Chemical Process Utilities
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Lecture No # 53
Refrigeration System Components

Welcome to the refrigeration system components lecture under the aegis of chemical process utilities as you recall that we were discussing about the different concepts of refrigeration and refrigeration as you know that it is an integral part of chemical process utilities. So in the previous lecture, we discussed about the concept of refrigeration. We discussed about the refrigeration systems and cycle, we had a discussion about the refrigerator system components including compressors.

We discussed about the compression ratio, compression efficiency and the various factors those who are affecting the compressor efficiency apart from this we discussed about the compressor capacity control. Number of ways through which you can control the compressor capacity then we had a brief discussion about the condensers especially air cooled condenser water cooled condenser and evaporative type of condensers. And we discussed about the utilization and what is the importance of the condenser in the refrigeration system?

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Now in this particular lecture we are going to discuss about the cooling tower. We will discuss about the different evaporators like liquid coolers air cooler or gas cooler, throttling device has

the thermal expansion valve, constant pressure expansion valve, float valve. We will discuss about the capillary tubes apart from this different auxiliary devices.

They are also the the integral part of refrigeration system this including the accumulators, receivers, oil separator, strainers, solenoid valves dryers, check valve, defrosters or defrost controllers and then we will discuss about the vapour compression refrigeration system.

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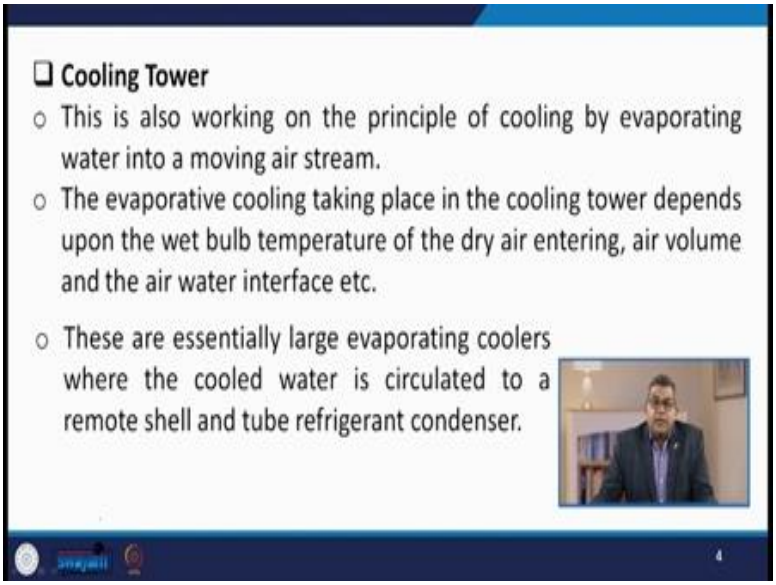

So let us talk about the cooling tower, although in a separate lecture we had deliberated or you can say the exhaustive discussion about the cooling towers but again in the refrigeration system, they are also integral part. So this is also working on principle of cooling by evaporating water into a moving air system. Now, this evaporative cooling it takes place in the cooling tower. It depends on the wet bulb temperature of the dry air entering air volume and the air water interface.

And if you go through the cooling tower concept you will understand that. What is the wet bulb temperature? And what is the concept of the air water interface. Now. These are the essentially large evaporating coolers where the the chilled water is circulated to a remote shell and tube refrigerant condenser.

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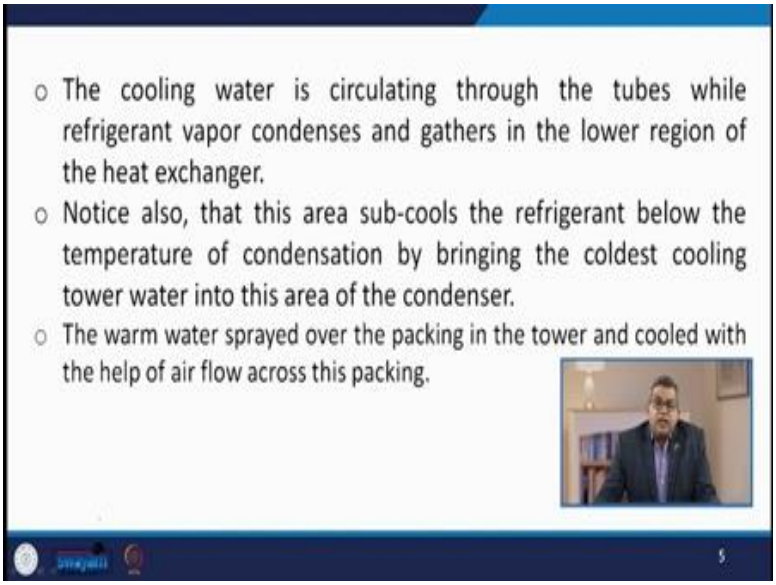

The cooling water is circulating through the tubes while refrigerant vapour condenses and gathers in the lower region of the heat exchanger. Now, this Particular area sub cools the refrigerant below the temperature of the condensation by bringing the coldest cooling tower water into this area of the condenser. Now the warm water is spread over the packing in the tower and cooled with the help of air flow across this particular packing.

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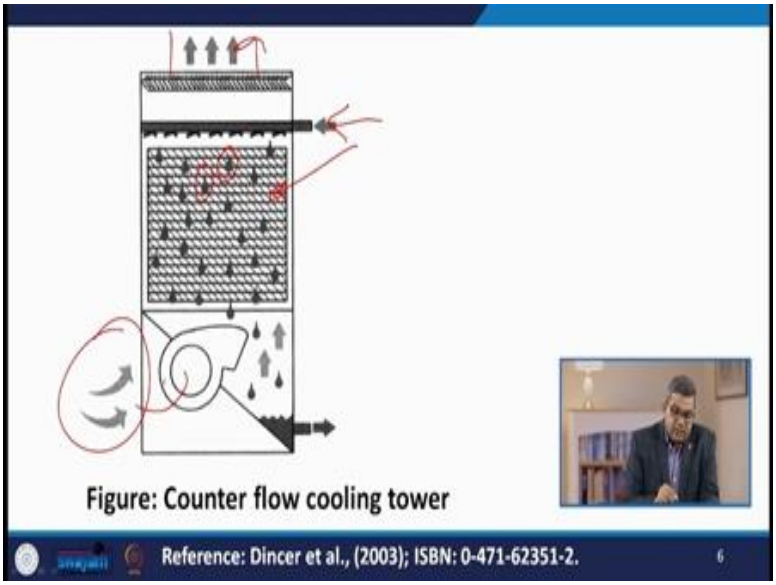

Here you see here the air is circulating through this one and this is the packing, the mesh size you can see and these are the droplets and here the water is circulated and this is the exhaust air outlet.

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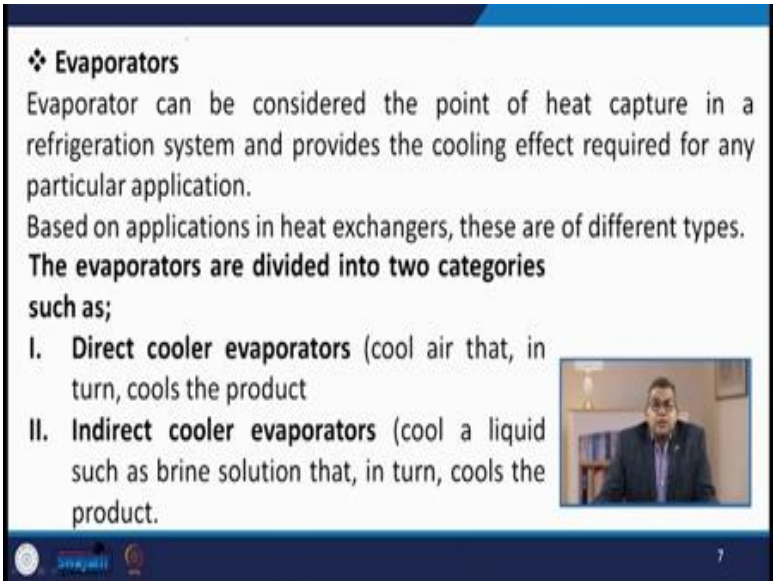

Now let us talk about the evaporators. Now evaporator, this can be considered the point of heat capture in refrigeration system and provide the cooling effect required for any particular application. Now based on applications in heat exchanger there are different types of evaporators. So the evaporator when we are talking about a different type of evaporators then again there may be a need of a classification or categories so the evaporators they are basically divided into 2 categories.

One is the direct cooler evaporators, the cool air that in turn cools the product and and indirect cooler evaporators cooler liquid such as brine solution that in turns cools the product.

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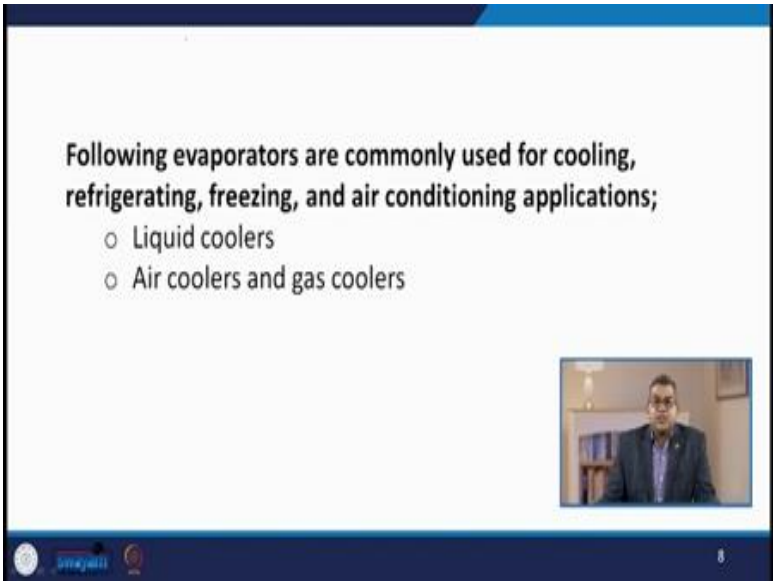

Now they there are various evaporators. They are commonly used for the cooling refrigerating, freezing and air conditioning applications like liquid coolers air cooler and gas coolers etc.

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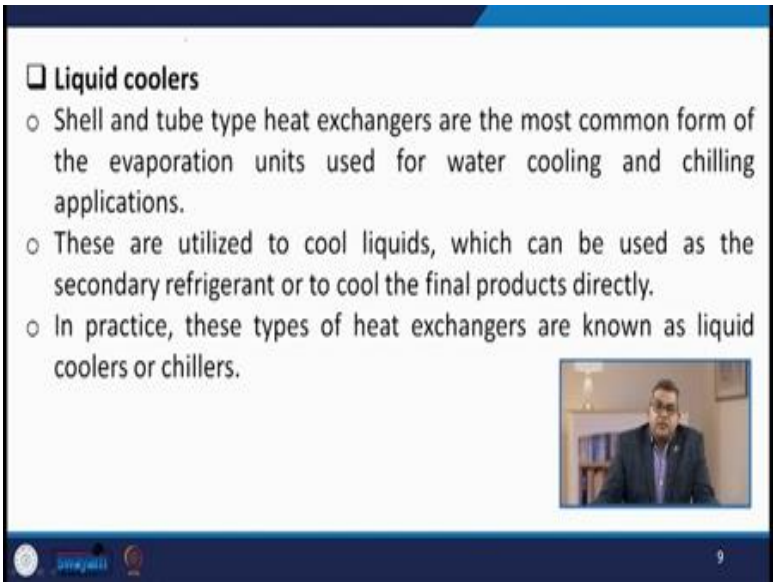

So let us talk about the liquid coolers. Now shell and tube type of heat exchangers. They are the most common form of evaporation units used for water cooling and chilling applications. Now, these are utilized to cool liquids which can be used as the secondary refrigerant or to cool the final product directly. So in practice, these types of heat exchangers they are known as liquid cooler or chillers.

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Now, there are some applications in food and refrigeration industries like chilling drinkable water, chilling milk after pasteurization. It can be used for refrigeration system in the process cooling operation then water for the air conditioning coils.

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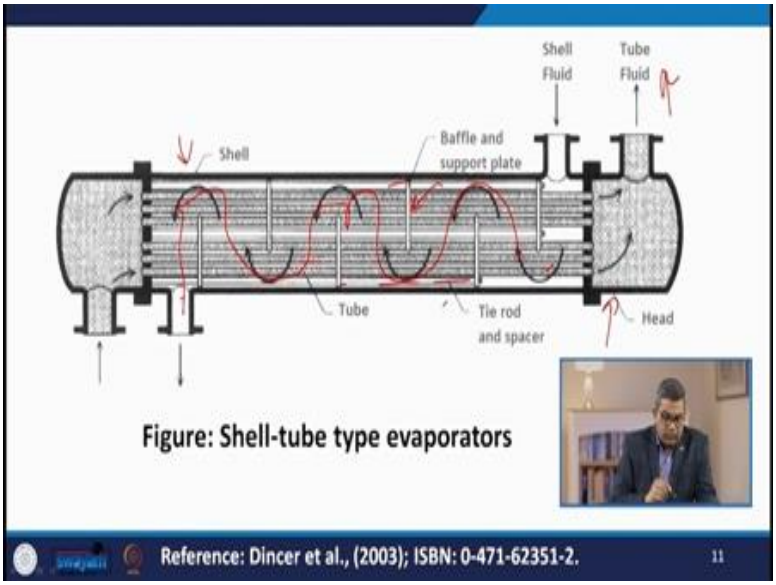

Now here you see that this is the typical photograph or figure of shell and tube, type of evaporators. Now, this is the shell and this is duly supported by baffles and support plates. And here, you see that this is the tube side fluid and head and these baffles are supported with the tie rods and this is the tube. So the shell side tube and you can see the circulating path of the fluid in this arena.

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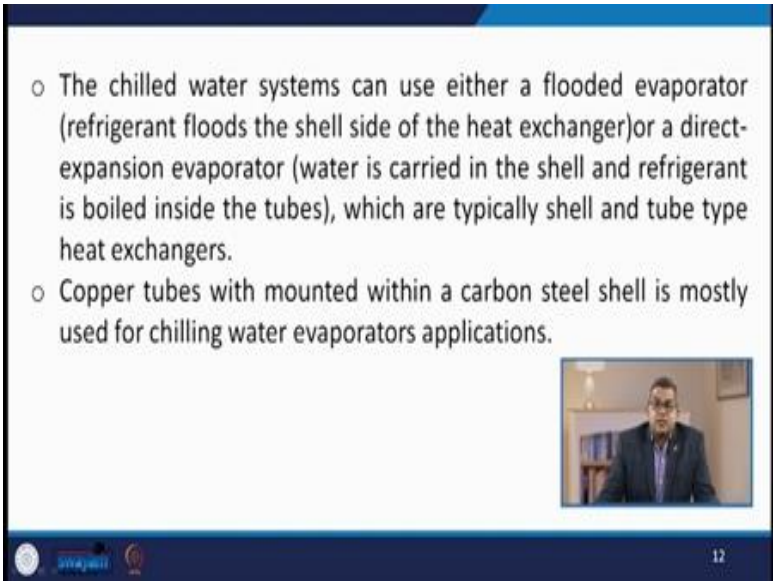

Now the chilled water system this can use either a flooded evaporator that is the refrigerant flooded with the shell site of the heat exchanger or the direct expansion evaporator. Now water is carried in the shell and refrigerant is boiled inside the tube, which are typically; shell and tube type of heat exchanger. Now copper tubes are usually mounted with a carbon steel shell. This is the mostly used for the chilling water evaporating applications.

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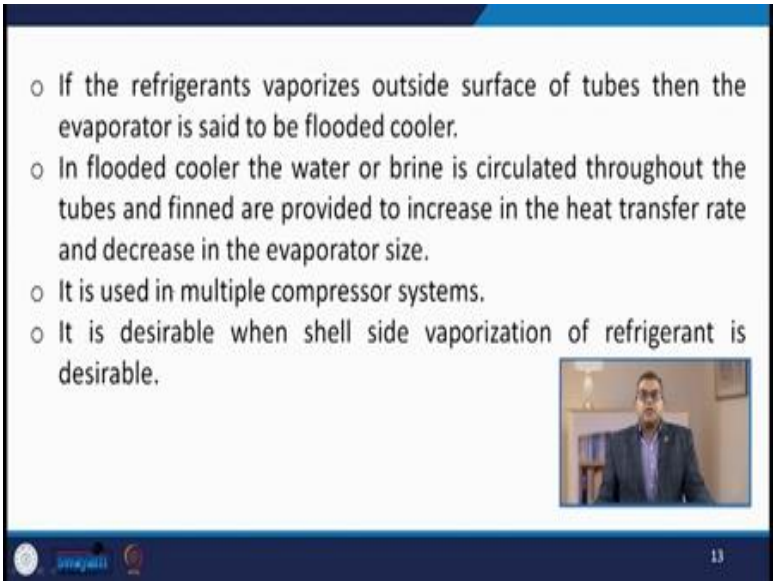

Now if the refrigerant vaporizes outside the surface of the tube, then the evaporator; is said to be called a flooded type of cooler now in flooded cooler the water or brine is circulated throughout the tubes and fins are provided to increase the heat transfer rate and decrease the evaporator size. Now, it is used in multiple compressor type of system. Now it is desirable when shell side, vaporization of refrigerant is desirable.

Now if the vaporized inside the tube it is called the cooler. Now in dry cooler the refrigerant; are flowing through the tubes and the water or brine is circulated through the shell side. Now let us talk about the air and gas coolers.

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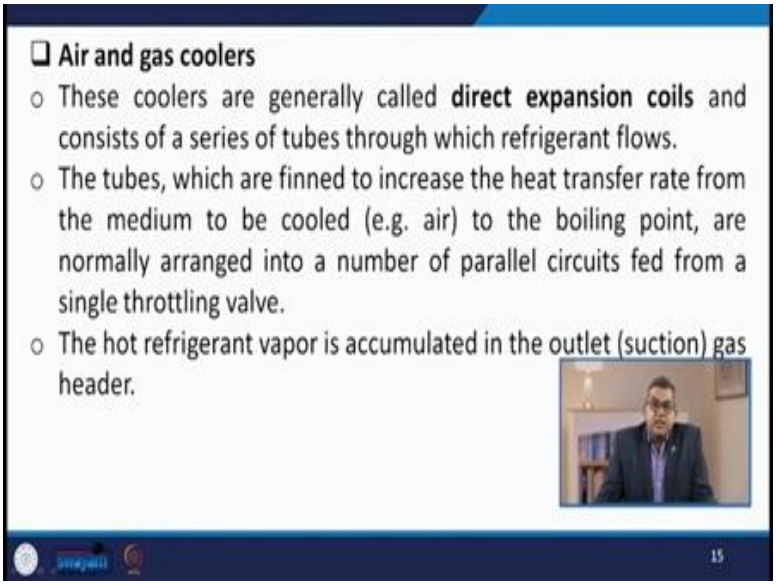

Now these coolers are generally called the the direct expansion coils and consists of a series of tubes through which refrigerant flows. The tubes which have finned to increase the heat transfer

rate from the medium to be cooled that is sometimes referred as air to the boiling point. And they are normally arranged into a number of parallel circuits fed from a single throttling valve. The hot refrigerant vapor is accumulated in the outlet suction gas header.

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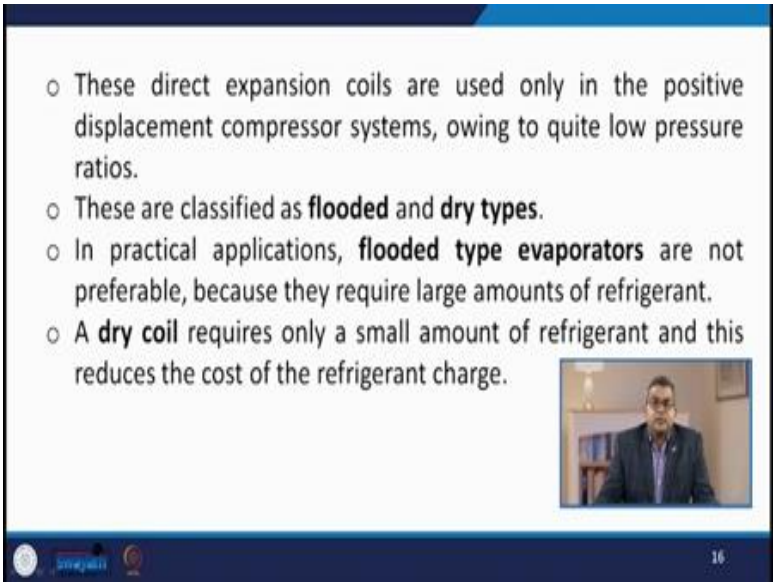

Now these direct expansion coils are sometimes used only in the positive displacement compressor type of a system owing a quite low pressure ratio. Now these are classified as the flooded and dry type in practical applications flooded type evaporators are not preferable because they required large amount of refrigerant. A dry coil requires only a small amount of refrigerant and this reduces the cost of refrigerant charges.

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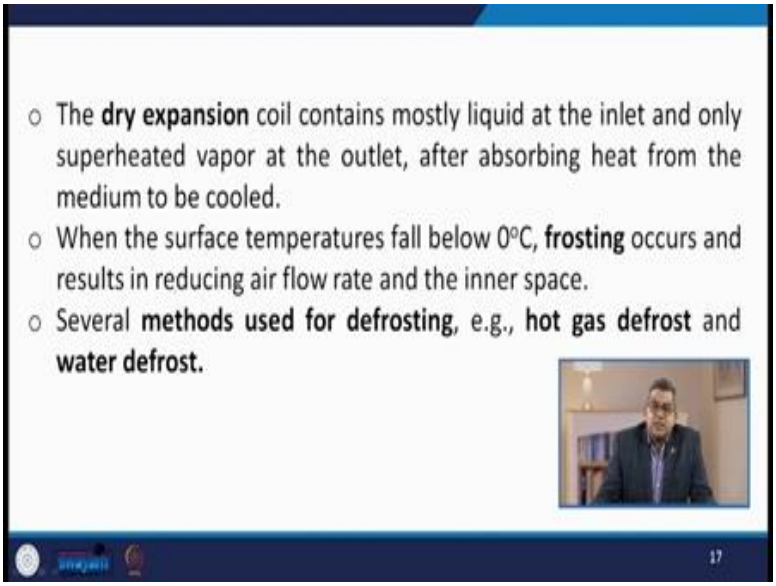

The dry expansion coil sometimes they contain mostly liquid in the inlet and only superheated vapour at the outlet and after absorbing heat from the medium to be cooled. When the surface

temperature fall below 0 degree Celsius frosting occurs and the results in reducing air flow rate and in the inner space. Now several methods being used for defrosting like hot gas defrosters and water defrost.

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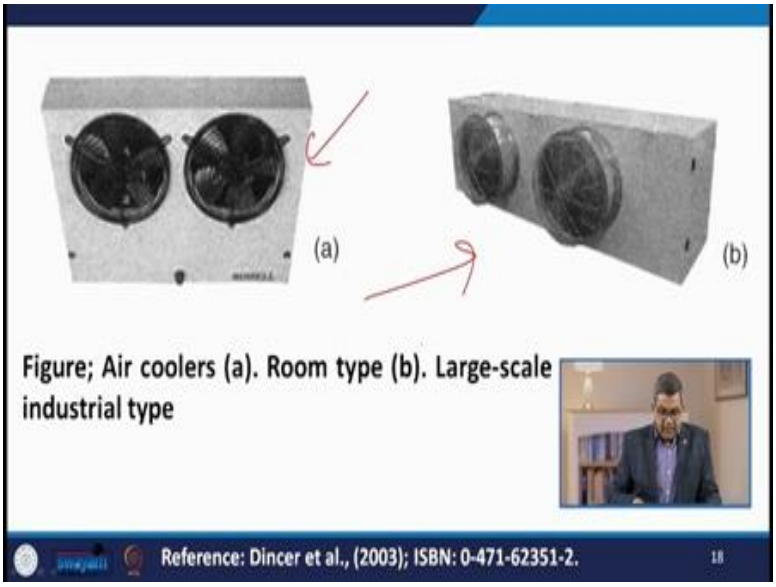

Now here you see that these are the air coolers. These are the room type of air coolers and this is the large scale, industrial type of coolers.

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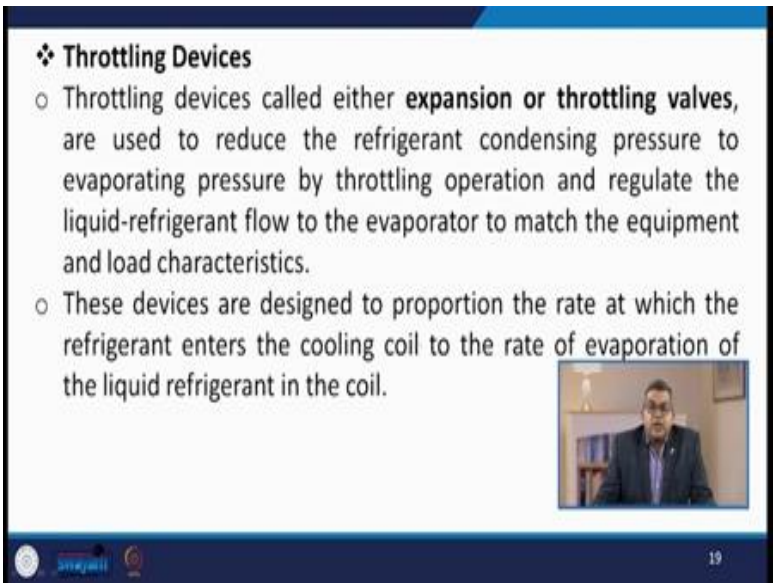

Now let us talk about the throttling device. Now the throttling device, they are the integral part of any refrigeration system and they are called either expansion or throttling valve. Basically, they are used to reduce the refrigerant condensing pressure to evaporating pressure by throttling operation and regulate the liquid refrigerant flow to the evaporator to match the equipment and load characteristics.

Now these devices are designed to proportion the rate at which the refrigerant enters the cooling coil to the rate of evaporation of the liquid refrigerant in the coil.

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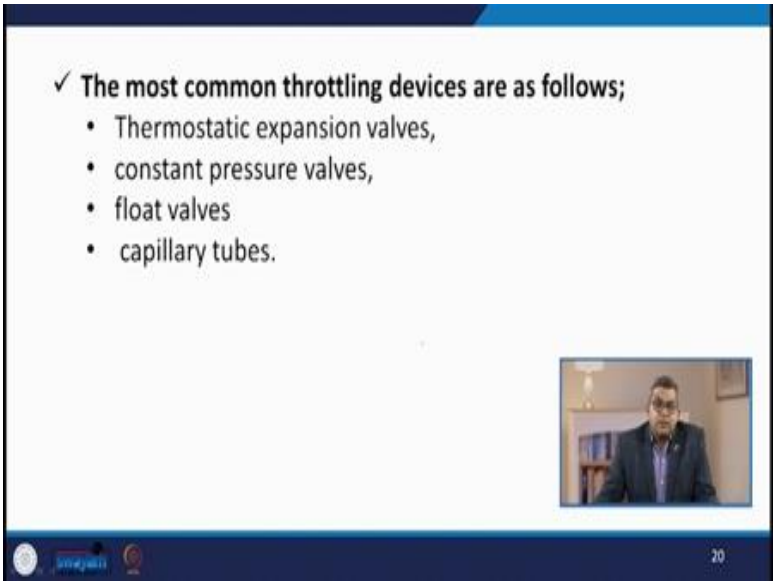

There are various kinds of throttling devices. The most common throttling devices are the thermostatic expansion valves the constant pressure valves, float valves and the capillary tubes.

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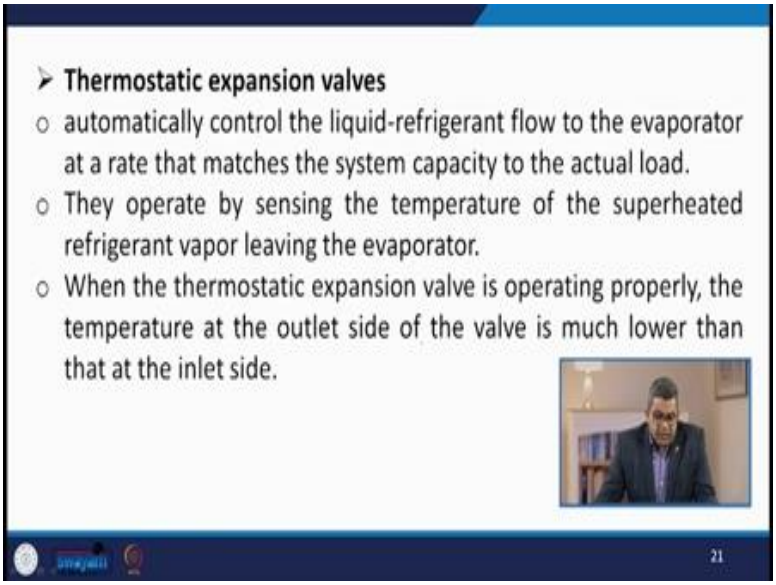

Now let us talk about the thermostatic expansion valves. Now they are basically automatic type so automatically control the liquid refrigerant flow to the evaporator at a rate that matches the system capacity to the actual load. Now they operate by sensing the temperature of superheated refrigerant vapor leaving the evaporator. Now when the thermostatic expansion valve is

operating properly the temperature at the outlet side of the valve is much lower than that at the inlet side.

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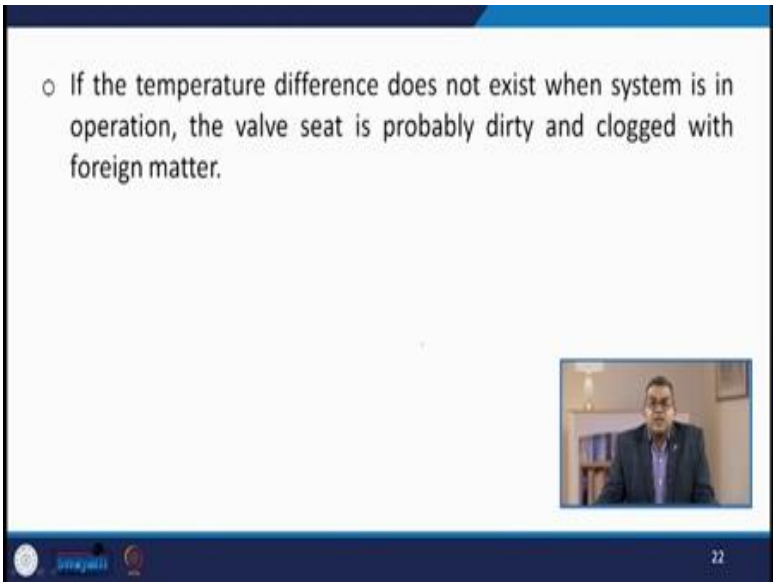

Now, if temperature difference does not exist, when the system is in operation the valve seat is probably dirty and clogged with foreign matter.

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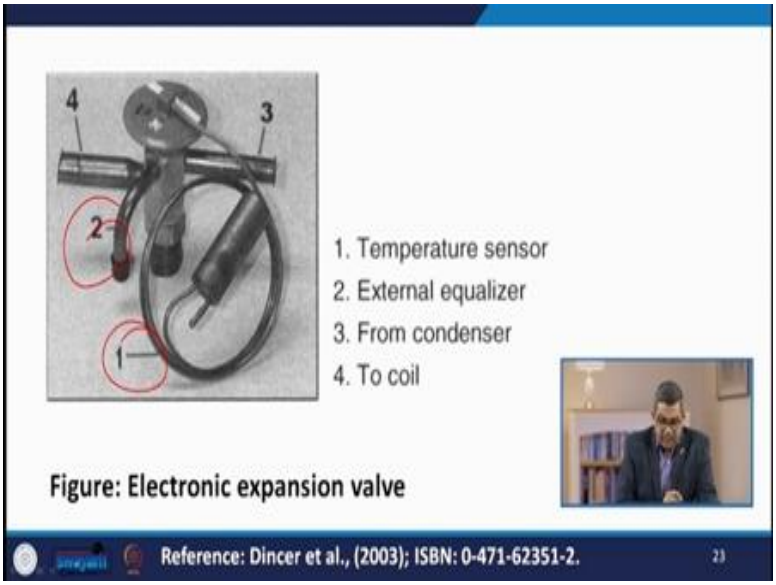

Now here you see that this is the electronic expansion valve. Now here this is the temperature sensor and this is the external equalizer. This is the inlet line from the condenser and this particular line goes to the coil.

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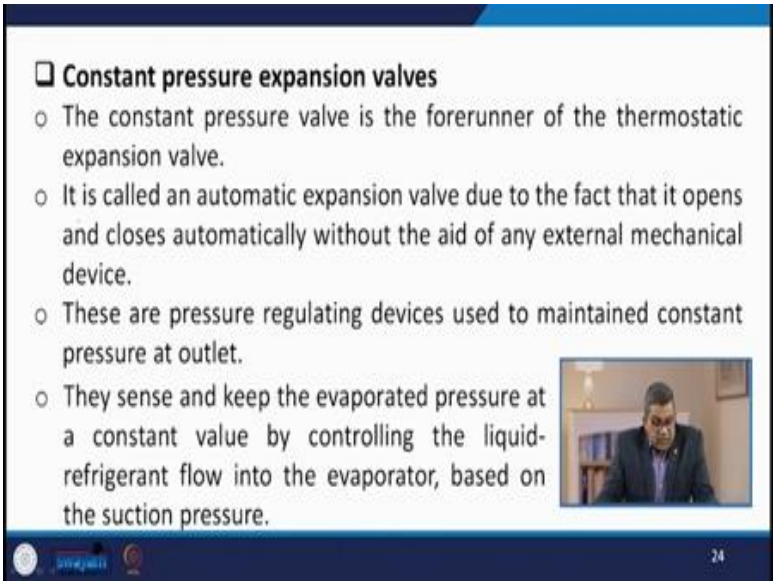

Now the let us talk about the constant pressure expansion valve the constant pressure valve is the Forerunner of the thermostatic expansion valve. And sometimes it is called an automatic expansion valve due to the fact that it opens and closes automatically without the aid of any kind of external mechanical device. Now, these are pressure regulating devices used to maintain the constant pressure at outlet.

They senses that and keep the evaporated pressure at a constant value by controlling the liquid refrigerant flow into the evaporator and that is based on the suction pressure.

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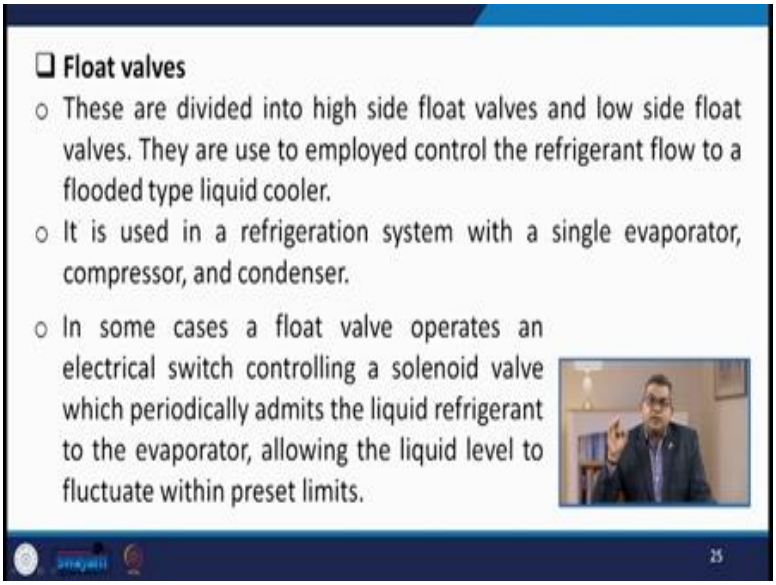

Let us talk about the float valves. Now these are divided into high side float valves and low side float valves. They are used to employ the control over the refrigerant flow to a flooded type of liquid cooler. Now, it is used in refrigeration system with a single evaporator

compressor and condenser. In some cases a float valve operates an electrical switch controlling to a solenoid valve which periodically admits the liquid refrigerant to the evaporator and allowing the liquid level to fluctuate within the preset limit.

Capillary tubes, the capillary tube is the simplest type of refrigerant flow control device used in place of an expansion valve. Now the capillary tubes are small diameter tubes through which the refrigerant flows into the evaporator.

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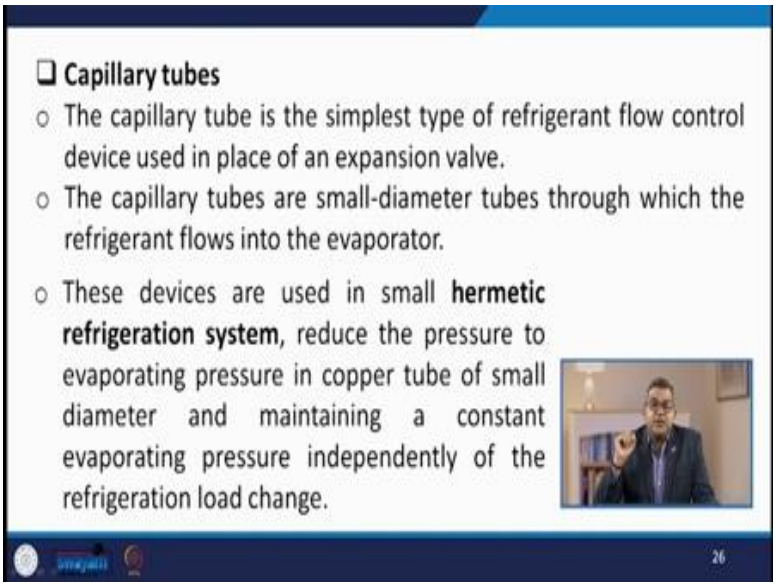

Now these devices are used in small hermetic refrigeration system reduce the pressure to evaporating pressure in copper tube of small diameter and maintaining a constant evaporating pressure independently of the refrigeration load change.

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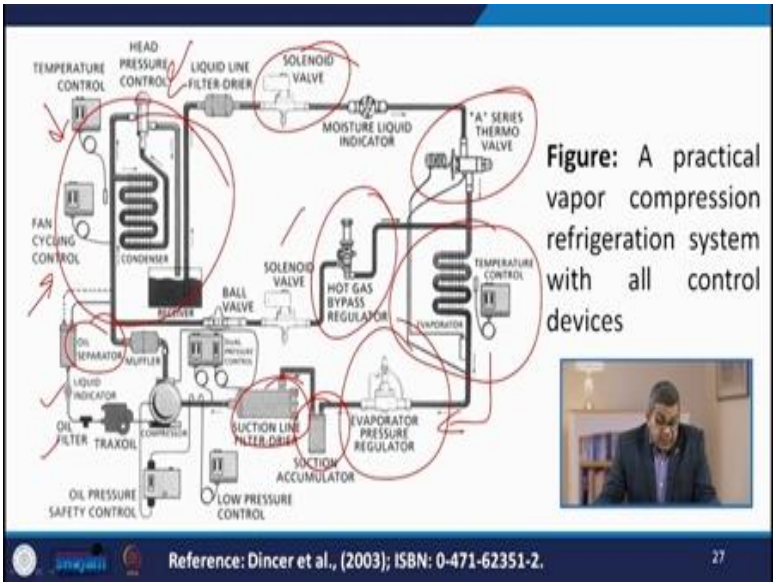

Figure: A practical vapor compression refrigeration system with all control devices

Now, here you see this is the practical vapor compression refrigeration system with all kind of control device and you see that how mammoth it is the task. Here you are having this evaporator with the equipped with the temperature control device and usually when we are talking about the evaporator it should be a series of thermo valves with the hot gas bypass regulator.

And here you are maintaining the evaporator pressure and the flow line is just like this and suction accumulator suction line filter dryer etc. And here you see the major component that is called the condenser which is here and this is attached with the solenoid valve and all kind of devices like fan cycling, cool control temperature, control head, pressure control, all these things they are connected with the condenser.

Apart from this or other allied accessories, like muffler oil separator liquid indicator of oil filter all these things are attached to this vapor compression refrigeration system. So you see that the purpose of this particular figure is to introduce that how complex this particular system is. And we need to have a very precise control and we need to have a proper instrumentation while handling, this vapor compression refrigeration system. So if you see this particular figure, we have used various kinds of auxiliary devices.

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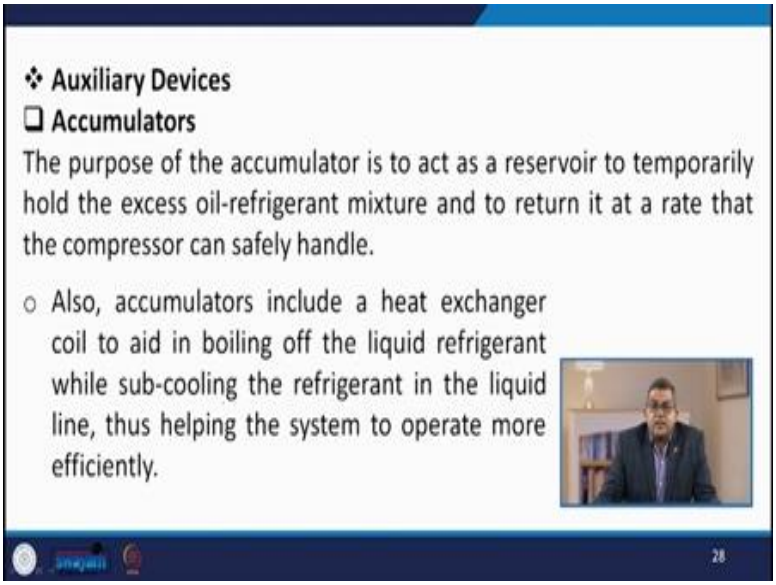

So when we talk about the auxiliary devices, then there are various auxiliary devices like accumulators. Then we are having the different type of valves temperature control etc. Now let us talk about the accumulator. Now the purpose of accumulator is to act as a reservoir to temporarily hold the excess of oil refrigerant mixture and to return it at a rate that the compressor can safely handle.

Also accumulator include a heat exchanger coil to add in the boiling of the liquid refrigerant while sub cooling the refrigerant in the liquid line. Therefore it helps the system to operate more efficiently.

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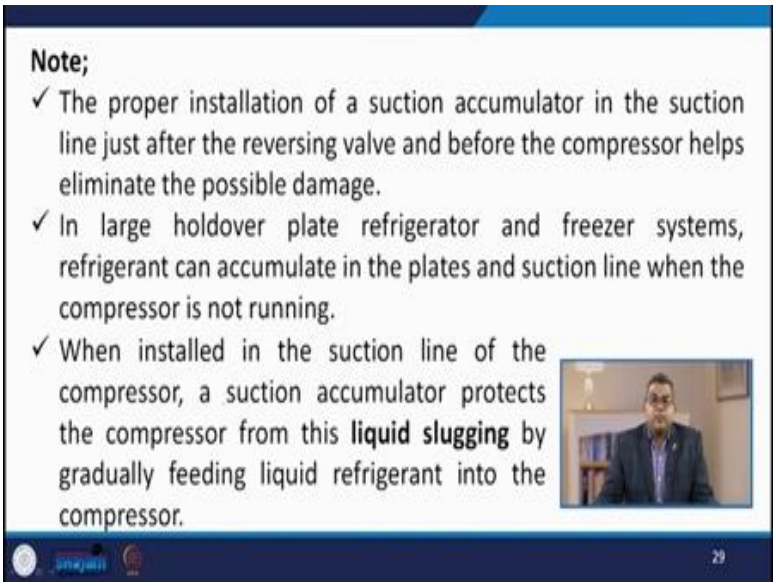

Now the proper installation of a suction accumulator in the suction line just after the reversing valve and before the compressor it helps to eliminate any kind of possible damage in large hold over the plate refrigerator and freezer system. The refrigerant can accumulate in plates and suction line when the compressor is not running. So when installed in the suction line of the compressor suction accumulator protects the compressor from this particular liquid slugging by gradually feeding liquid refrigerant into the compressor.

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Now here you see this is the typical photograph of an accumulator. This accumulator should be selected according to the tonnage of refrigeration system, according to the evaporator temperature and according to the holding capacity.

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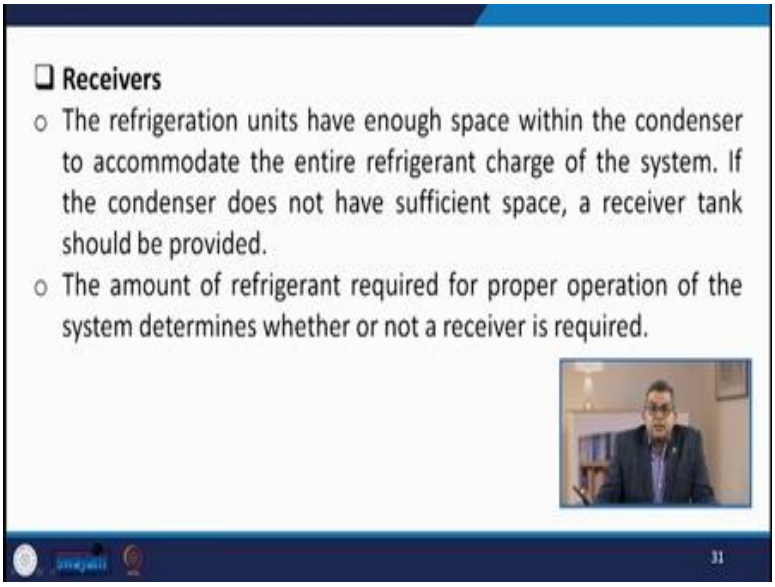

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Now next is the receiver the refrigeration units that have enough space within the condenser to accommodate the entire refrigerant charge of the system. Now if the condenser does not have sufficient space a receiver a tank should be provided. The amount of refrigerant required for proper operation of the system this determines whether or not a receiver is required or required or not required.

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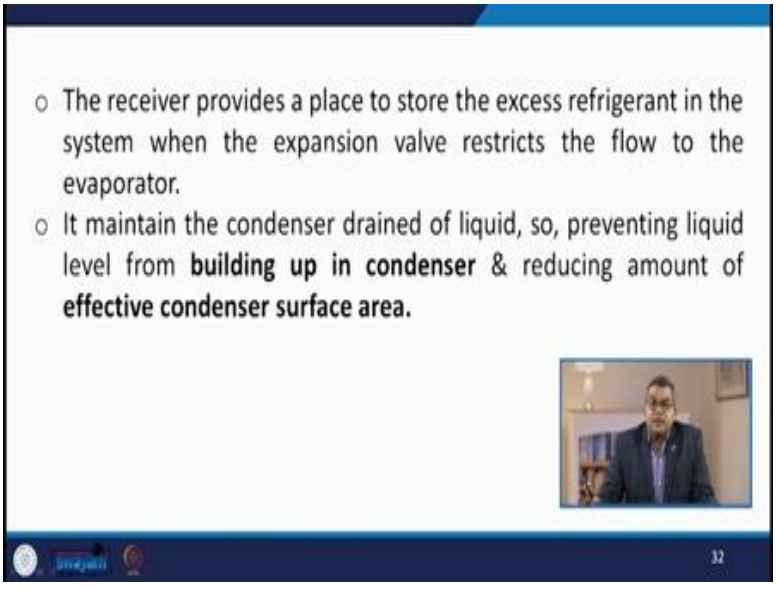

Now this the receiver they provide a place to store the excess refrigerant in the system when the expansion valve restricts the flow to the evaporator it usually maintain the condenser

drained of liquid. So preventing liquid level from building up in condenser and reducing amount of effective condenser surface area.

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Now here you see that the typical photograph of receiver. This is the horizontal type of receiver and this is the vertical type of receiving both are having their own speciality and due to the design consideration one can use the appropriate type of receiver based on the requirement.

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Then there are certain oil separators and they are used to remove oil in due course of time because during the circulation refrigerant may accumulate some some sort of traces of oil and these oil needs to be separated from the main refrigerant to make the system more and more efficient. So this these oil separators they provide the oil separation and limit oil carry over to approximately 0.0003 to 0.001% of total amount of refrigerant.

And depending on system characteristics, like operating condition refrigerant start or stop or load or unload frequency etc. Now these separators are normally used for large variety of refrigerants the like ammonia R 134a or propane. So all the separators they require the mounting of an external float assembly to control return from the separator to the compressor strainers.

Over the period of time of a circulation of the refrigerant in the piping system these refrigerant may have certain type of dirt, dust, debris this may be because of the metal chip removal because of the corrosion and may be because of the some problems in the internal lining etc. So the basic purpose of a strainer is to remove the foreign matter like dirt metal chips from the refrigerant line.

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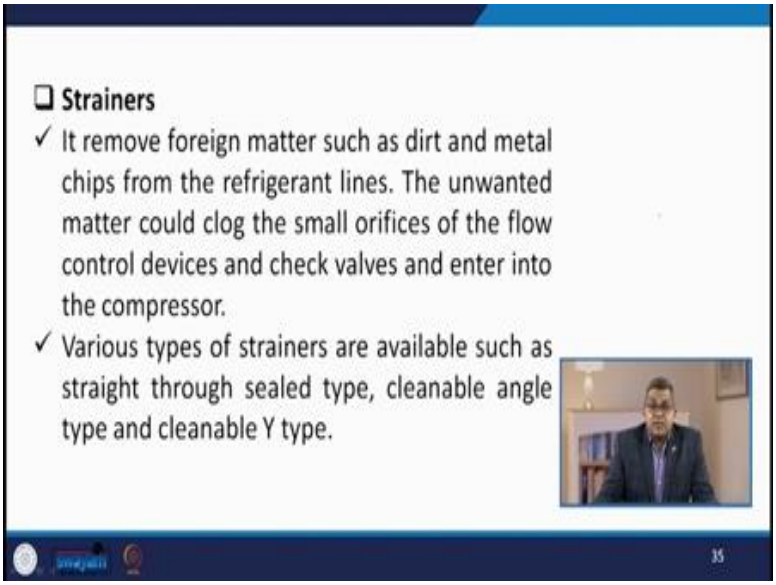

The unwanted matter they can clog the small orifice of the flow control device even the throttling device and check valves and enter into the compressor. Now the various types of strainers available as on date such as state through seal type, cleanable angle type and cleanable y type. Next is the dryer in refrigeration system moisture is the single most detrimental factor in the refrigeration system.

So the refrigeration systems they are equipped with dryers. And there are various factors those who are influencing in the selection of the correct size of dryer. One is that the type and amount of refrigerant.

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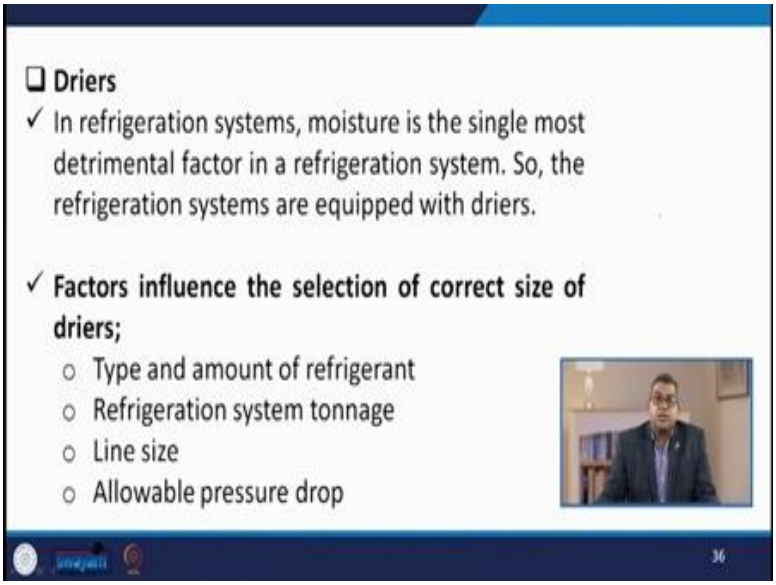

Basically we are dealing with the quantity and the quality then refrigeration, system with respect to the tonnage then the line size and allowable pressure drop.

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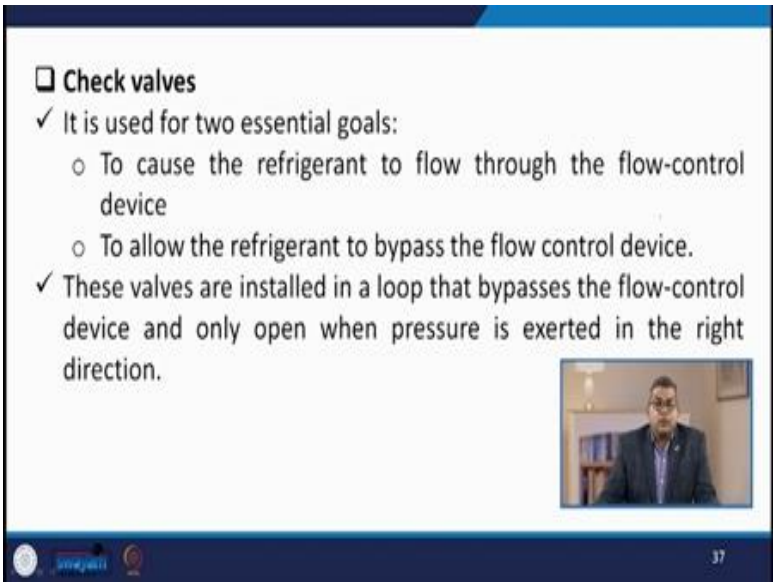

Next is a check valve now it is used for 2 basic essential goals. One is to cause the refrigerant to flow through the flow control device and second is to allow the refrigerant to bypass the flow control device. Now these valves are installed in a loop that bypasses the flow control device and only upon when pressure is exerted in the right direction.

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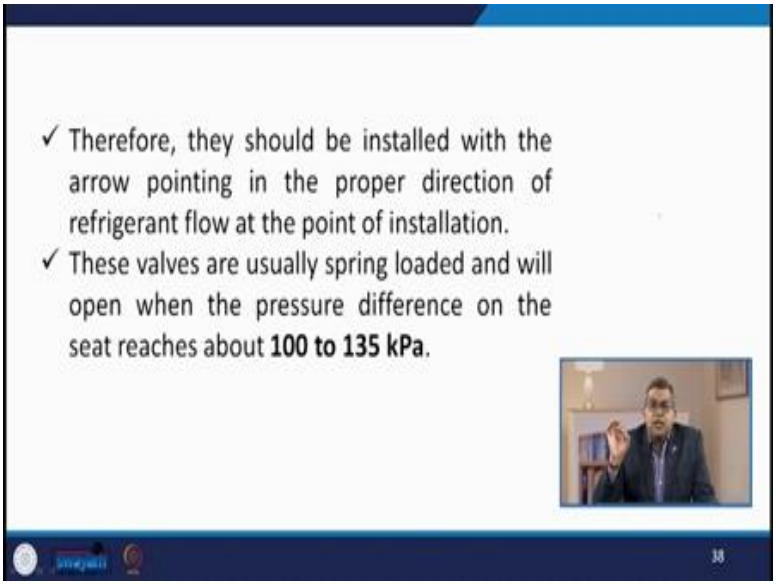

So therefore they should be installed with the arrow pointing in the proper direction of the refrigerant room, at the point of installation. Now, these valves are usually spring loaded and opens when the pressure difference on the seat reaches around about 100 to say 135 kilo Pascal.

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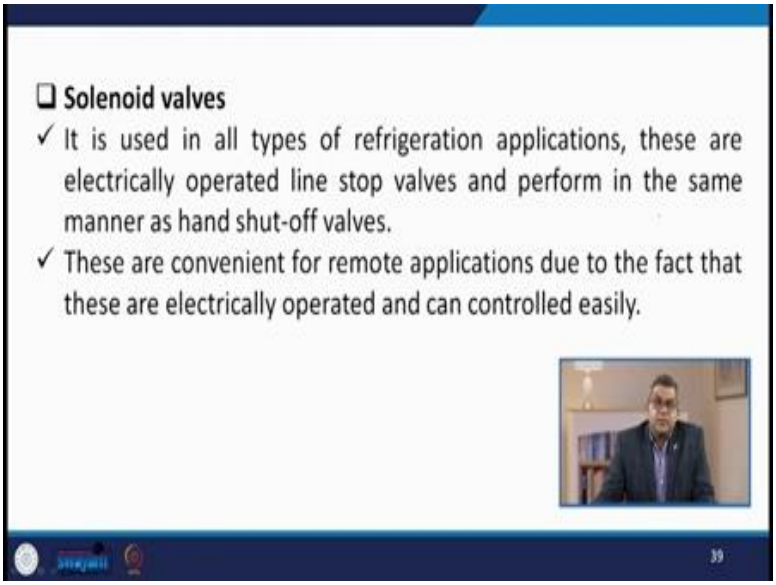

Solenoid valves now it is used in all type of refrigeration applications and these are electrically operated line stop valves and perform in same manner as hand shut off valves. Now these are convenient for remote application due to the fact that these are electrically operated and can control easily.

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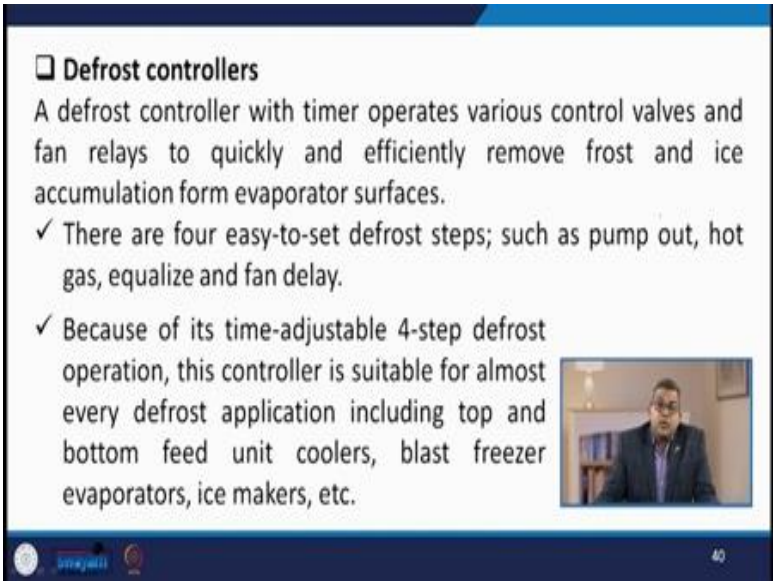

Defrost controllers and defrosting is again an essential phenomena in the refrigeration system so a defrost controller with the timer this operates various control valves and fan delays to quickly and efficiently remove the frost and ice accumulation from evaporator surfaces. Now there are 4 easy to set defrost type such as pump out, hot gas, equalize and fan delay now, because of its time, adjustable four step defrost operation. This controller is suitable for almost every defrost application including top and bottom feed unit cooler, blast, freezer evaporator ice makers etc.

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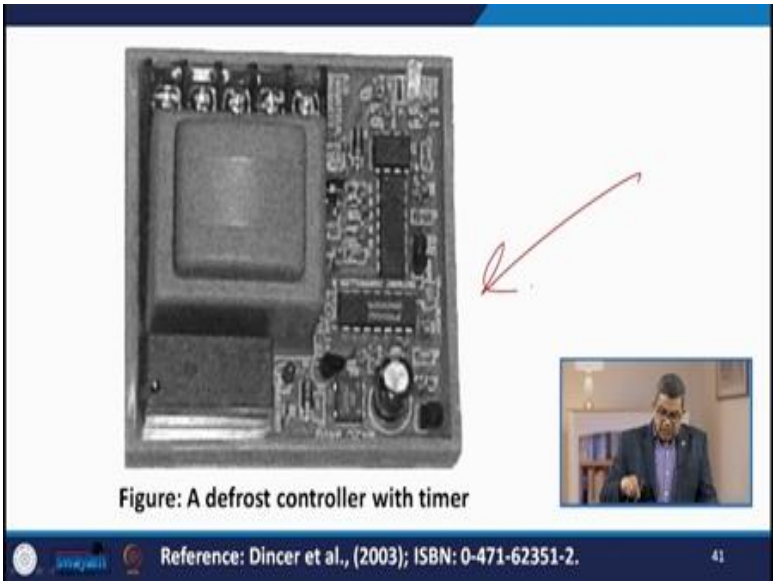

Now here you see the defrost controller with the timer.

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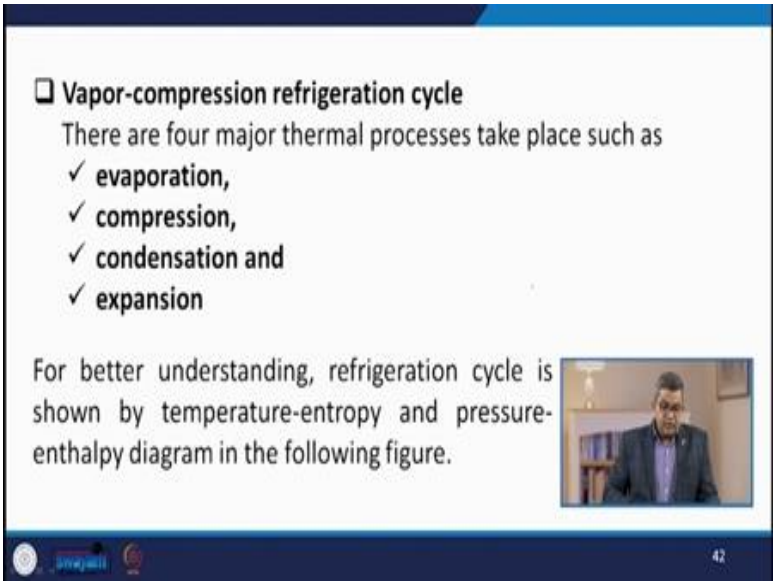

Now let us think about the vapour compression refrigeration cycle. Now there are 4 major steps or you can say that thermal processes. They usually carried out in the vapour compression refrigeration cycle. One is evaporation compression condensation and expansion. It is a usual thermodynamic cycle for better understanding the refrigeration cycle is usually shown by the temperature entropy or pressure enthalpy diagram.

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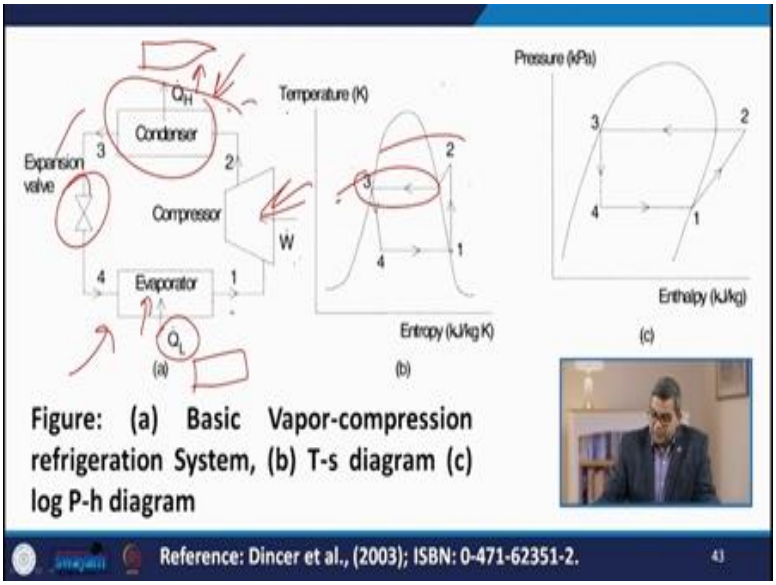

Now here you see this is the comprehensive figure here you are. This is the usual refrigeration cycle. You are having a low temperature source and a high temperature sink. So Q L amount of heat is being extracted through the evaporator and it passes through the compressor and it goes to the condenser where the Q H amount of heat being discharged either to the atmosphere or sink and goes to the expansion valve.

You need to carry out work W work over the compression. So this is the basic vapour compression refrigeration system. Now when you need to carry out or because sometimes for the thermodynamic calculation you need to have the T this T s diagram that is a temperature and entropy diagram apart from this P h diagram. So you can represent this with the help of this like from evaporator from for stage 1 to Stage 2 when this is the isentropic operation.

And then it goes to the condenser line that is again this particular operation. So this is represented with this T s diagram and this P h pressure enthalpy diagram.

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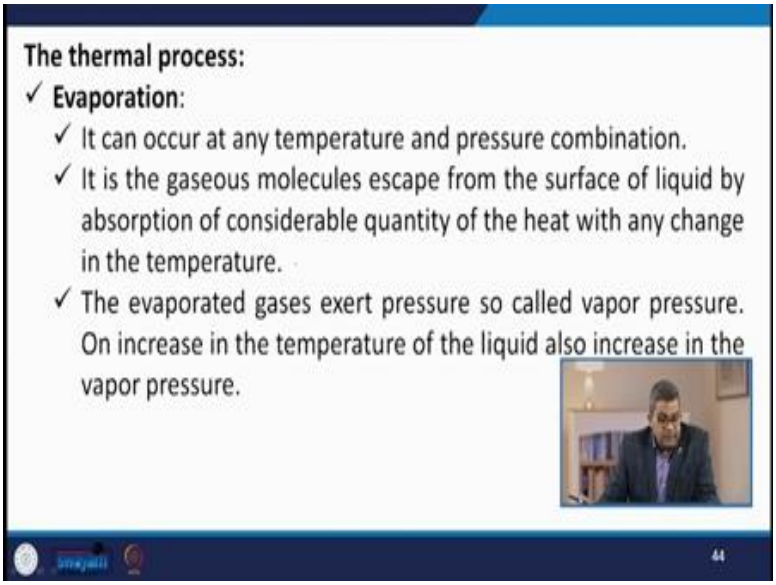

Now in a elaborative manner the evaporation process. It can occur at any temperature and the pressure combination. It is the gaseous molecule escape from the surface of liquid by the absorption of considerable quantity of heat with any change in the temperature. It is a usual phenomena of evaporation. The evaporated gases they exert pressure and that is so called the vapor pressure on increasing the temperature of the liquid this also increase the vapour pressure.

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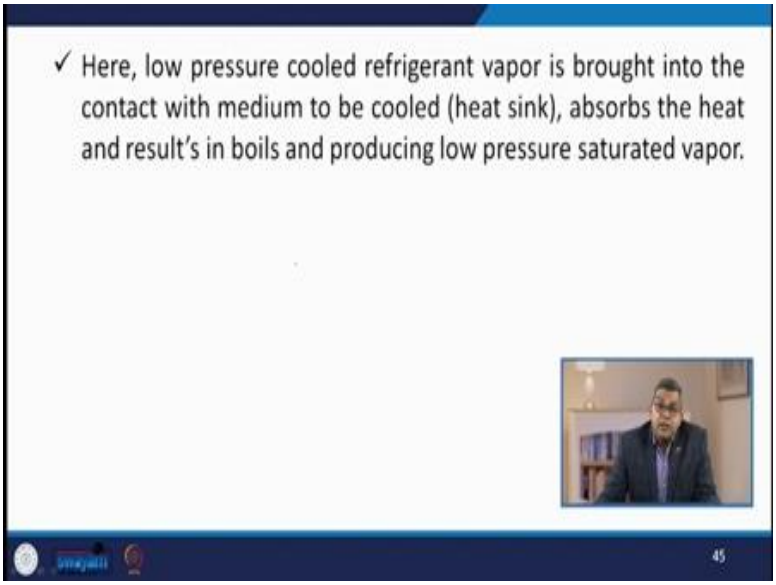

So the low-pressure cooled refrigerant vapour is brought into the contact with the medium to be cooled and that is called the heat sink and absorbs the heat and results in boil and producing low pressure saturated vapour.

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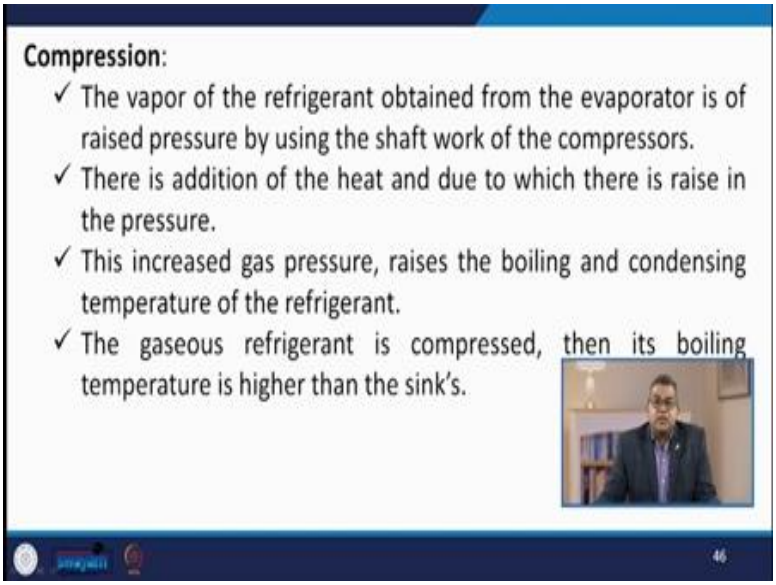

Now let us talk about the compression. The Vapour of the refrigerant is obtained from the evaporator is of raise the pressure by using the shaft work of the compressor. Now there is addition of heat and due to which there is a raise in the pressure because the compressor the work is employed on the compression. Now, this increased gas pressure rises in the boiling and condensing temperature of the refrigerant.

The gas was refrigerant is then compressed and it is boiling temperature is higher than that of the sinks. Next step is the condensation. Now this process includes changing vapor into liquid

by extracting heat. So whatever heat being absorbed apart from the work being carried out through the compressor. This you need to exchange or do you need to extract the heat. Now the condensing temperature of refrigerant is higher than the same. Therefore heat transfer condenses the high pressure refrigerant into the saturated liquid.

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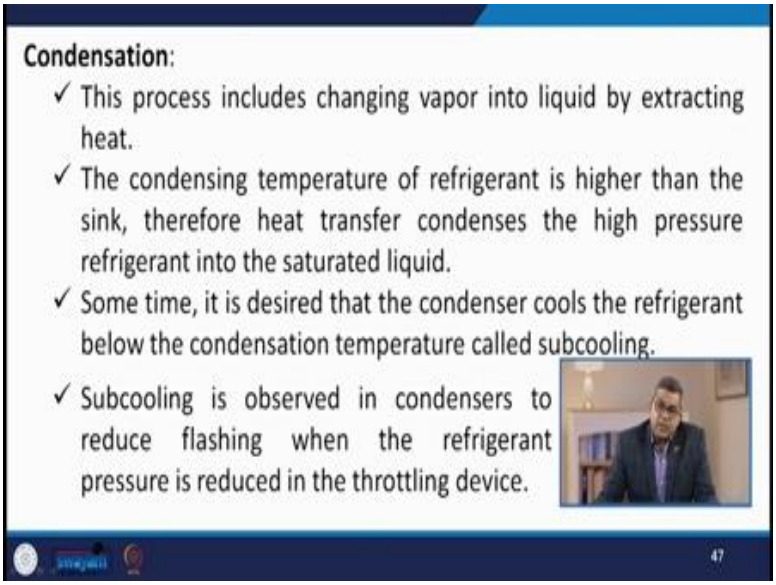

So sometimes it is desired that the condenser cool the refrigerant below the condensation temperature and that is called the sub cooling. Now sub cooling is observed in condenser to reduce the flashing when the refrigerant pressure is reduced in the throttling device. The next step is expansion. The condensed liquid is returned to the beginning and some throttling device such as valve orifice plate or capillary tube for the expansion is used to reduce the pressure of liquid and the boiling temperature of the refrigerant should be below the heat source.

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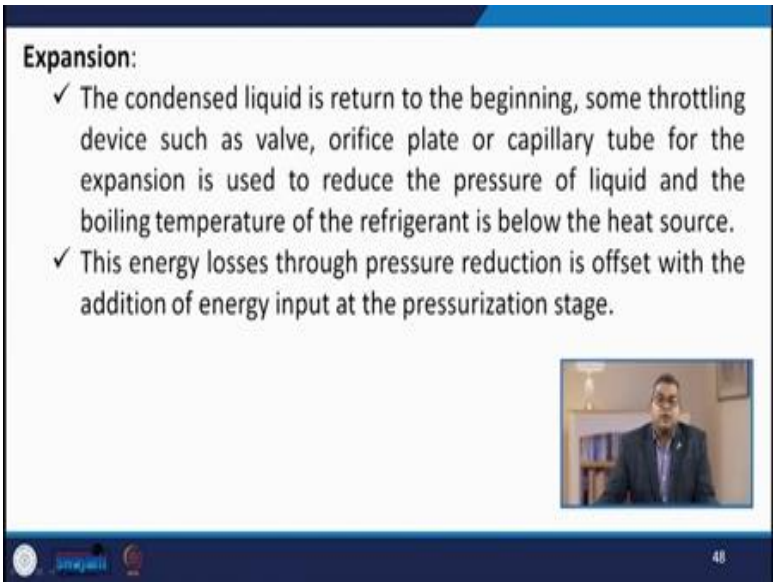

Now this energy loss through a pressure reduction is offset with the addition of energy input in the pressurization stage.

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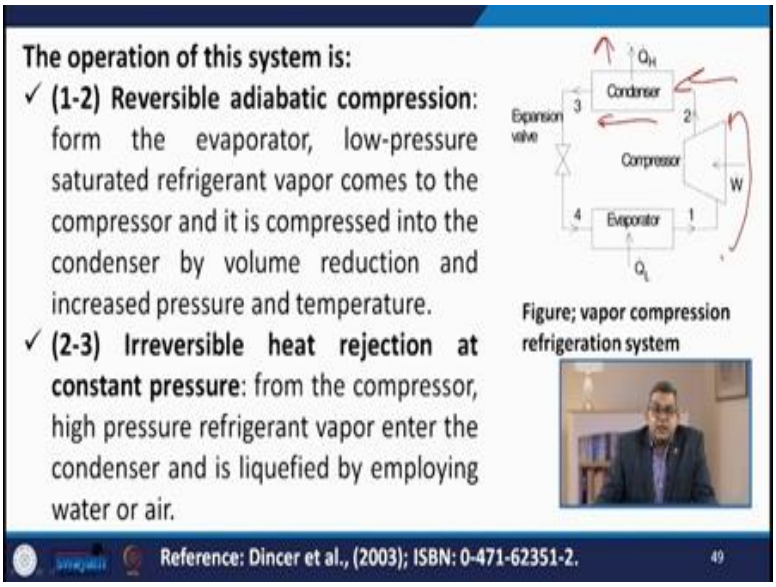

Now here you see that the operation of the system is described now from stage 1 to 2. This is the reversible adiabatic compression from the evaporator. The low pressure saturated refrigerant vapour comes out to the compression and it is compressed into the condenser by volume reduction and increase pressure and temperature. Now in reversible heat rejection from this stage to this from the compressor the high pressure refrigerant vapour enter the condenser and is liquefied by employing water or air.

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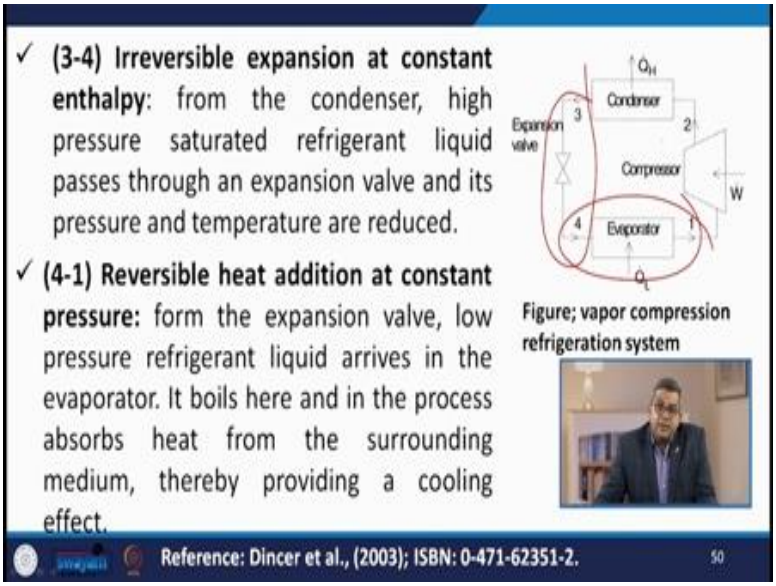

That is the usual phenomena which we described. Now from this stage to this stage that is irreversible expansion at the constant enthalpy. So from the condenser high pressure saturated

refrigerant liquid passes through the expansion valve and its pressure and temperature they are reduced. And during the evaporation of from stage 4 to 1. The reversible heat addition at constant pressure from the expansion valve low pressure refrigerant liquid arrives in the evaporator.

It boils here and in the process abpsorbs heat from the surrounding medium and thereby providing a cooling effect. Now this particular aspect is clearly represented in this T s and P h diagram which we have described earlier. So in this particular lecture we discussed about the various component in the refrigeration system various auxiliary units like oil separator strainers etc there use and their importance.

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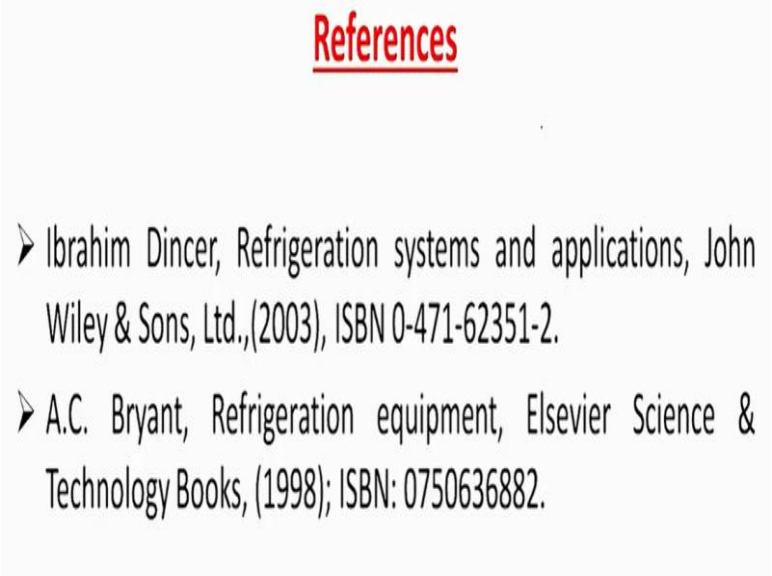

Apart from this we discussed the basic concept of vapour compression refrigeration cycles. For your convenience we have enlisted couple of references and if you wish you can go through all these references thank you very much.