Upstream LNG Technology
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Lecture – 48
Compressors used in natural gas systems

Welcome, after learning about the compression and the fundamentals about the compression systems in terms of the determination of the power and the work by the compressor; now we shall go to the Compressors used in the natural gas systems.

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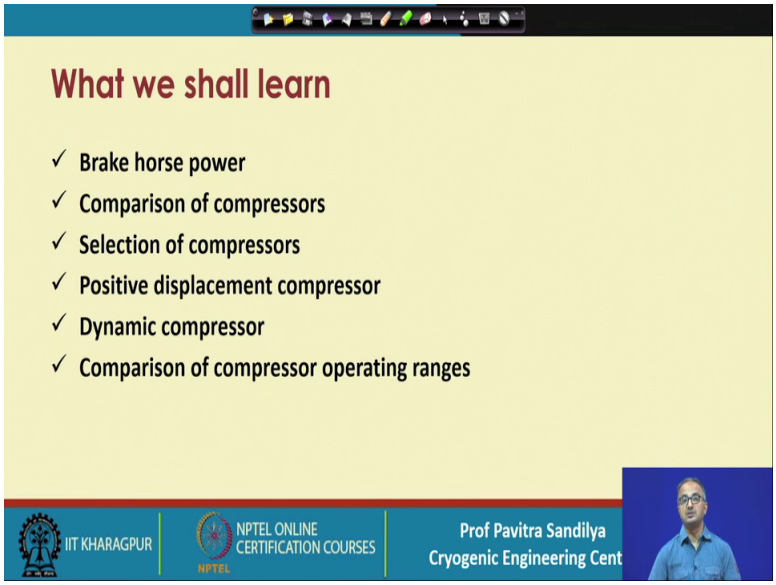

So, in this lecture we shall be learning about brake horse power the we shall be comparing the various compressors. Then we shall learning we shall learn about the selection criteria of the compressors, then about some compressor that is positive displacement and the dynamic compressors. And we shall be ending with the comparison of the operating ranges of the various types of compressors.

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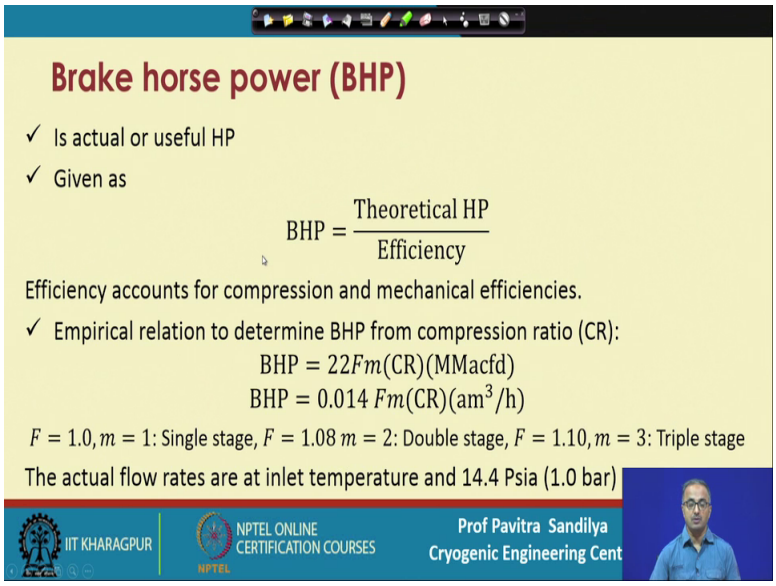

First let us look into the Brake Horse Power; this is the actual horse power of the compressor and given by this particular expression as a ratio of the theoretical horsepower to the efficiency of the compressors.

And we have learnt about the efficiencies in our earlier lecture and the brake horsepower is given by these correlations and in these correlations, we find it depends not only on the compression ratio but also on some factors and the number of stages, which are given like this here that; F is 1 for single stage, for double stage we have F has 1.08, for triple stage we have F as 1.10 and these actual flow rates are at the inlet temperature and 1 bar. So, these actual flow rates are given in terms of the one in the temperature and the one bar.

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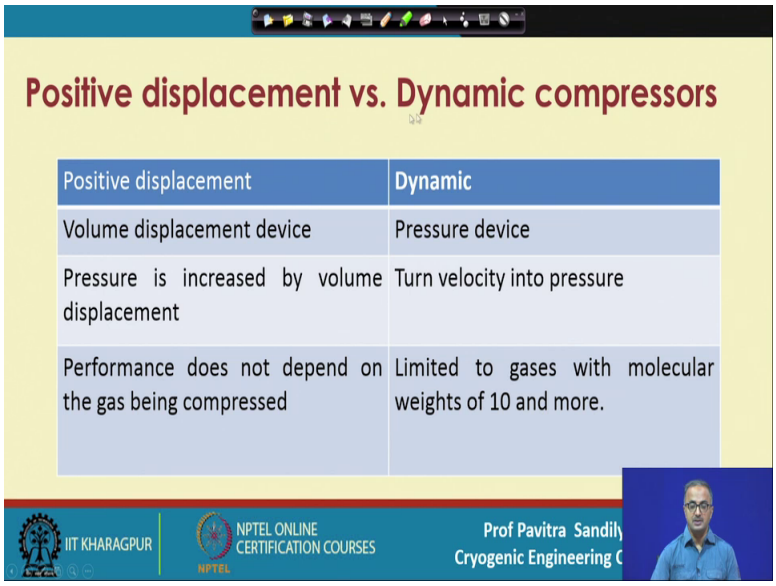

So, here we have some comparison between the positive displacement and the dynamic compressors. Here this works based on the displacement of a certain volume whereas, this is a pressure device; that means, it creates a pressure to drive the particular fluid.

Now in this we have the pressure gets increased by the volume displacement whereas, this in this case the pressure rise is converted into kinetic energy; that is velocity of the fluid. Then in this the pressure performance does not depend on the gas being compressed; whereas, in this case it is limited to gases with molecular weights, about 10 or more.

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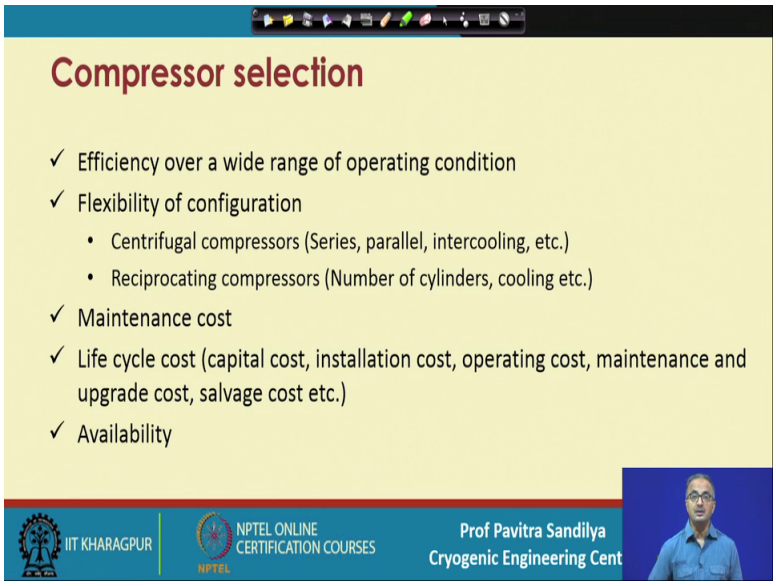

Now, to select compressor we have to look into this criteria that efficiency it should be efficient over a wide range of operating conditions; then flexibility of the configuration. For example in case of centrifugal compressors we may have series parallel or we should have can have intercooling also.

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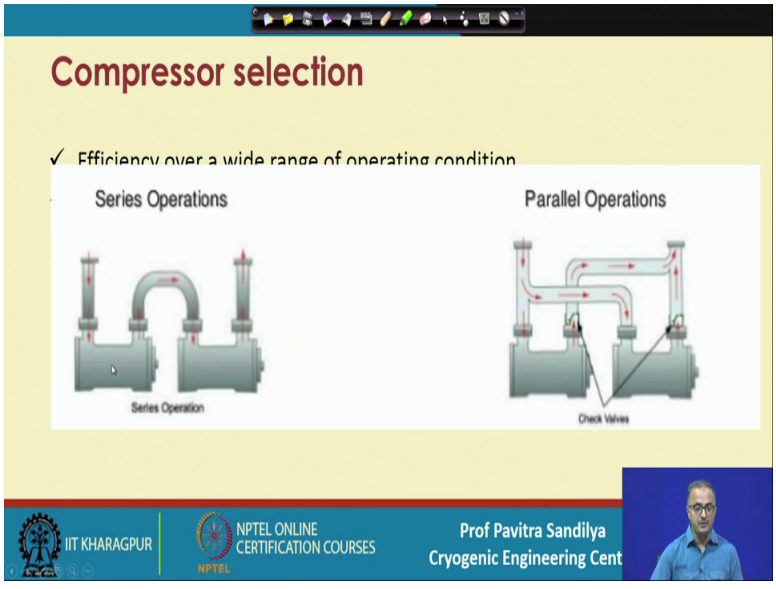

So, here we have shown some configurations like the, this is how we are putting two centrifugal compressors in series and here we have put the two compressors in parallel. So, parallel means that we had have the single input and this is getting distributed

between the two compressors and the outlet are again taken together and deliver it is from one port. So, this is the parallel configuration

And then we have reciprocating compressors may have number different numbers of cylinders and some cooling. And then the maintenance cost , the life cycle cost life cycle cost means the capital cost that is the actual cost of the equipment, the installation cost, operating cost, maintenance and upgrade cost, salvage cost etcetera. So, all these are included in the life cycle cost and the availability of the particular compressor.

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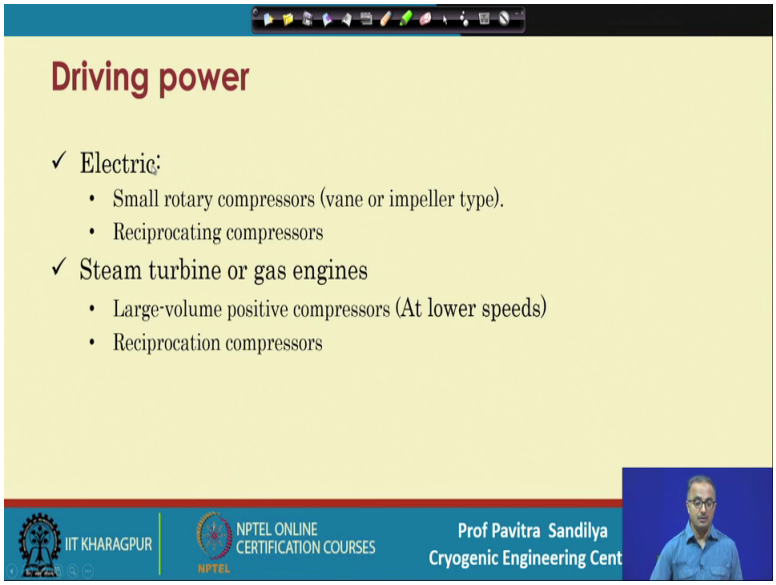

Now, the driving power for these compressors can be different; one is electrical electricity that is for small rotary compressors and reciprocating compressors we can use electricity. And we may have it from some steam turbine or gas engines and this is used for large volume positive compressors at lower speeds or for reciprocating compressors; that means, reciprocating compressor can either run on electricity or by the use of the steam turbines.

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In the positive displacement compressor, the movement is caused by a trapping a fixed amount of the gas and the forcing this trapped volume into the discharge pipe.

Now, their classification different types of these displacement pumps first reciprocating and then we have rotary. So, let us first look into the reciprocating type which is very common in the natural gas industry.

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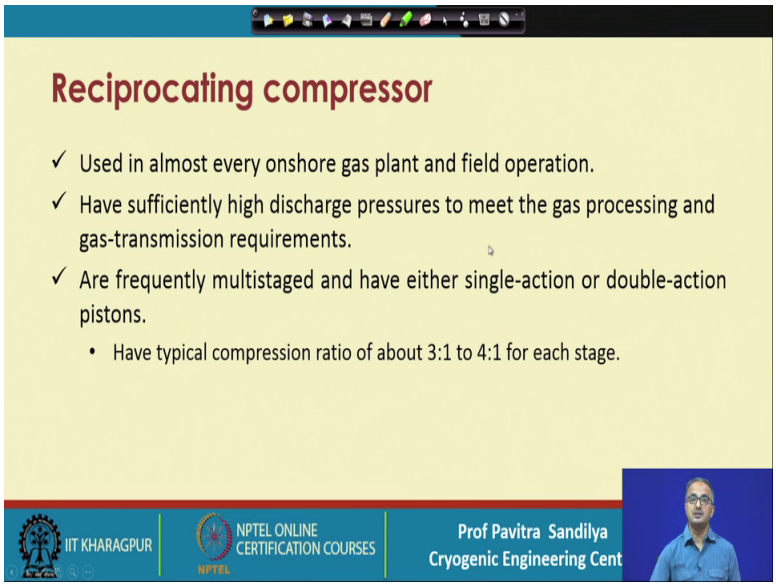

So, here it is that this is used in almost every onshore gas plant, and field operation and have sufficiently high discharge pressures to meet the requirement in the transmission

and processing lines. And generally we have multi stage not single stage multi stage of these compressors with either single section or double section; that means, if we have single section there could be intermittency in the delivery and to make it a continuous operation we use multiple sections.

And generally the compression ratio is between 3 is to 1 to 4 is to 1.

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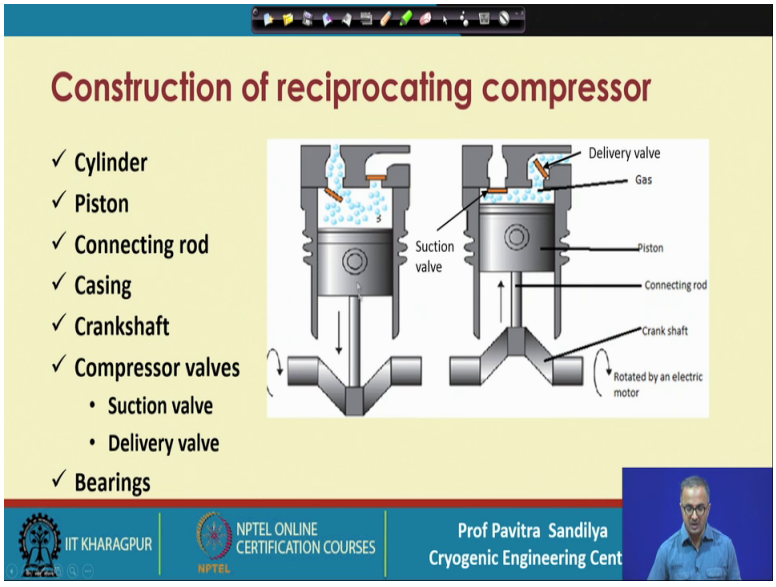

And here we have a typical construction of these compressors that there is a piston which is moving up and down by some connecting rod which is given within a crankshaft here which is rotated by some electric motor and here we find we have one inlet port.

And another is the outlet or delivery port; so what we find that when this particular piston is moving down then the inlet port is open whereas, the discharge port is closed. So, in this way we are able to suck in some fixed volume of the gas then when this piston moves up then what happens? This inlet port is closed whereas; the delivery port is open now this entire gas is now taken out from the delivery port.

So, this we will find this alternately the inlet port and the outlet port are closing and open opening and that is how we are able to drive out the gas; it is like a syringe we are using at our to deliver our we are for injecting some kind of you know medicine in our body. For similar manner we are moving the piston to and flow some when it is going away then we are sucking in and when it is pushing we are delivering out the particular gas.

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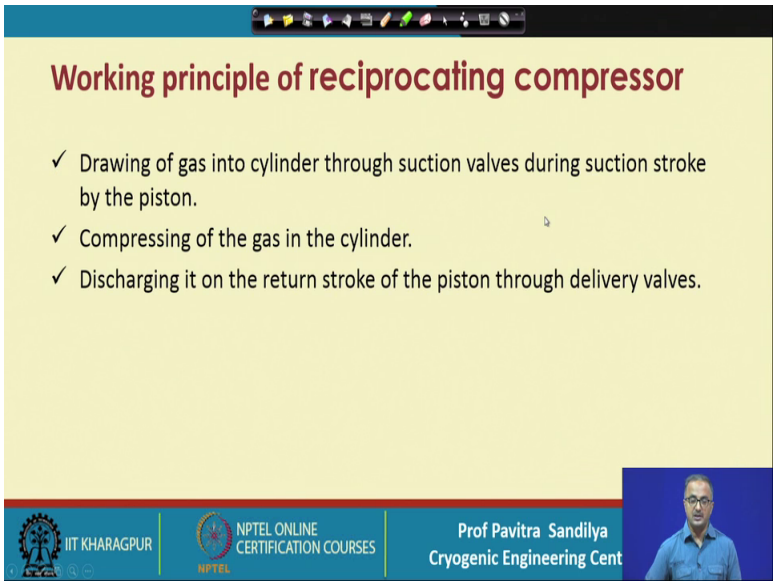

So, we find that this, the gas is drawn within some during suction stroke and when then we compress the gas.

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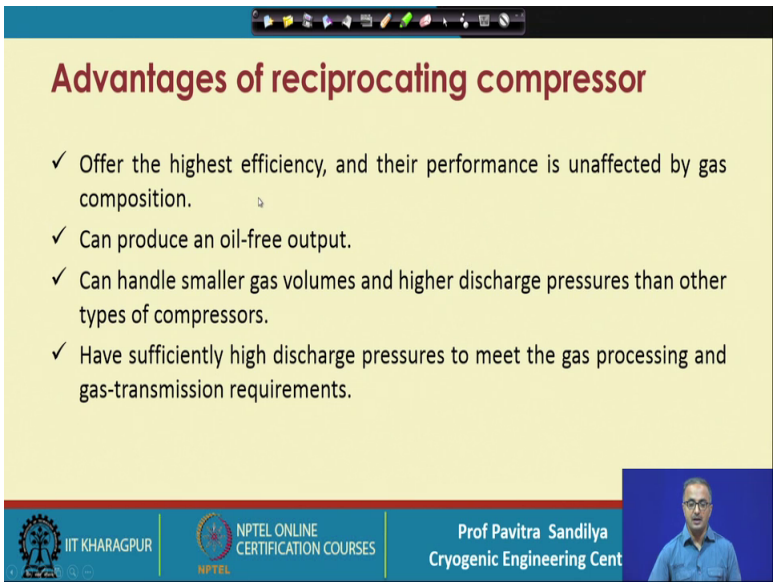

And then we the return stroke we deliver the particular gas to the delivery valves. Now, there are some advantages of the reciprocating compressors they offer very high efficiency and their performance is generally unaffected by the gas composition. They can produce all free output and they can also handle smaller volumes and with high

discharge pressure and then other types of compressors. And they have high discharge pressure to meet the gas processing and the transmission requirements.

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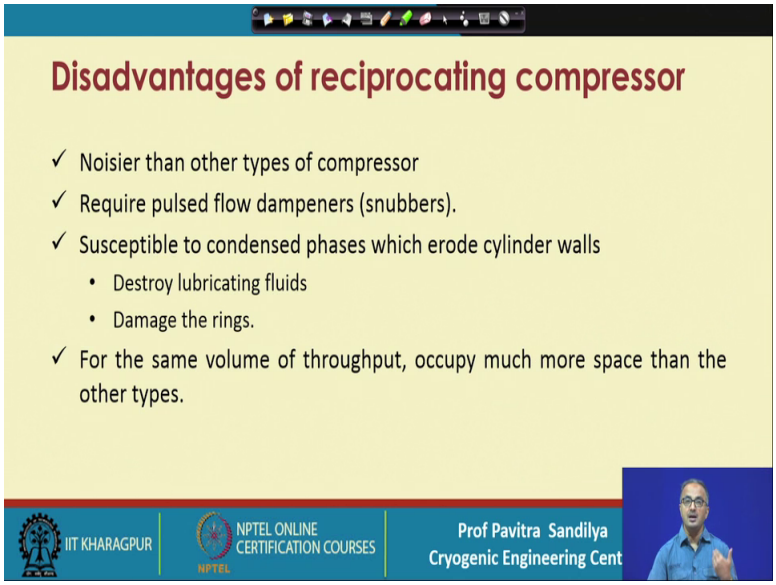

On the other end these are some of the disadvantages they are quite noisy. And because if we are not using multiple pistons then we will find that it could be a pulsed flow and this is calls snubbers are used to make some uniformity in the outlet flow.

But they are susceptible to condensed phases which erode the cylinder walls that is destroy the destroy lubricating fluids or damaged the rings. And for the same volume of throughput occupy much more space than the other types of the compressor; so, they are quite bulky.

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Now, under rotary compressor we have oil rotary screw compressor and the oil injected rotary screw compressor. We shall be confining ourselves only to reciprocating one because all this compressor there many many many compressors used in the industry and here we are just taking the glimpses of the ones which are more common.

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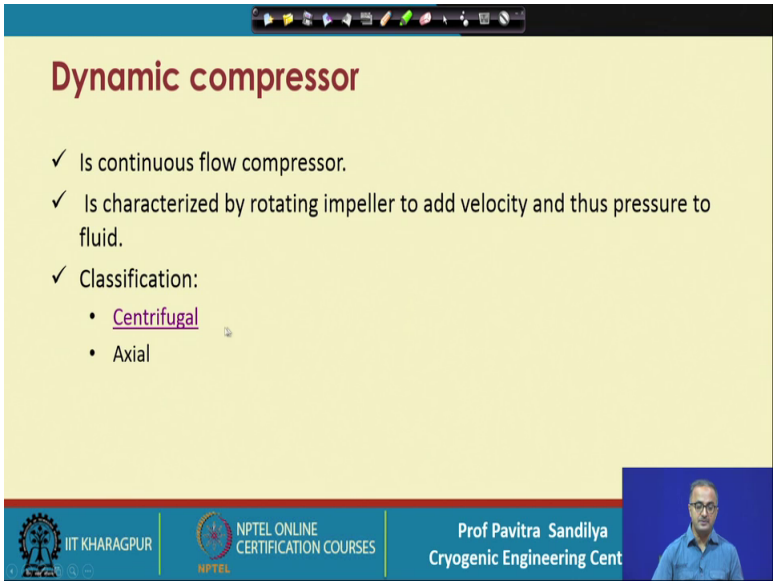

Now we go to the dynamic compressor, in this case we will find unlike the reciprocating or the positive displacement compressors; here we have the continuous flow of the gas.

And it is characterized by some rotating impeller to add to the kinetic energy to the of the to the fluid and thus pressurize the particular gas.

Again we have two types one is centrifugal another is axial; we shall be looking into only centrifugal compressors.

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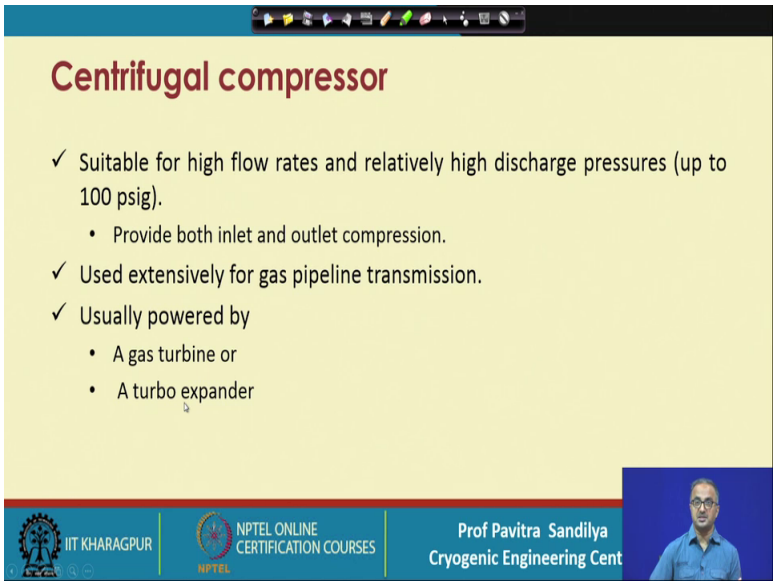

Now, these have high flow rates and relatively high discharge pressures up to about 100 psig. And they provide both inlet and outlet compressions and it is also a quite extensively used in the gaps pipeline transmission, and generally powered by gas turbine or turbo expander and not electricity unlike the reciprocating compressor.

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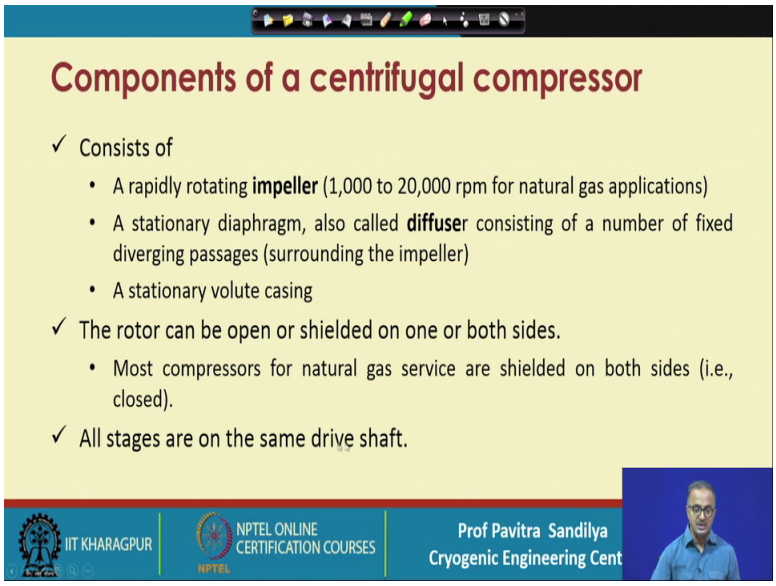

So, here are the compo components of this compressor; we have one impeller which is rotating at a quite high speed. The speed may vary between 1000 to 20000 RPM. And then we have a stationary diaphragm all a all the diffuser through which the it is a diverging section through which the gas after getting compressed goes out and then we have a stationary volute section.

The rotor may be shielded or may be open on both or the one side. And for natural gas services they are they are closed; that means, they are shielded from both the sides and all the stages are placed on a single shaft which is rotating.

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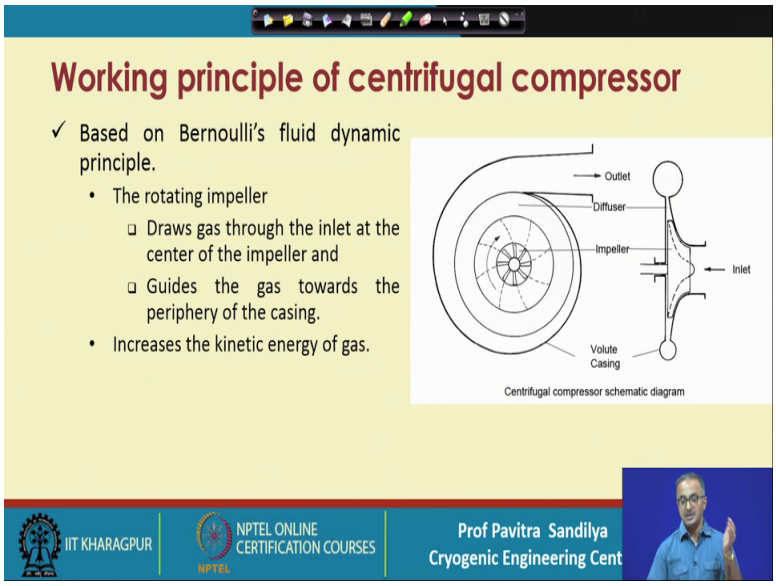

Now, the working is based on the Bernoulli's principle here; here we see that here we have the impeller and through the impeller this the particular fluid is coming through out through the impeller. And then what happens? When it reaches the impeller this get rotated and by rotating what we are doing? We are increasing the centrifugal force and that is increasing the velocity of the fluid as it moves towards the tip of the impeller. So, this impeller are helping the gas to be directed in one particular direction and this way we find that as the gas moves from the inner to the outer periphery that from v this the gas increases its kinetic energy.

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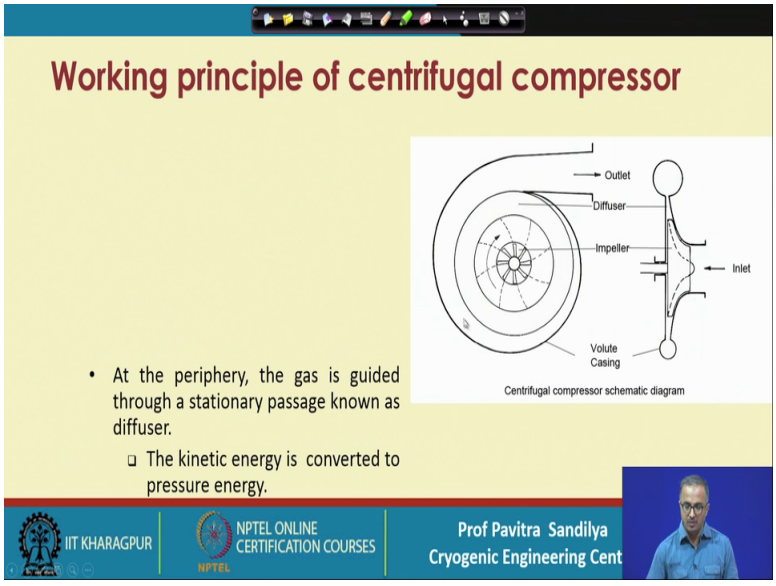

And now what happens? Once it reaches this outer periphery; it is guided to some stationary passage and it goes towards the, this outlet to the volute section. And what happens during this period this kinetic energy is again converted to the pressure energy.

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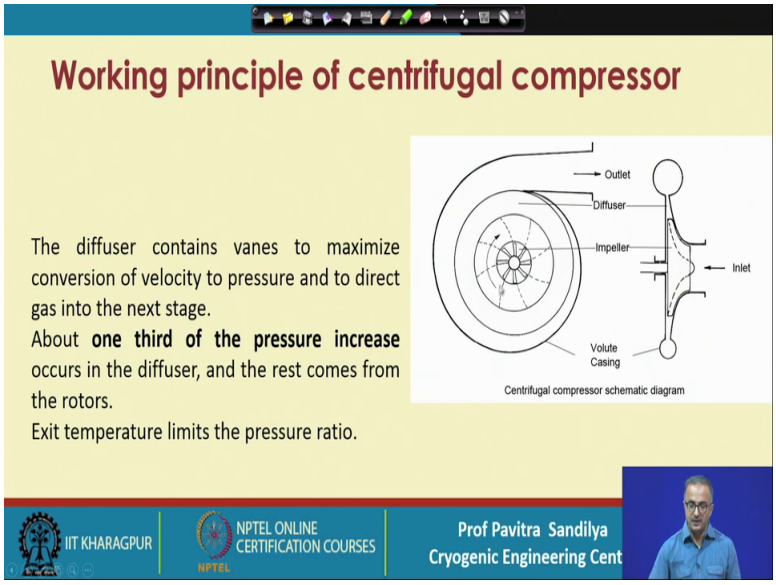

And that then what happens? A diffuser contains some vanes; so, in this is a diffuser section it contains some vanes to maximize the conversion of the kinetic energy to the pressure energy and to direct the gas into the next stage. And then what we find that about one third of the pressure increase occurs in the diffuser and the rest comes from the rotors and the exit temperature limits the pressure ratio.

Because as we found in the last lecture that we cannot allow too much of temperature rise due to compression because we are having some limitations on the material of construction. So, if the temperature there is an exit temperature limit for the particular pressure ratio.

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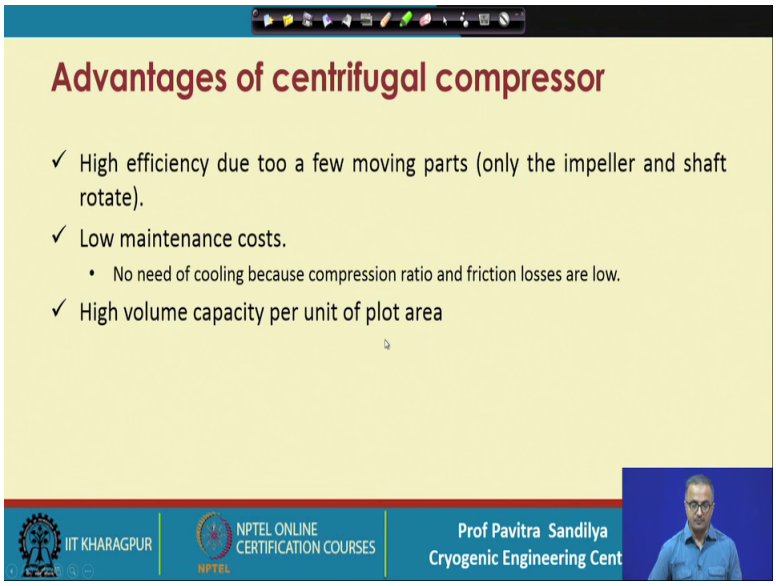

Now, the advantages of these compressors are that they are quite highly efficient due to a few moving parts. Then they have low maintenance cost and high volume capacity per unit area.

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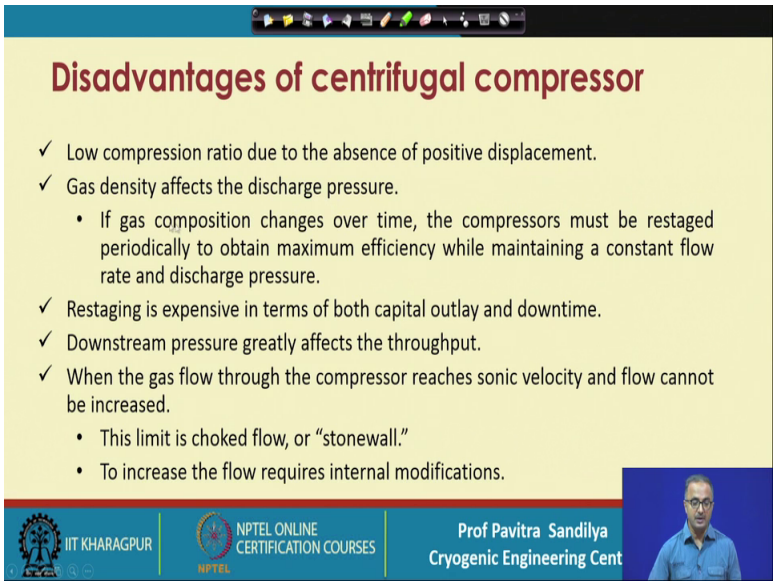

And the disadvantages are that they have low compression ratio compared to the reciprocating type.

Then gas density affects the discharge pressure if gas composition changes over time then the compressor must be restaged periodically to obtain maximum efficiency and

keeping the constant flow rate and the discharge pressure. And this restaging is an expensive matter because it needs a capital outlay and the some downtime; that means, you have to shut down the plant to make this restaging.

And the downstream pressure greatly affects the throughput and the when the gas flows to the compressor; it reaches if it reaches sonic velocity then what happens? If the there is no more flow that we call there is a choked flow; that means, even if we are increasing the pressure beyond this we are not able to increase the flow rate or the throughput of the compressor.

So, we say the compressor has choked; that means, it can the bit increase in the pressure we cannot increase the throughput of the compressor. And this kind of situation may be avoided by some internal modifications; this and this situation is not faced in case of the reciprocating compressors.

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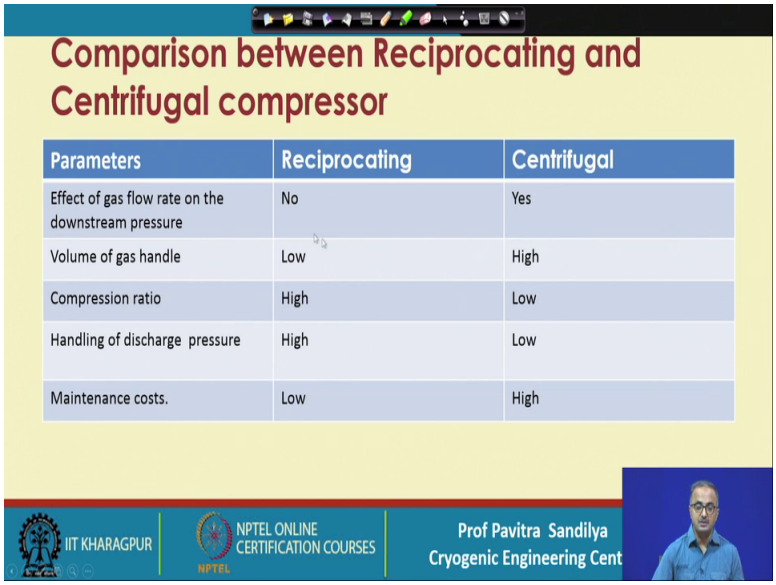

And then we have; this is the table where we are comparing the reciprocating and the centrifugal compressors, which are very common in the natural gas systems. So, first with respect to the effect of the gas flow rate on the downstream pressure; we find there is no effect whereas, this is affected by the in the centrifugal compressors. The volume of gas handle is low in case of central reciprocating compressors then for the centrifugal compressors.

Whereas for the pressure rise that is obtained that is higher in case of reciprocating compressors than for the centrifugal compressor. That means, if you want high pressure ratio at a low flow rate, you will choose the reciprocating compressor. On the other hand if you want high flow rate and low pressure rise; you should use the centrifugal compressor.

The discharge pressure is higher than for the for the reciprocating compressor than for a centrifugal compressor.

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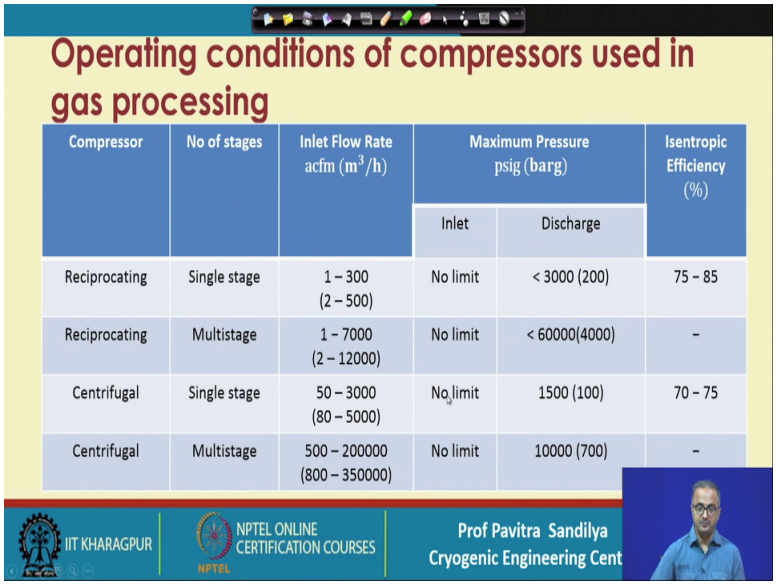

And the maintenance cost is generally low for the reciprocating compressor than for the centrifugal compressor. And here we have the various operating ranges for these two types of compressors here we find the reciprocating the single stage compressor.

We have this is the range of the flow rate this is the actual flow rate and this for this figure is the cubic feet per meter, this figure is for cubic meter per hour. And we find that there is no limit to the maximum pressure at the inlet whereas, disturbed pressure is within 3000 psig or 200 bar g. And this is the isentropic efficiency; this is for the multi stage reciprocating compressor here we find by multi staging we are able to increase the inlet flow rate and also able to increase the maximum achievable pressure.

Similarly, for the centrifugal force for single stage this is the inlet flow rate and we find this inlet flow rate is more than that can be handled by the reciprocating compressor. And

also we find that the discharge pressure is lower than that for the reciprocating compressor and the isentropic efficiency is almost similar to that of the reciprocating compressor; whereas, a multi stage reciprocating compressor.

We have this is the inlet flow rate which is more than for the single stage and this is there is no limit to the maximum pressure at the inlet side. Whereas, this is the outlet pressure which is more than for the single stage centrifugal, but is less than the multistage reciprocating compressor. So, these are some typical values for the inlet flow rate and the pressure rise that is achievable for these two types of compressors.

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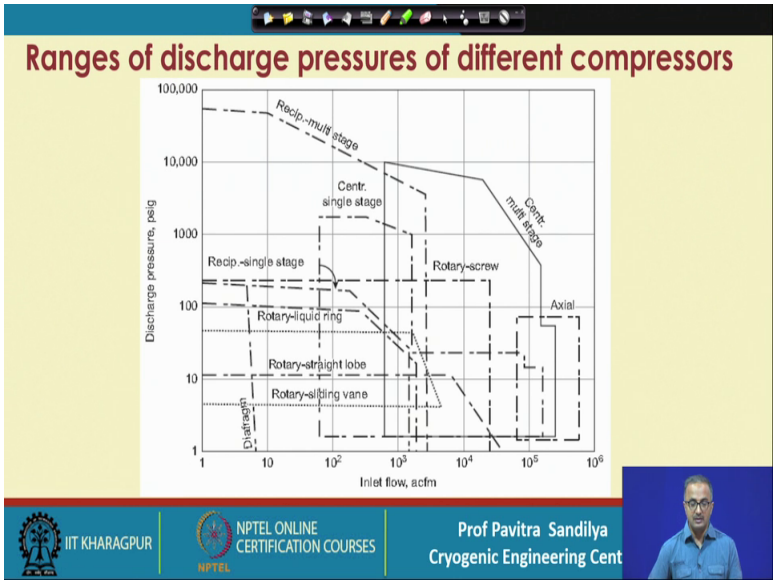

Next we come to another graphical representation of the selection of the compressors. What we do that on this x axis we brought the inlet flow rate whereas, on the y axis we put the discharge pressure. So, depending on the as I told that depending on the flow rate required that is throughput and the discharge pressure, we have to go for the selection.

So, here the different types of the compressors have been shown the rotary compressors, then we have the centrifugal multistage, reciprocal multistage, the centrifugal single stage, rotary screw compressors axial compressors the diaphragm compressors.

So, we see that depending on the flow rate and the discharge pressure; we go for different types of compressors. And we also find there are many many overlaps in this particular figure; overlap means we are given with multiple options to choose from. So,

the options I have already shown in one of slides earlier. So, not only the inlet pressure and the discharge pressure also you have to look at the other factors like cost, maintenance etcetera to decide upon the particular type of compressor.

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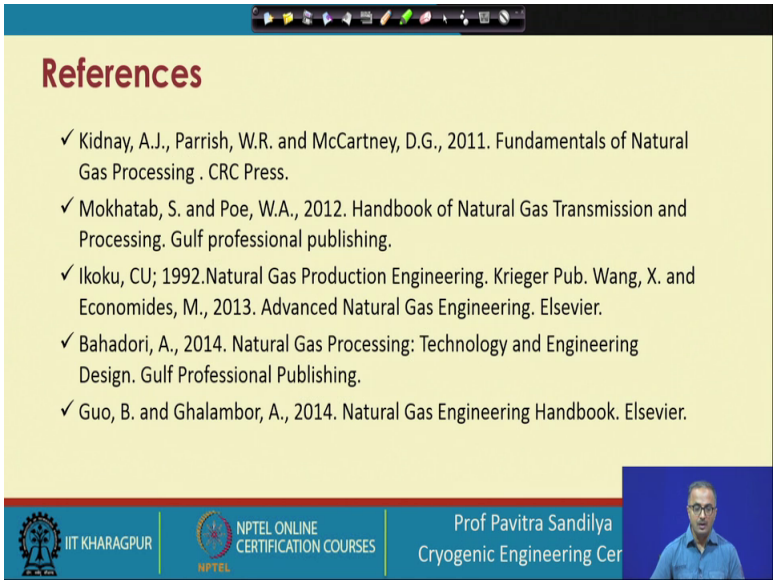

All these topics can be found in these references for more detailing.

Thank you.