REFRIGERATION BASICS

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Temperature/Pressure/heat & Heat Transfer

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Refrigeration is cooling by removal of heat. In reality we cannot remove heat; we can only move heat from a place where it is not wanted to a place where it is less objectionable.

When heat is moved, the temperature of the substance drops and where heat is moved its temperature rises.

Prior to introduction of air conditioning /refrigeration technology cooling and preservation of food was achieved by using naturally produced ice. In winter ice from lakes and ponds was cut and stored in insulated rooms for use during summer. Most of this ice was used for food preservation, restaurants and homes. Man made ice appeared just at the end of last century and first mechanical refrigerator was introduced in 1910.

In today's world there are innumerable applications of refrigeration and it is impossible to learn each independently. Instead if one concentrates on learning basic cycle and principles one would be able to understand any type of refrigeration system. That is because the principles of mechanical refrigeration and essential components are same for all kind of systems, only the size, arrangement of components and their locations are different. It is therefore necessary to understand basics of vapour compression refrigeration.

The normal examples of use of refrigeration in our day-to-day life are domestic refrigerator and room or window air conditioners.

The five basic categories of mechanical refrigeration are -

1. Comfort air conditioning
2. Process air conditioning
3. Commercial Refrigeration
4. Low temperature refrigeration
5. Cryogenics

1. COMFORT AIR CONDITIONING

The comfort air conditioning involves cooling/heating, humidifying/dehumidifying, circulate/ventilate, filter/odour removal from air. When all these aspects are tackled then it is comfort air conditioning. Room air conditioner is therefore in true sense is not technically a comfort air conditioner since only partial cooling aspect is handled and it does not have heating or humidity control mechanism. All these requirements can be build in Air handling units used in central plants.

The temperature and humidity conditions accepted as comfortable are 68 to 75 deg F (20deg C to 23.8deg C) and 20% to 60% relative humidity with 75deg F (23.8deg C)and 50 % as goal. The ASHRAE comfort chart given in Fundamentals volume 2009, gives complete details about human comfort requirements.

2. PROCESS AIR CONDITIONING

Process air conditioning is meant for things to be kept at particular temperature rather than human beings as objects. Applications are manufacture of textiles, pharmaceuticals, printing, multi colour printing, paper manufacture, photo films, audio/video cassettes, hospitals, computer rooms etc.
to the surroundings at a lower temperature & this energy is unavailable for doing any useful work between the two temperatures involved-(Definition given in Automotive Design and Development-in Annexure under definitions)

$\Delta S = \Delta Q/T$ or $\Delta q = T x \Delta S$ where T is absolute temperature and ?S is increase/decrease in entropy

Since in universe some activity is constantly taking place in all the above mentioned processes such as mechanical work, electrical work or chemical work including lights and solar energy, and all these forms are finally converting into or generating heat which is the lowest form of energy, the law of thermodynamics states that entropy of universe is constantly increasing.

3. COMMERCIAL REFRIGERATION

Commercial refrigeration covers cooling and freezing foods; it also involves production of ice. Grocery stores & super markets make extensive use of

commercial refrigeration. Household refrigerators and freezers are smaller versions of these. Normally the temperature is controlled either between 35deg F to 45deg F (1.7deg C to 7.22deg C) or for freezers between -20deg F to -30deg F (-29deg C to-35deg C)

4. LOW TEMPERATURE REFRIGERATION

Low temperature refrigeration covers use of mechanical refrigeration to cool and freeze variety of products such as blood plasma, semen, and temperatures can go as low as -70deg C.

5. CRYOGENIC APPLICATION

Cryogenic applications include such applications as space simulators, metallurgy, and gas liquefaction, testing chambers etc. requiring lower than -70deg C temperatures
Every mechanical refrigeration system using vapour compression cycle has four basic components- 1) Evaporator/cooling coil 2) Compressor 3) Condenser 4) metering device/expansion device.

In addition to this a fluid called refrigerant circulates through each component for moving heat and it travels in a particular direction in cooling mode.

HEAT

The purpose of mechanical refrigeration is to pump out the heat from areas or medium where heat is not wanted to the place where it is not objectionable to reject heat.

Since we are going continuously going to deal with heat it is necessary to understand some basics on this aspect.

FIRST LAW OF THERMODYNAMICS

First law of Thermodynamics: It is the law of conservation of energy. It states that energy cannot be created or it cannot be destroyed. We can only transfer one form of energy in to another form.

There are main four forms of energy such as light, electrical appliances, chemical reactions, and mechanical work.

As per the law of conservation of energy, all energies finally degenerate in heat. When mechanical work is done heat is generated, chemical reactions generate exothermic heat, electrical energy generates heat and solar or light energy also generate heat.

Heat is a form of energy. It is not a solid, liquid or gas and it cannot be measured by weight or volume. Heat is considered to be the lowest form of energy.

ENTROPY

This concept is defined by the term entropy. Entropy measures the molecular disorder of a system. The more mixed the system, the greater is the entropy, and conversely an orderly or unmixed configuration is one of low entropy.

Entropy (Specific) is expressed as kJ/kg.K. It is defined as a measure of energy unavailable for useful work or wasteful energy. A certain portion of energy added to a system at high temperature is later lost from the system

SECOND LAW OF THERMODYNAMICS

The second law states that heat will always flow from higher temperature to lower temperature as the water flows from higher potential to lower potential. The concept is irreversibility & it differentiates and quantifies processes that only proceed in a certain direction. Larger is the irreversibility in a refrigeration cycle operating with a given refrigeration load between two fixed temperature levels, larger is the amount of work required to operate the cycle. Irreversibility includes pressure drops in lines and heat exchangers, heat transfer between fluids of different temperatures, and mechanical friction. Reducing total irreversibility in a cycle improves the cycle efficiency and performance.

MOLECULES & RELATIONSHIP WITH TEMPERATURE

The smallest particle of a substance is molecule. This is true for any substance, whether gas, liquid or solid.

As the temperature drops the vibrating velocity of molecules reduces and as the temperature is increased the molecules vibrate at higher speeds. At absolute zero temperature the molecules do not vibrate and therefore do not create any resistance to

flow of energy like electricity or heat and therefore when materials reach nearer to this absolute zero temperature these substances are called super conductors.

Temperature therefore can be defined as the property which indicates the average velocity of the molecules of a substance. It can also be defined as measure of intensity of heat in a substance.
As the temperature of a substance is increased the molecules vibrate more rapidly and move little further apart. The density change is very little to be noticed. The substance does not change its state up to a particular temperature.

When further heat is applied, the molecules cannot keep their bond intact and break apart changing the state of a substance either from solid to liquid or from liquid to gas.

For example the R 22 molecules are 52 times farther apart as gas than as liquid. This separation causes density decrease of about 98 %. The change of state causes a big change in spacing and arrangement of molecules but very little change in the vibrating velocity of molecules. A great deal of heat is required for this change of state but it does not show on thermometer.

The density of a substance is a measure of how tightly the molecules are packed in a substance. It is measured as weight per unit volume, or pounds per cubic foot (kg/m3).

The BOILING TEMPERATURE is called SATURATION TEMPERATURE in mechanical refrigeration work.

In reality every substance has only one boiling point since boiling point is the temperature when fluid gets converted to vapour at sea level conditions, whereas every substance has many saturation temperatures. The saturation temperature is also a boiling point corresponding to the pressure. The refrigerant boils/evaporates when pressure is reduced and the same refrigerant condenses when pressure is increased.

SENSIBLE AND LATENT HEAT

Internal energy is measured at the molecular level. As explained above individual molecules of a system are in continuous motion and this motion contributes to molecular energy. This portion of internal energy associated this molecular motion is known as sensible energy.

The heat that can be sensed/measured on thermometer is called sensible heat and during sensible heating the substance does not change its state.

The internal energy is also related to intermolecular forces between molecules of the system. The forces that bind molecules are strongest in solids and weakest in gases. If sufficient energy is added to a solid or liquid, the phase change takes place when molecular binding breaks. The energy added to make this phase change is known as Latent energy. Latent heat is part of internal energy. The sensible and latent energy changes do not make any chemical changes in a substance of a system and only changes form

The heat that cannot be measured on thermometer is called latent heat and is associated with change of state of a substance.

ENTHALPY

Enthalpy is the sum of internal energy (u) and the product of pressure and volume(pv) or flow energy

H= u+pv
Thermodynamics is the study of energy change rather than the study in absolute values of energy, and the use of arbitrary reference, or datum is acceptable.

Refrigeration air conditioning systems are all in the category of flow processes, and hence only flow energy is considered with any datum level.

Hence in refrigeration systems we call the total heat which is the sum of sensible and latent heat as enthalpy. It is measured in BTU's.

Technically anything above -46deg F contents heat but we view it relatively. Technically we should therefore address as how much heat energy substance contains rather than how cold it is.

Temperature therefore measures heat content of a substance. It does not measure heat energy that is required to change the state of a substance. The two

scales normally used to measure temperature are Centigrade and Fahrenheit.

To convert centigrade in to Fahrenheit we use formula as Temperature in 0F = temperature in 0Cx9/5 +32

HEAT TRANSFER AND HEAT EXCHANGE

Heat transfer or heat exchange is the movement of heat from one place to another, either within the substance or between substances. Since mechanical refrigeration is the business of refrigeration people heat transfer is the main objective of them.

Heat content deals with how much heat energy is content in a substance where as heat transfer deals with how much heat is moved from one substance to another.

When heat is transferred, the heat content of the substance from where it is moved drops by the same amount that the heat content of the destination substance increases.

Like all forms of energy, heat flows from a high energy level to a lower energy level, just like water. If we connect two ponds of water containing same level of water there will be no flow, If however one pond is at higher level than other then water will flow from higher level to lower level by gravity.

Similarly heat will not flow without a temperature difference. It will always flow from warmer to colder substance, irrespective of its heat content. Just like water bigger the temperature difference, faster will be heat transfer.

Heat flows in 3 ways- Conduction, Convection, and Radiation.

To be continued...