Refrigeration and Air-conditioning
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Lecture No. # 31
Refrigeration System Components: Expansion Devices

Welcome back in the last lecture, I discussed capillary tubes and automatic expansion devices in this lecture. I shall discuss the rest of the expansion devices.

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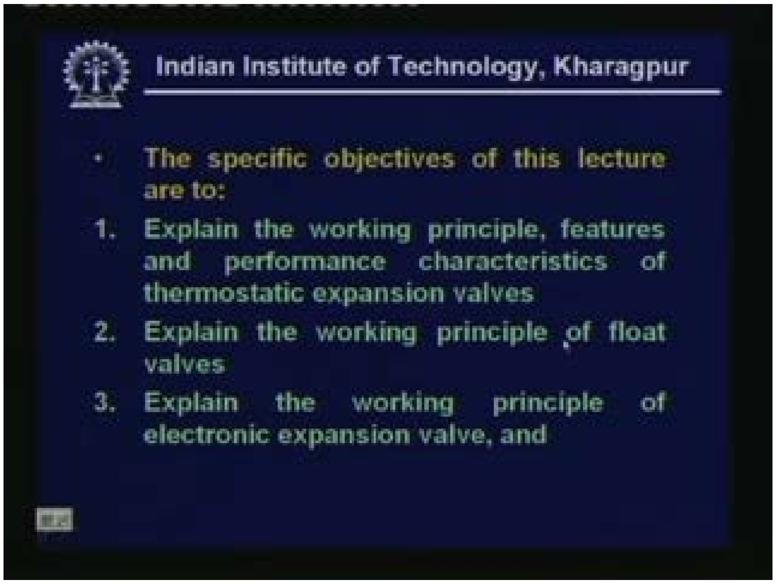

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- The specific objectives of this lecture are to:

1. Explain the working principle, features and performance characteristics of thermostatic expansion valves
2. Explain the working principle of float valves
3. Explain the working principle of electronic expansion valve, and

So the specific objectives of this particular lecture are to explain the working principle features and performance characteristics of thermostatic expansion valves, explain the working principle of float valves, explain the working principle of electronic expansion valves and discuss some practical issues. At the end of the lecture you should be able to explain with a sketch the working principle of a thermostatic expansion valve, explain its performance characteristics and variations available, explain the working principle of high and low side float valves, explain the working principle of electronic expansion valves and finally discuss practical issues to be considered while selecting expansion devices.

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Thermostatic Expansion Valves (TEV)

- Thermostatic expansion valve is the most versatile among all the expansion valves
- It is most commonly used in refrigeration systems
- A thermostatic expansion valve maintains a constant degree of superheat at the exit of evaporator
- Thus it protects the compressor by ensuring that no liquid enters into the compressor

So let us discus first the thermostatic expansion valves abbreviated as TEV a thermostatic expansion valve is the most versatile among all the expansion valves. It is most commonly used in refrigeration systems. A thermostatic expansion valve maintains a constant degree of superheat at the exit of exit of evaporator. It does not maintain a constant temperature but it maintains a constant degree of super heat at the exit of evaporator. Thus it protects the compressor by ensuring that no liquid enters into the compressor. This is the biggest advantage of thermostatic expansion valves.

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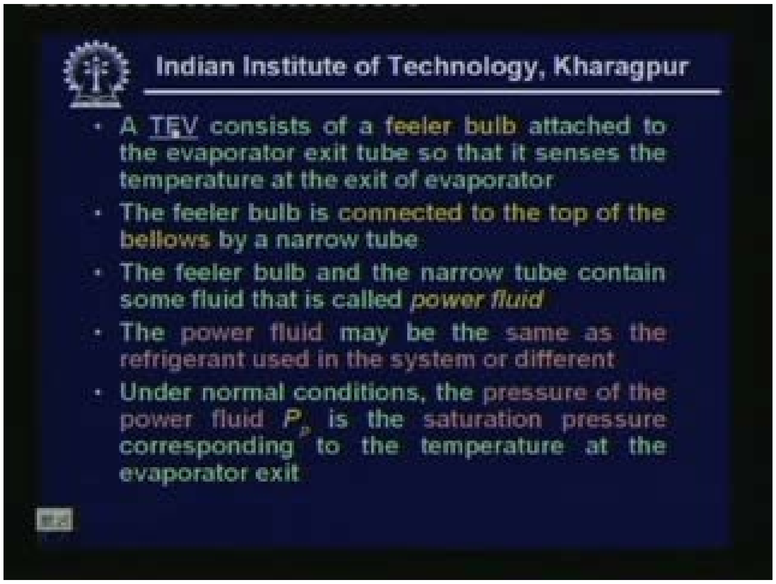

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- A TEV consists of a feeler bulb attached to the evaporator exit tube so that it senses the temperature at the exit of evaporator
- The feeler bulb is connected to the top of the bellows by a narrow tube
- The feeler bulb and the narrow tube contain some fluid that is called *power fluid*
- The power fluid may be the same as the refrigerant used in the system or different
- Under normal conditions, the pressure of the power fluid P_p is the saturation pressure corresponding to the temperature at the evaporator exit

So now let me describe the working principle of a thermostatic expansion valve. A thermostatic expansion valve consist of a feeler bulb attached to the evaporator exit tubes. So that it senses the temperature at the exit of evaporator the feeler bulb is connected to the top of the bellows by a narrow tube. The feeler bulb and the narrow tube contains some fluid that is called as power fluid the power fluid may be the same as the refrigerant used in the system or different okay. So now let me show the picture of that.

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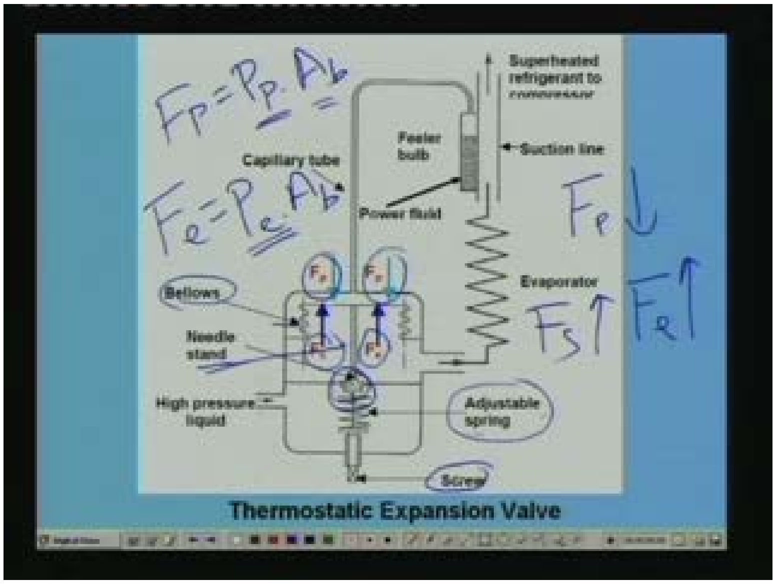

Thermostatic Expansion Valve

This shows the schematic of a thermostatic expansion valve you can see that this is the inlet to the valve so the high pressure refrigerant liquid from the condenser side enters into the valve. At this point then it flows through this artifice and its pressure reduces across the artifice. And the low pressure refrigerant flows out through the valve and enters into the evaporator. It take the heat from the surroundings. It becomes a vapor and goes out to the compressor okay. Now if you look at the valve oh, as I was, as I have already mentioned this valve consist of a feeler bulb. This is the feeler bulb and this feeler bulb is attached to the suction line. That is the exit of the evaporator okay. So there should be a good thermal contact between the feeler bulb and the refrigerant tubing and the feeler bulb is connected to the thermostat body with a narrow capillary tube okay. So the capillary tube connects the feeler bulb to the thermostat body okay. And the feeler bulb the thermostat space above the bellows and the capillary tube are filled with a fluid called as power fluid okay.

So this entire space plus this space in the capillary tube and this entire feeler bulb space is filled with a power fluid okay. The power fluid can be same as the refrigerant or it can be a different fluid okay. And if you look at the body of the thermostat you will see that it consist of a bellows okay. This is the bellows, you can also use the diaphragm okay. It can be either a diaphragm or a bellow. But I have shown here a bellows and this bellows is connected to a needle stand okay. So you have the needle stand here. So bellows is directly connected to the needle stand and you have the needle. And this position of the needle decides the area available for the refrigerant flow okay.

At this point the area available for the refrigerant flow depends upon the position of the needle stand. And the position of the needle stand in turn depends upon the balance between various forces acting across the bellows. For example if you look at the bellows the downward force is Fp okay and this Fp is due to the pressure of the power fluid okay. So you can write Fp is is equal to some Pp into Ab where Pp is the pressure exerted by the power fluid and Ab is the area of the bellows okay. So this is the force which is trying to push thee bellows down and trying to push the bellows down means the needle stand also will be pushed down. And what are the forces opposing this motion? The forces opposing these motions are first because of the evaporator pressure that is Fe okay. This is the force upward force due to the evaporator pressure this is equal to Pe into Ab where Pe is the evaporator pressure. And in addition to that you also have the spring force Fs okay.

So spring force Fs is acting upwards and force Fe due to evaporator pressure is acting upwards and the force due to power fluid is acting downwards okay. So the point at which the balance takes place in the steady state and at what point the balance takes place. That decides the area available for the refrigerant flow through the artifice which in turn depends decides the refrigerant flow rate okay. So this is the construction and you can see that there is an adjustable screw here. And using the screw you can adjust the stiffness of the spring that means you can adjust the force exerted by the spring okay, by turning the screw. So that what I have already explained and under normal circumstance the pressure of the power fluid Pp is the saturation pressure corresponding to the temperature at the evaporator exit okay. So let me go back once again.

So the pressure acting here, let say that is Pp this pressure corresponds to the saturation pressure. That means Pp is equal to P saturated pressure corresponding to the temperature existing. At this point if you are assuming that there will be a perfect thermal contact between the feeler bulb and the refrigerator tubing. Then the temperature inside the feeler bulb will be same as the temperature inside the refrigerator tubing okay. That means this feeler bulb temperature also will be Ts and if you have a two phase fluid inside the feeler bulb then the pressure exerted by the power fluid is nothing but saturated pressure at this temperature that is Psat at Ts.

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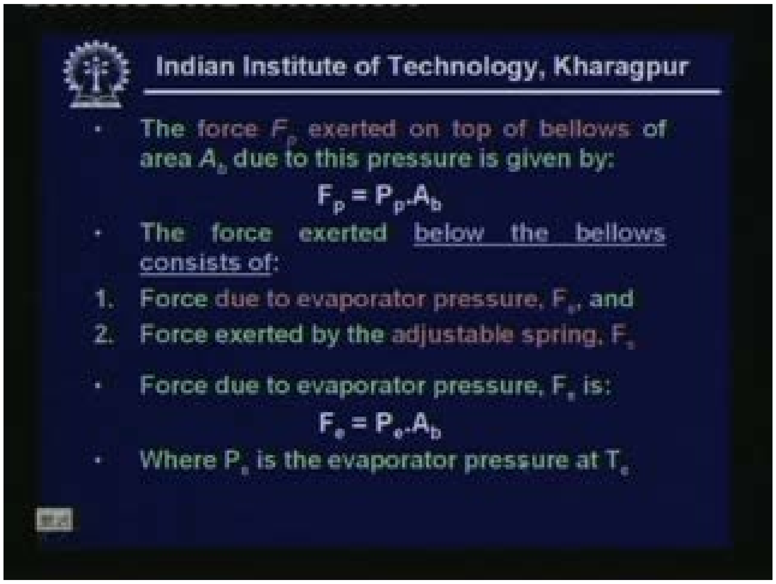

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- The force F_p exerted on top of bellows of area A_b due to this pressure is given by:

$$F_p = P_p \cdot A_b$$

- The force exerted below the bellows consists of:

1. Force due to evaporator pressure, F_e, and
2. Force exerted by the adjustable spring, F_s

- Force due to evaporator pressure, F_e is:

$$F_e = P_e \cdot A_b$$

- Where P_e is the evaporator pressure at T_e

Now the force this is I have already explain to you the force Fp exerted on the top of the bellows of area Ab is given by Fp is equal to Pp into Ab. And the force exerted below the bellows consists of as I have already discussed first, the force due to evaporator Fe and force exerted by the adjustable spring Fs and force due to evaporator pressure Fe is given by Fe is equal to Pe into Ab where Ab is the area of the bellows and Pe is the evaporator pressure okay. Evaporator pressure at temperature Te.

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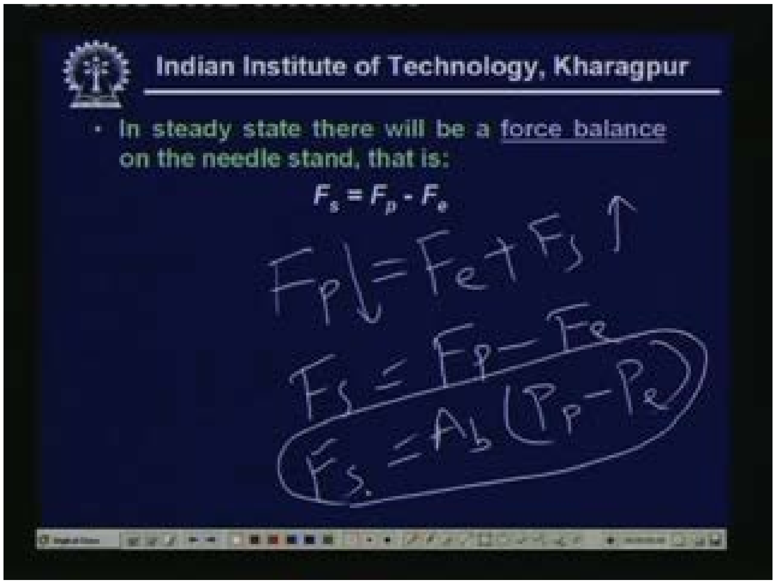

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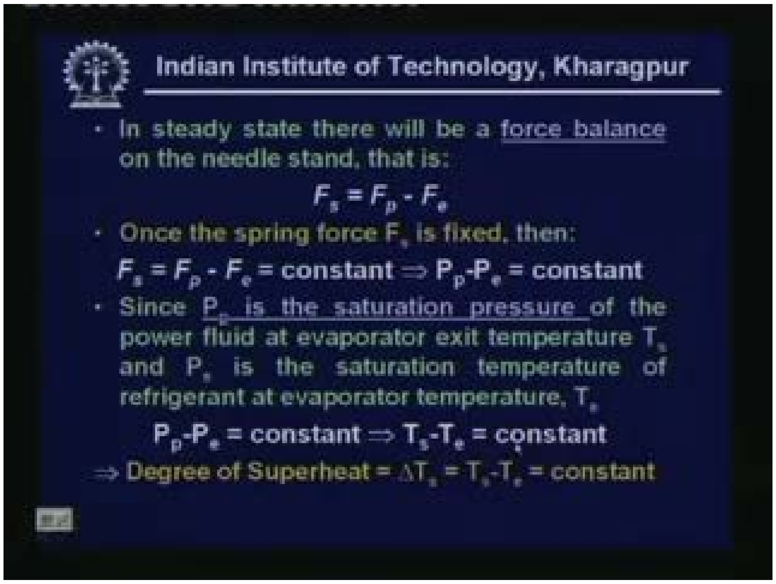
- In steady state there will be a force balance on the needle stand, that is:

$$F_s = F_p - F_e$$

$$F_p \downarrow = F_e + F_s \uparrow$$

$$F_s = F_p - F_e$$

$$F_s = A_b(P_p - P_e)$$



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- In steady state there will be a force balance on the needle stand, that is:

$$F_s = F_p - F_e$$

- Once the spring force F_s is fixed, then:

$$F_s = F_p - F_e = \text{constant} \Rightarrow P_p\text{-}P_e = \text{constant}$$

- Since P_p is the saturation pressure of the power fluid at evaporator exit temperature T_s and P_e is the saturation temperature of refrigerant at evaporator temperature, T_e

$$P_p\text{-}P_e = \text{constant} \Rightarrow T_s\text{-}T_e = \text{constant}$$

$\Rightarrow$ Degree of Superheat = $\Delta T_s = T_s\text{-}T_e$ = constant

Now in steady state there will be a force balance on the needle stand. That means Fs is equal to Fp minus Fe this is because Fe in that downward force is equal to Fp. That should be equal to the upward force this is the force acting in the downward direction. This should be equal to the upward force upward force is Fe plus Fs okay. So that means Fs is equal to Fp minus Fe okay. And this is equal to you can write this in terms of Ab that is bellows area into pressure acting on the bellows due to the power fluid minus evaporator pressure Pe okay. So at steady state finally you have Fs is equal to Ab into Pp minus Pe. Once the spring force f is fixed then Fs is equal to Fp minus Fe is equal to constant. That implies that Pp minus Pe is equal to constant because the area of the bellows remain constant okay. So once you set the spring force then the difference between the downward pressure and upward pressure will remain constant. Now since Pp is the saturation pressure of the power fluid at evaporator exit temperature Ts and P is the saturation temperature of refrigerant at evaporator temperature Te Pp minus Pe is constant implies that Ts minus Te is is equal to constant okay.

That means once you fix the spring force and if you keep the spring force constant then the difference between the downward force and the upward force remains constant always. And this is proportional to the pressure acting on the both the bellows and pressure acting below the bellows difference between these two pressures and these two pressures are nothing but the saturation pressure corresponding to the exit temperature and the evaporator temperature okay. Once the pressure difference is constant that means the temperature difference also should be constant. And this temperature difference is nothing but the degree of super heat okay. So Ts minus Te is constant means degree of superheat that is delta Ts is is constant.

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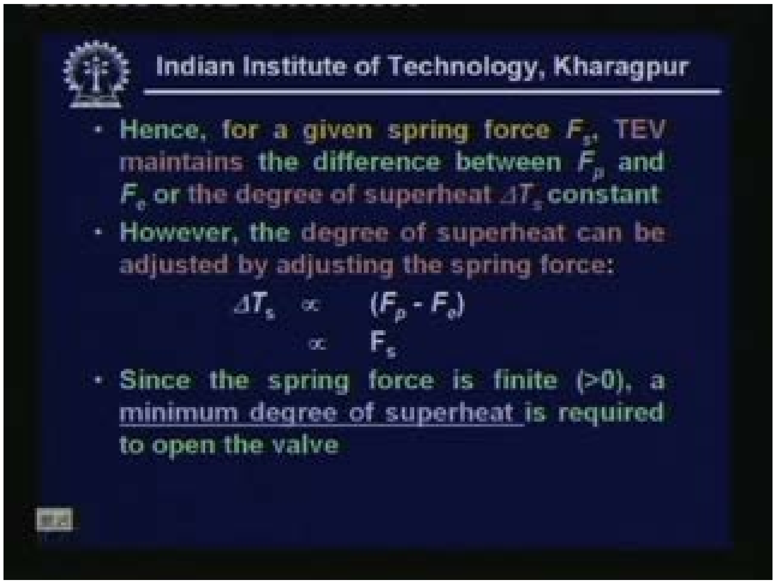

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- Hence, for a given spring force F_s, TEV maintains the difference between F_p and F_e or the degree of superheat ΔT_s constant
- However, the degree of superheat can be adjusted by adjusting the spring force:

$$\Delta T_s \propto (F_p - F_e)$$
$$\propto F_s$$

- Since the spring force is finite (>0), a minimum degree of superheat is required to open the valve

So for a given spring force Fs the thermostatic expansion valve maintains the difference between Fp and Fe or degree of superheat delta Ts constant always. However the degree of super heat can be adjusted by adjusting the spring force and we have seen that the delta Ts that is the degree of superheat is proportional to spring force Fs which is equal to Fp minus Fe okay. So if you increase the spring force the degree of superheat increases if you reduce the spring force degree of super heat reduces. Since the spring force is finite a minimum degree of super heat is required to open the valve.

So if you once you have the spring it always exerts a finite amount of force okay. It can never become zero right. That means Fs is always greater than zero Fs is always greater than zero means Fp minus Fe is always greater than zero. That means Pp minus Pe is always greater than zero okay. And Pp minus Pe is zero means degree of superheat should always be greater than zero. That means you should have a finite amount of super heat only when only then the valve can open okay. So that is the meaning of this the, this is shown in this picture so you can see that here the degree of superheat delta Ts is plotted in the x-axis okay. And the y-axis you have the percent of percent opening okay, percent opening of the valve.

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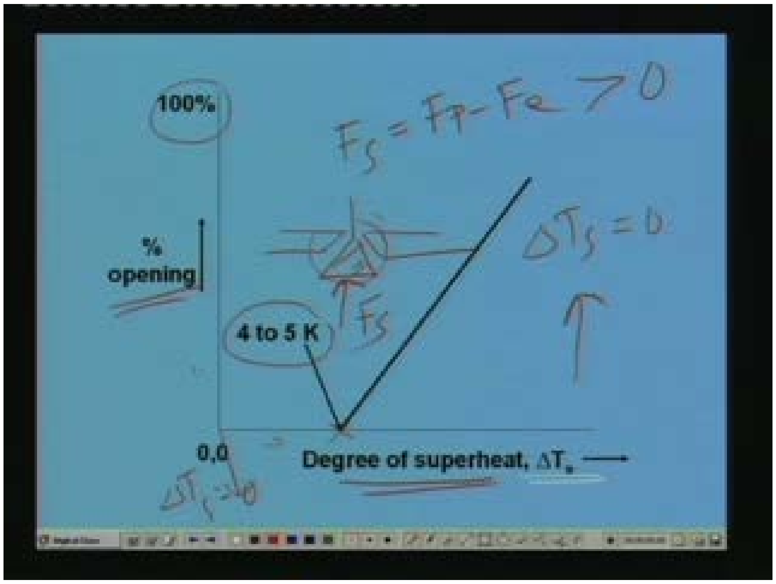

When the percent opening is zero that means the flow rate is zero percent opening is hundred percent means the mass flow rate is maximum okay. So I was mentioning that at this point degree of superheat is zero okay. Once the degree of superheat is zero you have Fs is equal to FP minus Fe right this as i said is always greater than zero okay. So this is greater than zero means you have a net at this condition when delta Ts is zero okay. There is a state of imbalance. That means there will be an higher downward force okay. This higher downward force will close the needle okay. If you look at the needle you have the needle like this okay. So this is the needle. So this needle will be pushed upwards because of the spring force okay, that means it will be completely closed.

So you want this to open you must provide some minimum degree of superheat delta Ts okay. So if you, as you go on increasing the degree of superheat it will not open till it reaches the minimum value. Only at this point the needle starts moving downwards okay only then you will have some finite mass flow rate okay. And normally the spring force is a set in such a way that a minimum degree of superheat of is about four to five Kelvin is required to open the valve okay.

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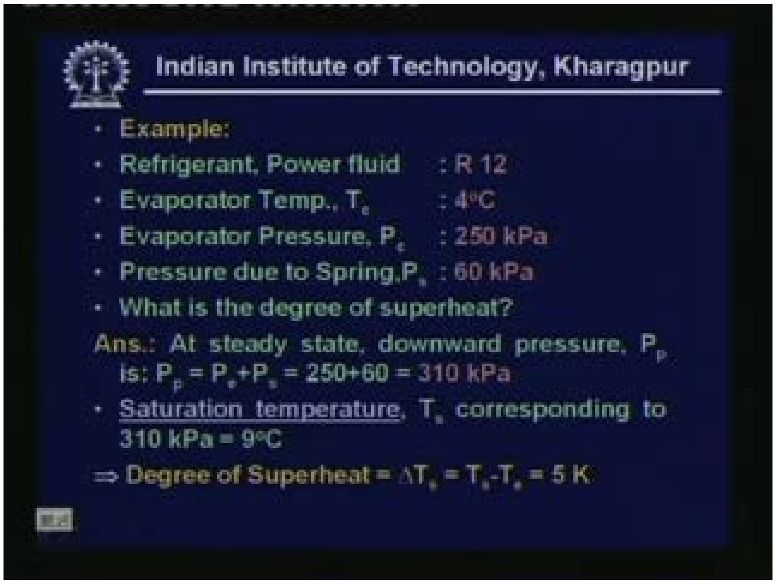

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- Example:
- Refrigerant, Power fluid : R 12
- Evaporator Temp., T_e : 4°C
- Evaporator Pressure, P_e : 250 kPa
- Pressure due to Spring, P_s : 60 kPa
- What is the degree of superheat?

Ans.: At steady state, downward pressure, P_p is: $P_p = P_e + P_s = 250+60 = 310$ kPa

- Saturation temperature, T_s corresponding to 310 kPa = 9°C

$\Rightarrow$ Degree of Superheat = $\Delta T_s = T_s - T_e = 5$ K

Now let me give a small example let us say that we have a thermostatic expansion valve which you just power fluid as R twelve and the refrigerant is also R twelve and the evaporator temperature is four degree centigrade. And the evaporator pressure which is nothing but the saturation pressure at four degree centigrade from the refrigerant property data base is found to be two fifty kilo Pascal. Let us say that the pressure exerted due to the spring Ps is sixty kilo Pascal okay. So we know the evaporator pressure Pe and the spring pressure Ps. So we have to find out what is the degree of superheat. So it is a very simple problem at steady state we know that the downward pressure Pp is equal to Pe plus Ps okay. So Pe is equal to two fifty kilo Pascal and Ps is sixty kilo Pascal so Pp is equal to three ten kilo Pascal okay. So Pp is nothing but the saturation pressure corresponding to the exit temperature Ts okay. So we know the saturation pressure. So I gave we can find out what is the corresponding saturation temperature okay. So if you look at the refrigerant property table. You can find that at three ten kilo Pascal the saturation temperature of R twelve is nine degree centigrade. That means Ts is nine degree centigrade once Ts is nine degree centigrade the degree of superheat that is delta Ts that is Ts minus Te that is equal to nine minus four which is equal to fife Kelvin okay. So that means this valve has the degree of superheat of five Kelvin okay. This is decided by you can see that from this example this is this slowly depends upon your spring pressure. If you increase the spring pressure you will find that the degree of super heat increases.

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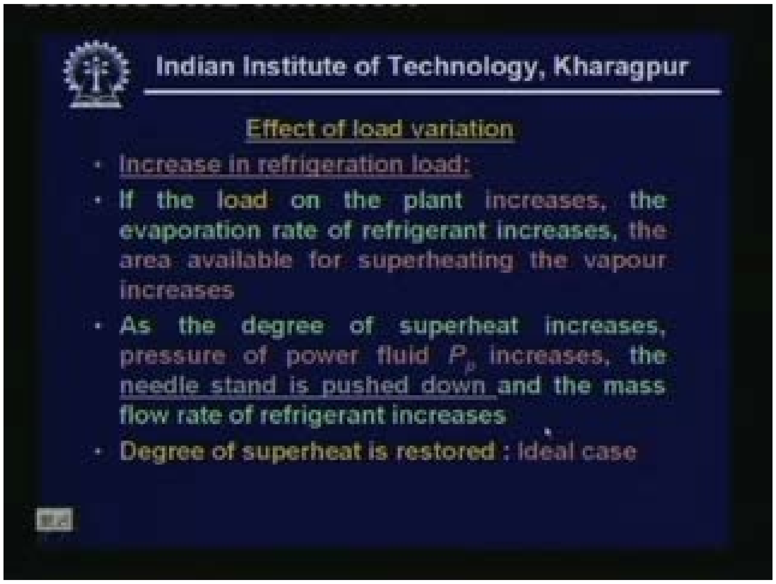

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Effect of load variation

- Increase in refrigeration load:
- If the load on the plant increases, the evaporation rate of refrigerant increases, the area available for superheating the vapour increases
- As the degree of superheat increases, pressure of power fluid P_p increases, the needle stand is pushed down and the mass flow rate of refrigerant increases
- Degree of superheat is restored : Ideal case

Now let us look at the effect of load variation. How does the valve adjust to different loads? First let us look at increase in refrigeration load. What happens when load increases? If the load and the plant increases the evaporation rate of refrigerant increase. The area available for superheating the vapor increases as a result the degree of superheat increases okay. The degree of superheat increases means the pressure of power fluid Pp increases why Pp increases because once the degree of superheat increases means the temperature at the exit of the evaporator Ts that increases. And the, this temperature is sensed by the feeler bulb okay. That means the feeler bulb temperature increases once the feeler bulb temperature increases the power fluid which is stored inside the feeler bulb feeler bulb. Its temperature also increases once the power fluid temperature increases its pressure increases okay.

So ultimately when the load increases the pressure in the feeler bulb increases. This pressure is acting on the bellows okay. So the pressure acting on the bellows increases when the load increases. So what happens when the pressure acting on the bellows increases. So when the pressure acting on the bellows increases needle stand is pushed down and the mass flow rate of refrigerant increases okay.

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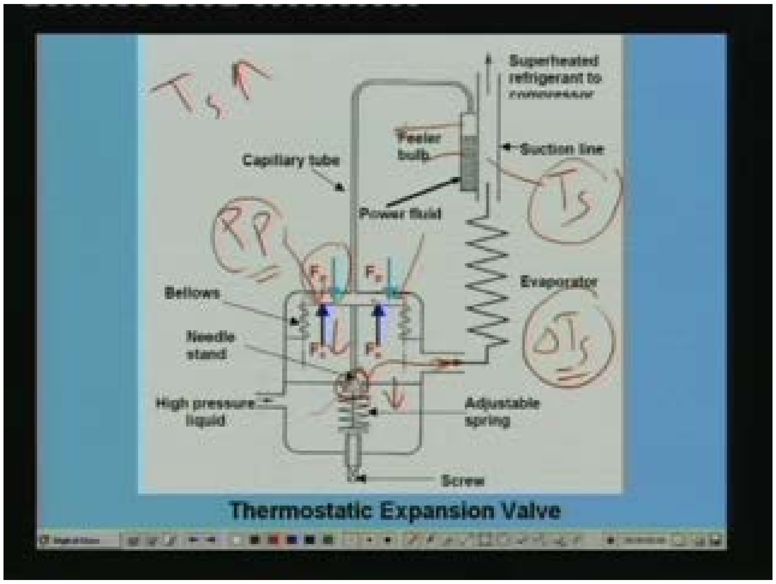

Thermostatic Expansion Valve

You can see here that as I was telling you lets say that this is the temperature Ts once Ts increases. This fluid becomes warmer once this fluid becomes warmer the pressure inside increases. That means the pressure acting on the bellows Pp increases. So the balance is disturbed momentarily. Since this pressure increases the downward force Fp increases once the downward force Fp increases. This needle stand will be pushed down okay. That means this portion will be pushed down once this is pushed down you can see that the area available for refrigerant flu increase.

Once the area available for refrigerant flu increase more refrigerant enters into the evaporator. Once more refrigerant enters into the evaporator this temperature reduces because the degree of superheat reduces. Once the degree of superheat reduces this pressure also reduces. So again a new this comes comes back to the original pressure okay. Again the degree of superheat delta Ts is restored okay. So degree of superheat is restored and this is the ideal case right.

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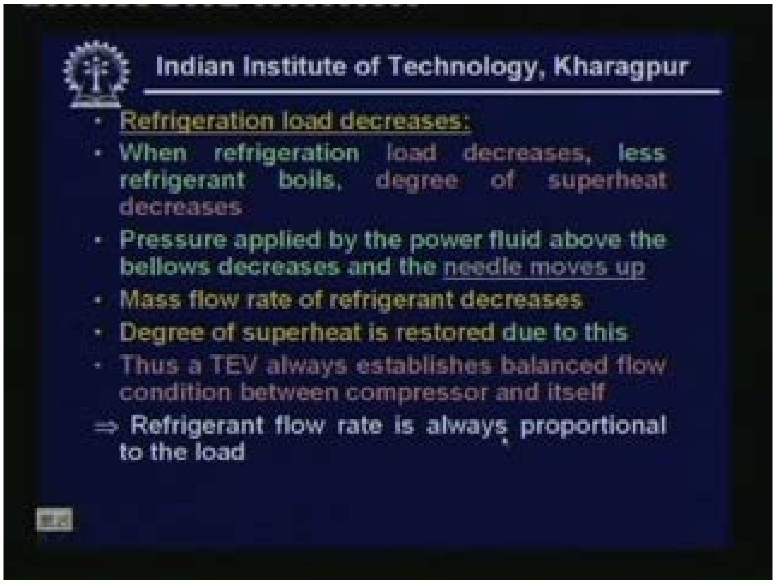

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- Refrigeration load decreases:
- When refrigeration load decreases, less refrigerant boils, degree of superheat decreases
- Pressure applied by the power fluid above the bellows decreases and the needle moves up
- Mass flow rate of refrigerant decreases
- Degree of superheat is restored due to this
- Thus a TEV always establishes balanced flow condition between compressor and itself

⇒ Refrigerant flow rate is always proportional to the load

Now what happens when the refrigeration load decreases we know that once the when the refrigeration load decreases less refrigerant boils. That means degree of superheat decreases once the degree of superheat decreases pressure applied by the power fluid above the bellows decreases. This is because the temperature of the power fluid decreases. So pressure also decreases once temperature of the power fluid decreases needle moves up.

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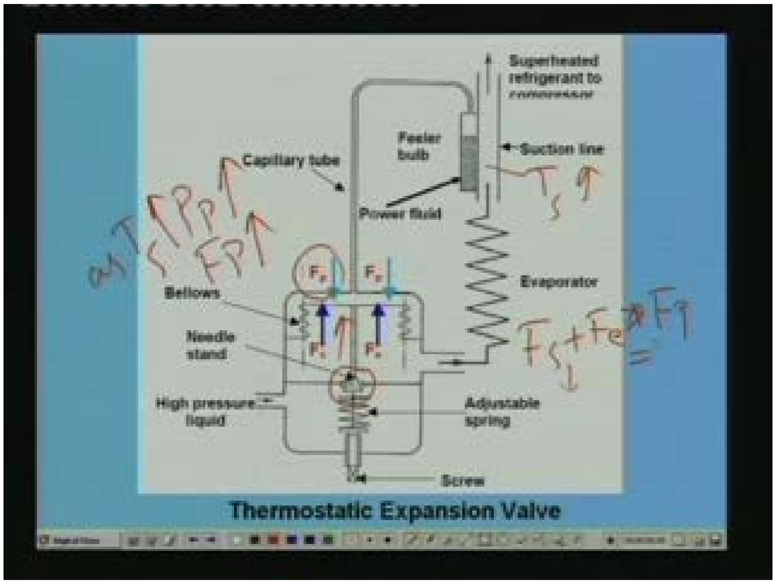

This is opposite to what happens when the load increases okay. This force reduces. That means momentarily Fs plus Fe will be greater than Fp and this is greater than Fp this will move up okay. Once this moves up actually the spring force reduces and a new balance point is established and the, at this new balance point the area available for refrigerant flu reduces because the needle has moved up. So once it moves up means area available for the refrigerant to flow through the artifice reduces. Once the refrigerant flow rate reduces the superheat increases. That means this temperature again increases once this temperature increases pressure in the power fluid Pp increases okay.

So as Ts increases Pp increases once pp increases Sp increases okay. Once Sp increases you will find the balance is restored okay. Fs plus Fe will become Fp right so this balance is restored at a lower flow rate okay. So that is what you have to keep in mind. So mass flow rate of refrigerant decreases. So degree of super heat is again restored due to this thus a TEV always establishes balance flow condition between compressor and itself okay. That is why this is a very effective expansion device okay. So refrigerant flow rate is always proportional to the load. So that is the reason why the thermostatic expansion valve is most versatile and tits very effective okay. So it is something like a closed loop control okay.

So it takes the feedback from the feeler bulb and takes the corrective action and this corrective action is in a in the line of our requirement okay. That means when the load increases it increases the flow rate to meet the increases load similarly when the load reduces it reduces the flow rate to again to meet the reduced load okay. So in addition to providing the required pressure drop it also controls the flow rate in a required manner okay. It this is unlike your automatic expansion valve which I discussed in the last lecture where you will find that when the load increases. Actually the refrigerant flow rate reduces okay. Whereas when the load reduces refrigerant flow rate increases in the automatic expansion valve.

Of course in automatic expansion valve evaporator temperature always remains constant. That will not be the case in thermostatic expansion valve. When the load varies the balance point may occurs at a different evaporated temperature but what remains constant is the degree of superheat okay. So that is the difference between these two types of valves.

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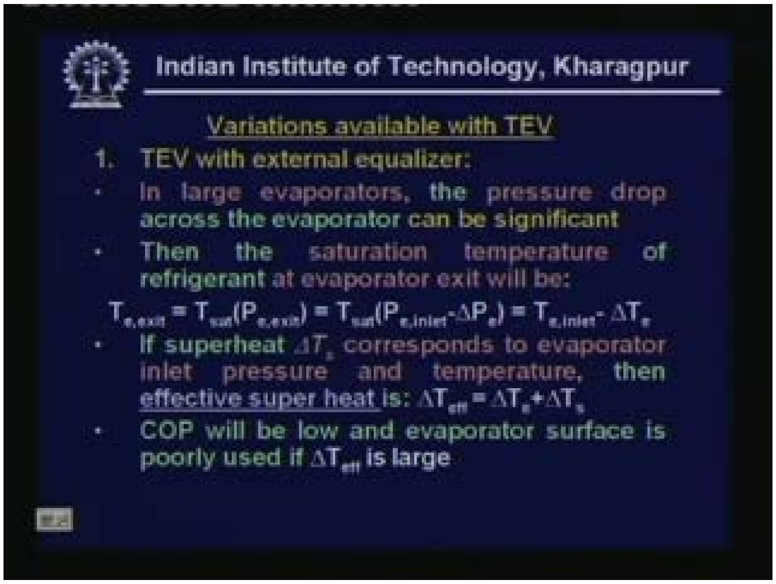

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Variations available with TEV

1. TEV with external equalizer:
- In large evaporators, the pressure drop across the evaporator can be significant
- Then the saturation temperature of refrigerant at evaporator exit will be:

$$T_{e,exit} = T_{sat}(P_{e,exit}) = T_{sat}(P_{e,inlet} - \Delta P_e) = T_{e,inlet} - \Delta T_e$$

- If superheat ΔT_s corresponds to evaporator inlet pressure and temperature, then effective super heat is: $\Delta T_{eff} = \Delta T_e + \Delta T_s$
- COP will be low and evaporator surface is poorly used if ΔT_{eff} is large

Now let us look at variations available with thermostatic expansion valve. First variation is that thermostatic expansion valve with external equalizer in large evaporators the pressure drop across the evaporator can be significant. Then the saturation temperature of refrigerant at evaporator exit will be saturation temperature at evaporator exit is nothing but saturation temperature at exit pressure okay. So Te exit this is the saturation temperature at the exit of the evaporator. This is nothing but the saturation temperature at this for exit pressure and exit pressure is nothing but inlet pressure minus delta P okay. Delta P is the pressure drop across the evaporator when this pressure drop across the evaporator is negligible or zero. Then you find that exit temperature is same as the inlet temperature because the exit pressure is same as the inlet pressure. But you find that in large evaporators especially single path evaporators delta P can be very high once delta P is very high this difference will be large and you will find that the exit temperature will be inlet temperature minus some delta Te okay and this delta Te is proportional to your delta Pe okay.

So if superheat delta Ts corresponds to evaporator inlet pressure and temperature then effective super heat is equal to delta T effective is delta Te plus delta Ts okay. So COP will be low and evaporator surface is poorly used if delta T effective is large what it means is, let us say that you have selected a thermostatic expansion valve which senses the inlet pressure of the evaporator. And the exit pressure of the evaporator it sensed by the power fluid and a degree of super heat is fixed accordingly okay.

So if there is a large special drop across the evaporator then you find that the exit pressure evaporator exit pressure will be very low and the corresponding saturation temperature at the exit also will be low. See, you find that the actual superheat at the exit will be much higher than the set super heat okay. Because the actual super heat is nothing but the set superheat plus temperature drop due to pressure drop okay. And that means you find that in the actual case because of the large pressure drop most of the evaporator area is dry because of the larger superheat. That means evaporator will not be utilized properly okay. In addition to that when you have a large superheat system performance also will affected adversely okay.

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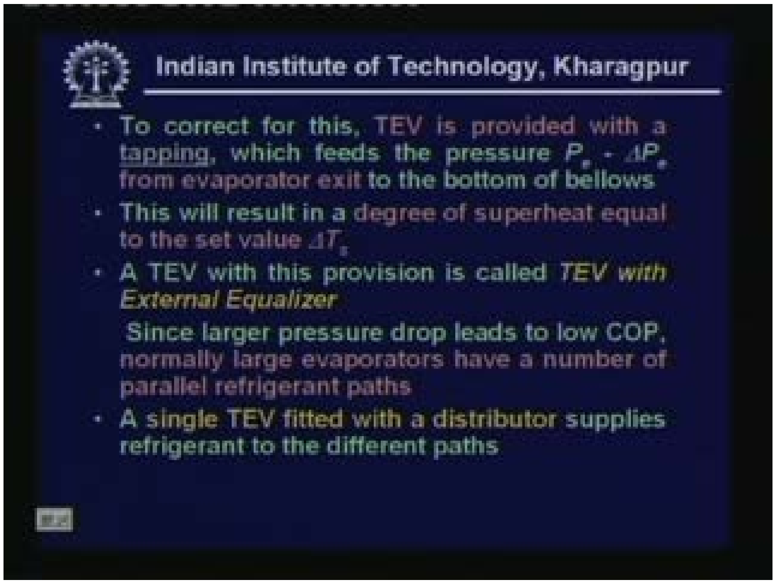

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- To correct for this, TEV is provided with a tapping, which feeds the pressure P_e - ΔP_e from evaporator exit to the bottom of bellows
- This will result in a degree of superheat equal to the set value ΔT_s
- A TEV with this provision is called *TEV with External Equalizer*

Since larger pressure drop leads to low COP, normally large evaporators have a number of parallel refrigerant paths

- A single TEV fitted with a distributor supplies refrigerant to the different paths

So to correct for this thermostatic expansion valve is provided with tapping which feeds the pressure Pe minus delta Pe from evaporator exit to the bottom of the bellows. So what we do is to take care of this one instead of sensing the inlet pressure of the evaporator. The modified thermostatic expansion valve will work based on the exit pressure of the evaporator not with the, not based on the inlet pressure of the evaporator. Once it is based on the exit pressure of the evaporator then you find the actual pressure will be the set super heat okay. Let me show a picture.

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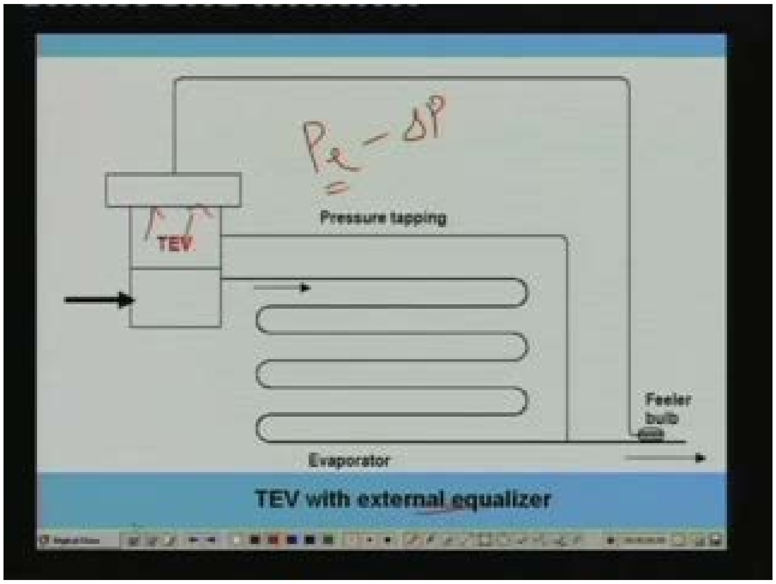

TEV with external equalizer

Okay, so this is the schematic of a thermostatic expansion valve with external equalizer okay. This is called as the external equalizer the difference as you can see here is the let us say that this is the bellows okay. Let me just say that this is the bellows right. So here the pressure acting is pressure due to the feeler bulb that is Pp and the downward pressure is not the pressure at the inlet of the evaporator. But that is the pressure at the outlet of the evaporator okay. That means you take a pressure tapping at the outlet of the evaporator and that pressure will be acting bellow the bellows okay. So this called as that TEV with external equalizer normal evaporator what happens is this partition will not be there. So the pressure acting here will be inlet pressure itself P inlet, okay, in the normal this thing. But when there is a large special drop we modify this one and we go for this kind of external tapping okay. So that the pressure opposing this one will be Te minus delta P okay not Pe right.

So this will result in a degree of super heat equal to the set value delta Ts a TEV with this provision is called as thermostatic expansion valve with external equalizer. Since larger pressure drop leads to low COP normally large evaporators have a number of parallel refrigerant paths. Of course this does not really solve the problem that means if you have a very large pressure drop if you have designed a system in such away that you have very large pressure drop in the evaporator okay. If you are taking care of it by providing a thermostatic expansion valve with external equalizer that will solve the problem of the thermostatic expansion valve. But that will not improve the performance of the system as such because large pressure drop across the evaporator is not good from the performance point of view. So in in actual practice what is done is whenever there is a large evaporator with large evaporator length normally parallel paths are provided okay. That means instead of using a single path the refrigerant is split into parallel paths.

So there by you can reduce the flow rate through each path and the length of the each path also can be reduced thereby you can reduce the pressure drop across the evaporator okay. So as a a single even then a single thermostatic expansion valve fitted with a distributor supplies refrigerant to the different paths. That means you can have a same if you have a evaporator with multiple paths you do not have to have many thermostatic expansion valves a single expansion valve is enough okay. But you have to use a distributor along with the thermostatic expansion valve which will distribute the refrigerant into different paths okay.

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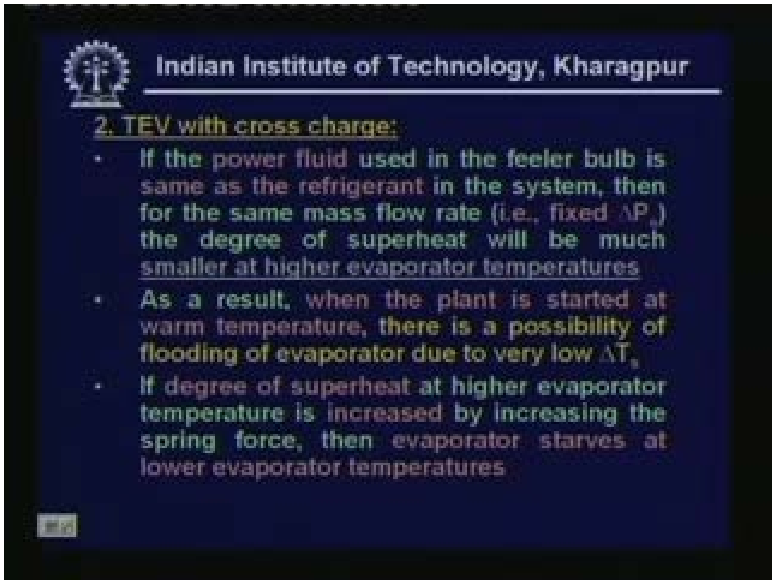

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2. TEV with cross charge:

- If the power fluid used in the feeler bulb is same as the refrigerant in the system, then for the same mass flow rate (i.e., fixed ΔP_s) the degree of superheat will be much smaller at higher evaporator temperatures
- As a result, when the plant is started at warm temperature, there is a possibility of flooding of evaporator due to very low ΔT_s
- If degree of superheat at higher evaporator temperature is increased by increasing the spring force, then evaporator starves at lower evaporator temperatures

So that was the first variation available and the second variation is what is known as thermostatic expansion valve with cross charge. If the power fluid used in the feeler bulb is same as the refrigerant in the system then for the same mass flow rate. That means I fixed a delta Ps the degree of superheat will be much smaller at higher evaporator temperatures. That means as I said in the example I have shown you. Let us say that you have a refrigeration system which uses R twelve as a refrigerant and you have you have a thermostatic expansion valve which also uses R twelve as the power fluid okay. This is what is known as the straight charged thermostatic expansion valve. That means the refrigerant and the power charge power fluid both are same okay. When both are same you will find that at higher evaporator temperature the degree of superheat will be much smaller than the degree of superheat at low evaporator temperatures okay. For that means for the same spring force the degree of superheat will be different at different evaporated temperatures okay.

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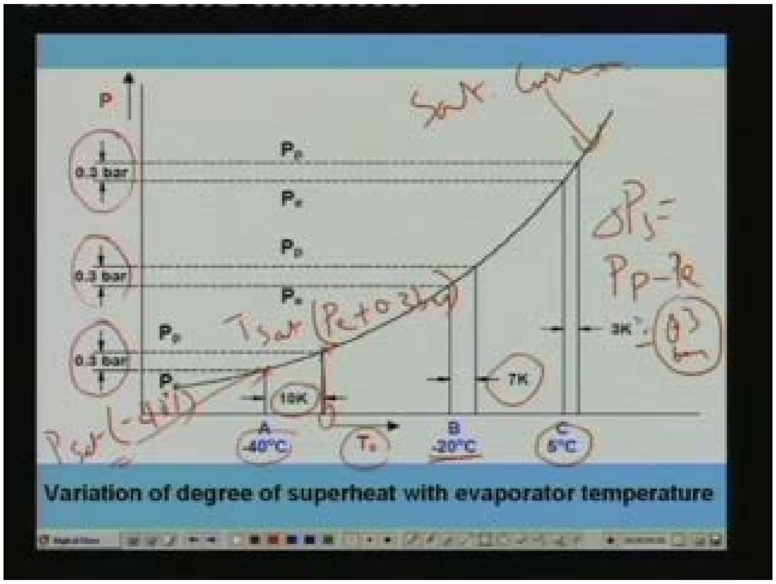

Variation of degree of superheat with evaporator temperature

So let me show this with the help of a schematic you can this is the saturation curve okay. Our saturation curve that is P sat and this is pressure verses temperature okay. So you can see that let us say that I have fixed the spring in such a way that I get a delta Ps due to spring this is equal to Pp minus Pe. Let us say that I have set it as point three bar okay. I have fixed this at point three bar and when the evaporator temperature is minus forty degree centigrade the, then you will find that for this point three bar pressure difference you get a degree of superheating of ten Kelvin okay. How do you get this degree of superheating of ten Kelvin all that you have to do is you have to find out this pressure this pressure corresponds to saturated pressure at minus forty degree centigrade okay.

So you get some pressure value and then you have to get this temperature and how do you get this temperature? This temperature is nothing but saturation temperature at evaporator pressure Pe plus point three bar okay. So in one case you use the temperature to find the saturation pressure and for finding the superheat temperature you have to use the pressure values and then find the, this temperature. So the degree of superheat is nothing but this temperature minus this temperature. So you find that at minus forty degree centigrade the degree of superheat is ten Kelvin. Now if the same system operates at minus twenty degree centigrade and if you have not change the spring force then again the pressure difference will remain point three bar. Then you find that the degree of super heat reduces to seven Kelvin okay. That means from ten Kelvin it reduces to seven Kelvin.

Now if the same system is operated at five degree centigrade and again the same spring force is maintained. And the same difference is maintained you find that the degree of superheat has reduced to three Kelvin okay. That means as the system operates as if from minus forty degree centigrade to five degree centigrade. The degree of superheat has reduced from ten Kelvin to three Kelvin. So you will find that if you operated at much higher evaporator temperature the degree of superheat becomes very small okay. So at higher, at still higher Te you will find the degree of superheat will be very small okay. That means it almost approaches zero okay. And first of all why do you where do you encounter this kind of a situation where the same system is operated over such a large evaporator temperatures. You may not during the normal designing condition you may not operate the system under such a high evaporator temperature variation okay.

But when the system is started or during the pull down during each pull down the evaporator temperature has to begin from a very warm temperature. And it has to come back to its design temperature okay. So during every pull down pull down you will find that the evaporator temperature is varying from a very high value to a very low value okay. This kind of a situation is encountered for example in a freezing unit okay. In a ice cream making unit or some other freezing unit or even in a domestic refrigerator where the freezer is maintained at about minus twenty degree centigrade or so okay. So during every pull down this thing the evaporator temperature has to start right from the ambient temperature of say plus thirty degree centigrade and it has to come down to minus twenty degree centigrade okay. So you find that there is a large temperature variation okay.

So if you have set the degree of superheat at minus twenty degree centigrade. Then you find that when the system is operating at higher evaporator temperature the degree of superheat becomes almost zero okay. Now what is the problem when the degree of superheat becomes very small when the degree of superheat becomes small. As I said when the plant is started a warm temperature there is a possibility of flooding of evaporator due to very low delta Ts okay. If degree of superheating is not sufficient then more refrigerant may enter okay. There is no load or higher refrigerant flow will be there to the evaporator. So evaporator may get flooded and flooding as you know may lead to slugging of the compressor okay. So this has to be avoided right.

So if do you now one way of avoiding this is to increase the degree of superheat at higher evaporator temperatures okay. That means what you can do is you set the spring force in such a way that at higher evaporator temperature you increase it to let us say ten Kelvin okay. That means you have to increase the spring force or you have to increase the delta Ps okay. So increase the delta Ps in such a way that at higher evaporator temperatures you are getting higher degree of superheat. So this will take care of the problem of flooding. But what happens when the evaporator comes to the design evaporator temperature? You will find that when it is operating as a designed evaporator temperature under the higher degree of superheating, you will find that the, this degree of superheating may become twenty Kelvin or more okay. I am just giving an example right. That means the degree of superheat becomes very very large at low evaporator temperatures.

And as you know that the degree of super heat is be becoming very large. Most of the evaporating area is simply being used for sensible heat heating of the refrigerant okay. That means the heat transfer rate will be very low and the system efficiency will be poor okay. So this is the problem. So if you set the degree of superheat for lower temperature then you may have a problem of flooding when the evaporator temperature is high okay. On the other hand if you set the degree of superheat for higher temperature then the degree of superheat may become very large at lower evaporator temperature. And this may lead to the starving of the evaporator and poor performance of the system okay. So what is the solution all this is happening because we have used the same fluid in the feeler bulb as that of the refrigerant system okay.

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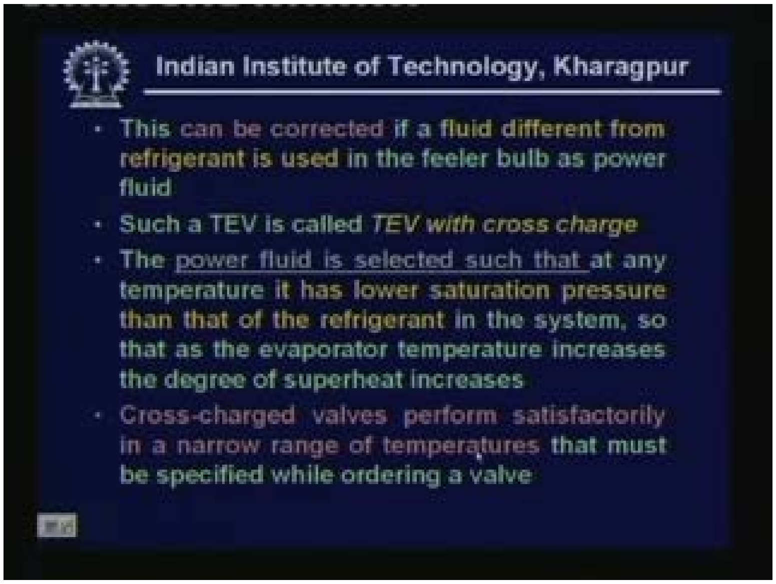

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- This can be corrected if a fluid different from refrigerant is used in the feeler bulb as power fluid
- Such a TEV is called *TEV with cross charge*
- The power fluid is selected such that at any temperature it has lower saturation pressure than that of the refrigerant in the system, so that as the evaporator temperature increases the degree of superheat increases
- Cross-charged valves perform satisfactorily in a narrow range of temperatures that must be specified while ordering a valve

So one alternative is to use a different fluid in the feeler bulb okay. That means the problem can be corrected if the fluid different from the different from the refrigerant is used in the feeler bulb as power fluid such a thermostatic expansion valve is called as thermostatic expansion valve with cross charge. The power fluid is selected such that at any temperature it has lower saturation pressure than that of the refrigerant in the system. So that as the evaporator temperature increases the degree of superheat increases.

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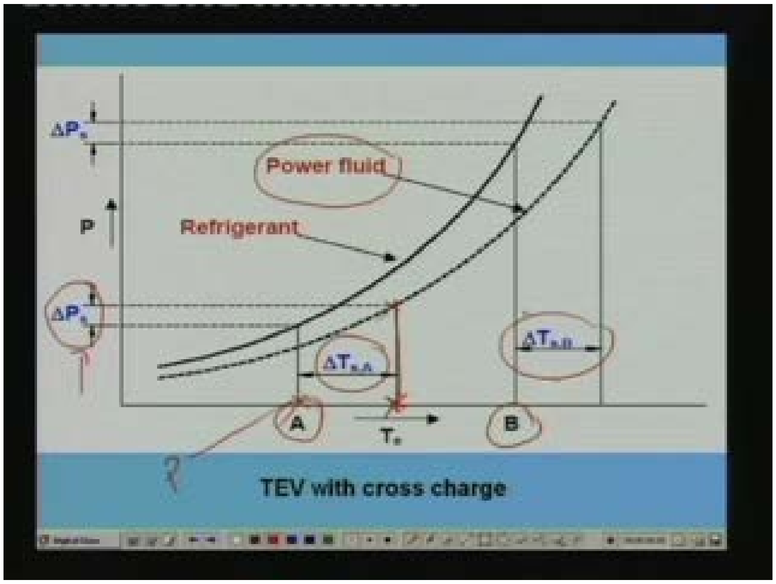

TEV with cross charge

That means we use a different fluid in okay. This again shows the saturation curve for example this is the saturation curve of the refrigerant okay. And this is the saturation curve of the, as you can see the power fluid right and you can see that at any temperature the power fluid has a lower saturation pressure corresponding to the refrigerant okay. So what is he advantage of this is like this. You can see that if you are operating the system at this evaporator temperature and if you have this if you have set the spring force such that the pressure difference is delta Ps then this is the degree of superheat okay.

And how do you get the degree of superheat you know this temperature. So you can find out this pressure okay. And you know this delta Ps. So you can find out this pressure and this temperature is obtained from the saturation temperature characteristics of the power fluid not the refrigerant okay. So if you know the characteristic then you can find out this temperature okay. So from that you can find out what is the degree of super heat. Now this is the degree of superheat at low evaporator temperature at high evaporator temperature. Also you find that the degree of superheat is much larger than when you used same fluid as the power fluid. That means, for example if the same fluid is used as the power fluid then this would have been the degree of superheat okay.

Because this is the delta Ps this could have been the delta Ts with the straight charge. That means the same fluid as that of as that of the refrigerant. But by using the crosses charge we could maintain a high degree of superheat even at higher evaporator temperatures okay. So that is the advantages using cross charge okay. So whenever you have the problem of operating the system over a wide evaporator temperature is normally used a crossed charged thermostatic expansion valve okay. Of course cross charged valves performs satisfactorily in a narrow range of temperatures. It does not mean that it will operate satisfactorily over any temperature range but it operates satisfactorily over a over a certain temperature range only okay. And when you are selecting the valve you must specify the range of operation okay.

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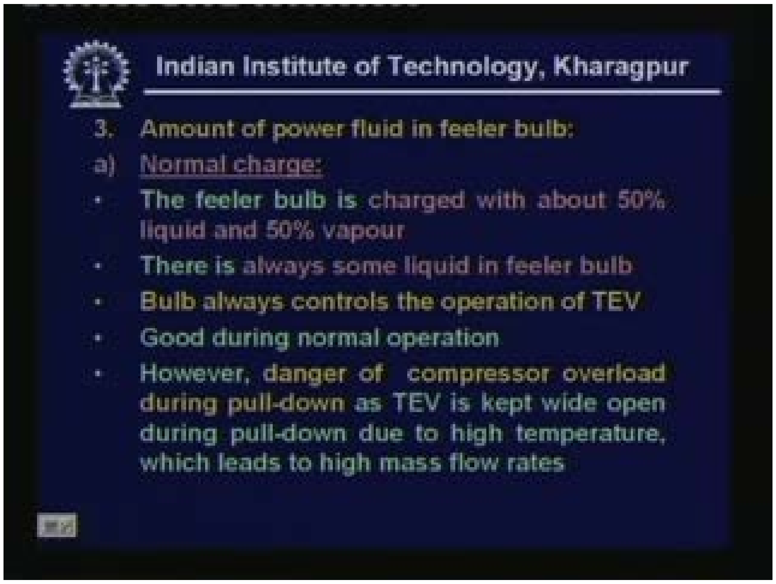

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3. Amount of power fluid in feeler bulb:

a) <u>Normal charge:</u>

- The feeler bulb is charged with about 50% liquid and 50% vapour
- There is always some liquid in feeler bulb
- Bulb always controls the operation of TEV
- Good during normal operation
- However, danger of compressor overload during pull-down as TEV is kept wide open during pull-down due to high temperature, which leads to high mass flow rates

Now the third variation third variation is possible depending upon the amount of power fluid present in the feeler bulb okay. So based on this you can have a thermostatic expansion valve with what is known as the normal charge. What do you mean by normal charge? Normal charge means the feeler bulb it charged with about fifty percent liquid and fifty percent vapour. So when you have this kind of a normal charge there is always some liquid in feeler bulb. And once there is some liquid in feeler bulb always, you will find that the bulb always controls the operation of thermostatic expansion valve and this kind of a thermostatic expansion valve is good during normal operation.

But you will find that when you are using the normal charge there is the possibility of compressor getting overloaded during pull down time okay. As the thermostatic expansion valve is kept wide open during pull own due to high temperature which will lead to high mass flow rates okay. So let me explain this i hope you remember the pull down characteristics of the compressor anyway let me just quickly draw it.

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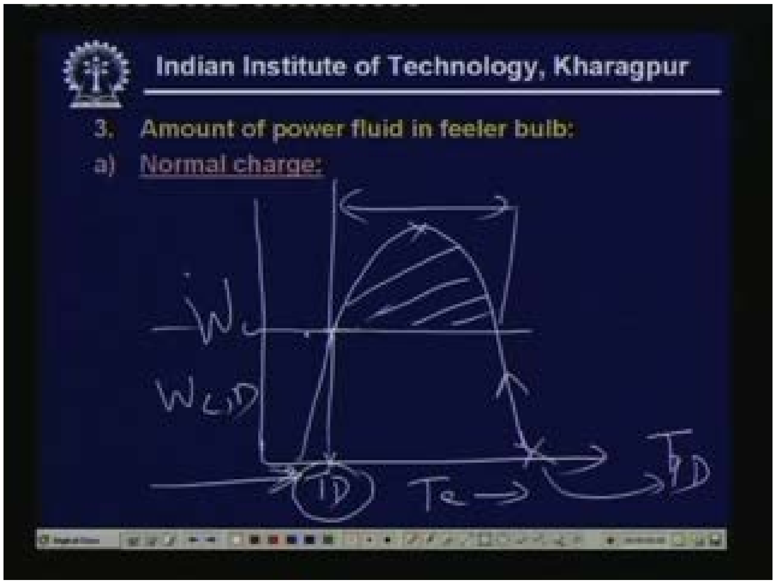

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3. Amount of power fluid in feeler bulb:

a) Normal charge:

We have seen while discussing the compressor characteristics. That you have this kind of a, let us say this is evaporator temperature variation. Then the compressor power okay, varies in this fashion right. And if you are starting the system at this point during the pull down normally system will be, temperature will be high and let us say that your designing temperature is somewhere here okay. This is your T design the, and this is your temperature at the beginning of the pull down right. So if you remember, if your operating the system like this the power requirement first increases sharply like this right and it reaches a peak then it comes down okay, and finally comes to the design point right.

That means you would, you find that, if you have, if you remember, if you have selected a motor which will operate satisfactorily at the design point. That means if your motor gives only this much power, design power then you find that during this portion the motor is overloaded right. So this is what is known as motor overloaded during the pull down time okay. This happens if you remember, because of the fact that during the pull down time the mass flow rate of the refrigerant will be very high. Because the compressor volume pressure ratio will be small. So it will operate at high volumetric efficiency and also that density of the refrigerant will be high okay. So initially the mass flow rate of refrigerant through the compressor will be very large even though the enthalpy difference across the compressor is small okay. Since the mass flow rate is very small, very high, the power requirement will be very high in the beginning okay. After some time as the pressure ratio increases the mass flow rate through the compressor reduces.

So the power requirement also reduces okay. That is how we get this kind of a curve right. So the power peak or the motor overload is taking place because of the higher mass flow rate okay. And when you are using a thermostatic expansion valve with normal charge the feeler bulb will always sense the temperature at the exit of the evaporator which will be very high during the pull down time. Since its temperature is high the pressure inside the feeler bulb will be very high. Once the pressure inside the feeler bulb is high the pressure acting on the bellows will be high. That means the bellows will be pushed down that means the needle will be pushed down there will be higher area available for refrigerant to flow.

So there will be higher flow rate okay since there is a higher mass flow rate they power requirement of the compressor also will be high okay. So if you are not designed the motor properly then there is a danger of motor getting overloaded right. So this is the problem with normal charge okay, otherwise normal charge is very good during normal operation.

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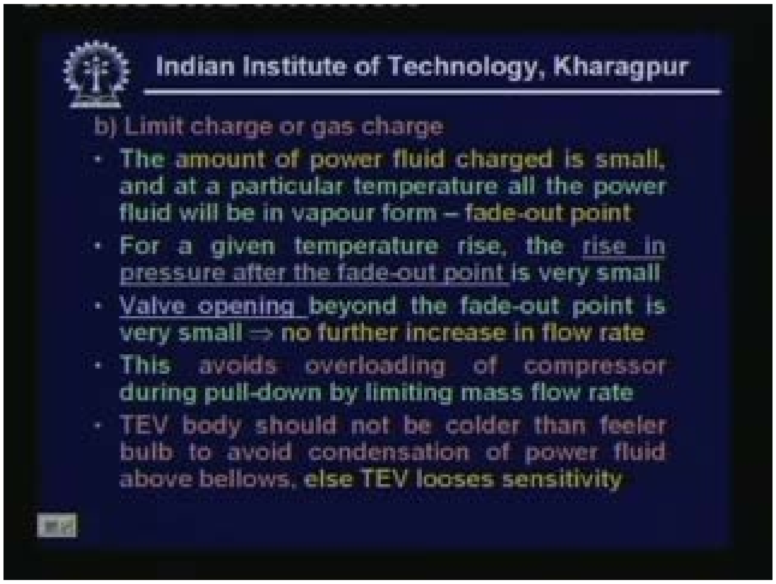

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b) Limit charge or gas charge

- The amount of power fluid charged is small, and at a particular temperature all the power fluid will be in vapour form – fade-out point
- For a given temperature rise, the rise in pressure after the fade-out point is very small
- Valve opening beyond the fade-out point is very small ⇒ no further increase in flow rate
- This avoids overloading of compressor during pull-down by limiting mass flow rate
- TEV body should not be colder than feeler bulb to avoid condensation of power fluid above bellows, else TEV looses sensitivity

So you have the second possibility that is what is known as limit charge or gas charge. So here the amount of power fluid charged is small and at a particular temperature all the power fluid will be in vapour form okay. This is known as fade out point and for a given temperature rise the rise in pressure after the fade out point is very small okay. So as I said let me explain this.

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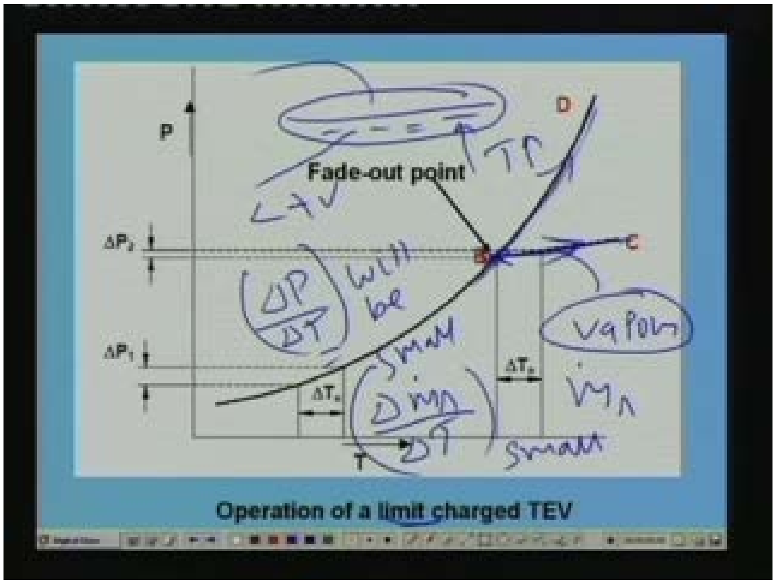

Operation of a limit charged TEV

Okay, so this system is for the limit charge system okay. So up to this point you have in the bulb let us say this is the feeler bulb okay. So you have liquid plus vapour so as the temperature increases here this liquid will evaporate right. And you have charge the liquid in such a manner that at this point all the liquid will evaporate right. Once all the liquid evaporates you have only vapour in the feeler bulb okay. That means at from this point onwards the pressure variation will not be along this saturation curve line but along this line okay. This line corresponds to the pressure rise because of the temperature rise only because of not because of evaporation or anything.

And you find that during this portion the rate of change of pressure with temperature is much smaller compared to this one okay. That means what that means from this point onwards your delta P by delta T will be small okay. This is small means what the needle opening will be small the needle opening will be small means mass flow rate of refrigerant does not vary much okay. That means from beyond this point onwards if you write let us say that delta mass flow rate divided by delta T let us say this will be small okay. Because from this point onwards you do not have any more liquid right okay. So beyond the fade out point no further increase in flow rate. So What is the advantage of this if there is no further increase in flow rate beyond this point the overloading of compressor can be avoided during pull down time okay.

So the advantage of using this limit charge valve or gas charge valve is that whenever the system operates during the pull down you find that will not open beyond a certain point okay. Whatever be the temperature right. That means the flow rate reaches a particular value and it will not increase beyond that point. That means you are restraining the power input or power requirement of the compressor. There by you can avoid the overload of the motor okay. However there is a, one problem with this that you have to take care that the thermostatic expansion valve body should not be colder than the feeler bulb to avoid condensation of power fluid above bellows. Otherwise the thermostatic expansion valve looses sensitivity.

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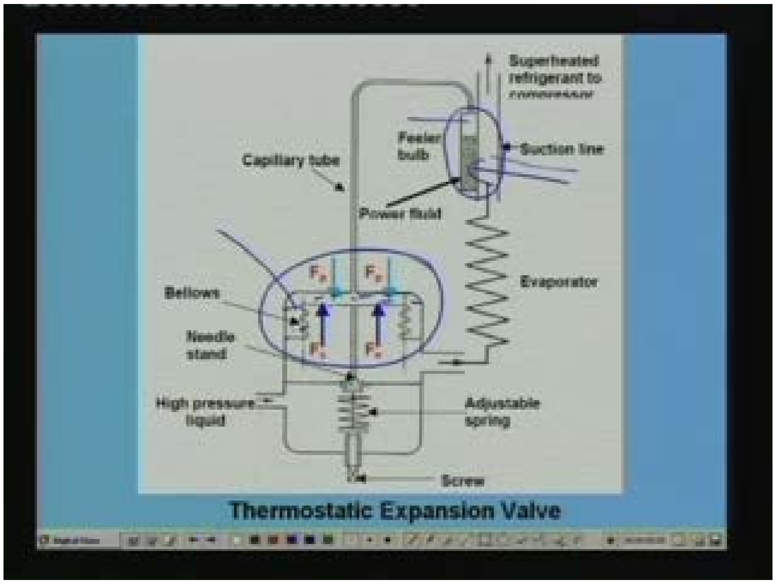

Thermostatic Expansion Valve

What does it mean is let us say that this portion is much colder than this portion okay. And when you have only vapour here then since this portion is colder all the vapour will come here and it will collect here in a liquid form okay. It will condense here once it condenses in liquid form here this will lose the sensitivity okay. So it will not respond properly to the suction line temperature okay. So this has to be avoided that means this portion can should not be colder than this portion.

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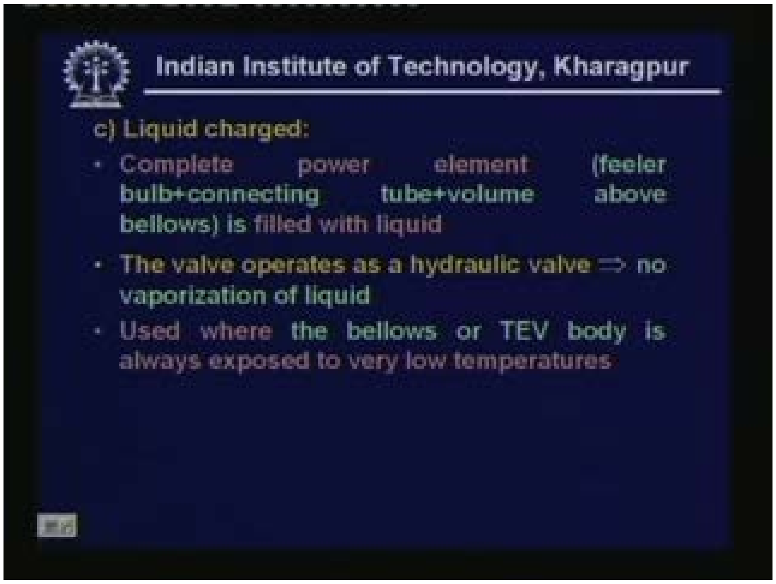

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c) Liquid charged:

- Complete power element (feeler bulb+connecting tube+volume above bellows) is filled with liquid
- The valve operates as a hydraulic valve ⇒ no vaporization of liquid
- Used where the bellows or TEV body is always exposed to very low temperatures

Okay, then you have finally, you have, what is known as the liquid charged liquid charge means here the complete power element. That means the feeler bulb plus connecting tube plus volume above the bellows is filled with liquid once you fill it with liquid the valve simply operates as a hydraulic valve and there is no vaporization of liquid. And when do you use this kind of valve. This kind of valve is rarely used but this is used used where the bellows or the thermostatic expansion valve body is always exposed to very low temperatures okay. So whenever you cannot avoid keeping it in a very low temperature environment. Then you can have you can go for liquid charged bodies where the problem of condensation will never arise because always you have only liquid right okay. So these are the various variations available with thermostatic expansion valves.

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Selection of TEV

- TEVs are normally selected from manufacturers' catalogs, based on application, refrigeration capacity and type of working fluid
- Design of TEV could be different to suit different requirements such as single evaporators, multi-evaporators etc.

Now let us look at selection of thermostatic expansion valve. Thermostatic expansion valves are normally selected from manufactures catalogs based on application refrigeration capacity and type of working fluid okay. So manufactures give catalogues to suit various applications and various loads etcetera. And the design of thermostatic expansion valves could be different to suit different requirements such as single evaporators multi evaporators etcetera.

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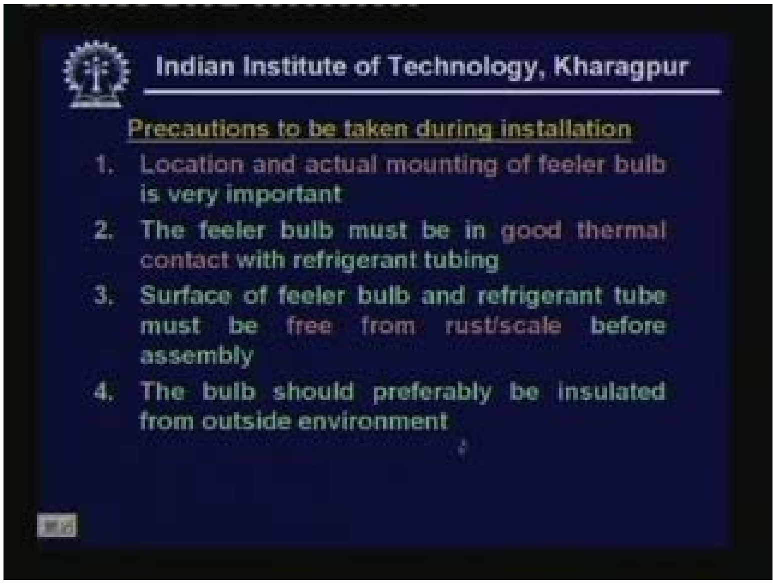

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Precautions to be taken during installation

1. Location and actual mounting of feeler bulb is very important
2. The feeler bulb must be in good thermal contact with refrigerant tubing
3. Surface of feeler bulb and refrigerant tube must be free from rust/scale before assembly
4. The bulb should preferably be insulated from outside environment

Now there are certain precautions you must observe while installing the thermostatic expansion valves what are the precautions location first is the location and actual mounting of feeler bulb. This is very important feeler bulb must be in good thermal contact with the refrigerant tubing. Let me give a small example while location is important for example let us say that this is your refrigerant tubing okay.

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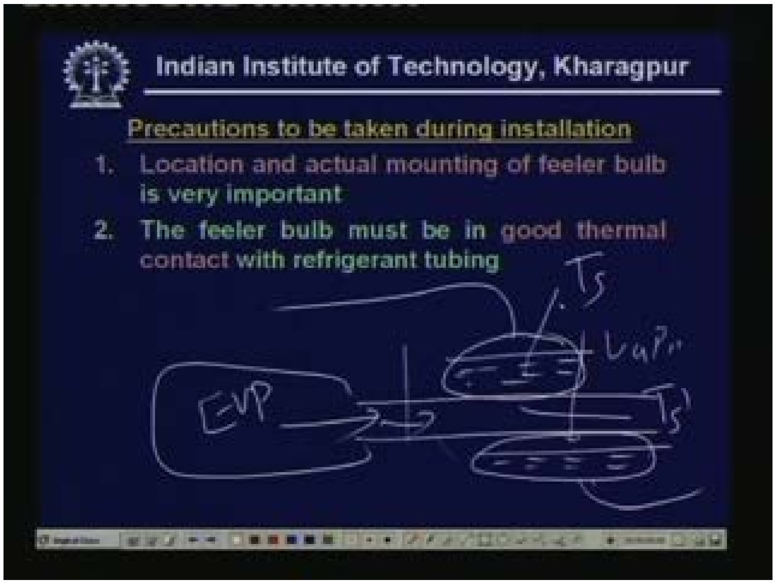

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Precautions to be taken during installation

1. Location and actual mounting of feeler bulb is very important
2. The feeler bulb must be in good thermal contact with refrigerant tubing

Here you have the evaporator okay, and refrigerant is flowing through here okay. If, and feeler bulb you must keep somewhere here in this portion right. Beyond this point, suppose your keeping the feeler bulb like this right. This is the wrong way of installing because if you are keeping the feeler bulb like this you find that the liquid is not in contact with the bulb okay. Liquid because the gravity will settle down and what is in contact with the tube is vapour okay. Once the vapour is contact in contact with the tubing it will not respond properly to load changes. So the valve will not be sensitive.

So what is the correct way the correct way is to keep the valve in this manner feeler bulb, in this manner. So that liquid will always remain in contact with the refrigerant tubing and it will respond properly to the load variations okay. That is what is the meaning of keeping the feeler bulb mounting the feeler bulb properly okay. And there must be some good thermal contact between this otherwise the temperature here will be different if there is no good thermal contact okay. So there must be perfect thermal contact between the bulb and the refrigerant tubing and surface of feeler bulb. And refrigerant tube must be free from rust scale before assembly okay, rust or scale will offer thermal resistant again the temperature difference will be more okay. So that must be avoided and the bulb should preferably be insulated from outside environment okay, for output sensitivity.

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Salient features of TEV

1. Provides excellent flow control
2. Evaporator operates efficiently ; starving and flooding is avoided
3. Ensures a minimum amount of superheat and thereby avoids slugging of compressor
4. Relatively expensive
5. Cannot be used in applications where a close approach between the fluid to be cooled and evaporator temperature is desired due to requirement of a minimum amount of superheat

And what are the salient features of thermostatic expansion valves. It provides excellent flow control evaporator operates efficiently because we have seen that you can control the superheat properly. That means you can avoid both starving as well as flooding of evaporator and this valve ensures a minimum amount of superheat. And thereby it avoids slugging of compressor of course provided you select the thermostatic expansion valves suitably okay. However there are certain disadvantages. Disadvantages are these valves. A valve is relatively expensive compared to other types of valves.

And this valve cannot be used in applications where a close approach between the fluid to be cooled and evaporator temperature is desired due to requirement of a minimum amount of superheat. That means when you want the external fluid the temperature to be very close to the refrigerant temperature. Then you cannot use this kind of valve because this kind of valve will always maintain a certain amount of superheat okay. So generally you cannot use this of course one possible solution is to have a perfect counter flow type of evaporator okay. Where you can have close approach at you can use thermostatic expansion valve okay.

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Float valves

- Float valves are normally used in large systems with flooded evaporators
- The valve opens or closes depending upon the liquid level as sensed by a buoyant member, the float (a hollow metal ball, hollow cylinder or a pan)
- The float valve always maintains a constant liquid level in the float chamber

The float chamber may be placed on the low pressure side (low side float valve) or on the high pressure side (high side float valve)

Now let me quickly explain the float valve float valves are normally used in large systems with flooded evaporators. The valve opens or closes depending upon the liquid level as sensed by a buoyant member the buoyant member is called as the float and this float can be a hollow metal ball or a hollow cylinder or a pan. This float valve you must have seen normally we use it. So this kind of a float valve in our water tanks and all okay. To prevent the overflow of water in overhead water tanks okay. The refrigerant float valve is also somewhat similar in operation right. And a float valve always maintains a constant liquid level in a chamber called as the float chamber. The float chamber may be placed on the low pressure side. Then you can call it as a low side float valve or on the high pressure side in which you case you call it as a high side float valve.

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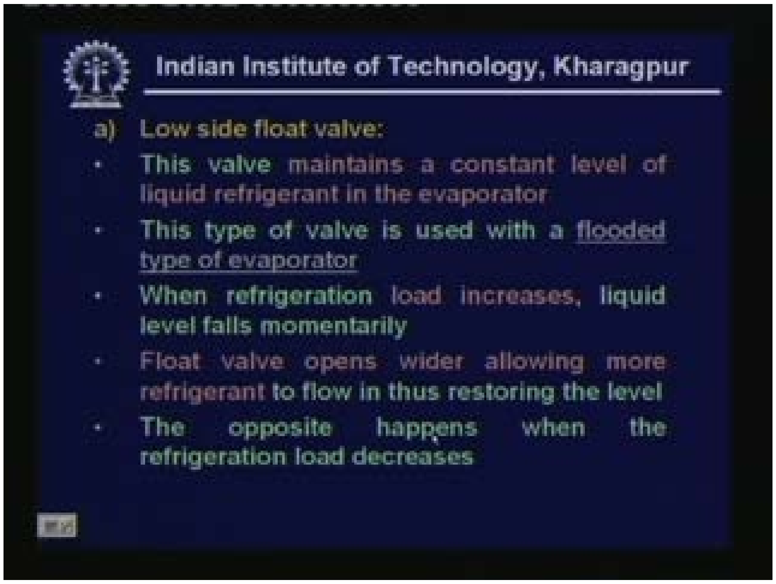

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a) Low side float valve:

- This valve maintains a constant level of liquid refrigerant in the evaporator
- This type of valve is used with a flooded type of evaporator
- When refrigeration load increases, liquid level falls momentarily
- Float valve opens wider allowing more refrigerant to flow in thus restoring the level
- The opposite happens when the refrigeration load decreases

Now let us look at low side float valve. The low side float valve maintains a constant level of liquid refrigerant in the evaporator this type of valve is used with a flooded type of evaporator.

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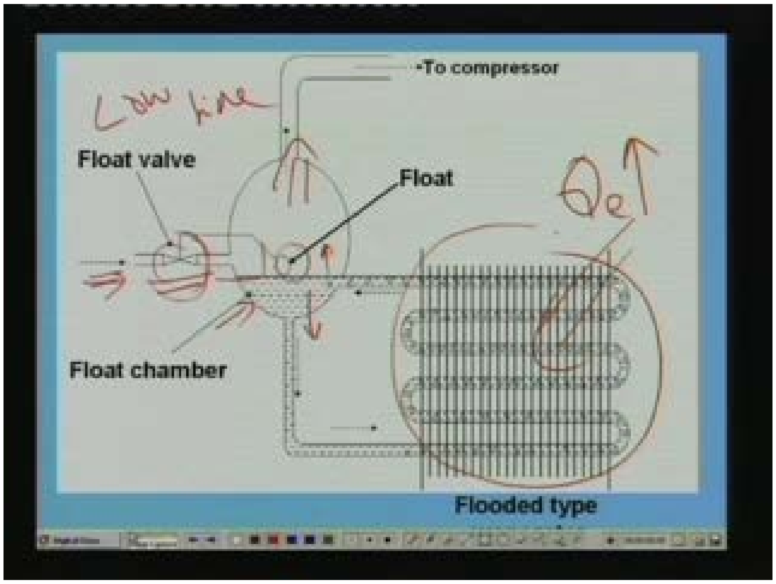

If you remember I have discussed. This while discussing flooded type of evaporators, this is the low side low side float valve okay. So this your float chamber and this is the flooded type evaporator okay. And this is your float right so you can see that this is the flooded type of evaporator and this float valve will always maintain this liquid level okay. What happens when the liquid level drops? First of all when this liquid level drops, when the load and the evaporator increases let us say that load and the evaporator is increasing when the load and the evaporator increases this evaporation rate increases. So higher mass will leave the float chamber higher mass leaves the float chamber means this level will drop when this level drops that is sensed by, this float and this will open the float valve wider okay. There will be wider opening of the float valve when the float valve is open wider more refrigerant will flow into the float chamber and the level is restored okay. And the reverse happens, when the load falls and the level rises momentarily. Then this float will move up once the float moves up this valve will be closed. Once this valve is closed, not fully, but the opening becomes narrow. Once the opening becomes narrow less refrigerant enters into the float chamber again the level is restored okay. So this, what I have explained when refrigerant load increases liquid level falls momentarily. Float valve opens wider allowing more refrigerant to flow thus restoring the level the opposite happens when the refrigeration load increases decreases.

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b) High side float valves:

- Maintains a constant liquid level in high side float chamber placed at the exit of condenser
- When refrigeration load increases, more vapour is generated in evaporator
- Condensation in the condenser increases, which increases level of liquid in float chamber
- Valve opens more to allow more liquid into evaporator
- Reverse happens when load falls

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So the high side float valves this maintains the constant liquid level in the high side float chamber okay. This is placed at the exit of condenser.

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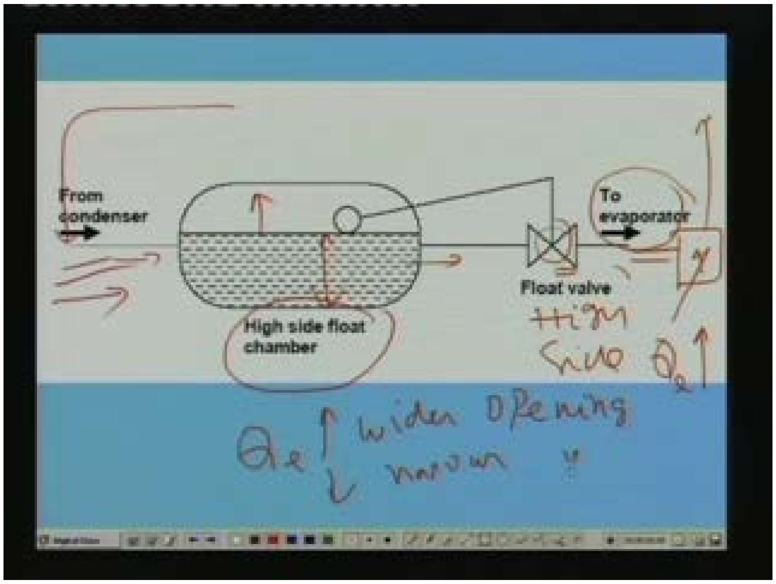

That means you have a high side float chamber. This is placed between the condenser and the evaporator okay. So this is the high side float valve right. So refrigerant enters from the condenser it first comes to the high side float valve. Then it flows to through this float chamber then it flows through the float valve and through the float valve it enters into the evaporator okay. Now let me quickly explain and this float valve will always maintain this level. What happens okay, when the load increases or reduces let us say that you have the evaporator here okay. And load on the evaporator increases when load and the evaporator increases more refrigerant will boil. Once a more refrigerant boils more refrigerant will condense here. That means more refrigerant will flow into the high side float chamber. That means the level will increase here. Once the level increases this float wall is such that it will open more okay. That means when the level increases opening will be wider once the opening is wider more liquid will flow through the valve into the evaporator okay.

That means when Qe increases wider opening okay. Wider opening means higher flow rate. And similarly when Qe reduces there will be narrower opening right. So that is how the level is controlled and thereby the load is taken care of okay. So this is the principle of high side float valve. You can see that both low side float valve as well as high side float valve responds a to the load in a proper manner. That means when the load increases they supply more mass flow rate and when the load reduces they supply less mass flow rate normally the float valve. As I have already mentioned is used along with flooded type of evaporators. And flooded type of evaporators are very efficient because of high heat transfer rates and all. So they are mainly used in large refrigeration systems.

So you find that in large refrigeration systems the expansion device used is normally the float type of expansion device okay. Okay, I have already explained this when refrigerant load increases more vapour is generated. In evaporator condensation the condenser increases which increase the level of liquid in float chamber valve opens more to allow more liquid into evaporator. But unlike low side float valve the high side float valve can be used with both dry as well as flooded type of evaporators.

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Electronic expansion valves

- A thermistor senses the presence or absence of liquid refrigerant at the exit of evaporator
- If liquid is present (during reduced load condition), then thermistor temperature decreases and its resistance increases
- The current through the heater, which is in series with thermistor decreases and the valve opening becomes narrower
- Due to the narrow opening, mass flow rate of refrigerant decreases

Now let me quickly explain another type of expansion valve. This is known as electronic expansion valve. This electronic expansion valve consist of a thermistor which senses the presence or absence of liquid refrigerant at the exit of evaporator. First of all what is the thermistor unlike a resistor I am sure that you know that for a thermistor. As a temperature increases resistance decreases okay. So this is the principle of thermistor right. So this electronic expansion valve uses the thermistor. And this thermistor senses the presence or absence of liquid refrigerant at the exit of evaporator if liquid is present when liquid is present during reduced load condition all the refrigerant may not evaporate. So there could be some liquid at the exit of the evaporator when liquid is present then thermistor temperature decreases and its resistance increases okay.

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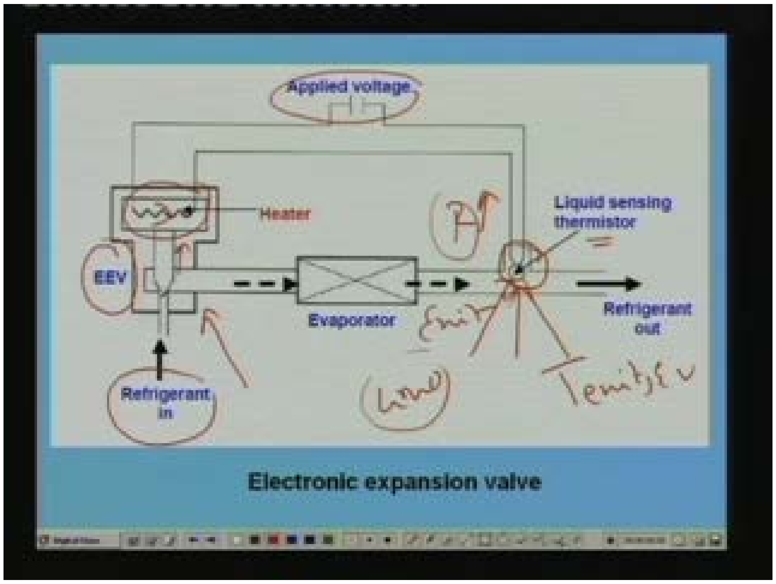

So let me show the picture now it will be clear. So as I told you have the, this is the body of the electronic expansion valve. And it consist of a heater which is in series with the thermistor and this thermistor is located at the exit of the evaporator. You can see that, so this senses the exit temperature of the evaporator okay. And as I said when there is liquid here okay, once liquid is there there will be good heat transfer here. And the thermistor temperature will be low. When the thermistor temperature is low its resistance increases and when you are applying a fixed voltage across the circuit you will find that since this resistance is increasing the current reduces okay. And since the heater is in series with the thermistor the current through this heater reduces okay. Once the current reduces the heating output reduces. Once the heating output reduces this will move up the needle moves up and there will be less refrigerant flow through the electronic expansion valve.

Once the less refrigerant flows through the expansion valve at a balance point the liquid vanishes. Again this temperature increases. Then the resistance again reduces there will be higher current there will be wider opening okay. So that is the principle of electronic expansion valve. So you can see that it has a heater a thermistor and you have to apply a fixed voltage okay.

So as I said that the current through the heater which is in series with thermistor decreases. When the load increases and the valve opening becomes narrower. I am sorry when the load decreases the valve becomes narrower and due to the narrow opening mass flow rate of refrigerant decreases okay, and reverse happens when there is no liquid.

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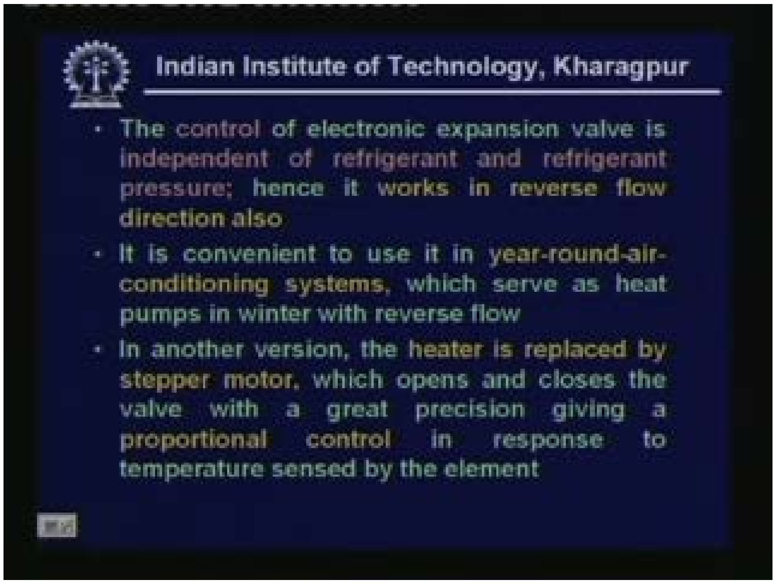

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- The control of electronic expansion valve is independent of refrigerant and refrigerant pressure; hence it works in reverse flow direction also
- It is convenient to use it in year-round-air-conditioning systems, which serve as heat pumps in winter with reverse flow
- In another version, the heater is replaced by stepper motor, which opens and closes the valve with a great precision giving a proportional control in response to temperature sensed by the element

The control of electronic expansion valve is independent of refrigerant and refrigerant pressure. Because the unlike other expansion valve this is the specialty of this type of expansion valve it does not depend on the type of refrigerant used and the refrigerant pressure okay. So it can a work in reverse direction also. As a, result this kind of valves are, can be used in year-round-air conditioning system. Which work has air conditioners in summer and as heat pumps in winter okay. When it is working as heat pump in winter you have to reverse the refrigerant flow direction okay.

So that is possible when you are using electronic expansion valve. And in another version the heater is replaced by a stepper motor which opens and closes the valve with a great precision giving a proportional control in response to temperature sensed by the element okay. That means in more modern versions you can replace the heater by a stepper motor and this stepper motor operation is controlled by the thermistor okay. So you can have a modulating control okay. Or you can have a proportional controls you can very finely control the refrigerant flow rate. Of course electronic expansion valve compared to other types of valves are quite costly okay. And they are not really very widely used because of this reason.

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Expansion devices : General rules

1. The valve capacity should neither be too large nor too small
   - A large valve will lead to:
     - overfeeding of refrigerant causing flooding,
     - hunting
   - A small valve results in:
     - Insufficient capacity
     - Balance point at low evaporator temperature

Now let me quickly look at some general rules to be observed while selecting and installing expansion devices. The valve capacity should be neither too large nor too small. When the capacity is too large that means you have selected a very large valve you will find that the valve will over feed refrigerant. And this may cause flooding and slugging and this may also result in hunting hunting means frequent closing and opening okay. These are the problems with large valve. And what are the problems with small valve if you select a small valve. This will result in insufficient capacity. That means starving of evaporator and balance point at low evaporator temperature okay. So you have to select the right valve depending upon your refrigeration capacity.

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2. Operation during winter

- Since condenser pressure is low, the pressure difference across expansion valve will be low, hence, balance point occurs at lower evaporator temperature
- This decreases efficiency of the system
- To prevent this, some times the condenser pressure is kept artificially high during winter months
- Thus the advantage of low condenser temperature is lost

And the second point is operation during winter. Since condenser pressure is low during winter the pressure difference across expansion valve will be low okay. Hence balance point occurs at lower evaporator temperature. Remember that for an expansion device other than your electronic expansion device the flow rate is proportional to flow area and also the pressure difference between the condenser and the evaporator. So during the winter condenser pressure will be low because the heat rejection temperature will be low. So condenser pressure reduces. Once condenser pressure reduces your pressure difference across the expansion device reduces. Once the pressure difference across the expansion device is reduces mass flow rate reduces. So the balance point will be established at a at a lower evaporator temperature. So that again the Pc minus Pe that is the pressure difference across the valve is sufficient okay. So you will find that in winter the expansion valve will be operating at lower condenser temperature and also lower evaporator temperature.

And you know that operating at lower evaporator temperature is not efficient. Because this will lead to poor COP etcetera okay. So this is one of the problems with this kind of expansion devices. So this decreases the efficiency of the system to prevent this sometimes the condenser pressure is kept artificially high during winter months okay. So you will actually lose the advantage of operating the condenser at lower condenser temperatures because of this limitation of the expansion devices okay.

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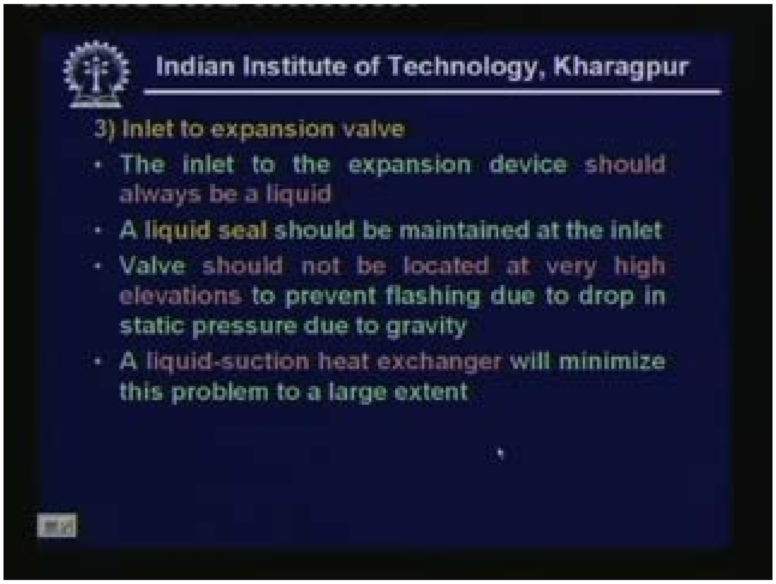

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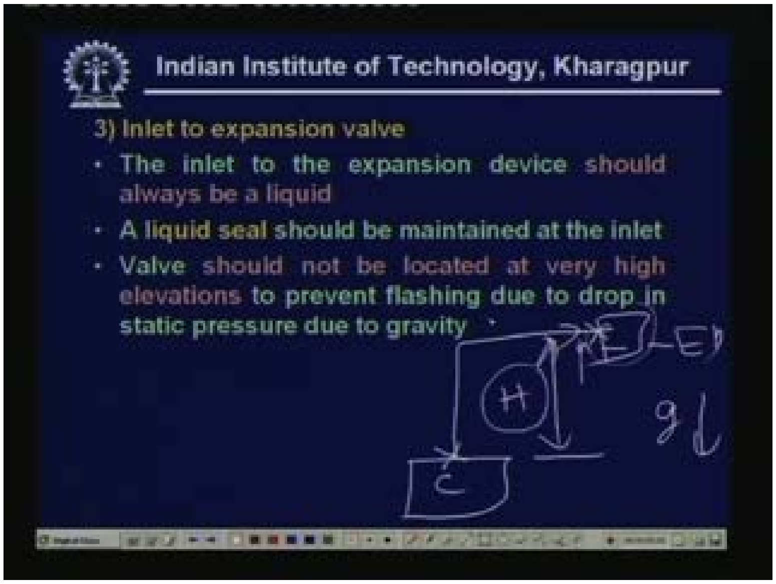
3) Inlet to expansion valve

- The inlet to the expansion device should always be a liquid
- A liquid seal should be maintained at the inlet
- Valve should not be located at very high elevations to prevent flashing due to drop in static pressure due to gravity
- A liquid-suction heat exchanger will minimize this problem to a large extent

And the third point is inlet to expansion valve should always be liquid. That means you must always feed liquid refrigerant to the expansion device. So to ensure this you must have a liquid seal at the inlet to the expansion device and valve should not be located at very high elevations to prevent flashing due to drop in static pressure due to gravity okay. (Refer Slide Time 00:59:03 min)



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3) Inlet to expansion valve

- The inlet to the expansion device should always be a liquid
- A liquid seal should be maintained at the inlet
- Valve should not be located at very high elevations to prevent flashing due to drop in static pressure due to gravity

That means when you have the condenser here let us say that your condenser is here. And if you are keeping the valve here okay. Acceleration due to gravity is like this and this is your expansion device this is the condenser then the refrigerant has to flow from this point to this point okay. So there is a large height okay. So the pressure at this point will be less than the pressure at this point due to the static height okay. And if this pressure difference is too small too large then during the flow from this point to this point some flashing may occur and some vapour may enter into the expansion device okay. So this has to be avoided okay. It at not very high elevations and liquid suction heat exchanger also will minimize this problem to a large extent okay. So these are the practical problems and practical points to be considered while using and installing the expansion devices.

Thank you.