GCP
ENERGY SPECIALIST CURRICULUM

ENERGY EFFICIENCY SPECIALIST
BEYOND SMART CITIES



WHAT SHOULD YOU LEARN



Heat transfer

Conduction (Energy transfer in a solid)

Convection (Energy transfer in a fluid)

Radiation (Does not need a material to travel through)

Law of Conservation of Matter

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).

✓Conduction (Energy transfer in a solid)

✓Convection (Energy transfer in a fluid)

✓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.

✓Typical units of measure for conductive heat transfer are:
Per unit area (for a given thickness) Metric (SI) : Watt per square meter (W/m^2)

✓Overall 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.

✓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

Typical units of measure for rate of radiant heat transfer Metric (SI)
Watt per square meter (W/m²)

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 dissipated 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 CO₂ 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



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 m³/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.



1 barrel of oil = 42 U.S. gallons (gal) = 0.16 cubic meters (m³)

1 kilowatt (kW)	1 kilojoule / 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.

