**3. STEAM SYSTEM**

**3.1 Introduction**

Steam is produced by adding heat to water which is used as a fuel for power generation. Steam is again used in processing industry such as sugar, paper, fertilizer, refineries, petrochemicals, chemical, food, synthetic fibre and textiles to get the processed product. The following characteristics of steam make it so popular and useful to the industry:

* Highest specific heat and latent heat
* Highest heat transfer coefficient
* Easy to control and distribute
* Cheap and inert

**3.2 Properties of Steam**

Water can exist in the form of solid, liquid and gas as ice, water and 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 be formed [1]

**Liquid Enthalpy**

Liquid enthalpy is the "Enthalpy" (heat energy) in the water when it has been raised to its boiling point to produce steam, and is measured in kCal/kg, its symbol is hf. (also known as "Sensible Heat") [1]

**Enthalpy of Evaporation (Heat Content of Steam)**

The Enthalpy of evaporation is the heat energy to be added to the water (when it has been raised to its boiling point) in order to change it into steam. There is no change in temperature, the steam produced is at the same temperature as the water from which it is produced, but the heat energy added to the water changes its state from water into steam at the same temperature.

When the steam condenses back into water, it gives up its enthalpy of evaporation, which it had acquired on changing from water to steam. The enthalpy of evaporation is measured in kCal/kg. Its symbol is hfg. Enthalpy of evaporation is also known as latent heat.

The temperature at which water boils, also called as boiling point or saturation temperatureincreases as the pressure increases. When water under pressure is heated its saturation temperature rises above 100 °C. From this it is evident that as the steam pressure increases, the usable heat energy in the steam (enthalpy of evaporation), which is given up when the steam condenses, actually decreases. When the steam contains moisture the total heat of steam will be where ***x*** is the dryness fraction. The temperature of saturated steam is the same as the water from which it is generated, and corresponds to a fixed and known pressure. Superheat is the addition of heat to dry saturated steam without increase in pressure. The temperature of superheated steam, expressed as degrees above saturation corresponding to the pressure, is referred to as the degrees of superheat.

**The Steam Phase Diagram**

Phase change from water to steam can be expressed in a graphical form. Figure below illustrates the relationship between the enthalpy and the temperature at various different pressures, and is known as a phase diagram.

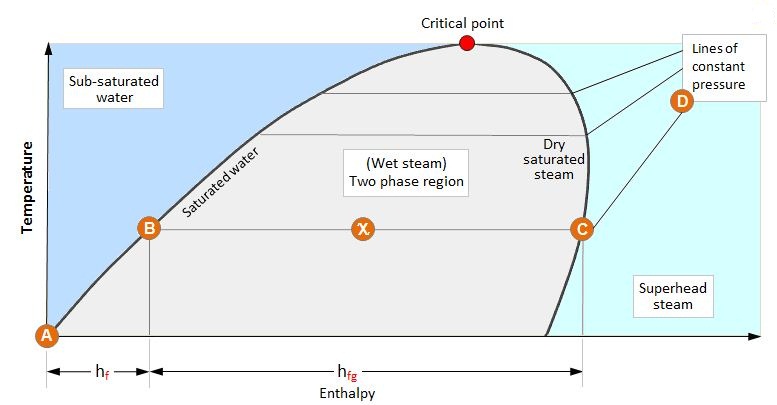


Fig: Phase diagram

As water is heated from 0°C to its saturation temperature, its condition follows the saturated liquid line until it has received all of its liquid enthalpy, hf (**A- B**). Further heat added at point **B** changes its phase to saturated steam and continues to, (**B - C**). As the steam/water mixture increases in dryness, its condition moves from the saturated increase in enthalpy while remaining at saturation temperature, hfg liquid line to the saturated vapour line. Therefore at a point exactly halfway between these two states, the dryness fraction (*x*) is 0.5. Similarly, on the saturated vapour line the steam is 100% dry. Once it has received all of its enthalpy of evaporation, it reaches the saturated vapour line. If it continues to be heated after this point, the temperature of the steam will begin to rise as superheat is imparted (**C - D**). The saturated liquid and saturated vapour lines enclose a region in which a steam/water mixture exists - wet steam. In the region to the left of the saturated liquid line only water exists, and in the region to the right of the saturated vapour line only superheated steam exists.

The point at which the saturated liquid and saturated vapour lines meet is known as the critical point (374.15°C and 221.2 bar). As the pressure increases towards the critical point the enthalpy of evaporation decreases, until it becomes zero at the critical point. This suggests that water changes directly into saturated steam at the critical point. Above the critical point only gas may exist. The gaseous state is the most diffuse state in which the molecules have an almost unrestricted motion, and the volume increases without limit as the pressure is reduced. The critical point is the highest temperature at which liquid can exist. Any compression at constant temperature above the critical point will not produce a phase change. Compression at constant temperature below the critical point however, will result in liquefaction of the vapour as it passes from the superheated region into the wet steam region. Above the critical pressure the steam is termed supercritical [1].

**3.2 Steam distribution system**

# Steam is one of the most important input in process industry for heating or drying purpose. Improper distribution or utilization of steam can make the loss of system efficiency. In order to reduce the energy loss in the environment, proper steam distribution network should be set up which will increase the efficiency of the system [2]

The main components of a steam distribution system are boiler, piping, radiators, a condensate tank, steam traps and air vents. Condensate water coming out from the radiator is transferred to the condensate tank from where the condensate water is pumped into the boiler. Steam traps contain steam in the radiators until it condenses back to water. Air vents allow air out of a system to make way for incoming steam [3].

The main function of steam distribution system is to distribute the steam from the boiler to the heat exchangers, steam turbines and process vessels. Proper design of the steam distribution system ascertain the transfer of steam from one end to the other end with least possible loss of energy. After the utilization of latent heat from the steam, it condenses to liquid which is then transferred to the boiler in order to ensure minimum loss of energy [4].

One of the reason for loss of energy from the system is through the leakage of steam from the steam lines. However condensate leaks results in loss of heat as well as treated water. Ultrasonic leak detector can be used to detect any possibility of leak from the steam line. Efficiency of a system can be increased by improving the insulation, detecting and repairing steam and condensate leaks, maintaining the steam traps and condensate pumps and providing water treatment. Proper insulation of steam lines and condensate pipes is required to ensure saving of energy [5].

**Classification of steam distribution system**

Steam distribution system is classified into following two ways

(a) One pipe steam

(b) Two Pipe steam

***One pipe steam****:* In one pipe steam distribution system, steam expands, filling pipes and radiators nder its own pressure produced by the heat in the boiler. Air must leave the pipes and radiators as steam expands to allow the steam into the radiators. Air vents let air out of the pipes and radiators to make room for the expanding steam, and then close automatically using a plug mounted to a bimetal element that moves when in contact with steam. There must be enough air vents and the vents must working, for air to escape in a timely manner. Sometimes, vents are plugged with scale. Sometimes, main pipes with large volumes of air don’t have large enough air vents and must vent their air through tiny radiator vents, distant from the boiler.

With one pipe steam, gravity returns condensed water to the boiler through the same single pipe it used to rise into the radiators. The most common energy problem with one pipe steam is uneven heating caused by parts of the distributed system being air locked pressurized by air that cannot escape the system. Adding large volume of air vents to the ends of main supply pipes can make a dramatic difference in the performance and efficiency of one pipe systems. Replacing undersized or malfunctioning radiator vents allows steam to move more quickly into the radiators. Special thermostatically controlled air vents restrict the flow of air out of the radiator, and thus control the flow of steam into the radiator. These controls, called radiator temperature controls can prevent oversized radiators from emitting too much heat [3].

***Two pipe steam:***With two pipe steam distribution systems, automatic valves operated by bimetal elements called steam traps hold the steam in the radiator until it condenses into water. When the steam condenses into water, the trap opens, allowing condensate to return to the boiler through the return pipe. There should be no steam at the boiler or in the condensate tank near the boiler. If there is steam present at the boiler, then steam is flowing through the radiators without condensing and without liberating its heat – a waste of energy. The temperature of the return pipe near the trap indicates whether steam or water is flowing through the pipe. Large steam traps are located on the main return lines to stop steam. They have reservoirs for collecting condensate so that they can remain closed during most of the steam cycle expect when they dump their load of condensate. They are called float and temperature traps or inverted bucket traps. Two pipe system are often open to the atmosphere at the condensate tank to let air escape through return pipes as steam rises from the boiler. Radiator air vents will sometimes improve the heating capacity of radiators farther away from the boiler. Large vents on main pipes may be necessary to speed steam delivery to remote parts of larger two pipe steam distribution system [3].

**3.3 Steam pipe sizing and designing**

Proper pipe sizing is very critical for the good health of the steam distribution system in a plant. Design of the pipe diameter is based on the amount of pressure required at the user point. Generally if the pressure required is high, then diameter of the pipe is small and vice versa. Again reducing the diameter of the pipe will reduce the capital cost, but the heat loss from the surface will be more. Considering the large diameter of the pipe will increase the cost of installation, also at the same time there will be higher radiation losses from the larger surface area. Thus design of optimized size of the pipe is based on velocity or pressure drop. Typical velocities of steam are given in table below

|  |  |
| --- | --- |
| **Steam** | **Velocity ( m/sec)** |
| Exhaust steam | 20 - 30 |
| Saturated steam for heating | 18 - 30 |
| Saturated steam for power | 30 - 40 |
| Super heated steam | 45 - 65 |

In addition to the design of the proper pipe size, condensate drain should be there which is produced due to some heat loss to the atmosphere during the travel of steam [2].

# Size of the pipe in a steam distribution system is dependent on the two factors as follows

# The initial pressure at the boiler and the allowable pressure drop of the total system. The total pressure drop in the system should not exceed 20% of the total maximum pressure at the boiler. This includes all drops – line loss, elbows, valves etc.

# Steam velocity, erosion and noise increase with velocity.

# Fluid will flow from one end to the other end of the pipe if the energy at the inlet section (point 1) is more than that at the outlet section (point 2 The difference in energy is used to overcome frictional resistance between the pipe and the flowing fluid

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# This is illustrated by the equation

# Where

# *hf* = head loss to friction, m

# *f* = friction factor, dimensionless

# *L* = length, m

# *u*= flow velocity, m/s

# *g*= Gravitational constant

# *D*= pipe diameter, m

# It is useful to remember that

# Head loss to friction (*hf*) is proportional to the velocity square (*u2*)

# The friction factor is an experimental coefficient which is affected by factors including

# The Reynolds number

# The reciprocal of velocity

# In practice whether for water pipes or steam pipes, a balance is drawn between pipe size and pressure loss. The steam piping should be sized, based on permissible velocity and the available pressure drop in the line selecting a higher pipe size will reduce the pressure drop anf thus the energy cost. However, higher pipe size will increase the initial installation cost. By use of smaller pipe size, even though the installation cost can be reduced, the energy cost will increase due to higher pressure drop. It is to be noted that the pressure drop change will be inversely proportional to the fifth power of diameter change. Hence, care should be taken in selecting the optimum pipe size [1].

**3.4 Steam traps: Operation and maintenance, Performance assessments**

A steam trap is essentially a control valve with a simple mechanism which allows it to distinguish between steam and condensate. It is arranged so that it opens to allow condensate to be passed but closes (hence trapping) when presented with steam. Traps can be welded, flanged or screwed into the take off branch, or they can be attached to the branch by means of a ‘ universal connector’.

1. **Mechanical Traps**

Here separation of steam and condensate can be done by density. They open to condensate and close to steam by the action of float. The float, which operates the trap via a lever, may be either a ball **( ball float trap)** or a bucket **(inverted bucket trap)**

1. **Thermostatic Traps**

In this case traps open or closes by the difference in temperature between steam and cooled static condensate. The discharge valve of the trap is operated by the thermostatic element. This element can either be a balanced pressure type (bellows or capsule) or a bimetallic type. Thermostatic traps should be located at some distance from the mains to allow the condensate to cool sufficiently so that, when hot steam reaches the trap, the sensing element will close the trap and only re open on cooling of the condensate.

1. **Thermodynamic Traps**

The control of steam and condensate is by a disc in the control chamber of the thermodynamic trap. Variations in energy above the disc (largely pressure) and energy below the disc (largely kinetic)cause the disc to rise and fall. The action is an intermittent blast type discharge (thermodynamic disc trap). A diffuser can be fitted to minimize the blast effect from the traps [6].

Steam trap helps in removing the condensed steam, air and dissolved gases from the steam distribution network. Dissolved gases and air act as an insulator from being transferring heat from the fluid to the wall of the pipeline. If condensate is not removed, the steam lines becomes lines carrying water but transmitting little heat. If dissolved air is not removed, the steam carries significantly less heat since the pressure of the steam is reduced by the pressure of the air. If dissolved CO2 is not removed, carbonic acid is formed resulting in corrosive effect upon pipes. Any of these things can happen if steam traps fail closed. If steam traps fail open and they are open to the air, the effect is the same as of there were a large leak in a steam line. Thus, steam trap maintenance can be a very important source of energy cost savings [5].

**Maintenance of steam traps**

Dirt is one of the most common causes of steam traps blowing steam. Dirt and scale are normally found in all steam pipes. Bits of jointing material are also quite common. Since steam traps are connected to the lowest parts of the system, sooner or later this foreign matter finds its way to the trap. Once some of the dirt gets logged in the valve seat, it prevents the valve from shutting down tightly thus allowing steam to escape. The valve seal should therefore be quickly cleaned, to remove this obstruction and thus prevent steam loss.

In order to ensure proper working, steam traps should be kept free of pipe-scale and dirt. The best way to prevent the scale and dirt from getting into the trap is to fit a strainer. Strainer is a detachable, perforated or meshed screen enclosed in a metal body. It should be borne in mind that the strainer collects dirt in the course of time and will therefore need periodic cleaning. It is of course, much easier to clean a strainer than to overhaul a steam trap. At this point, we might mention the usefulness of a sight glass fitted just after a steam trap.

Sight glasses are useful in ascertaining the proper functioning of traps and in detecting leaking steam traps. In particular, they are of considerable advantage when a number of steam traps are discharging into a common return line. If it is suspected that one of the traps is blowing steam, it can be quickly identified by looking through the sight glass.

In most industries, maintenance of steam traps is not a routine job and is neglected unless it leads to some definite trouble in the plant. In view of their importance as steam savers and to monitor plant efficiency, the steam traps require considerably more care than is given.

One may consider a periodic maintenance schedule to repair and replace defective traps in the shortest possible time, preferable during regular maintenance shut downs in preference to break down repairs [1].

Guide to steam trap selection

Actual energy efficiency can be achieved only when

* Selection
* Installation and
* Maintenance of steam traps meet the requirements for the purpose it is installed.

The following table below gives installation of suitable traps for different process applications.

|  |  |  |
| --- | --- | --- |
| **Application** | **Feature** | **Suitable trap** |
| Steam mains | i. Open to atmosphere, small capacity, ii. Frequent change in Pressure, iii. low pressure high pressure | Thermodynamic trap |
| Equipments i. Reboiler, ii. Heater, iii. Dryer, iv. Heat exchanger etc | i. Large Capacity, ii. Variation of pressure and temperature is undesirable, iii. Efficiency of the equipment is a problem | Mechanical trap, Bucket, Inverted Bucket, Float |
| Tracer Line, Instrumentation | Reliability with no overheating | Thermodynamic and bimetallic |

**Performance assessment methods for steam traps**

Steam trap performance assessment is basically concerned with answering the following two questions:

* Is the trap working correctly or not?
* If not, has the trap failed in the open or closed position?

Traps that fail 'open' result in a loss of steam and its energy. Where condensate is not returned,

the water is lost as well. The result is significant economic loss, directly via increased boiler plant costs, and potentially indirectly, via decreased steam heating capacity. Traps that fail 'closed' do not result in energy or water losses, but can result in significantly reduced heating capacity and/or damage to steam heating equipment [1].

**Visual Testing** Visual testing includes traps with open discharge, sight glasses, sight checks, test tees and three way test valves. In every case, the flow or variation of flow is visually observed. This method works well with traps that cycle on/off, or dribble on light load. On high flow or process, due to the volume of water and flash steam, this method becomes less viable. If condensate can be diverted ahead of the trap or a secondary flow can be turned off, the load on the trap will drop to zero or a very minimal amount so the visual test will allow in determining the leakage [1].

**Sound testing:** Sound testing includes ultrasonic leak detectors, mechanics stethoscopes, screwdriver or metal rod with a human ear against it. All these use the sound created by flow to determine the trap function like the visual method. This method works best with traps that cycle on/off or dribble on light load. Traps which have modulating type discharge patterns are hard to check on high flows. (examples are processes , heat exchangers, air handling coils, etc). Again by diverting condensate flow ahead of the trap or shutting off a secondary flow as mentioned under visual testing, the noise level will drop to zero or a very low level if the trap is operating correctly. If the trap continues to flow heavily after diversion it would be leaking or blowing through [1].

**Temperature Testing:** Temperature testing includes infrared guns, surface pyrometers, temperature tapes, and temperature crayons. Typically they are used to gauge the discharge temperature on the outlet side of the trap. In the case of temperature tapes or crayon, they are set for a predetermined temperature and they indicate when temperature exceeds that level. Infrared guns and surface pyrometer can detect temperatures on both sides of the trap. Both the infrared and surface pyrometers require bare pipe and a clean surface to achieve a reasonable reading. The temperature reading will typically be lower than actual internal pipe temperature due to the fact that steel does have some heat flow resistance. Scale on the inside of the pipe can also effect the heat transfer. Some of the more expensive infrared guns can compensate for wall thickness and material differences. Blocked or turned off traps can easily be detected by infrared guns and surface pyrometers, as they will show low or cold temperatures. They could also pick up traps which may be undersized or backing up large amounts of condensate by detecting low temperature readings [1].

**3.5 Energy conservation opportunities**

**1. Monitoring Steam Traps** For testing a steam trap, there should be an isolating valve provided in the downstream of the trap and a test valve shall be provided in the trap discharge. When the test valve is opened, the following points have to be observed:

**Condensate discharge**––Inverted bucket and thermodynamic disc traps should have intermittent condensate discharge. Float and thermostatic traps should have a continuous condensate discharge. Thermostatic traps can have either continuous or intermittent discharge depending upon the load. If inverted bucket traps are used for extremely small load, it will have a continuous condensate discharge [1].

**Flash steam**–– Flash steam can be idenfied by the whitish cloud that floats out intermittently whereas if the blue steam blows out continuously it is a leaking steam [1].

**2. Continuous steam blow and no flow indicate, there is a problem in the trap**

Whenever a trap fails to operate and the reasons are not readily apparent, the discharge from the trap should be observed. A step-by-step analysis has to be carried out mainly with reference to lack of discharge from the trap, steam loss, continuous flow, sluggish heating, to find out whether it is a system problem or the mechanical problem in the steam trap [1].

**3. Avoiding Steam Leakages** Steam leakage is a visible indicator of waste and must be avoided. It has been estimated that a 3 mm diameter hole on a pipeline carrying 7 kg/cm2 steam would waste 33 KL of fuel oil per year. Steam leaks on high-pressure mains are prohibitively costlier than on low pressure mains. Any steam leakage must be quickly attended to. In fact, the plant should consider a regular surveillance programme for identifying leaks at pipelines, valves, flanges and joints. Indeed, by plugging all leakages, one may be surprised at the extent of fuel savings, which may reach up to 5% of the steam consumption in a small or medium scale industry or even higher in installations having several process departments. To avoid leaks it may be worthwhile considering replacement of the flanged joints which are rarely opened in old plants by welded joints [1].

**4. Providing Dry Steam for Process**

The best steam for industrial process heating is the dry saturated steam. Wet steam reduces total heat in the steam. Also water forms a wet film on heat transfer and overloads traps and condensate equipment. Super heated steam is not desirable for process heating because it gives up heat at a rate slower than the condensation heat transfer of saturated steam.

It must be remembered that a boiler without a superheater cannot deliver perfectly dry saturated steam. At best, it can deliver only 95% dry steam. The dryness fraction of steam depends on various factors, such as the level of water to be a part of the steam. Indeed, even as simple a thing as improper boiler water treatment can become a cause for wet steam. As steam flows through the pipelines, it undergoes progressive condensation due to the loss of heat to the colder surroundings; The extent of the condensation depends on the effectiveness of the lagging. For example, with poor lagging, the steam can become excessively wet. Since dry saturated steam is required for process equipment, due attention must be paid to the boiler operation and lagging of the pipelines.

Wet steam can reduce plant productivity and product quality, and can cause damage to most items of plant and equipment. Whilst careful drainage and trapping can remove most of the water, it will not deal with the water droplets suspended in the steam. To remove these suspended water droplets, separators are installed in steam pipelines.

The steam produced in a boiler designed to generate saturated steam is inherently wet. Although the dryness fraction will vary according to the type of boiler, most shell type steam boilers will produce steam with a dryness fraction of between 95 and 98%. The water content of the steam produced by the boiler is further increased if priming and carryover occur.

A steam separator may be installed on the steam main as well as on the branch lines to reduce wetness in steam and improve the quality of the steam going to the units. By change of direction of steam, steam seperators causes the entrained water particles to be separated out and delivered to a point where they can be drained away as condensate through a conventional steam trap [1].

**5. Utilising Steam at the Lowest Acceptable Pressure for the Process**

A study of the steam tables would indicate that the latent heat in steam reduces as the steam

pressure increases. It is only the latent heat of steam, which takes part in the heating process when applied to an indirect heating system. Thus, it is important that its value be kept as high as possible. This can only be achieved if we go in for lower steam pressures. As a guide, the steam should always be generated and distributed at the highest possible pressure, but utilized at as low a pressure as possible since it then has higher latent heat.

However, it may also be seen from the steam tables that the lower the steam pressure, the lower will be its temperature. Since temperature is the driving force for the transfer of heat at lower steam pressures, the rate of heat transfer will be slower and the processing time greater. In equipment where fixed losses are high (e.g. big drying cylinders), there may even be an increase in steam consumption at lower pressures due to increased processing time. There are, however, several equipment in certain industries where one can profitably go in for lower pressures and realize economy in steam consumption without materially affecting production time.

Therefore, there is a limit to the reduction of steam pressure. Depending on the equipment design, the lowest possible steam pressure with which the equipment can work should be selected without sacrificing either on production time or on steam consumption [1].

**6. Proper Utilization of Directly Injected Steam**

The heating of a liquid by direct injection of steam is often desirable. The equipment required is relatively simple, cheap and easy to maintain. No condensate recovery system is necessary. The heating is quick, and the sensible heat of the steam is also used up along with the latent heat, making the process thermally efficient. In processes where dilution is not a problem, heating is done by blowing steam into the liquid (i.e.) direct steam injection is applied. If the dilution of the tank contents and agitation are not acceptable in the process (i.e.)direct steam agitation are not acceptable, indirect steam heating is the only answer.

Ideally, the injected steam should be condensed completely as the bubbles rise through the liquid. This is possible only if the inlet steam pressures are kept very low-around 0.5 kg/cm2 and certainly not exceeding 1kg/cm2. If pressures are high, the velocity of the steam bubbles will also be high and they will not get sufficient time to condense before they reach the surface [1].

**7. Minimising Heat Transfer Barriers**

The metal wall may not be the only barrier in a heat transfer process. There is likely to be a film

of air, condensate and scale on the steam side. On the product side there may also be baked-on product or scale, and a stagnant film of product. Agitation of the product may eliminate the effect of the stagnant film, whilst regular cleaning on the product side should reduce the scale. Regular cleaning of the surface on the steam side may also increase the rate of heat transfer by reducing the thickness of any layer of scale, however, this may not always be possible. This layer may also be reduced by careful attention to the correct operation of the boiler, and the removal of water droplets carrying impurities from the boiler [1].

**Filmwise Condensation**

The elimination of the condensate film, is not quite as simple. As the steam condenses to give up its enthalpy of evaporation, droplets of water may form on the heat transfer surface. These may then merge together to form a continuous film of condensate. The condensate film may be between 100 and 150 times more resistant to heat transfer than a steel heating surface, and 500 to 600 times more resistant than copper [1].

**Dropwise Condensation**

If the droplets of water on the heat transfer surface do not merge immediately and no continuous condensate film is formed, 'dropwise' condensation occurs. The heat transfer rates which can be achieved during dropwise condensation, are generally much higher than those achieved during filmwise condensation.

As a larger proportion of the heat transfer surface is exposed during dropwise condensation, heat transfer coefficients may be up to ten times greater than those for filmwise condensation. In the design of heat exchangers where dropwise condensation is promoted, the thermal resistance it produces is often negligible in comparison to other heat transfer barriers. However, maintaining the appropriate conditions for dropwise condensation have proved to be very difficult to achieve.

If the surface is coated with a substance that inhibits wetting, it may be possible to maintain dropwise condensation for a period of time. For this purpose, a range of surface coatings such as Silicones, an assortment of waxes and fatty acids are sometimes applied to surfaces in a heat exchanger on which condensation is to be promoted. However, these coatings will gradually lose their effectiveness due to processes such as oxidation or fouling, and film condensation will eventually predominate.

As air is such a good insulator, it provides even more resistance to heat transfer. Air may be between 1500 and 3000 times more resistant to heat flow than steel, and 8000 to 16000 more resistant than copper. This means that a film of air only 0.025 mm thick may resist as much heat transfer as a wall of copper 400 mm thick. Of course all of these comparative relationships depend on the temperature profiles across each layer.

The more resistant the layer to heat flow, the larger the temperature gradient is likely to be. This means that to achieve the same desired product temperature, the steam pressure may need to be significantly higher.

The presence of air and water films on the heat transfer surfaces of either process or space heating applications is not unusual. It occurs in all steam heated process units to some degree.

To achieve the desired product output and minimise the cost of process steam operations, a high heating performance may be maintained by reducing the thickness of the films on the condensing surface. In practice, air will usually have the most significant effect on heat transfer efficiency, and its removal from the supply steam will increase heating performance [1].

**8. Proper Air Venting**

When steam is first admitted to a pipe after a period of shutdown, the pipe is full of air. Further

amounts of air and other non-condensable gases will enter with the steam, although the proportions of these gases are normally very small compared with the steam. When the steam condenses, these gases will accumulate in pipes and heat exchangers. Precautions should be taken to discharge them. The consequence of not removing air is a lengthy warming up period, and a reduction in plant efficiency and process performance.

Air in a steam system will also affect the system temperature. Air will exert its own pressure within the system, and will be added to the pressure of the steam to give a total pressure. Therefore, the actual steam pressure and temperature of the steam/air mixture will be lower than that suggested by a pressure gauge.

Of more importance is the effect air has upon heat transfer. A layer of air only 1 mm thick can offer the same resistance to heat as a layer of water 25 µm thick, a layer of iron 2 mm thick or a layer of copper 15 mm thick. It is very important therefore to remove air from any steam system.

Automatic air vents for steam systems (which operate on the same principle as thermostatic steam traps) should be fitted above the condensate level so that only air or steam/air mixtures can reach them. The best location for them is at the end of the steam mains. The discharge from an air vent must be piped to a safe place. In practice, a condensate line falling towards a vented receiver can accept the discharge from an air vent [1].

In addition to air venting at the end of a main, air vents should also be fitted:

* In parallel with an inverted bucket trap or, in some instances, a thermodynamic trap. These traps are sometimes slow to vent air on start-up.

* In awkward steam spaces (such as at the opposite side to where steam enters a jacketed pan).
* Where there is a large steam space (such as an autoclave), and a steam/air mixture could affect the process quality [1].

**9. Condensate Recovery**

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 below 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 the boiler [1].

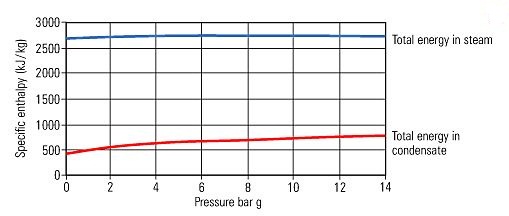


Fig: **Heat Content of Steam and Condensate at the Same Pressure**

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**10. Insulation of Steam Pipelines and Hot Process Equipments**

Heat can be lost due to radiation from steam pipes. The remedy is to provide easily detachable insulation covers, which can be easily removed when necessary. The various insulating materials used are cork, Glass wool, Rock wool and Asbestos [1].

**11. Flash Steam Recovery**

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 [1].

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

Flash steam available % =

where

S1 is the sensible heat of higher pressure condensate.

S2 is the sensible heat of the steam at lower pressure (at which it has been flashed).

L2 is the latent heat of flash steam (at lower pressure).

**12. Reducing the Work to be done by Steam**

The equipments should be supplied with steam as dry as possible. The plant should be made efficient. For example, if any product is to be dried such as in a laundry, a press could be used to squeeze as much water as possible before being heated up in a dryer using steam.

Therefore, to take care of the above factors, automatic draining is essential and can be achieved by steam traps. The trap must drain condensate, to avoid water hammer, thermal shock and reduction in heat transfer area. The trap should also evacuate air and other non-condensable gases, as they reduce the heat transfer efficiency and also corrode the equipment. Thus, a steam trap is an automatic valve that permits passage of condensate, air and other non-condensable gases from steam mains and steam using equipment, while preventing the loss of steam in the distribution system or equipment.

The energy saving is affected by following measures:

* Reduction in operating hours
* Reduction in steam quantity required per hour
* Use of more efficient technology
* Minimizing wastage.

When the steam reaches the place where its heat is required, it must be ensured that the steam

has no more work to do than is absolutely necessary. Air-heater batteries, for example, which provide hot air for drying, will use the same amount of steam whether the plant is fully or partly loaded. So, if the plant is running only at 50 percent load, it is wasting twice as much steam (or twice as much fuel) than necessary.

Always use the most economical way to removing the bulk of water from the wet material. Steam can then be used to complete the process. For this reason, hydro-extractors, spin dryers, squeeze or calendar rolls, presses, etc. are initially used in many drying processes to remove the mass of water. The efficiency with which this operation is carried out is most important. For example, in a laundry for finishing sheets (100 kg/hr. dry weight), the normal moisture content of the sheets as they leave the hydroextractor, is 48% by weight.

Thus, the steam heated iron has to evaporate nearly 48 kg of water. This requires 62 kg of steam. If, due to inefficient drying in the hydro-extractor, the steam arrive at the iron with 52% moisture content i.e. 52 kg of water has to be evaporated, requiring about 67 kg of steam. So, for the same quantity of finished product, the steam consumption increases by 8 per cent [1].

*Questions:*

1. *Name two functions of a steam trap?*
2. *On what factors steam pipe diameter depends?*
3. *What are the different types of traps?*
4. *How to maintain the steam traps?*
5. *What are the different ways to save energy in steam distribution system?*
6. *Give the performance assessment test for steam traps?*
7. *What are the ways by which steam distribution system is classified?*

***References***

1. *Bureau of Energy efficiency*, [www.bee-india.nic.in](http://www.bee-india.nic.in), accessed on 24th June, 2012.
2. Abbi, Y.P., Jain S.; *Handbook on Energy Audit and Environment Management,* Rajkamal Electric Press, New Delhi, 2006.
3. Krigger, J., Dorsi, C.; *Residential Energy: Cost Savings and Comfort for Existing Building.*
4. Seneviratne, M.; *A Practical Approach to Water Conservation for Commercial And Industrial Facilities,* Elsevier Ltd*,*2007
5. Diwan, P., Yaqoot.M.; *Energy Management, Pentagon Press*, New Delhi, 2010
6. Broughton, J.; *Process Utility Systems: Introduction to Design, Operation and Maintenance, Institute of Chemical Engineers*, 1994