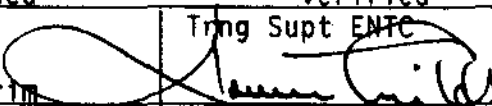



COURSE 225  
HEAT & THERMODYNAMICS

MODULE 1  
BASICS

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# Heat and Thermodynamics

## MODULE 1

### BASICS

#### Course Objectives

1. You will be able to define the following and state the units:
  - (a) Temperature.
  - (b) Heat.
2. You will be able to explain, in your own words, the following terms when applied to the various states of water:
  - (a) Saturation Temperature.
  - (b) Subcooled Liquid.
  - (c) Wet Steam.
  - (d) Saturated Steam.
  - (e) Superheated Steam.
3. You will be able to explain, in your own words, the following heat transfer mechanisms, and give an example of each mechanism:
  - (a) Conduction.
  - (b) Natural convection.
  - (c) Forced convection.
  - (d) Radiation.
4. You will be able to explain, in your own words, the following terms:
  - (a) Nucleate boiling.
  - (b) Partial film boiling.
  - (c) Dry out.
  - (d) Critical heat flux.
5. You will be able to state that a compressor will raise both the pressure and temperature of a gas and explain that an after cooler is used to reduce the volume of the receiver.
6. You will be able to state that the effect of heating a closed volume of gas is to raise its pressure and illustrate this principle with a gas "feed and bleed" example from the station.
7. You will be able to explain why it is important to know when a gas cylinder is effectively empty and state the test for this condition when the cylinder contains:
  - (a) Liquid Gas.
  - (b) Compressed Gas.

8. You will be able to explain why high energy in a compressed gas makes it dangerous for pressure testing purposes.

Enabling Objectives

1. You will be able to explain, in your own words, the following terms when applied to the various states of water:
  - (a) Sensible Heat.
  - (b) Latent Heat of Vapourization.
  - (c) Saturated Liquid.
2. You will be able to draw a graph of temperature against enthalpy as heat is added at constant pressure and complete the graph by doing the following:
  - (a) Label the areas.
  - (b) Indicate sensible heat region.
  - (c) Indicate latent heat region.
  - (d) Mark the saturation temperature.
  - (e) Indicate the subcooled region.
  - (f) Mark the point for saturated liquid.
  - (g) Mark the point for saturated steam.
  - (h) Indicate the superheated region.

Note: In this and all following modules, enabling objectives are not tested directly.

## BASICS

One of the most common problems from which we all suffer at some time or other, is that we try to rationalize a situation without returning to basic concepts. Although when we start to look, in detail, at some thermodynamic processes life can become complex, the majority of thermodynamic processes, with which we are familiar in our station, may be readily understood and explained using basic principles.

Before we can progress to look at some of the thermodynamic problems, it is essential that the basic items and concepts be understood if confusion is to be avoided.

### Temperature

Temperature is a measure of the intensity of heat of a substance. It indicates the ability of one substance to gain or lose heat with respect to another substance.

Thus TEMPERATURE is a measure of quality or grade of heat. Temperature should NOT be confused with the quantity of heat.

There are many temperature measurement scales used to compare temperatures, but today we generally only use the Celsius scale. As we know from previous experience the Celsius scale uses the freezing point and boiling point of water, at atmospheric pressure, as the lower and upper reference points of the scale. There are 100 divisions on this scale and thus the freezing point is at 0°C and the boiling point is at 100°C.

A point to note is that in symbol form, using S.I., a temperature of 10 degrees Celsius and a temperature rise of 10 degrees Celsius are BOTH shown as 10°C and obviously we need to take extra care to determine whether the given information is a point on a temperature scale, eg, 40°C or an interval eg, the difference between 90°C and 50°C is also 40°C.

### HEAT

#### Heat is a Form of Energy

The heat in a substance is associated with the motion of its molecules, ie, its internal energy. The hotter the substance the more vigorous the vibration and motion of its molecules. If heat is applied continuously to a solid it relaxes the cohesion of the molecules, and a point is reached at which the vibration of the molecules is such that the solid changes into a liquid in which the molecules can move about more freely. On further addition of heat

to the liquid the motion of the molecules is increased still more and a point is reached at which the liquid begins to change into vapour or gas. The heat applied dissociates the molecules of liquid from one another so that they fly apart and remain separate in the gaseous state.

The pressure exerted by a gas or vapour, in a vessel, is due to the impact of the molecules on the walls of the vessel. The hotter the gas, the greater the pressure, because the more violent is the motion of the molecules which, by molecular impact, cause a bigger force on the sides of the vessel. With these ideas in mind, as to the nature of heat, it is easier to imagine the molecular condition of the water and steam in the interior of a boiler.

### The Measurement of Heat

The quantity of heat that a substance contains is by no means obvious. If you were to see a block of steel in a foundry that had to be heated to 300°C you could not readily determine how much heat energy would be required. The rate at which the temperature of a material changes with the change of heat energy depends upon two factors as we shall see later: (a) the quantity of material involved (b) the nature of the material ie, how much heat is absorbed by a unit mass of the material for a unit rise in temperature.

All energy forms are measured in JOULES.

The symbol for heat energy is 'Q'.

Thus HEAT is the quantity of energy that a body possesses due to its temperature and depending upon the material, its state and mass.

### Specific Heat

Specific Heat may be simply defined as: The amount of heat energy required to change the temperature, of one kilogram of the material, one degree Celsius.

The units are Joules per kilogram per degree Celsius. (J/kg°C)

The symbol for specific heat is 'C'.

We may now relate heat and specific heat. We have already seen that the amount of heat a body required to realize a particular temperature change depends upon the mass of the body, the material of which it is composed, and the stated temperature change. Thus:

$$Q = m \times C \times \Delta T$$

$$J = kg \times J/kg^{\circ}C \times ^{\circ}C$$

Where 'Q' is the quantity of heat required to produce a temperature change of ' $\Delta T$ ' degrees Celsius in material with a mass 'm' having a specific heat 'C'.

### Example

Given 14 kg of water at 30°C. How much heat must be added to raise the temperature to 64°C if C for the water is 4.18 kJ/Kg°C. By simply substituting into  $Q = mC\Delta T$  we may determine the value of Q.

Thus  $Q = 14 \times 4.18 \times (64 - 30)$  k.Joules

kg x kJ/kg°C x °C

= 14 x 4.18 x 34

= 1989.7 kJ

Try this next example for yourself; you will find the answer at the end of the module.

Q1.1 In a 600 MW unit  $1300 \times 10^6$  Joules of energy per second are rejected to the condenser cooling water system. If the temperature rise of the cooling water is 11°C and the specific heat of the cooling water is 4.18 kJ/kg°C determine how much cooling water is needed every second.

\* \* \* \* \*

### Enthalpy

Enthalpy is the total heat value of fluid measured above a reference point. This is an arbitrary temperature that is convenient for reference such that fluid at 0°C has zero enthalpy.

The symbol for enthalpy is 'h'.

The units are in Joules/kilogram. (J/kg)

The values of enthalpy are laid out in the steam tables as we shall see later.

Before we progress to look at water, it would be an ideal point for you to reread the previous notes and if you feel you have understood them, try and write down the definitions for:

Temperature  
Heat

When you are satisfied that you know the definitions continue with the next section.

WATER

This remarkable fluid is used so widely for so many purposes that a lot of its characteristics are hardly recognized. We use water as a heat transfer fluid because it is cheap, easily purified and has an exceptional heat capacity.

When we speak of water we tend to think of it in its most familiar form, as a liquid and do not immediately register that it could also be a solid, vapour or gas. We are continually heating this substance in one part of the system and cooling it in another part and it is not surprising that we should pay a lot of attention to the behaviour of water when it is heated and cooled.

What happens to water when it is heated - get's hotter? Not necessarily so. When water is turning from liquid into steam, the temperature, which measures the hotness, remains constant. Of course, if we heat water as a liquid the temperature may rise. What else happens when water is heated? A change of state may take place, eg, the liquid may become vapour. What else happens? The enthalpy of the fluid increases. Can you think of anything else? What happens to the volume of the fluid? Right, it usually increases.

The same rationale may be applied to the cooling of the fluid. How do all these changes affect the rest of the fluid system? Very significantly - each change produces its own particular problem and unless we have knowledge as to how the fluid is behaving in the process, we have very little chance of being able to diagnose the cause of abnormal operation or produce a rationale for a particular event.

At a given pressure, the amount of enthalpy that the steam possesses will determine its state. Consequently, if we know either the state or the enthalpy of the fluid we can determine the other characteristic without too much problem.

To visualize a process we often use an aid and one of the most useful aids is the graph of temperature of the water, at constant pressure, which is plotted against the enthalpy of the fluid.

This graph is shown below and we will be referring to this on many occasions.

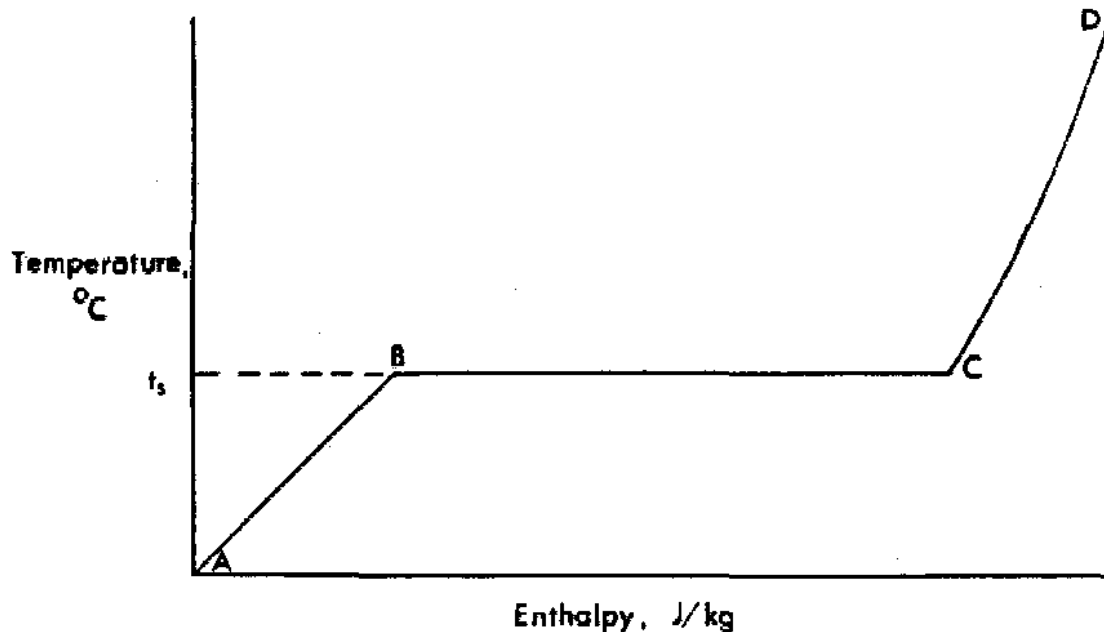


Fig. 1.1

An understanding of this simple graph provides the key to solving the majority of thermodynamic processes we can find in the station.

From the graph, starting at A, you can see that the temperature rises uniformly with increasing enthalpy until the temperature at B is reached. At this point further increase in enthalpy does not produce a corresponding temperature rise. This is because a change of state is taking place and the liquid is being turned into vapour, at constant temperature. Once all the liquid has been turned into vapour, point C, the temperature will continue to rise with the continuing increase in enthalpy, but not at the same rate as previously.

### Saturation Temperature

"Saturation temperature" is the temperature at which the liquid is changed into vapour and depends upon the pressure of the system. The higher the pressure, the higher the saturation temperature. The symbol for saturation temperature is  $t_s$ . The saturation temperature provides a very useful reference point as we will see.

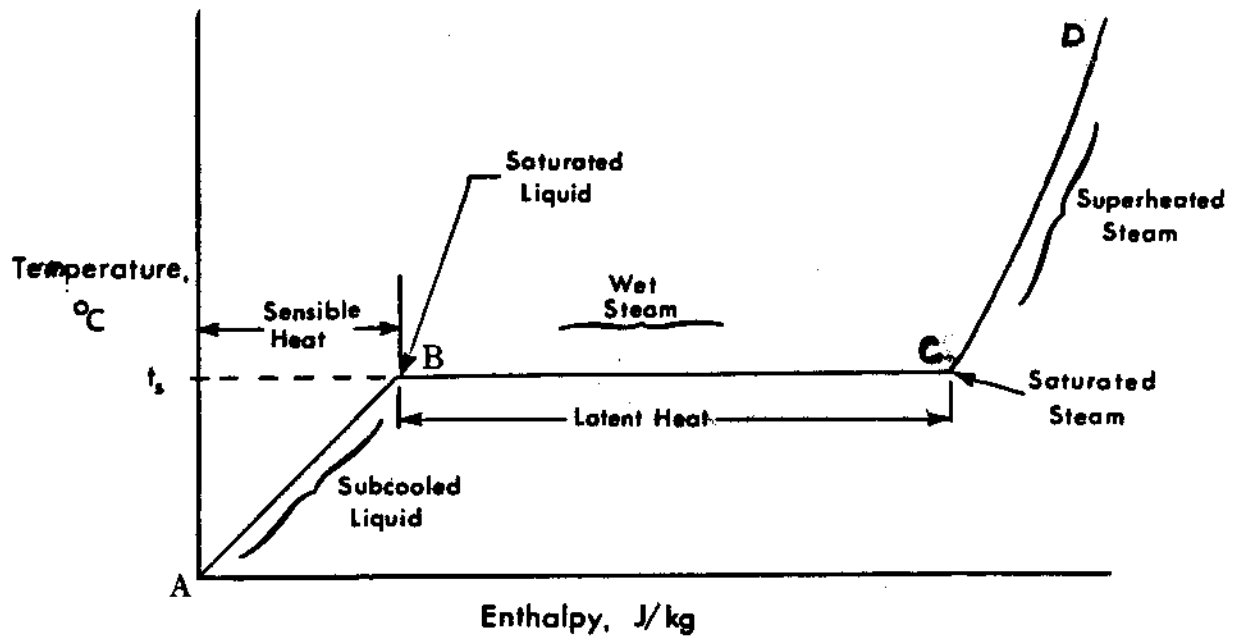


Fig. 1.2

### Sensible Heat - Points A and B

The enthalpy of the liquid is often referred to as "sensible heat". 'Sensible' because the addition of heat to the liquid is observed by a temperature rise. The sensible heat range is the enthalpy of liquid at 0°C to liquid at saturation temperature  $t_s$ . The addition of superheat C-D also produces a temperature rise but this is not referred to as "sensible heat".

### Subcooled Liquid

"Subcooled liquid" is liquid which has not received enough heat for the temperature to reach the saturation temperature and consequently exists at a temperature below  $t_s$ .

### Saturated Liquid - Point B

"Saturated liquid" is liquid which has received enough heat that it exists at the saturation temperature,  $t_s$ . We use the term 'saturated' because the liquid cannot absorb any more heat without the liquid starting to turn into vapour.

### Saturated Steam - Point C

"Saturated steam" is steam which has no liquid left and is saturated with the amount of heat which was required to change from a liquid at point 'B' to saturated vapour at point 'C'. Again it is saturated with heat because if any more heat was added the temperature would no longer remain constant but would start to rise again.

The heat which has to be added from point 'B' to point 'C' is called the latent heat of vapourization. 'Latent' or hidden because there is no temperature change to indicate that heat addition is occurring. The water is changing its state from liquid to vapour.

#### Wet Steam - Between Points B and C

"Wet steam" is steam which exists at the saturation temperature and may be anywhere between points B and C. If there is a lot of liquid in the mixture the condition of the steam will be close to B. If there is little moisture in the steam the condition will be close to C. Another way of describing wet steam is to say that this is steam which has not received all its latent heat. It is a mixture of fine moisture droplets and water vapour existing at the saturation temperature  $t_s$ .

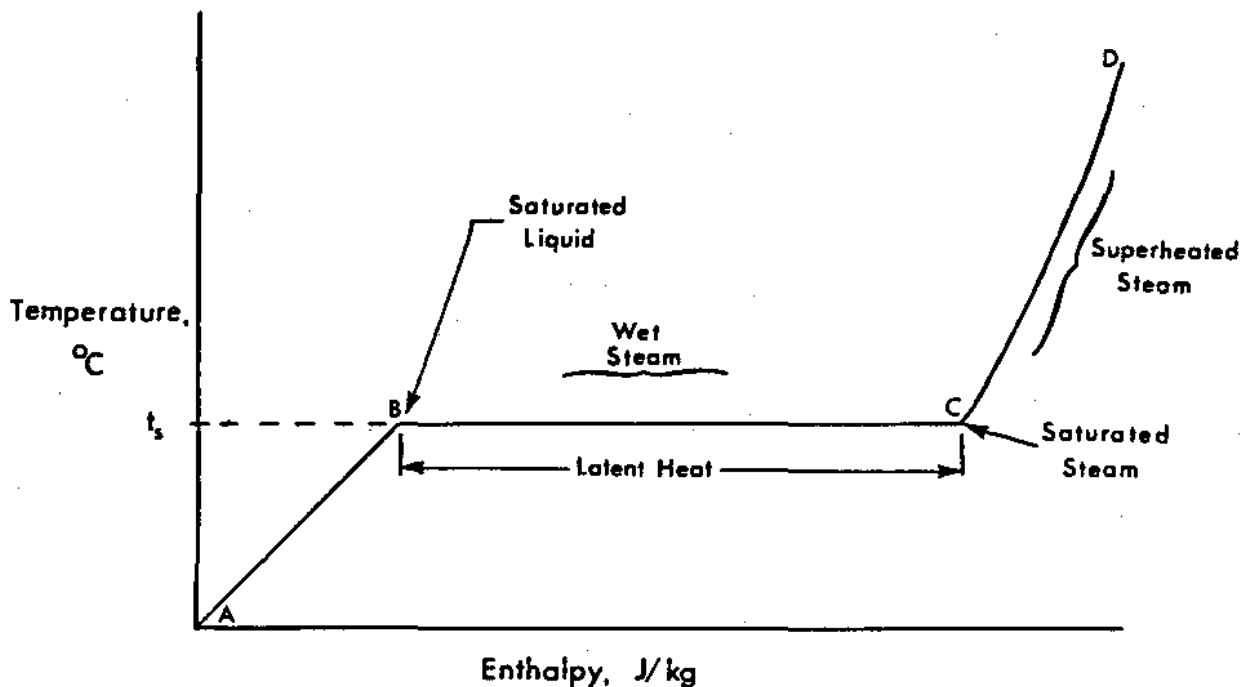


Fig. 1.3

#### Superheated Steam - Between Points C and D

"Superheated steam" is steam which has received all its latent heat and has been further heated so that its temperature is above  $t_s$ . The steam behaves like a gas once it is more than approximately 50°C above the saturation temperature.

#### Heat Transfer Mechanisms

There are three main mechanisms of heat transfer: conduction, convection, and radiation. Heat is transferred from a higher temperature substance to a lower temperature substance by at least one of these mechanisms. Let us look a little more closely at each mechanism.

### Conduction

Conduction involves heat transfer with no transfer of mass. Heat is transferred from particle to particle through a substance, while the particles themselves remain in the same relative positions in the substance. An example of heat transfer by conduction is the heat transfer through the steam generator tubes from the primary heat transport side to the light water side.

### Convection

Convection involves heat transfer that is accomplished by the movement of a fluid. As the fluid moves, it carries heat with it.

There are two types of convection:

- (a) Natural Convection: In natural convection, the movement of the fluid is due to density differences that occur in the fluid as heat transfer occurs. For example, as the water in the boiler is heated, it vaporizes to produce steam, which has a much lower density than the surrounding water. The steam thus rises through the water to the top of the boiler, carrying the heat added to it by the primary heat transport system.
- (b) Forced Convection: This type of convection makes use of pressure differences to force the fluid to move. The pressure differences are generated by equipment such as pumps, fans, and compressors. For example, the condenser cooling water is pumped through the condenser, picking up heat from the steam exhausted from the turbine and carrying the heat out to the lake.

### Radiation

The particles of a substance, because of excitation due to temperature, emit electromagnetic energy in the infrared range. This radiant energy that is emitted transfers heat from the substance. Heat is only transferred by radiation in significant amounts from high temperature sources. An example of heat transfer by radiation is the heat transferred through the film surrounding a fuel bundle when film boiling occurs and heat transfer due to forced convection is very small because of the massive reduction in the heat transfer coefficient when the  $D_2O$  changes from liquid to vapour. Initially, the heat transfer is by conduction through the vapour but the thermal conductivity of  $D_2O$  vapour is very low. The fuel sheath temperature thus rises, and as it rises, more and more heat is transferred by radiation.

Answer these questions and compare your answers with those at the end of the course.

Q1.2 Draw the graph of temperature against enthalpy for heat addition at constant pressure for water.

- (a) Label the axes.
- (b) Indicate sensible heat region.
- (c) Indicate latent heat region.
- (d) Mark the saturation temperature.
- (e) Indicate the subcooled regions.
- (f) Mark the point for saturated liquid.
- (g) Mark the point for saturated steam.
- (h) Indicate the superheated region.
- (i) Indicate the wet steam range.

When you have done this turn to the end of the module and check your answers.

When you have labelled the diagram correctly, describe the following when applied to various states of water, using your own words:

- (a) Saturation temperature.
- (b) Sensible heat.
- (c) Latent heat of Vapourization.
- (d) Subcooled liquid.
- (e) Saturated liquid.
- (f) Saturated steam.
- (g) Superheated steam.
- (h) Wet steam.

Q1.3 Explain the following heat transfer mechanisms in your own words and give an example of each mechanism:

- (a) Conduction.
- (b) Natural convection.
- (c) Forced convection.
- (d) Radiation.

\* \* \* \* \*

### Heat Transfer and Cooling of the Fuel

Many of the heat transfer processes associated with our CANDU power plants occur in a liquid medium and one of the most crucial, with respect to reactor operation, is removal of heat from the fuel. In this section we will examine this process in more detail.

Different heat transfer mechanisms are involved in cooling the fuel elements. Heat generated in the fuel pellets is transferred to the outer surface of the sheath by conduction. Assuming that no excessive boiling is occurring, removal of this heat by the coolant, i.e., heat transport  $D_2O$ , is through

- (a) forced convection when the heat transport fluid is circulated by pump, eg, HT, SDC, ECI, or
- (b) natural convection (thermosyphoning) when no pumps are available to circulate the heat transport fluid.

Let us look more carefully at the convective heat transfer process focusing on the occurrence of boiling in the coolant and the consequent effects on heat transfer and reactor operation.

Boiling is a process of evaporation associated with vapour bubbles in a liquid. Figure 1.4 illustrates natural convection boiling in a pool of liquid (at atmospheric pressure and saturation temperature) heated by a flat plate at higher temperature. Heat flux ( $Q/A$ ) which is the rate of heat transferred per unit surface area, is plotted against the difference in temperature between the heated plate or wall ( $T_w$ ) and the saturation temperature ( $T_{sat}$ ). The slope of the resulting curve represents the heat transfer coefficient. General characteristics of this type of boiling can be applied to forced convection boiling at various flow velocities and to other pressure and temperature conditions.

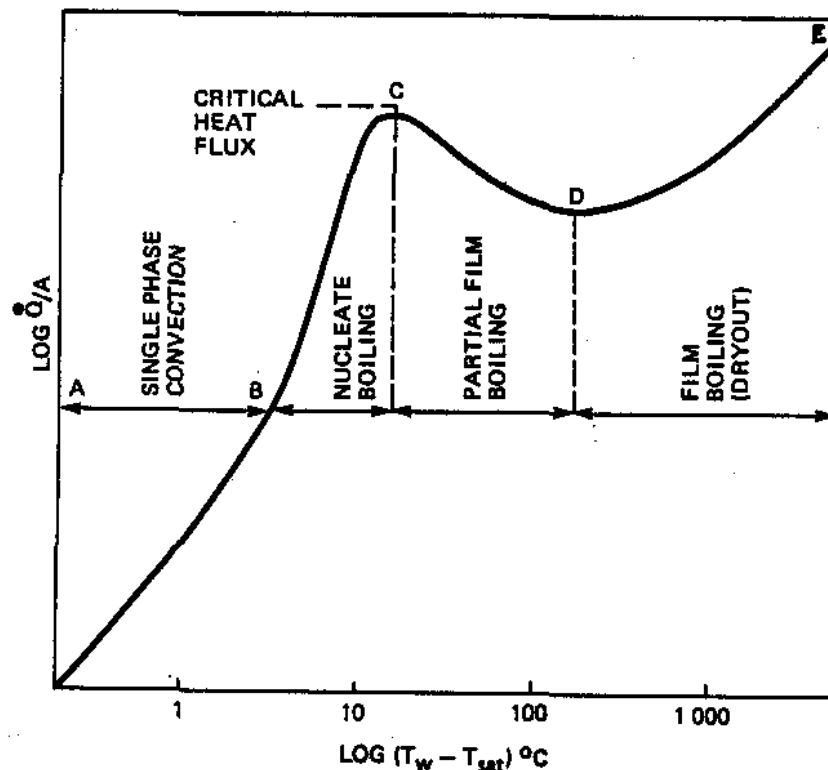


Figure 1.4 Boiling Regimes (Note log scales are used)

The process curve can be divided into four regions based on the mechanism of heat transfer. In the region A-B, single phase liquid convection is the mode of heat transfer. The temperature of the heating plate or wall is only slightly higher than the liquid saturation temperature and there is no boiling or bubble formation.

As the temperature difference ( $T_w - T_{sat}$ ) increases (region B-C), nucleate boiling is initiated. It is characterized by the formation of bubbles at specific nucleation sites on the heating surface. The vigorous mixing caused by the formation and rising of vapour bubbles results in a greater heat transfer coefficient in this region than in region A-B (evidenced by the increased slope of the boiling curve). The peak nucleate boiling heat flux, called "critical heat flux," is reached when so many nucleation sites become active and the bubbles so dense, that a vapour film forms over the heating surface preventing the flow of liquid to the surface.

When the "critical heat flux" is reached convective heat transfer decreases and eventually conduction and radiation predominate. The consequence is that in region C-D, despite the increased temperature differential, the heat flux decreases. The vapour film established is unstable in this region. It spreads over a part of the heating surface, breaks down, is replaced by violent nucleate boiling, and is reestablished. This characterizes partial film boiling.

At even higher values of ( $T_w - T_{sat}$ ), the heat transfer mechanism becomes more stable and the heat transfer coefficient begins to rise again but more slowly than in the nucleate boiling region, B-C. In region D-E, film boiling is stabilized and the heating surface is entirely covered by a thin layer of vapour. This condition is known as "dry out" and must be avoided. It is dangerous because in trying to attain the same high heat fluxes established under nucleate boiling, the heating surface temperature may become so excessive that it is above the melting point of the material.

If nuclear fuel is used as the heat source, operating at or near the critical heat flux region will impose thermal stresses on the fuel and fuel sheath due to the rapid changes in the heat transfer mechanism. This is further complicated by the varying nature of the neutron flux.

Using Figure 1.4 we have just described the process of natural convection boiling at atmospheric pressure and saturation temperature. The actual process in a fuel channel deviates from this simple model in many ways such as

- (a) the process is by forced convection
- (b) pressures are much higher

- (c) coolant enters the channel subcooled
- (d) the shape of the heat transfer surface is more complex, and
- (e) heat flux within the fuel channel is not uniform.

All these factors complicate the conditions present during boiling and impair our ability to predict critical heat flux and dry out more than in the case of pool boiling.

The practical conclusions that can be drawn from the above discussion are

- (a) limited nucleate boiling (at a heat flux well below the critical heat flux) improves heat transfer due to the vigorous mixing of the fluid by the vapour bubbles. This is why most CANDU reactors have been designed for this mode of boiling occurring in some fuel channels at high power, and
- (b) excessive nucleate boiling (at a heat flux too close to the critical heat flux) jeopardizes fuel safety since even a small increase in heat load can easily convert such boiling to film boiling and eventually dry out with overheating of fuel and fuel failures.

Q1.4 Explain in your own words the following:

- (a) Nucleate boiling.
- (b) Partial film boiling.
- (c) Dry out.
- (d) Critical heat flux.

#### Compressed Gas

Gas is compressed for a variety of reasons: to reduce its volume for storage, to raise its energy level so that it may provide useful work, and to raise its pressure above atmospheric so that it prevents air in leakage.

A compressor is the equipment used to raise the pressure of the gas; an electric motor usually supplying the energy for the compression work done. The mechanical energy used in the compressor raises the gas pressure and increases the average kinetic energy of the molecules and hence the gas temperature. In addition, a smaller amount of frictional heat is generated by the turbulence of the compression process further increasing molecular motion and hence temperature. The net effect of this heat (seen as increased gas temperature) during compression is to decrease the compressive effect, i.e., reduce or offset the decrease in volume caused by compression.

It is important to reduce the gas volume so that the size of the receiver is not unreasonable for the mass of gas which is required to be stored. The volume of the gas is reduced by cooling the gas using "after cooler" which is fitted after the compressor but before the receiver.

The change of volume with temperature is apparent on fixed volume systems such as the D<sub>2</sub>O storage tank and the moderator cover gas system. In both these systems, an increase in temperature will cause the gas pressure to rise and result in bleeding of gas from the system. Equally a cooling of the gas will cause the pressure to fall and result in gas being fed to the system.

Q1.5 Explain why gas increases in temperature when compressed and why an after cooler is necessary.

Q1.6 Explain the effect of heating a closed volume of gas and illustrate your answer with an application in the station.

Check your answers at the end of the course.

\* \* \* \* \*

Gas is a compressible fluid and requires large amounts of energy to raise the pressure.

Most of this energy is recoverable. If all the pressure energy is recovered in a very short time, eg, a compressed air tank ruptures, then this energy release produces an explosion.

This is the reason that pressure testing should not be performed using fluids that need very high energy input to raise their pressure, ie, gases and vapours. Fluids that do not need high energy input for compression, ie, liquids, should be used so that if the system being pressure tested fails, the release of energy is minimal.

### Storage of Gases

Gases may be stored as liquids or compressed gas depending upon the saturation temperature at the pressure involved. If the saturation temperature is well below ambient values, then the gas will probably be stored as compressed gas. If the gas has a saturation temperature equal to ambient or above, then the gas will probably be stored as a liquid.

It is important to know when a gas cylinder is becoming empty so that the cylinder remains uncontaminated. If the cylinder is allowed to become totally empty, reverse flow into the cylinder may occur (suck-back) which may introduce air, moisture. The presence of oxygen and moisture will allow corrosion to occur and may also create explosive conditions if the gas is flammable.

As the gas is used from a cylinder of compressed gas, the pressure falls as the mass of gas in the cylinder decreases. The cylinder should be isolated from service when there is still a positive pressure in the cylinder with respect to the system to which it is connected. A pressure of at least 30 psi or 200 kPa above system pressure should exist in the cylinders when considered "EMPTY".

The pressure in a liquefied gas cylinder does not change as gas is used. As a result, the pressure cannot indicate when the cylinder is empty. The only way that the cylinder can be checked for contents is to be weighed.

Q1.7 Explain why compressed gas should not be used for pressure testing.

Q1.8 Explain why gas cylinders should not be allowed to empty completely.

Q1.9 State how you would determine the contents of a compressed air and a liquefied gas cylinder.

\* \* \* \* \*

MODULE 1 - ANSWERSQ1.1

This time we want to determine the value of 'm'. If we rearrange the formula for the heat energy so that the mass is expressed in terms of C,  $\Delta T$  and Q we get:

$$m = Q / C \Delta T \text{ kg}$$

Substituting the given values,

$$Q = 1300 \times 10^6 \text{ J}$$

$$C = 4.18 \times 10^3 \text{ J/kg}^\circ\text{C}$$

$$\Delta T = 11^\circ\text{C}$$

$$\text{thus } m = \frac{1300 \times 10^6}{4.18 \times 10^3 \times 11} \text{ kg}$$

$$= 28.3 \times 10^3 \text{ kg of CCW every second}$$

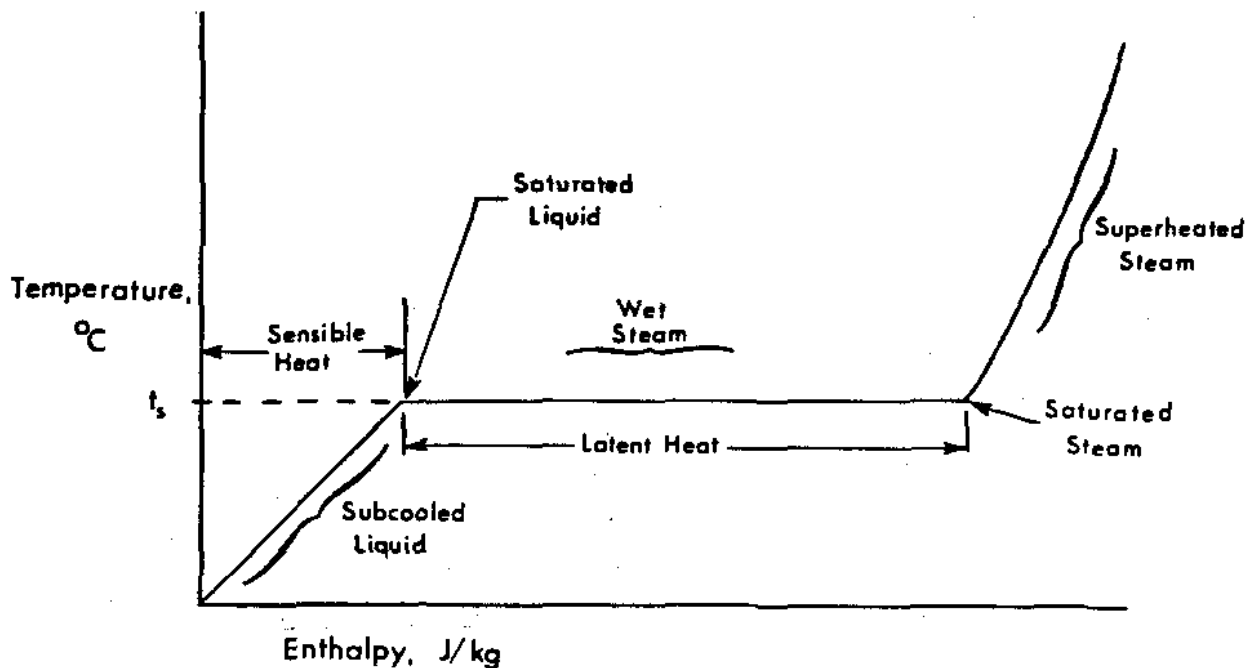
Q1.2

Fig. 1.5

Q1.3

- (a) Conduction of heat occurs through a material from the higher temperature to the lower temperature without movement of the molecules, eg, heat conducted through the fuel sheath.
- (b) Natural Convection of heat occurs due to the movement of fluid caused by density difference, eg, the thermosyphoning of the PHT system when the PHT pumps are shutdown:
- (c) Forced Convection of heat occurs due to the movement of fluid which is caused by pressure difference due to pumps, fans, etc eg, the heat is removed from the fuel bundles under normal power operation by forced convection.
- (d) Radiation of heat energy occurs from relatively hot materials due to electromagnetic radiation eg, the majority of heat from a fuel bundle is transferred by radiation when the bundle is surrounded by vapour as in film boiling.

Q1.4

- (a) Nucleate boiling is characterized by the formation of bubbles at specific nucleation sites on the heating surface. As the vapour bubbles rise from the heating surface they cause mixing in the liquid and subsequently increase the heat transfer coefficient.
- (b) Partial film boiling is characterized by the formation, breakdown and re-establishment of a vapour film on the heating surface. There are so many active nucleation sites on the heating surface that the vapour bubbles coalesce to form an unstable film on the heating surface. The heat transfer coefficient decreases.
- (c) Dry out is the term used to describe the formation of a stable film of vapour on the heating surface. It is dangerous to establish this condition because the heating surface temperature must be very high (even approaching the melting point) in order to attain high heat fluxes.
- (d) Critical heat flux is the peak heat flux reached under nucleate boiling conditions. It represents the point where so many nucleation sites become active and the vapour bubbles so dense that a vapour film tends to form on the heating surface.

Q1.5

The increase in molecular kinetic energy during compression causes the gas temperature to rise which tends to increase the volume of the compressed gas partially offsetting the compression effect. The volume is reduced using an after cooler, after the compressor and before the receiver, to reduce the size of the receiver.

Q1.6

A closed volume of gas will increase in pressure as the temperature rises. In a closed system which requires a constant pressure, this results in gas being bled from the system. An example occurs when the moderator temperature rises causing the cover gas pressure to rise and results in the operation of the bleed valves.

Q1.7

Gas is a compressible fluid and requires a large amount of energy to raise its pressure. Most of this energy is recoverable and if the system being pressured tested was to fail, the result would be an explosion. Incompressible fluids, ie, liquids require little energy to raise their pressure and should be used for pressure testing.

Q1.8

Gas cylinders that are completely empty can be subjected to reverse flow (suck-back) which can cause contamination due to the entry of oxygen and moisture. This may result in explosive conditions with flammable gases.

Q1.9

A compressed gas cylinder may be checked for contents by pressure.

A liquified gas cylinder may only be checked for contents by weight.

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