Refrigeration and Air Conditioning

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Lecture No. # 23

Refrigeration System Components: Compressor (Contd.)

Welcome back in the last three lectures. We discussed reciprocating compressors as you know reciprocating compressors is one of the positive displacement type of compressors okay. In this lecture I shall discuss other positive displacement type of compressors. We will not go into the detail. But I will briefly explain the working principle of these compressors and their typical performance characteristics.

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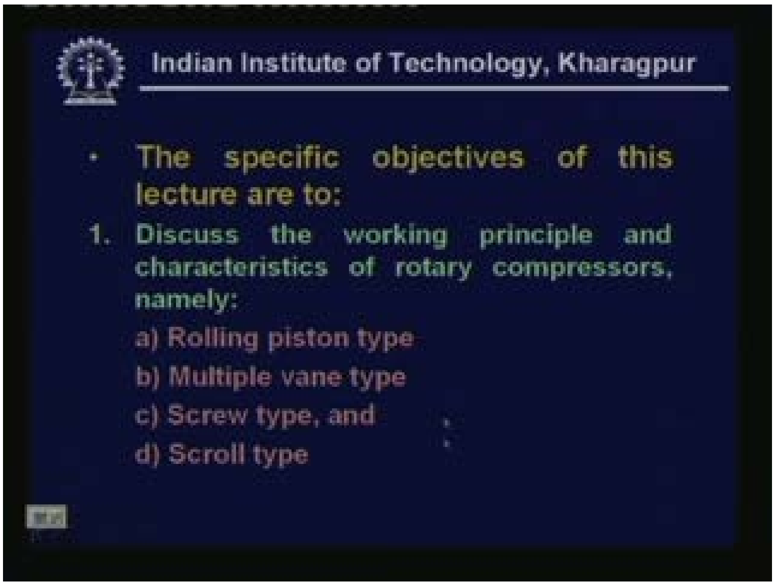

So the specific objectives of this particular lecture are to discuss the working principle and characteristics of rotary compressors namely rolling piston type multiple vane type screw type and scroll type.

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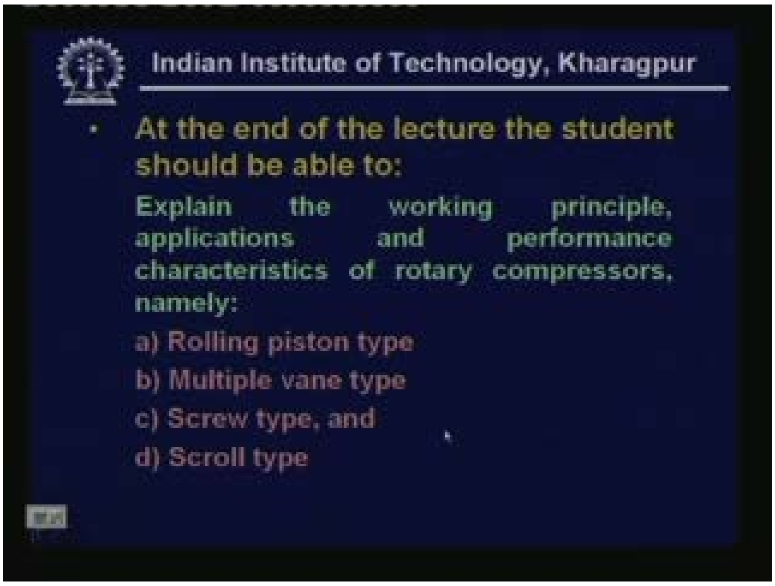

At the end of the lecture you should be able to explain the working principle applications and performance characteristics of rotary compressors namely. As I have already mentioned rolling piston type compressors multiple vane type compressors screw type and scroll type compressors.

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So let us begin with the first type of compressor. That is rolling piston type compressor rolling piston type compressors is also known as fixed vane type compressor they belong to the class of positive displacement type as compression is achieved by reducing the volume of the refrigerant. These compressors are used in small refrigeration systems. That means up to two kilowatt of refrigeration capacity and they are mainly used in domestic refrigerators or small air conditioners.

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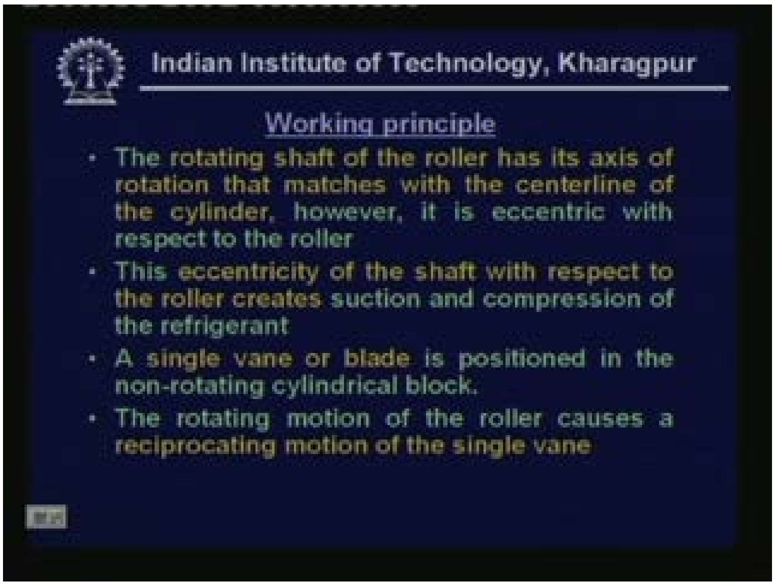

Now let us look at the working principle. Let me describe the working principle. First then I will show you the figure. In these compressors the rotating shaft of the roller has its axis of rotation that matches with the centerline of the cylinder however it is eccentric with respect to the roller. This eccentricity of the shaft with respect to the roller creates suction and compression of the refrigerant a single vane or blade is positioned in the non rotating cylindrical block. The rotating motion of the roller causes a reciprocating motion of the single vane okay.

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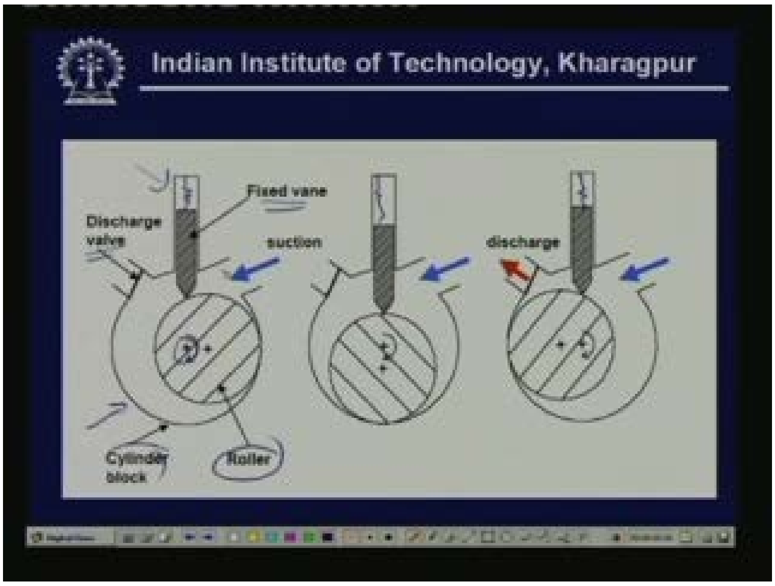

Now let me show you the picture of it and explain. So as I have already described this what compressor consist of a cylinder block this is the cylinder block and a roller okay. Now the axis of rotation the, this is the point the axis of rotation is eccentric with respect to the roller however it coincides with the centerline of the cylinder block okay. So that is the main principle behind the operation of this particular type of the compressor okay. The eccentricity between the axis of rotation and the centerline of the roller okay. And this cylinder block consist of as lot in which a fixed vane is mounted and normally this fixed vane is spring loaded okay. So you have a spring loaded fixed vane and as you can see that this type of compressor does not require a suction valve. So you do not have any valve on the suction side. But it uses a discharge valve. So you can see that the discharge valve but no suction valve. Now let me explain the working principle of this compressor.

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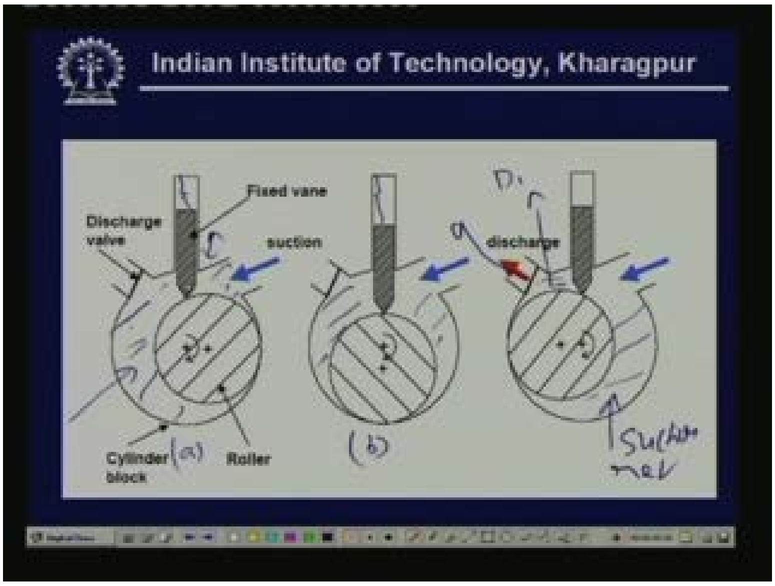

Let us begin at this point a. Let us say okay. Now the roller is at this position and this side you have refrigerant and this side also you have refrigerant. As the roller rotates in this direction the gas on this side it gets compressed and on this side you have a suction. So that is what is seen here in picture b okay. This gas is getting compressed because its volume is getting reduced at the same time on this side suction is taking place. Because its volume is increasing okay, further rotation of this compressor will compress the refrigerant such an extent that this pressure will exceed the condensing pressure discharge valve opens and the refrigerant goes out of the discharge valve okay. So again here you can see that you have the suction refrigerant and here you have the discharge okay. And as this roller is rotating this fixed vane will be reciprocating in this direction okay. And as I said you have a spring loaded fixed vane. So this spring loaded vane will always remain in contact with the roller. So that the point of sealing is obtained between the high pressure side and low pressure side okay. So this is the working principle and it is a very simple type of a compressor.

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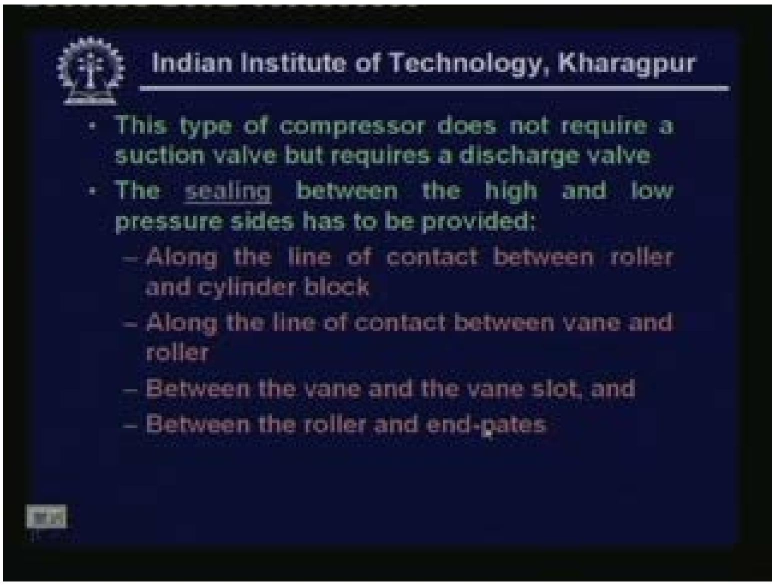

And as I have already explained this type of compressor does not require a suction valve. But it requires a discharge valve and the sealing between the high and low pressure sides has to be provided along the line of contact between roller. And cylinder block along the line of contact between vane and roller between the vane and the vane slot and between the roller and end plates. So let me explain this once again.

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So you have, as I have explained. For example if you look at this figure you have the high pressure refrigerant on this side and low pressure refrigerant on this side. And there are different leakage paths. What are the leakage paths for example refrigerant can leak like this that means this is one of the leakage pass okay. And again refrigerant and leak this way. So this is another leakage path. And refrigerant can also leak in this manner okay. That means between the gap, gap between the slot and the vane okay. And it can also leak from the end plates that means perpendicular to the screen okay. So these are the four leakage paths through which the high pressure refrigerant can leak back to the low pressure side. So you require sealing at all these four points okay.

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So the leakage is controlled through hydrodynamic sealing and matching between the mating component. That means what is done is layer of lubricating oil fills up this gaps between the roller and the cylinder block between the vane and the roller and between the slot and the vane and between the end plate and the roller okay. So this provides lubrication at the same time it also seals the gaps. As a result the leakage from the high pressure side to the low pressure side is minimized. Of course this is not enough you also have to manufacture them very accurately. So that the tolerance is very small that means the gap between these component or between these meeting components very small of the level of micro organism okay. So this is one of the important requirements okay. And as I said the effectiveness of the sealing depends on the clearance compressor speed surface finish and oil viscosity close tolerances and good surface finishing are required to minimize internal leakage. Hence manufacturing of the compressors is difficult compared to reciprocating type compressors.

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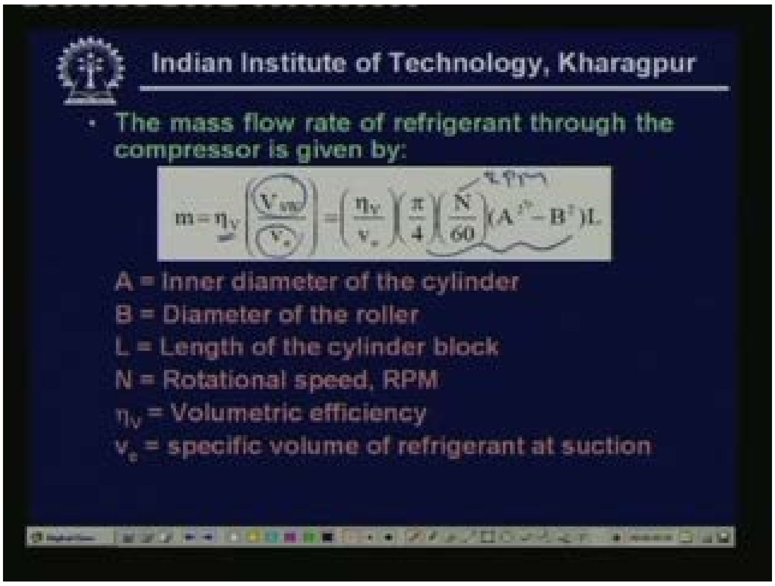

The mass flow rate of refrigerant through the compressor is given by, as you know the mass flow rate is equal to volumetric efficiency into displacement rate of the compressor divided by the specific volume of the refrigerant at compressor inlet that is what is shown in this equation. So this is your displacement rate and this is the specific volume at the compressor inlet and this is the volumetric efficiency now the displacement rate is nothing but this okay. Where N as you can see is the rotational speed in RPM. This is the RPM and A is nothing but the inner diameter of the cylinder B is the diameter of the roller and L is the length of the cylinder block okay. And so pi by four into A square minus B square L is the volume between the cylinder block and the roller okay. If you multiply that into the rotational speed that will give you the displacement rate and the actual mass flow rate is nothing but the displacement rate into the volumetric efficiency divided by the specific volume okay. That is what is shown in this equation.

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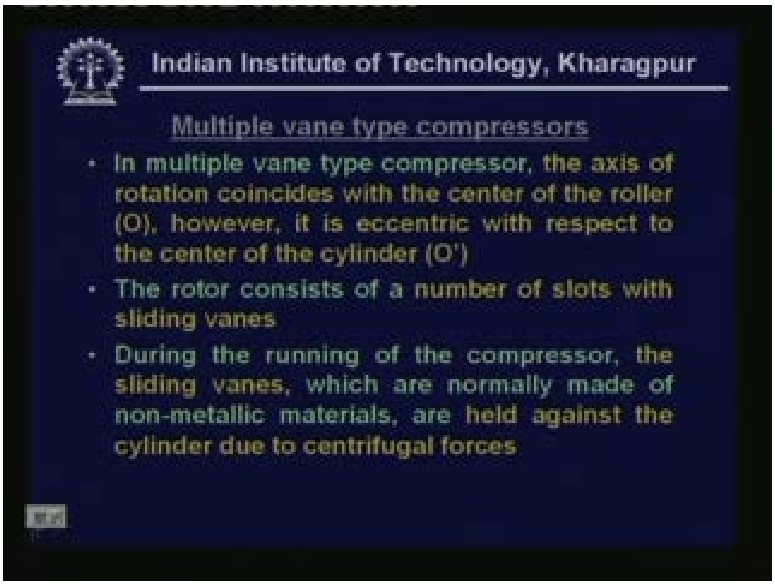

Now let us look at other type of positive displacement type of compressor that is multiple vane type compressor. Let me describe this compressor first in multiple vane type compressor the axis of rotation coincides with the center of the roller. However it is eccentric with respect to the center of the cylinder okay. So there is a difference between this type of compressor and the fixed vane type of compressor the rotor consists of a number of slots with sliding vanes. During the running of the compressor the sliding vanes which are normally made of non metallic materials are held against the cylinder due to centrifugal forces this is very important to remember.

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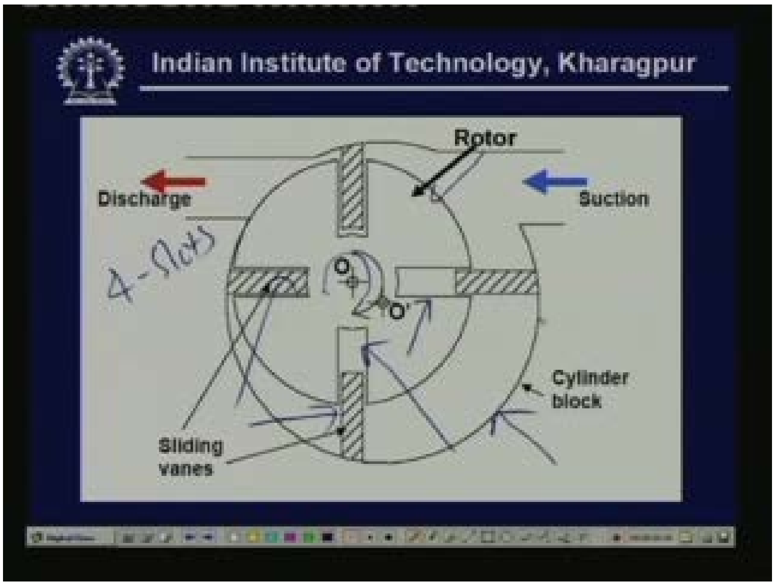

Now let me explain the working principle here. So again you have a rotor here this is the rotor and you have the cylinder block okay. And this rotor has a number of slots okay. These are the slots of the rotor this one this one okay. So in this particular figure I have shown four slots and each slot consist of a sliding vane okay. So this is the sliding vane this one sliding vane this sliding vane. So four slots means there are four sliding vanes and one thing, one important thing to notice here is this is the axis of rotation that is point O. So axis of rotation coincides with the center line of the rotor okay. That means the shaft rotating shaft and the rotor are coincidental okay. But this center of rotor is eccentric with respect to the center of the cylinder okay.

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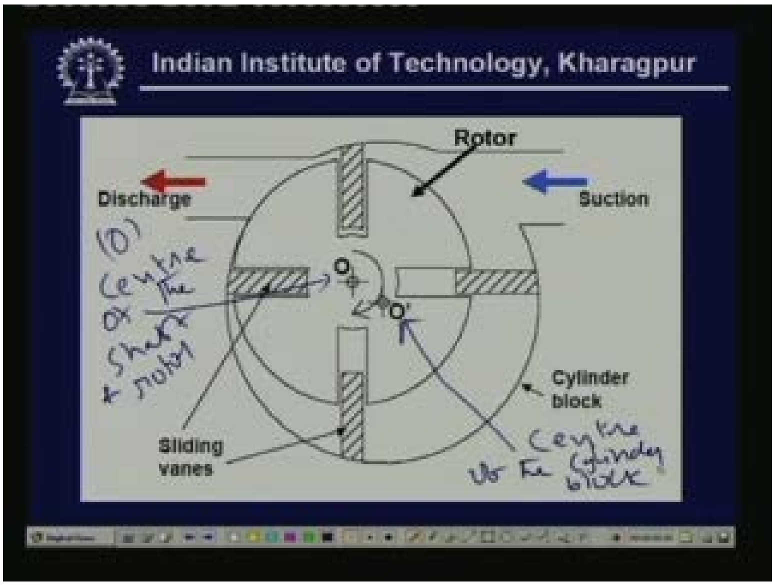

That means as I said this O is the centre of the shaft and rotor this is O and O dash is your centre of the cylinder block okay.

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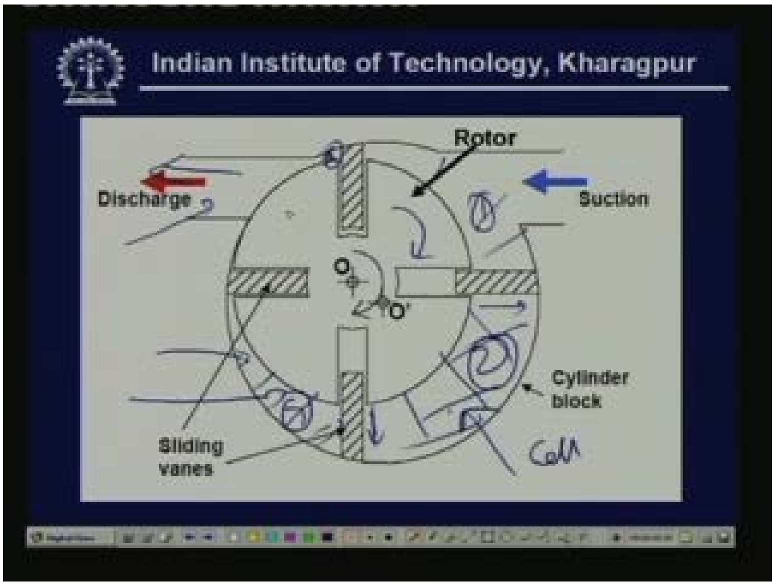

Now as let me explain the working principle there is an eccentricity between the axis of rotation and the cylinder block. So when the rotor rotates like this these vanes they will be slung out outwards. That means there will be slung outwards because of the centrifugal action. As a result these vanes will be pressing against the cylinder block.

Now all this space is filled with refrigerant okay. And this volume is varies as the rotor rotates. For example you look at this cell okay. Now this cell has this much volume okay this is the volume of the refrigerant in this particular cell. So as the rotor rotates and when this cell comes to this position its volume is reduced. That means its pressure will increase and with further rotation its volume is reduced further and its pressure increases further and at some point this compressed gas will be open to this discharge port okay.

When this is open to this discharge port it is designed in such a way that at the design point. This pressure will be equal to the condensing pressure or it will be slightly higher than the condensing pressure. So that the compressed gas will leave from the discharge port okay. And you can see that any point of time you have for example if you are using four sliding vanes you have four cells which are filled with the okay. So this is one, this is two, this is three and here is one four cells these four cells are filled with four refrigerant. And continuously the volume will be compressed and suction will be taking place continuously and compression will be taking place continuously okay. And you can also see that it does not have either suction port or discharge port.

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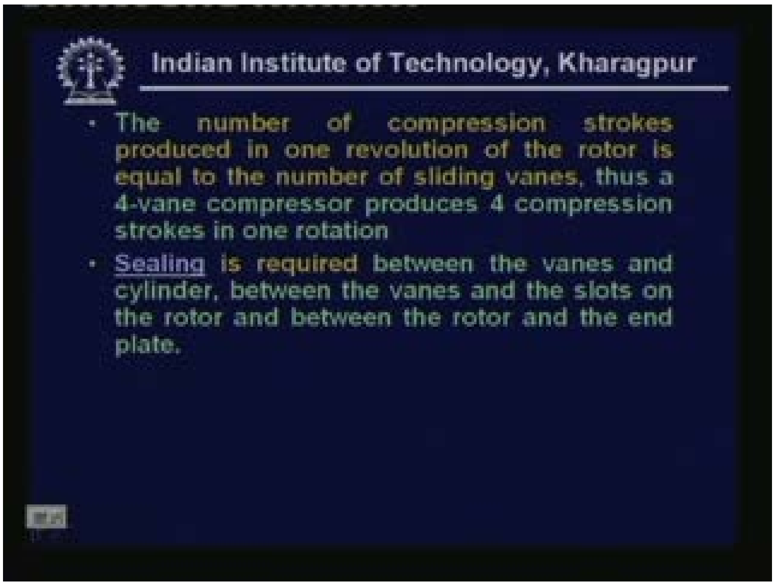

So number of compression strokes produced in one revolution of the rotor is equal to the number of sliding vanes thus a four vane compressor produces four compression strokes in one rotation. Of course it is not necessary that you have to have four vanes only you can also have different number of vanes. For example you can have two vanes or you can also have six vanes or four vanes like that normally four vanes or six vanes or more common okay. If you have four vanes they will be four cells and if you have six vanes there will be six cells okay. And again just like your fixed vane compressor sealing is required between the vanes and cylinder between the vanes and the slots on the rotor and between the rotor and the end plate okay. Let me show this on the figure.

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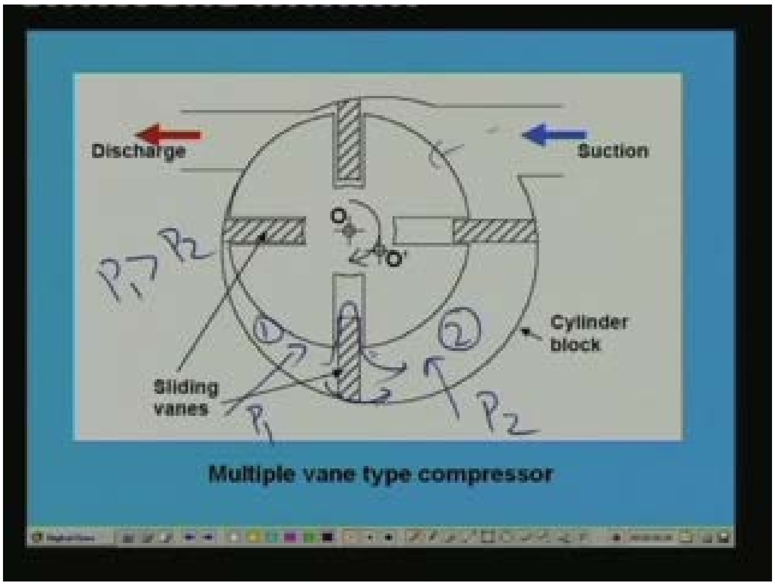

If you look at the, this figure. For example in this cell let us say that this is cell one okay. Here the pressure is P one and this is cell two and here the pressure is P two okay. So at this point of time P one will be greater than P two. So there is a pressure difference between this cell and this cell. So there will be a if there is a gap then that the refrigerant in cell one will try to flow back to the cell two okay. So what are the leakage paths here for example it can the leakage can take place like this okay. That means if there is a gap between the sliding vanes and the slot leakage can take place and the leakage can also take place like this if there is a gap between the vane and the cylinder block and leakage can also take place perpendicularly. If there is a gap between the, this roller and the end plate okay. So these are the three leakage paths through which the high pressure gas can leak back into low pressure side.

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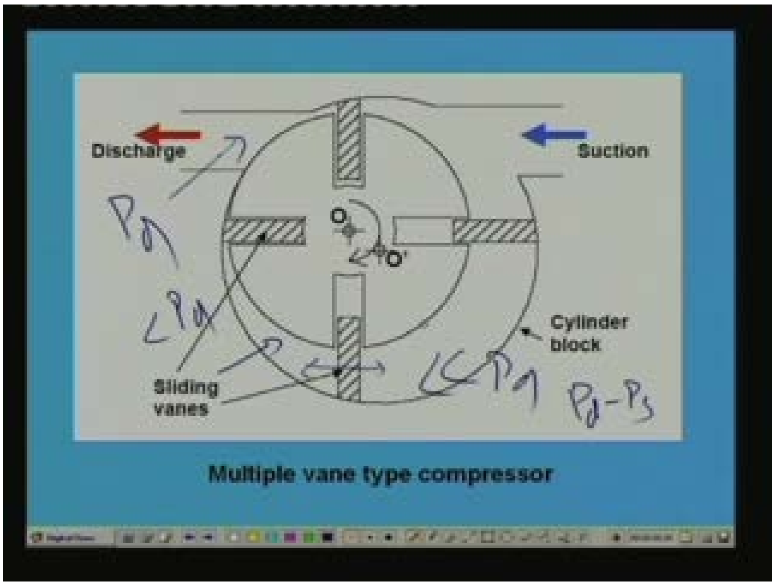

But unlike fixed vane compressor here the pressure difference available for leakage is less. For example, let us say that at this point only the pressure is P discharge okay. So here the pressure will be less that P discharge and here it will be further less than P discharge okay. So the pressure difference between any two adjacent cells in much less than P discharge minus P suction okay. That means the leakage rate also will be less. So the sealing is not as critical as the, that in fixed vane compressors.

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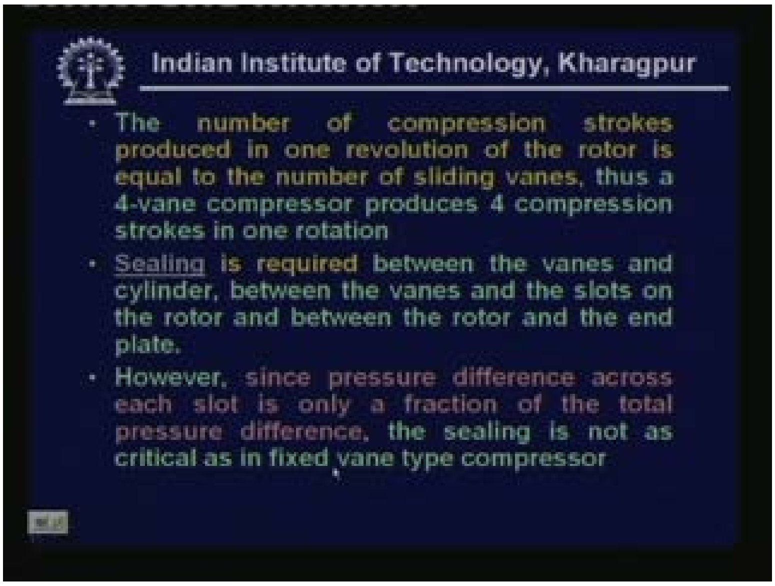

So that is what is mentioned here. However since the pressure difference across each slot is only a fraction of the total pressure difference the sealing is not as critical as in fixed vane type compressor.

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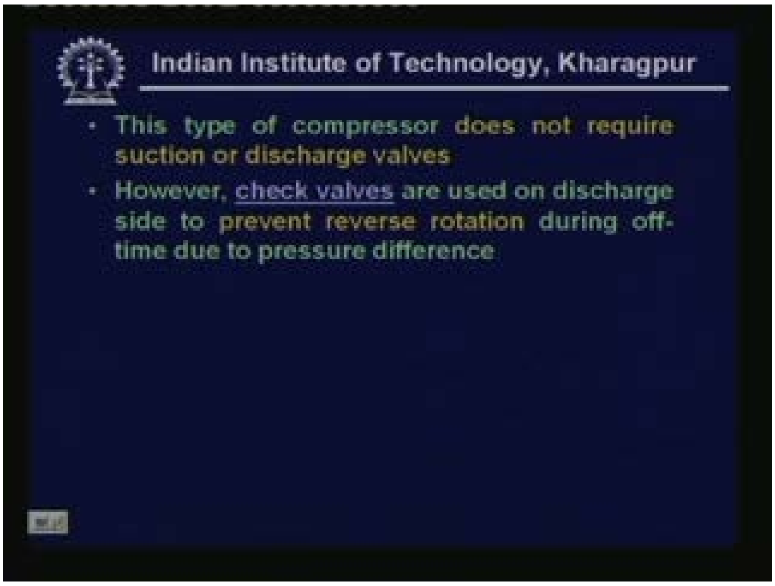

This type of compressor does not require. As I have already mentioned suction or discharge valves. However check valves are used on discharge side to prevent reverse rotation during off time due to pressure difference okay.

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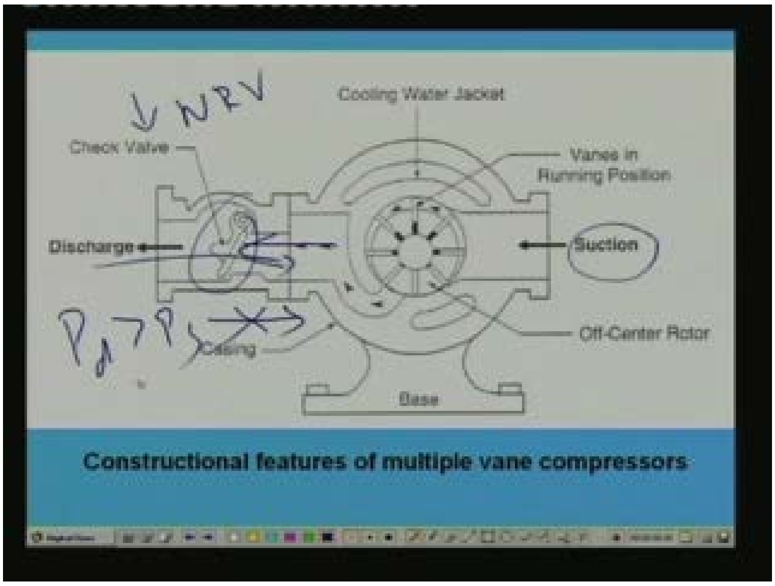

Let me show the, so this one shows the construction features of a multiple vane compressor. You can see that there is no valve on the suction side okay. However a check valve this is the check valve or non return valve is used on the discharge side okay. The purpose of this is that during the when the compressor is off. If this valve is not there since this pressure Pd is always greater than suction pressure back flow can take place. That means the refrigerant can flow back from discharge side to the suction side okay. And when this is flowing back then this will rotate the rotor will rotate in the opposite direction okay. So to prevent this one the check valve is used and the check valve will allow the refrigerant flow in this direction. But it will not allow refrigerant flow in this direction that is the purpose of the check valve.

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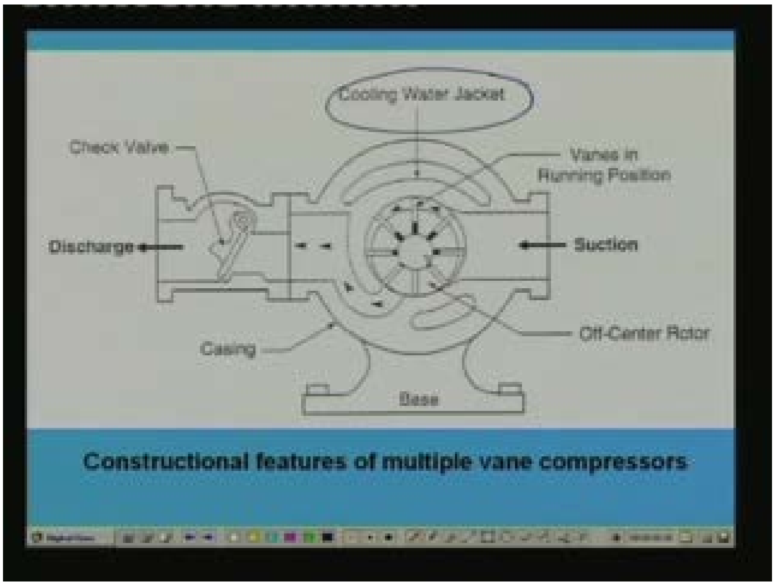

And you can see from this particular picture that there are cooling water jackets here for keeping the compressor cool okay. And this particular picture shows six vanes okay, one two three four five six seven in fact there are seven vanes here okay.

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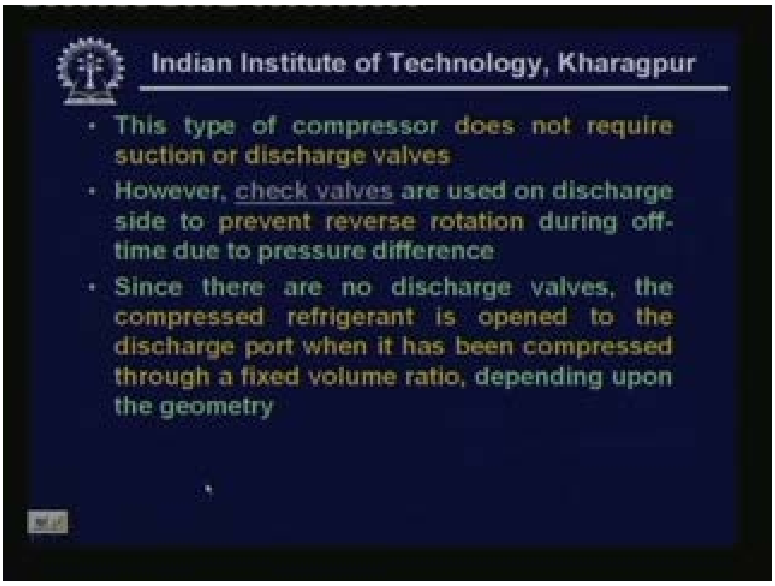

And since there are no discharge valves the compressed refrigerant is opened to the discharge port when it has been compressed through a fixed volume ratio depending upon the geometry. This is one of the typical characteristic of this multiple vane type of compressor. That mean they have what is known as a fixed built in volume ratio as you have seen there are no suction or discharge valves. Since there is no discharge valves when the rotor comes to a particular position the refrigerant the compressor refrigerant will be exposed to the discharge port okay.

That means the pressure becomes, I mean the discharge it is connected to the discharge side and the ratio between the volume at this point and the, of course of the ratio of the volume at this point and the volume when the slots are closed is known as the built in volume ratio okay. So all these fixed I mean all these multiple vane type of compressors have what is known built in volume ratio okay. Since the built in volume ratio is fixed which is depending upon the geometry the built in pressure ratio is also fixed okay.

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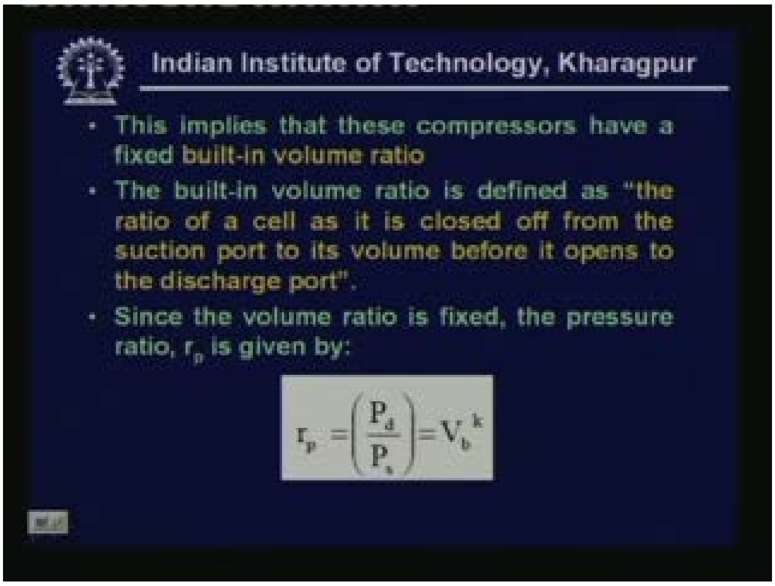

And this as, this is the, let me summarise this implies that these compressors have a fixed built in ratio. And the built in volume ratio is defined as the ratio of a cell. As it is closed off from the suction port to its volume before it opens to the discharge port. This is the definition of built in volume ratio. Since the volume ratio is fixed the pressure ratio rp is also fixed and this rp is given by Pd by Ps where Pd is the discharge pressure and Ps is the suction pressure. This is equal to the built in volume ratio to the power of k where k as you know is the isentropic index of compression.

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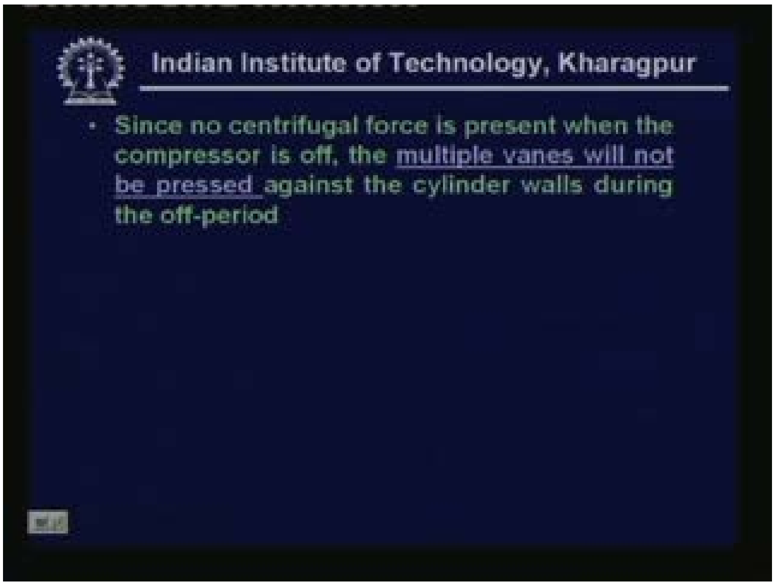

Since no centrifugal force is present when the compressor is off the multiple vanes will not be pressed against as the cylinder walls during the off period.

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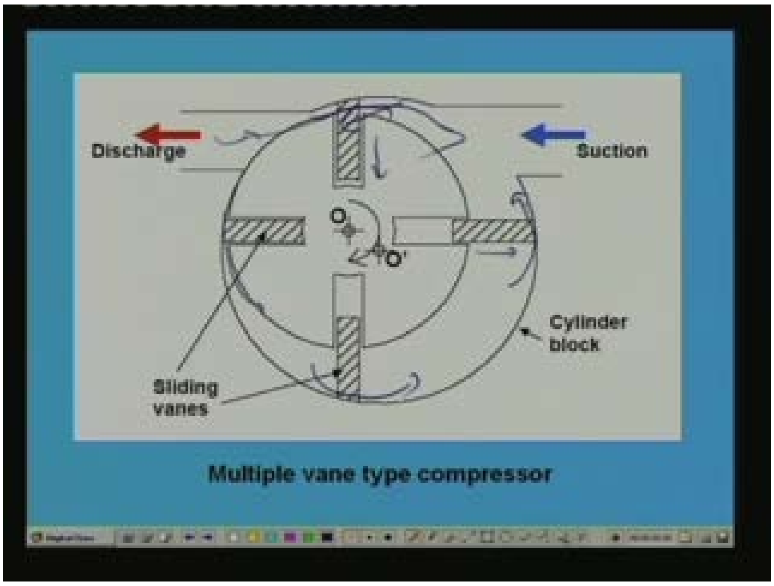

That means, let us say that when the compressor is off there is no centrifugal action when there is no centrifugal action. These vanes will not be pressed against as a cylinder block. For example if you look at this vane this will not be there will be no centrifugal action. So this will not be pressed against the cylinder block. So due to gravity it will fall down. Once it falls down a gap is created here. So as a result this high pressure gas can flow back through this gap on to the suction side. Similarly they will be refrigerant flow from this point okay. And the refrigerant flow like this refrigerant flow like this okay. So that means during the off position there is there is a possibility of pressure equalization on the discharge as well as suction sides.

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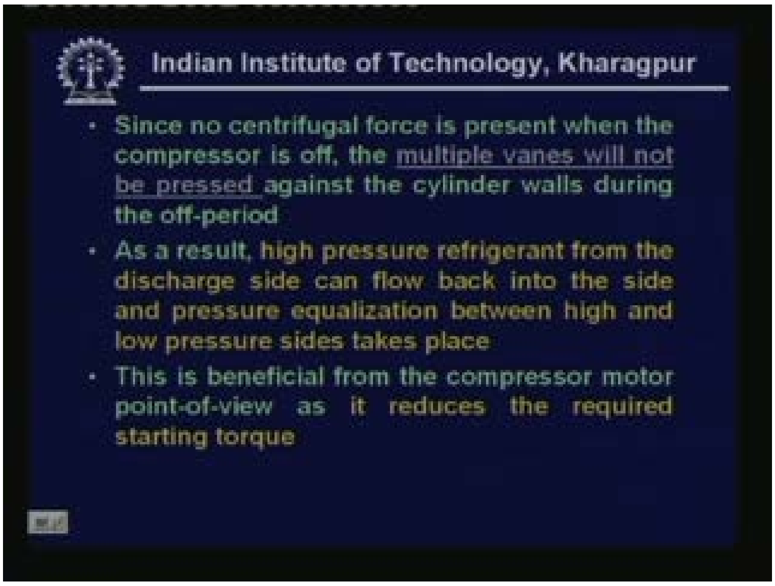

As a result high pressure refrigerant from the discharge side can flow back into the suction side and pressure equalization between high and low pressure sides takes place. This is beneficial from the compressor motor point of view as it reduces the required stating torque. As you know very well when pressure equalization takes place the motor has to start against the same pressure. That means there is no back pressure acting on the motor. So the required starting torque will be very less okay. So you can use a small smaller motor this is one of the advantages of having pressure equalization okay. Of course pressure equalization also has a disadvantages.

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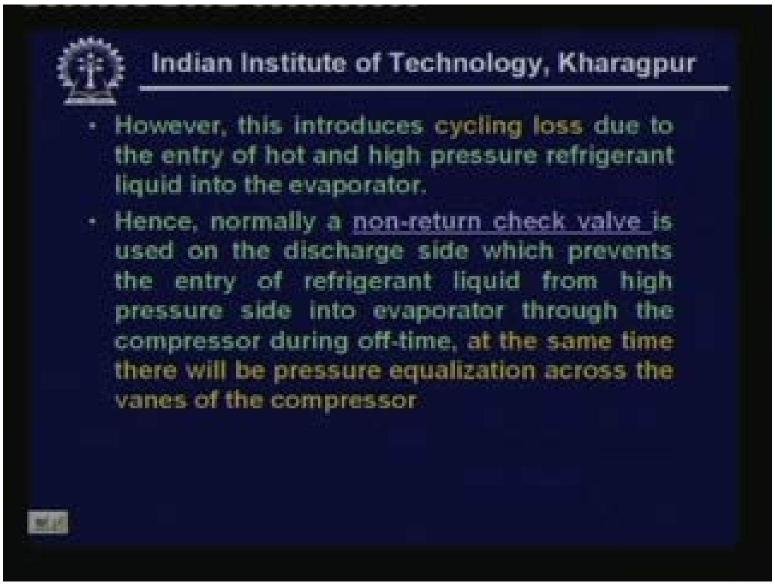

Let us look at what is the disadvantage of this. Whenever there is a pressure equalization it introduces what is known as the cycling loss okay. And what is cycling loss cycling loss is nothing but the entry of hot and high pressure refrigerant liquid into the evaporator. Hence normally a non return check valve is used on the discharge side which prevents the entry of refrigerant liquid from high pressure side into evaporator through the compressor during off time. At the same time there will be pressure equalization across the vanes of the compressor okay that means when you are using the non return valve.

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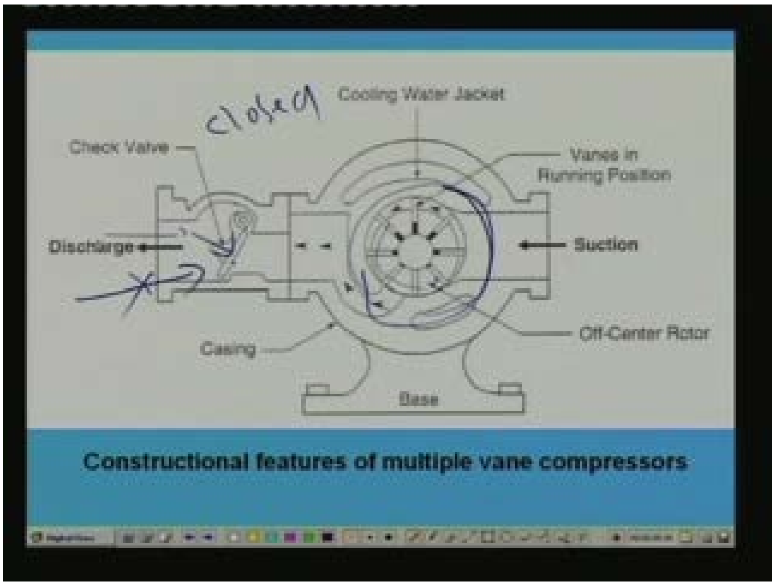

So during the off time this non return valve will be closed okay. This will be closed. So there will not be any refrigerant flow from this side to this side okay. But there will be refrigerant flow across these rotor. That means pressure equalization will take place at the roller but there will not be any pressure equalization in the overall system. As a result this roller can rotate since the pressure equalization is there the motor can rotate with less starting torque. At the same time the cycling losses are prevented because this non return valve will not allow this refrigerant liquid from the condenser to enter into the suction side okay. So that is the purpose of the non return check valve.

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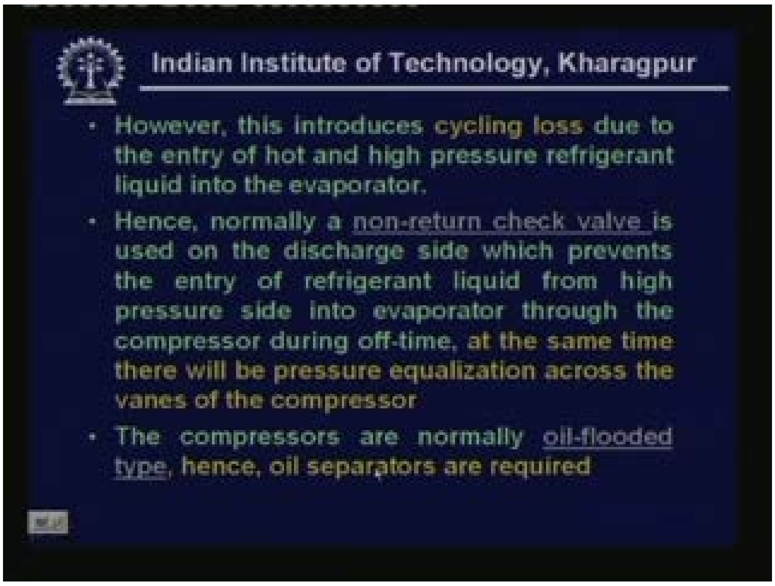

The compressor are normally oil flooded type. Hence oil separators are required as I said you have to do the sealing is required between the various leakage paths. And normally the sealing is achieved by using hydrodynamic lubrication. That means a lubricating oil is used to seal the leakage paths okay. So let me show this.

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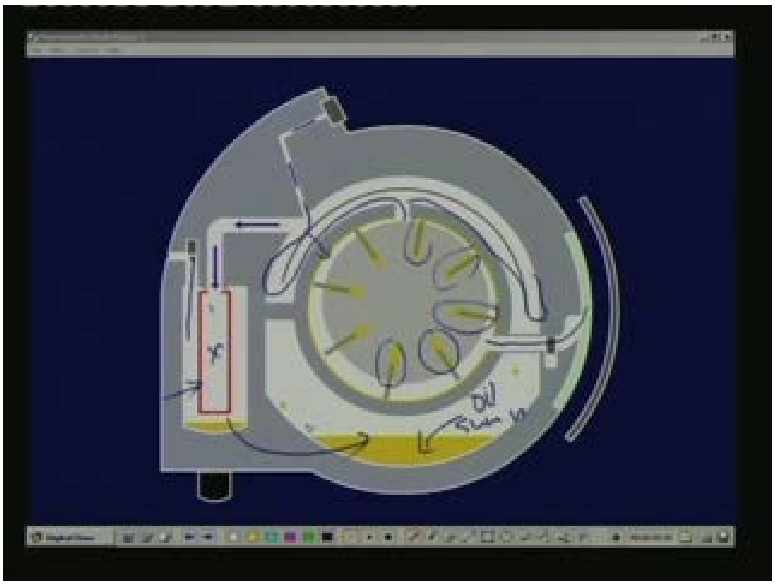

Okay, so this shows the animation of multiple vane type compressor you can see here that an oil separator is used this red side. This is the oil separator okay. And this is the oil sump oil sump and all this orange colour and here the orange colour means there is a thin film of lubricating oil between the sealing path. So that refrigerant leakage from the high pressure side to low pressure side is prevented okay. So refrigerant liquid I mean refrigerant vapour enters like this its gets compressed it comes out like this okay. It comes out like this and flows out like this and this as I said is the oil separator. This is the oil separator and here oil gets separated and refrigerant vapour only will go to the compressor and this separated oil will again come back to the oil sump through the oil return valve okay. So this is the principle. Of course this picture shows a suction valve but it is really not necessary to use a suction valve okay.

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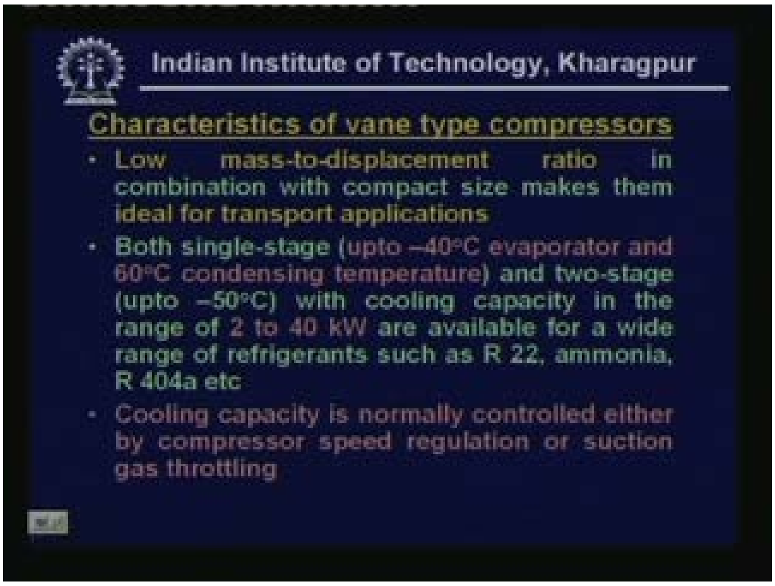

So let us look at the characteristics of vane type compressors in general vane type compressors have low mass to displacement ratio. And they are also compact as a result they are really ideal for transport applications where the compactness and less weight are important. And both single stage as well as two stage compressors are available. Single stage compressor means you can have achieve evaporator temperature up to minus forty degree centigrade when the condensing temperature is that sixty degree centigrade. And two stage compressors means they are available up to about minus fifty degree centigrade evaporator temperature. And normally the cooling capacities at present fall in the range of two to forty kilo watt.

And these compressors are available for a wide range of refrigerants such as R twenty-two ammonia R four not four a etcetera. And cooling capacity is normally controlled either by compressor speed regulation or suction gas throttling as I explained. What is the meaning of compressor speed regulation and suction gas throttling in the last lecture?

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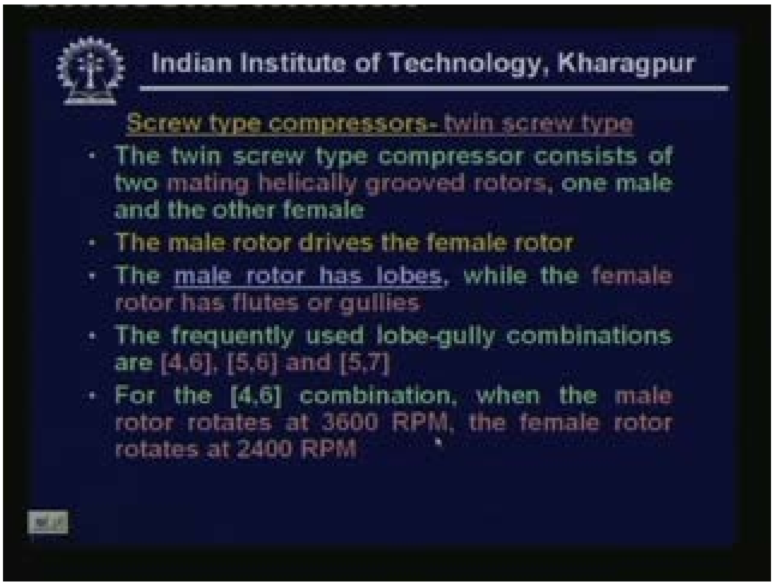

Now let us look at the other important type of positive displacement type of compressor that is what is known as screw type compressors. Screw type compressors can be either single screw type or twin screw type. So let us first look at twin screw type of compressor. The twin screw type compressor consists of two mating helically grooved rotors and one is the male rotor and the other one is the female rotor. The male rotor drives the female rotor the male rotor has lobes while the female rotor has flutes or gullies. Let me show this the frequently used lobe gully combinations are four four six five six and five seven for the four six combination when the male rotor rotates at three thousand six hundred RPM the female rotor rotates at two thousand four hundred RPM. So let me explain this with a picture.

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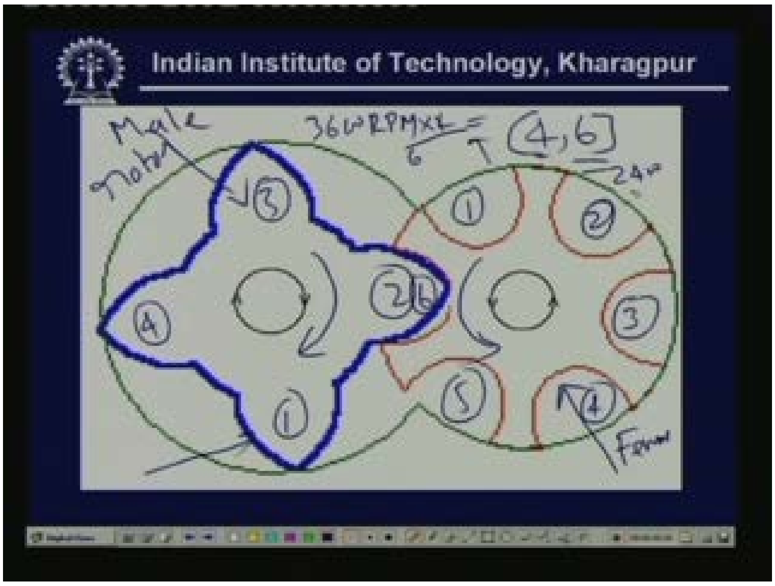

This is a four six combination okay and this is the male rotor and this is the female rotor and male rotor has lobes okay. This is one three four it has four lobes that is why you call this as four and the female rotor has six gullies okay. This is one two three four five six okay and this male rotor is the driving one and it drives the female rotor. So this rotates in this direction as this rotates in this direction the female rotor will be rotating in this direction. And as you can see that when since this is a four six combination when the male rotor has three thousand six thousand speed of three thousand six hundred RPM this one will have three thousand six. The female one will have three thousand six hundred RPM into four by six that means two thousand four hundred RPM okay.

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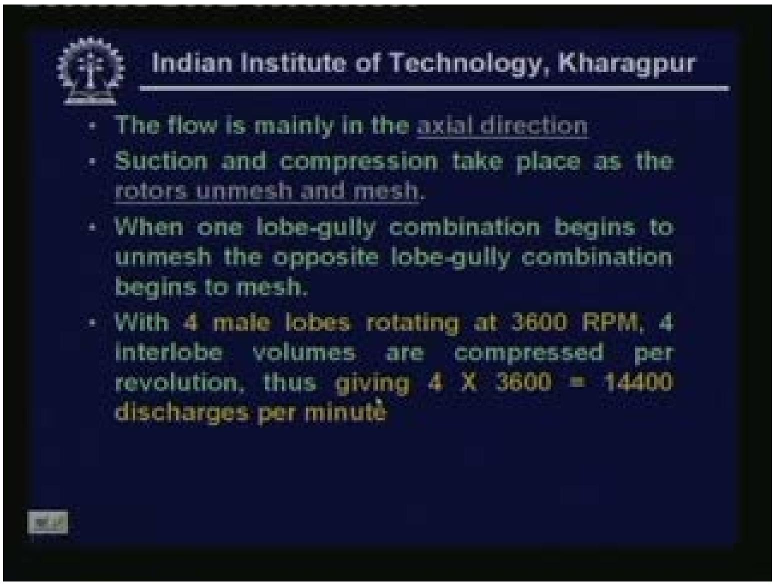

The flow is twin screw type of compressor. The flow is mainly in the axial direction. Let me show this.

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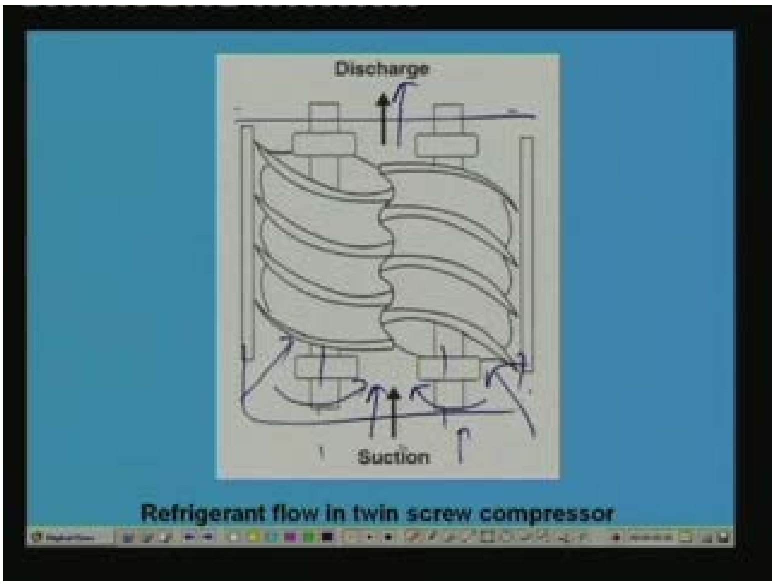

Okay, so this is again a cut view of a twin screw compressor this is the male rotor and this is the female rotor okay. So this will be rotating in this direction and this will be rotating. In this direction and suction gas enters like this it gets compressed and it leads the compressor in this manner okay. So both the female and male rotor are housed in a housing okay. You have a housing. So as you can see that the refrigerant flow is basically in the axial direction it flows in this direction. And this is the axis of rotation suction and compression take place as the rotors mesh and unmesh.

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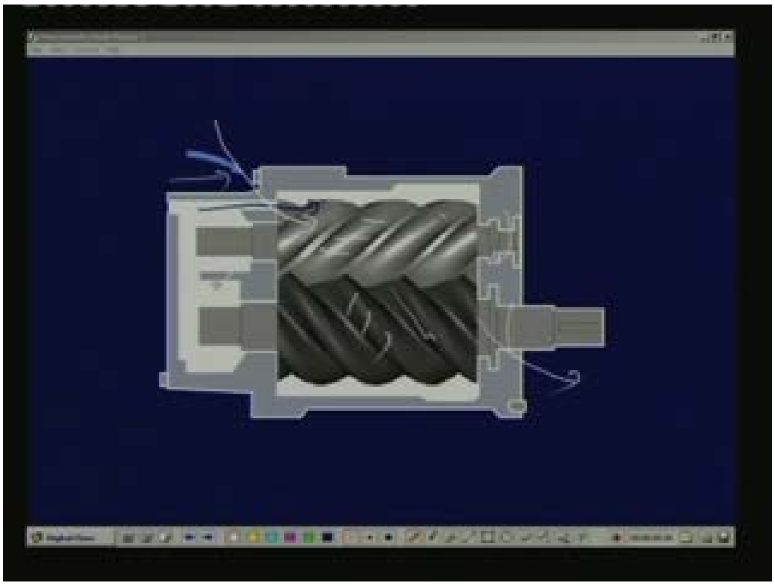

So let me show the animated picture of this you can see the animation. Here you have low pressure refrigerant enters like this okay. It is coming like this and its fills up this space. And as this one rotates it will be carried away along these gullies and the lobes. And finally it get compressed and it leaves the compressor in this fashion okay. So basically the flow direction is in this direction.

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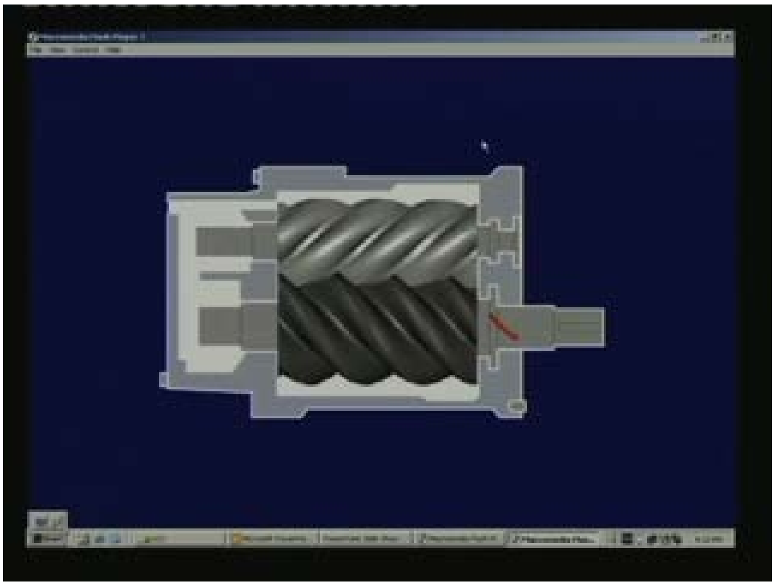

You can see the how the flow is taking place. The blue one is the suction gas blue colour and red colour indicates that it is getting compressed okay. And you have an outer cylinder casing where this twins screws are housed in the cylinder casting okay. So when one lobe gully combination begins to unmesh the opposite lobe gully combination begins to mesh with four main lobes rotating at three thousand six hundred RPM four inter lobe volumes are compressed per revolution. That means you have four into three thousand six hundred. That is fourteen thousand four hundred discharges per minute okay. So this depends upon the, if you have let us say six male lobes then it will be six into three thousand six hundred discharges per minute.

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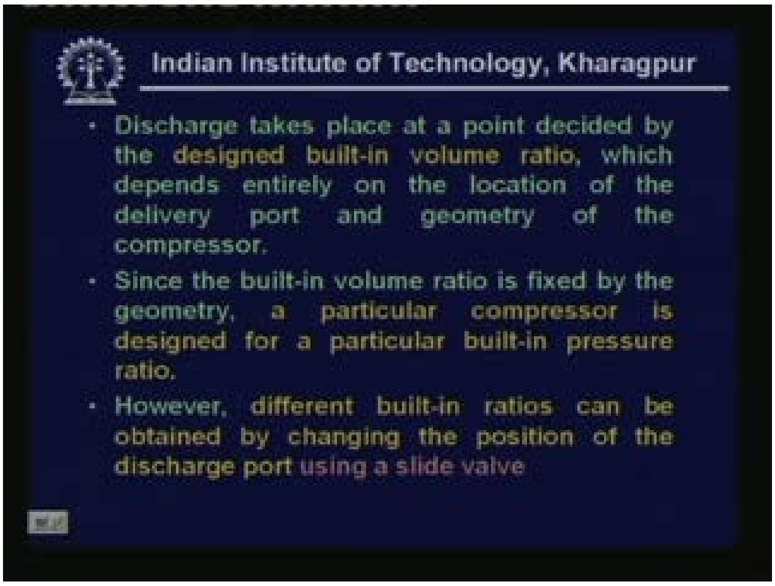

Discharge takes place at a point decided by the designed built in volume ratio. That means just like your multiple vane type of compressor. Here also you have what is known as the built in volume ratio and this built in volume ratio depends upon the location of the delivery port and geometry of the compressor. Since the built in olume ratio is fixed by the geometry a particular compressor is designed for a particular built in volume ratio. However different built in ratios can be obtained by changing the position of the discharge port using a slide valve.

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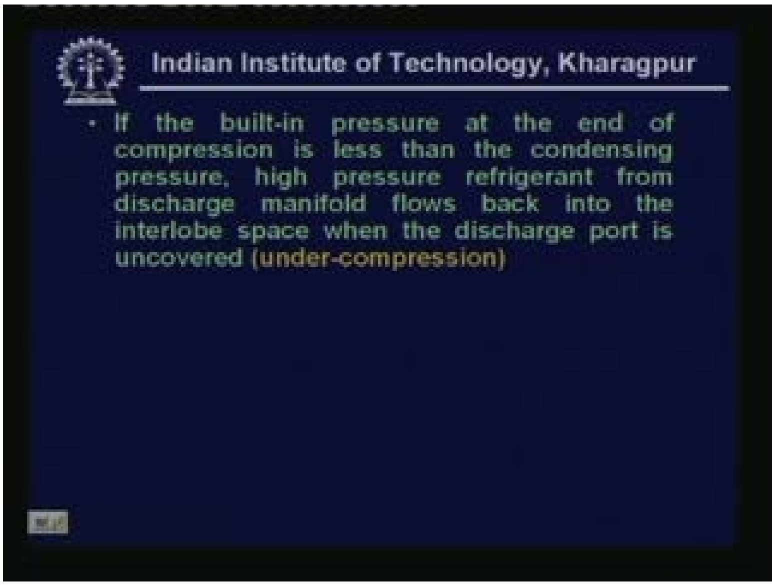

If the built in pressure at the end of the compression is less than the condensing pressure. High pressure refrigerant from discharge manifold flows back into the inter lobe space when the discharge port is under covered uncovered this is known as under compression okay. That means what happens is since you have typical twin screw compressor has a built in volume ratio okay, one that means the volume ratio is fixed. And the volume ratio as we have defined in the, for in case of multiple vane type of compressor is the ratio of the suction volume divided by the volume just before discharge takes place. Since this is fixed the compression ratio is also fixed. Because you know that the compression process in general obeys the equation PV to the power of n is constant.

So when the volume ratio is fixed the pressure ratio is also fixed okay. And as I said the built in volume ratio depends upon the geometry of the compressor. Once you fix the geometry of the compressor and the location of the discharge port the built in volume ratio is fixed that means the built in pressure ratio is also fixed. Since the built in pressure ratio is fixed let us say that you have a, you have some suction pressure. Let us say that suction pressure of two bar and let us say that built in pressure ratio is six. That means the discharge pressure will be two into six that is twelve bar. And if the condensing pressure is greater than twelve bar let us say that condensing pressure is thirteen bar. As you know the condensing pressure depends upon the available heat sink temperature. So it is possible for the condensing pressure to be higher than the built in pressure okay. If it is higher than built in pressure and let us say it is thirteen bar whereas the pressure developed in the compressor is twelve bar then when the discharge port is uncovered the condenser pressure is higher than the compressed refrigerant pressure.

That means there will be a reverse flow and this is what is known as under compression okay. You can also have the other on the other hand you can also have a scenario where the discharge pressure at the end of compression is much higher than the condensing pressure, this is known as over compression okay. So that means as soon as the discharge port is uncovered. Since that is a pressure difference between the condenser and the compressed gas the compressed gas will rush out of the discharge port. That means there will be a throttling of the refrigerant vapour at the discharge okay. So this is known as over compression. Both under compression as well as the over compressionare as for as the compressor performance is concerned. Because both will reduce the efficiency this is one of the typical problems of twins screw compressor. This you can call it as a problem if you are operating the system at off design conditions. But normally the compressors are designed to operate at design conditions. And if you design the compressor in such a manner that at the built in pressure is equal to your condensing pressure then you get the peak efficiency okay. You do not have any problem but it is possible for the compressor to operate at off design condition then you may have either under compression or over compression okay.

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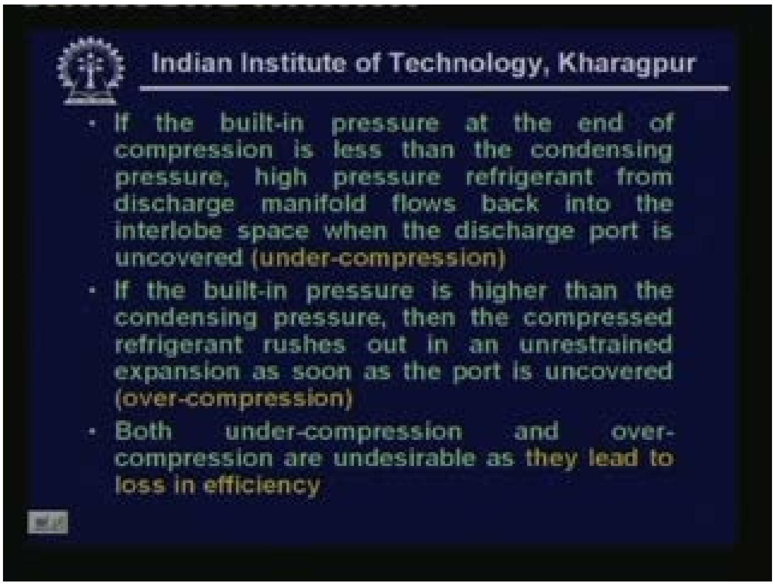

So as I said if the built in pressure is higher than the condensing pressure. Then the compressed refrigerant rushes out in an unrestrained expansion. As soon as the port is uncovered both under compression and over compression are undesirable as they lead to loss in efficiency.

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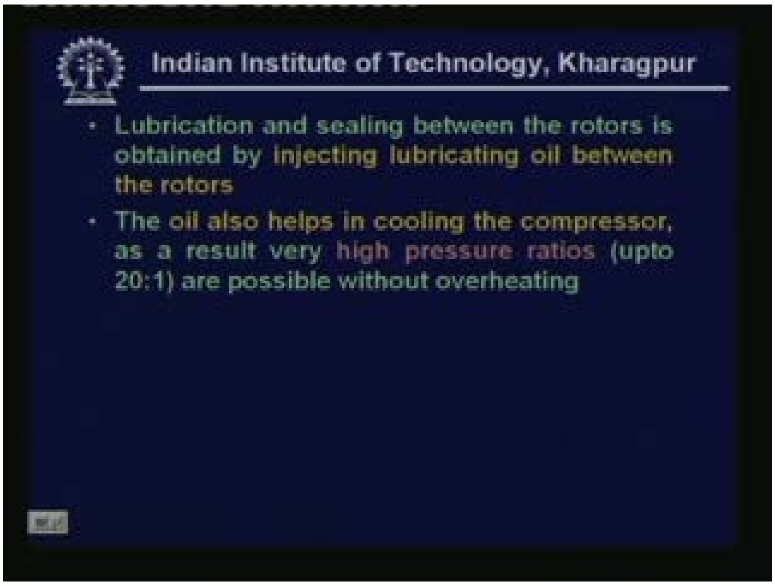

Lubrication and sealing between the rotors is obtained by injecting lubricating oil between the rotors. A large amount of lubricating oil is injected between the rotors the oil also helps in cooling the compressor. As a result very high pressure ratios are possible without overheating this is one of the major advantages of screw compressor. Since they are oil flooded and the lubricating oil can carry away lot of heat one can go for a large pressure ratio okay, typically as high as twenty is to one. That means instead of using a multi stage compression you can achieve a large compression ratio using a single stage screw compressor okay. And at the same time you can also keep the discharge temperature low because the oil carries the heat from the compressor. So the discharge temperature of the refrigerant will not be very high okay. Of course you can also use in some of the compressors instead of using lubricating oil people use a liquid refrigerant itself for sealing as well as for taking away the heat this is also possible. That means screw compressors can handle a mixer of liquid as well as vapour which is not possible in reciprocating type of compressors okay. So this is another advantage of screw type compressor.

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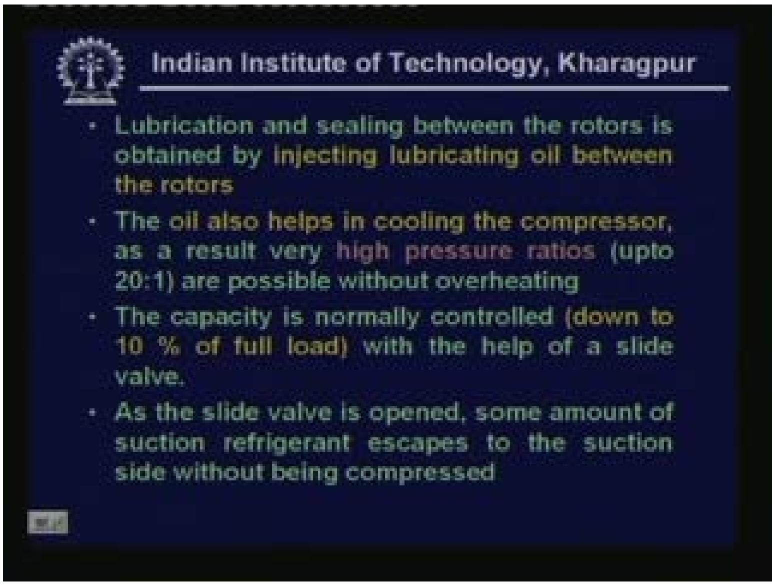

The capacity is normally controlled down to ten percent of full load with the help of a slide valve. So you can get really a smooth capacity control in this type of a compressor using a slide valve and what does the slide valve do? The slide valve as the slide valve is opened some amount of suction refrigerant escapes to the suction side without being compressed. Basically you can shift the point at which the compression begins there by you can control the mass flow rate of compressed refrigerant. That is how you control the capacity and as I mentioned the capacity can be reduced right from hundred percent to ten percent of full load in various steps.

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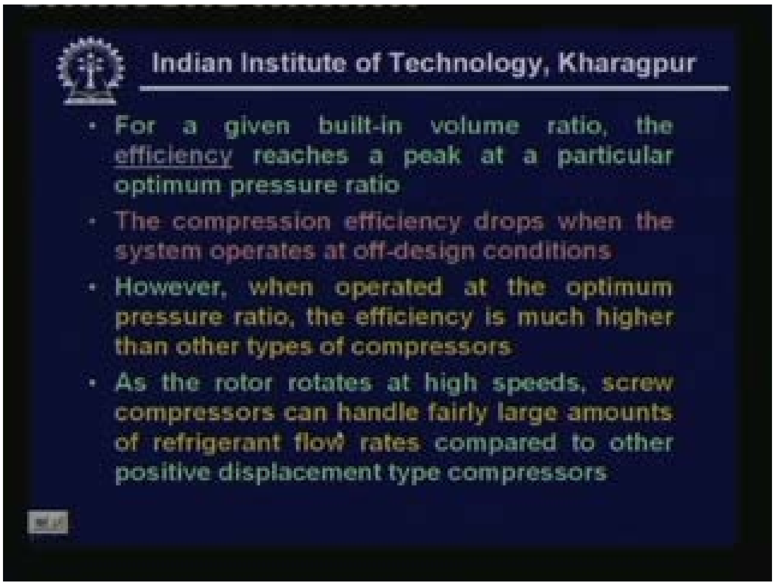

For a given built in volume ratio the efficiency reaches a peak at a particular optimum pressure ratio. As I have already mentioned. Let me show this.

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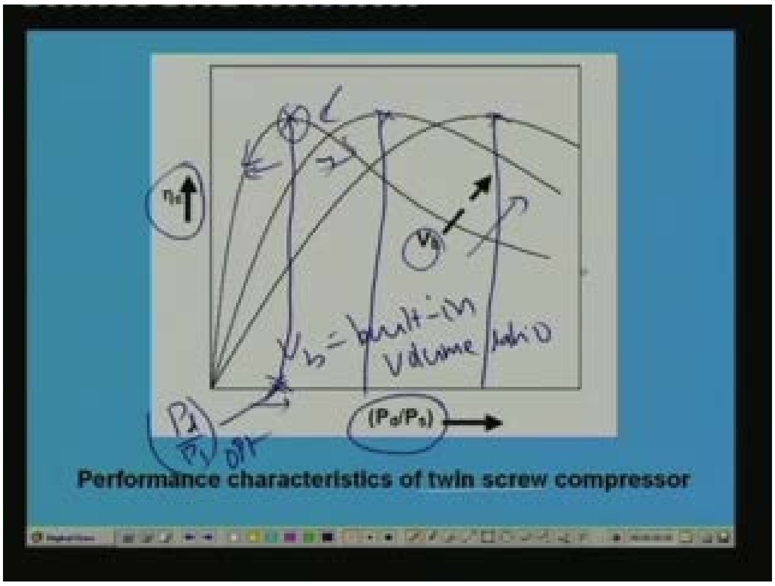

This is the typical performance characteristic of a twin screw compressor. So as you can see that here the compression efficiency this is the compression efficiency is plotted against pressure ratio Pd by Ps for different built in volume ratios okay. So Vb is your built in volume ratio and it is increasing in this direction and for a given built in volume ratio. For example let us take this one for a given built in volume ratio the compression efficiency increases as the pressure ratio increases. And it reaches a peak that means for this particular compressor efficiency is maximum at an optimum compression ratio this is your Pd by Ps optimum okay.

So if you design your compressor in such a way that at design point this is th compressor operates at this point. Then you get the maximum efficiency however at off design conditions the compression ratio can go this side or this side. So that means the efficiency will reduce when you move away from this peak point okay. And you can also see that as the built in volume ratio is varying the optimum pressure ratio at which the peak efficiency occurs also shifts okay. So compression efficiency drops when the system operates at off design conditions. However when operated at the optimum pressure ratio the efficiency is much higher than other types of compressors. You can get a compression efficiency as high as seventy percent or more. As the rotor rotates at high speeds screw compressors can handle fairly large amounts of refrigerant flow rates compared to other positive displacement type compressors.

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Screw compressors are available currently in the capacity range of seventy to four thousand six hundred kilo watts. So normally screw compressors compete with high capacity reciprocating compressor and low capacity centrifugal compressor that mean they occupy the space in between reciprocating compressors and the centrifugal compressors okay. They are available for a wide variety of refrigerants and applications compared to reciprocating compressors screw compressors are balanced. And hence do not suffer from vibration problems. Since you are not converting rotary motion into reciprocating motion in any of these rotary compressors not only screw compressor also in fixed vane. And multiple vane type of compressors these rotary type of positive displacement type compressors offer less vibration and less noise compared to reciprocating type of compressors okay. That is they are better balanced.

And screw compressors are rugged and are more reliable than reciprocating compressors. It is shown that they can run for continuously for thirty thousand to forty hours between major overhauls. This is cited as one of the principle advantages of screw compressor. That means between major overhauls the running time can be as high as thirty thousand to forty thousand hours okay. So they really do not require any major overhauling in between right. So this is very beneficial as far as the plant running is concerned okay.

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Now let us briefly look at the other type of screw compressor that is single screw compressor. This single screw compressors consists of a single helical screw and two planet wheels or gate rotors. The helical screw is housed in a cylindrical casing with suction port at one end and discharge port. At the other end suction and compression are obtained. As the screw and gate rotors unmesh and mesh the high and low pressure regions in the cylinder casing are separated by the gate rotors.

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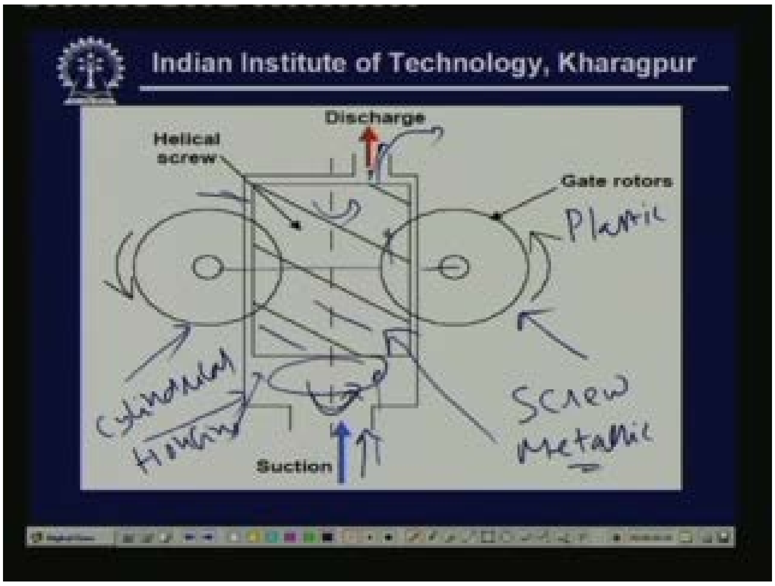

Okay, so let me show the schematic of single screw compressor. So as I said you have a single helical screw, this is the screw. This is the one, this is driven by a motor and it rotates in this direction and it also consists of two gate rotors or planet wheels okay. You have one gate rotor on this side one gate rotor on this side. And this helical screw is kept in a cylindrical housing okay. And this is the suction port and this is the discharge port. So suction gas enters like this okay. And the space between this region and the region between the planet wheels and the screw is occupied by the suction gas. And as this rotates in this direction the suction gas will be carried away and as it passes the gate rotor it undergoes compression. And when it reaches this point its pressure would have been equal to or slightly higher than the condensing pressure.

So that discharge will take place through the discharge port okay. So the gate rotor basically seals the high pressure region from the low pressure region normally the screws are metallic and the gate rotors are plastic. That means they are made up of plastic materials and helical screw is made of metallic material.

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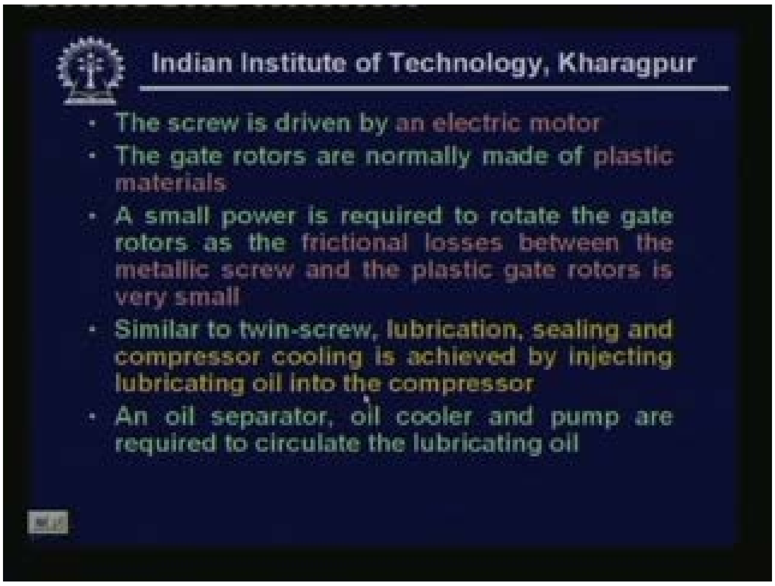

The screw as I said is driven by an electric motor and the gate rotors are normally made of plastic materials. A small power is required to rotate the gate rotors. As the frictional losses between the metallic screw and the plastic gate rotor is very small. Similar to twin screw lubrication sealing and compressor cooling is achieved by injecting lubricating oil into the compressor. Once you inject lubricating oil obviously you require an oil separator oil cooler and oil pump to circulate the lubricating oil and to reject the heat of compression. So this is the typical characteristics of single screw and twin screw type of compressors. As I said these compressors can handle a mixer of vapour and liquid. And in fact instead of using lubricating oil you can as well use refrigerant liquid itself for sealing and for carrying away the heat of compression okay. Now let us look at another very important.

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Type of positive displacement type of compressor this is known as scroll compressors scroll compressor is sometimes called as an orbital compressor. Let me describe the working principle scroll compressors are orbital motion positive displacement type compressors in which suction and compression is obtained by using two mating spiral shaped scroll members one fixed and the other orbiting. That means basically what we have here is two spiral shaped scroll members and one of them is fixed and the other one is orbiting okay. So let me just show the a downloaded clip.

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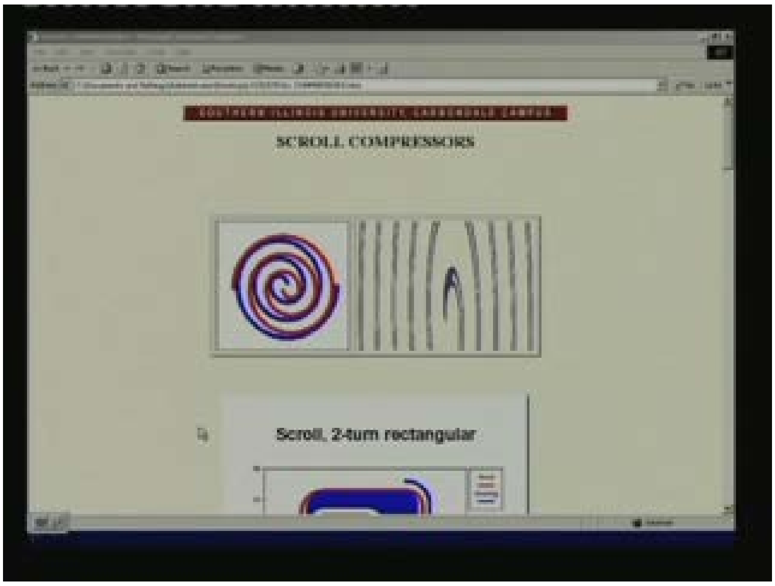

You can see the, this is downloaded from the internet and it is made by the southern Illinois university and this picture here shows. For example here this is one spiral member and this is the other spiral member. One is fixed, the blue one is fixed and the red one is orbiting as it orbits suction compression and discharge takes place okay. See you can see that the as the red one is orbiting you very well see that it is not rotating, it is orbiting okay. That is why you call it as orbital compressor and the blue one is fixed okay. So the gap between the blue and red scroll members is varying continuously this is what gives rise to suction and compression okay. And an anti rotation coupling is used to maintain a fixed angular relation of one eighty degrees between the fixed and orbiting scrolls. This is not shown in the picture but an anti rotation coupling is essential it has to maintain a one eighty degree phase different between the fixed and orbiting scrolls. Once again let me show the, how it works.

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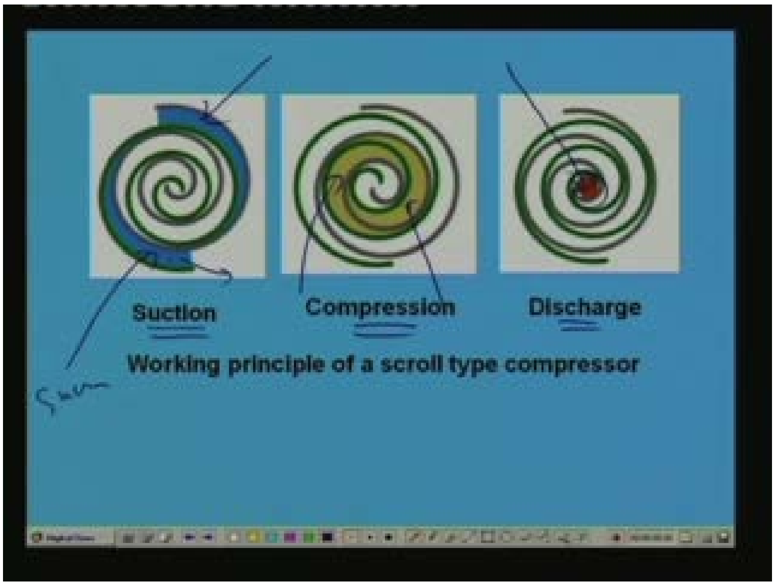

Okay, so this picture here shows the working principle of scroll type compressor. So what is shown here is suction compression and discharge. So this blue in this particular this thing this blue region is the suction gas. So you can see that the space between the two scrolls is fixed by the suction gas and as the orbiting scroll rotates this suction gas is moved from this periphery to the inner this thing okay. So this is the now this has occupied this region and at this point this volume is less than the volume at this condition okay. So some compression has taken place and with further rotation the gas is moved to the center okay. This red portion at this point the compression is completed and the pressure equals are slightly exceeds the condenser pressure. So the discharge valve is opened and discharge takes place.

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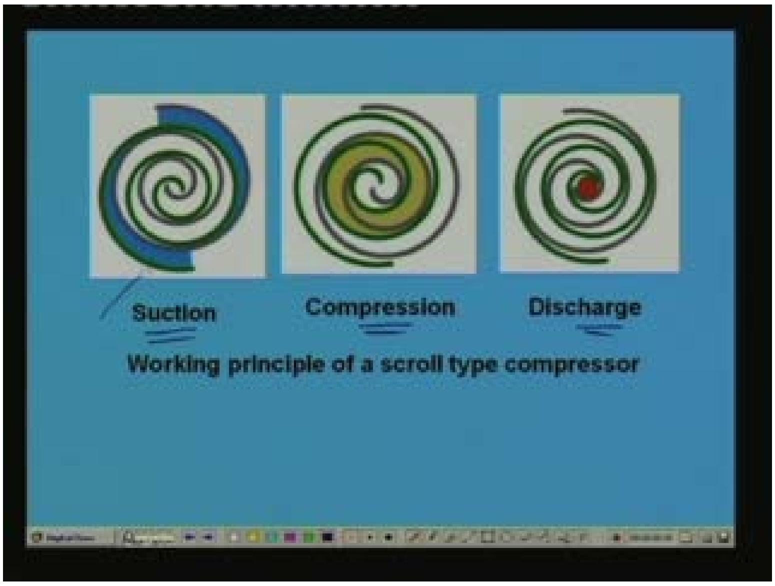

So you have the three steps suction discharge and compression and how the gas is moved from the periphery to the inner eye okay. So normally you have the suction port at the outside I mean at the periphery and the discharge port at the center okay. So this is the working principle of a scroll type compressor and each scroll member is open at one end and bound by a base plate at the other end. So let me show this.

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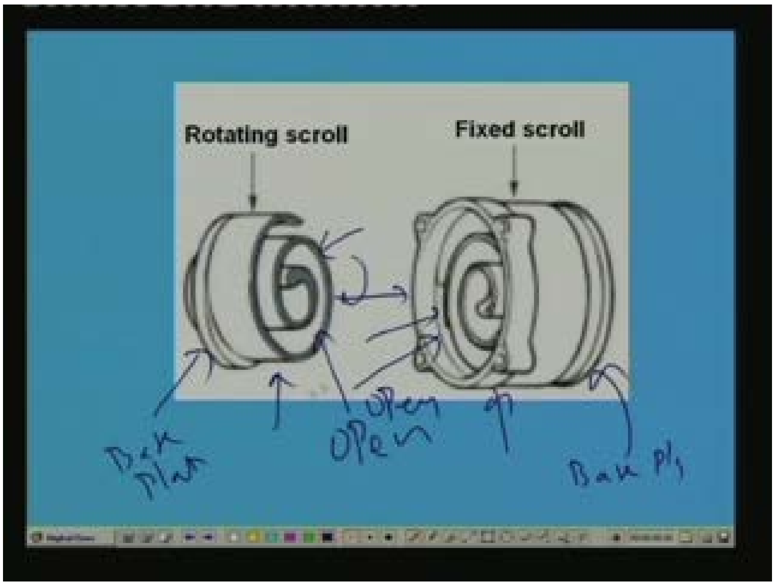

Okay, so this is picture is not very clear but here what is shown here is this is the rotating scroll and this is the fixed scroll and this is the scroll member okay. Again this is the scroll member and this is open on this side. This is open end and this is the open end okay. And this is the base plate and this side also you have a base plate okay. So basically when you assemble it this goes and sits inside and this will be orbiting in this direction okay.

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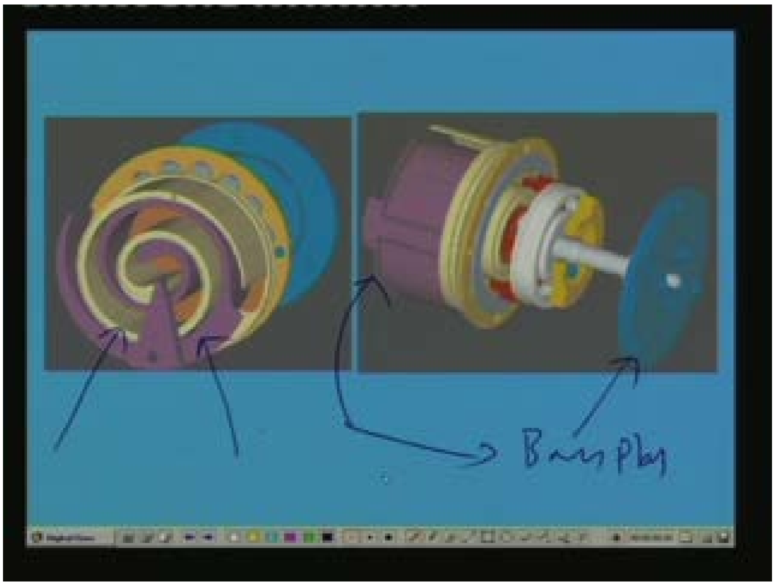

This picture shows the photograph from the side view and from the front view. And you can see here the two scroll members one is the violet coloured, one this is one and this is the other one okay. The violet coloured one is the fixed one and this one will be rotating okay. And you can see the one side it is open and this is the base plate right you have another base plate here. So another base plate is there okay.

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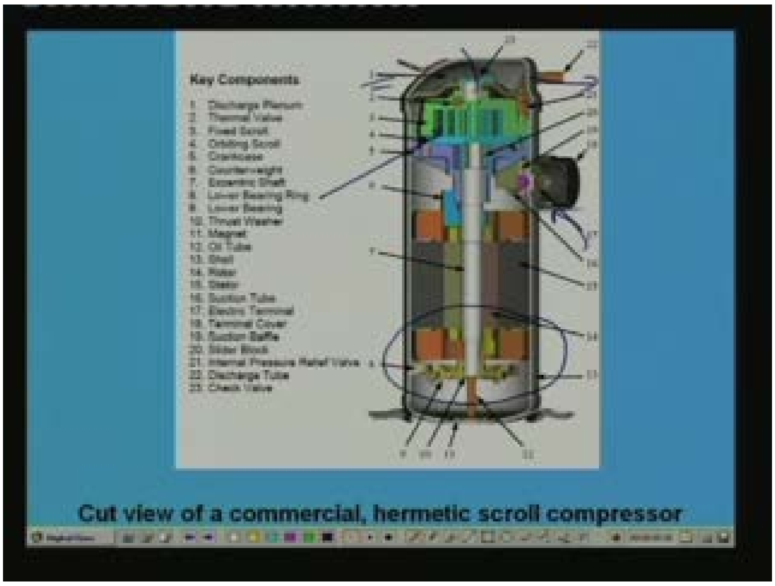

This shows a cut view of a commercial hermetic scroll compressor. So you can see the various key components in this one. Since this is the hermetic type of compressor the motor is also kept inside the same housing. So you have the discharge plenum as I said, as I explained you have the discharge plenum here discharge takes place through this okay. And suction takes place in this manner okay. And you have the motor here and the scrolls are kept here fixed and orbiting scrolls and various other components okay.

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Scroll compressors are used in small capacity three to fifty kilo watt refrigeration air conditioning and heat pump applications in fact they are becoming quite popular in this range. Because they offer many advantages they are normally hermetic type compressor capacity is normally controlled by variable speed inverter drives. Basically what is done is the frequency of the motor is varied okay. The frequency can be varied from as low as fifteen hertz to right up to one fifty hertz okay. That means you can get a very fine capacity control by controlling the speed of the motor okay. This, the popular method of controlling the capacity of scroll type of compressors okay. Of course one major problem with this scroll type of compressor is the manufacturing is relatively difficult due to the need for very close tolerances between the fixed and orbiting scroll members.

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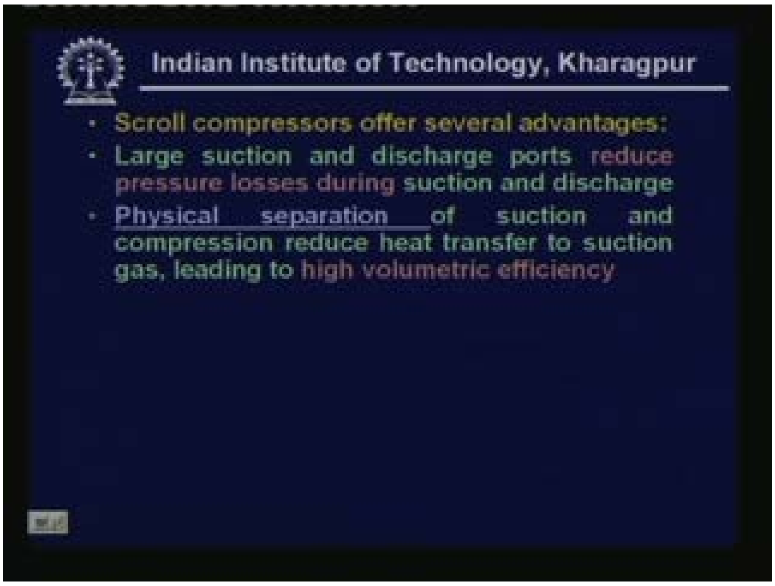

Scroll compressors offer several advantages first advantage is large suction and discharge ports reduce pressure losses during suction and discharge. So there will be higher volumetric efficiency and physical separation of suction and compression reduce heat transfer to suction gas leading to high volumetric efficiency. This is another typical advantage of this type of compressor.

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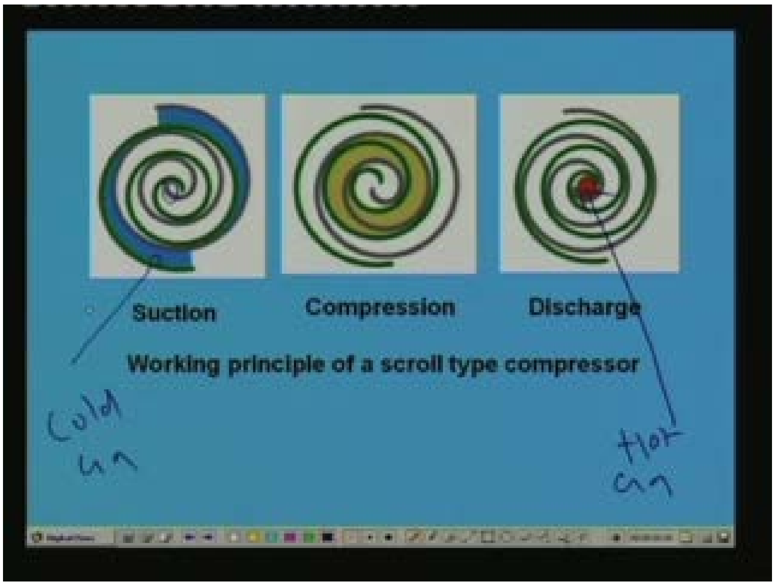

As you can see here suction is taking place here. So simultaneously discharge will be taking place somewhere here okay. So you for example this is the hottest hot gas let us say and this is your cold gas. Since they are physically separated heat transfer from the hot gas to the cold gas is minimised. As the result the density of the suction gas will not drop very much unlike in reciprocating compressor. As a result the volumetric efficiency will be high.

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In addition of course the re-expansion losses are quite less in this one and the flatter capacity versus outdoor temperature curves. And another advantage is that higher compression efficiency low noise and vibration compared to reciprocating compressors. They are compact with minimum number of moving parts. So because of these advantages scroll compressors are finding applications in many air conditioners and all. In fact this scroll compressor is pioneered by Japanese and they are becoming very popular in packaged air conditioners and small refrigeration systems okay.

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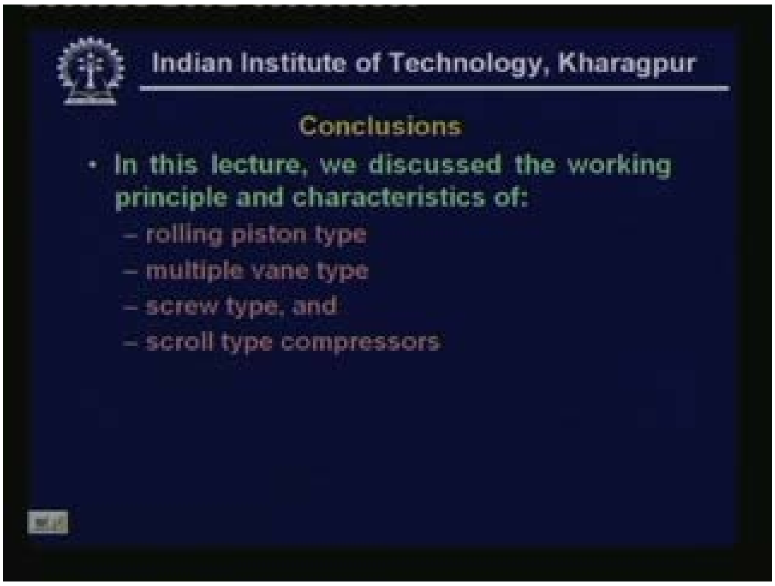

Now let me summarise what we have learned in this lesson. In this lecture we discussed the working principle and characteristics of rolling piston type compressors multiple vane type compressor screw type compressor. Both single screw and twin screw type compressors and scroll type compressors there are also other positive displacement type of compressor. What is known as tricodal type of compressor. But this is still not very popular not still under development okay. Whereas these four types have already been developed and they are available commercially okay. And this completes the discussion on positive displacement type of compressor.

As you can see we have spent more time on the reciprocating type. Because they are the real work house hearts of the refrigeration industry. However the other positive displacement types are also becoming popular okay. Since this is then basic course we are not discussed these compressors in detail. And in the next lecture I will discuss rotodynamic type of compressors mainly centrifugal compressor okay. So before I stop here I would like to give a home work problem. Let me read the homework problem.

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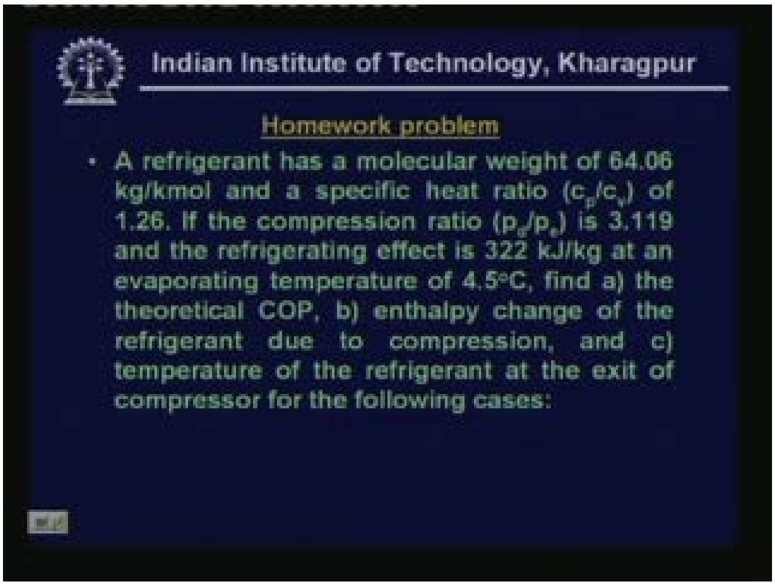

The problem is like this a refrigerant has a molecular weight of sixty-four point zero six kg per kilo mole and a specific heat ratio Cp by Cv of one point two six. If the compression ratio Pd by Pe is three point one one nine and the refrigeration effect is three twenty two kilo joule per kg at an evaporating temperature of four point five degree centigrade. Find a the theoretical COP b the enthalpy change of the refrigerant due to compression and c temperature of the refrigerant at the exit of compressor for the following cases. So what is given here is the molecular weight specific heat ratio compression ratio refrigeration effect. And the evaporating temperature okay and we have to find out the COP enthalpy change and the discharge temperature okay. And what are the different cases for which we have to find these values.

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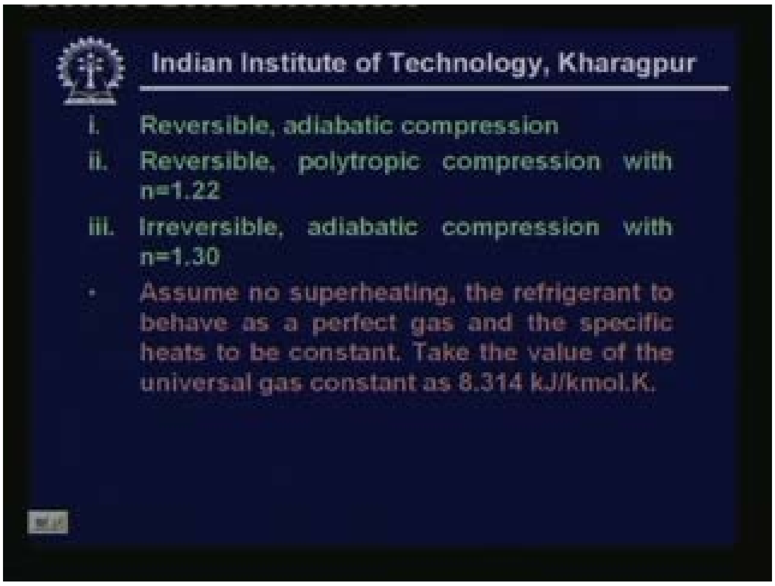

First one is reversible adiabatic compression, second one is reversible polytropic compression with polytropic index of one point two two third is irreversible adiabatic compression with index of one point three. And you can assume no superheating and the refrigerant to behave as a perfect gas and the specific heats to be constant take the value of the universal gas constant as eight point three one four kilo joule per kilo mole Kelvin. Let me give a hint. You have to, as I have already mentioned you have to assume the refrigerant to be a perfect gas. So you have to apply PV to the power of n is constant and also you also have can apply PV is equal to RT okay. These two equations you will be applying and for the reversible cases you have to you can find out the work input to the compressor by integrating integral vdp okay. From the suction pressure to the discharge pressure whereas for irreversible case you cannot use integral vdp for finding the work of compression. Because you do not know the process path okay. So what you have to do for the irreversible case is you have to find out the discharge temperature from the two equation PV to the power of n is constant and PV is equal to RT. And then apply energy balance across the compressor and find out the work input which is nothing but mass flow rate into enthalpy rise across the compressor okay. That will give you the work of compression for the irreversible case whereas for the other two cases you can find out work input from integral vdp okay. I will give you the answers to this problem in the next lecture.

Thank you.