Upstream LNG Technology
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Lecture – 47
Compression in natural gas systems

Welcome today we shall be looking into the Compression in natural gas systems.

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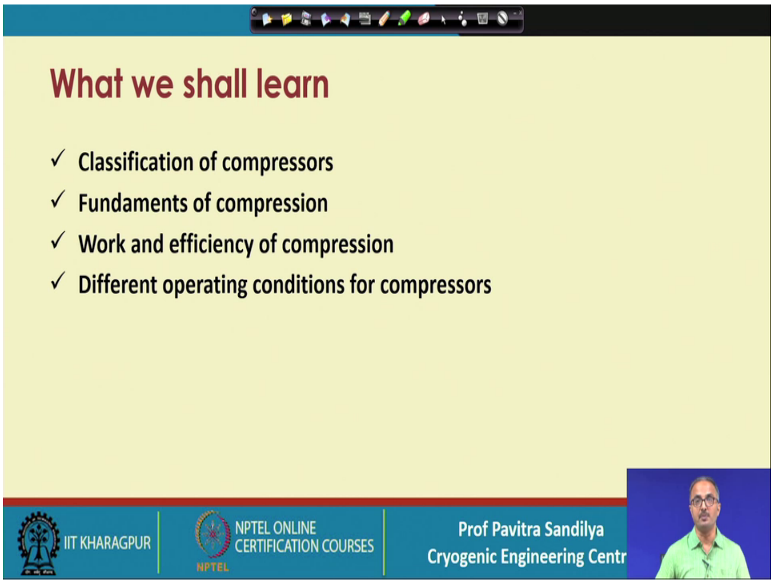

In this lecture what we shall learn? We shall learn about the various types of compressors from fundaments of compression. And the determination of the work and efficiency of compression and the different operating conditions for compressors.

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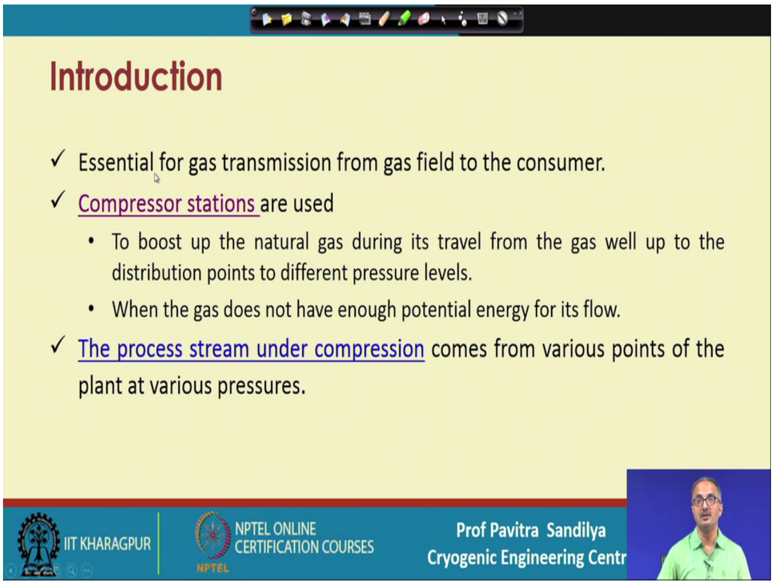

So first let us come to need the compression, we need compression why? Because of the gas transmission from the gas field to the consumer and because this we need compressor stations to boost up the natural gas during it; its travel from the gas well to the various distribution points at various levels why? Because of when gas does not have enough potential energy and potential energy is lost giving the flow to the various systems due to fictional or the causes.

So, we need to boost of the gas from time to time and that is them through the compressor station and this stations are of different type.

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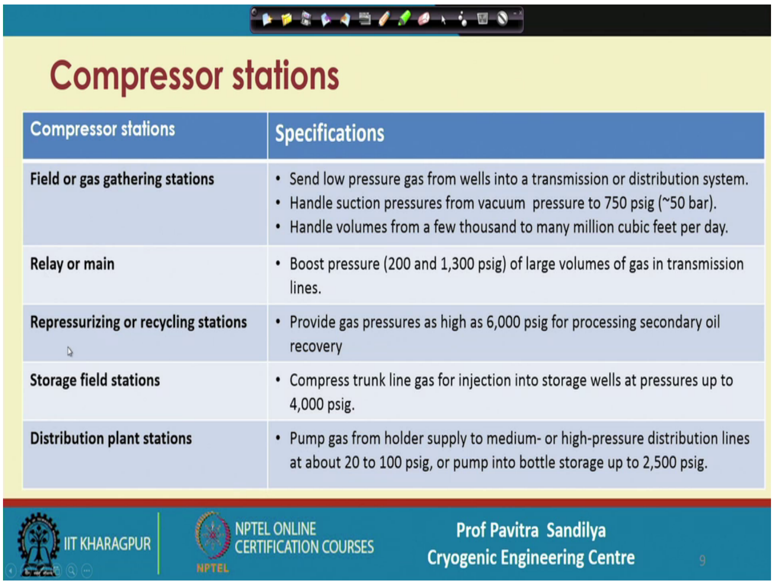

Like field or gas gathering stations relay or main station, repressurizing and storage field stations, distribution plant stations and in this find that find where all this different types of stations do different kinds of work for different levels of compression.

Here we find for field gas station, they send low pressure gas from wells into a transmission or distribution line. And the kind of pressure will be the handle is about 750 psig or about 50 bar g. And this the handle volume from a few thousand to many million cubic feet per day. Then this relay station part they are boosting the pressure from about 200 to 13 psig for of large volumes of gas in transmission lines.

Then we have repressurizing stations we provide gas pressure as high as 6000 psig for processing of secondary oil recovery. Then we have storage field stations, which compress the trunk line gas for injection into the storage wells at pressures up to 4000 psig. We shall get run what is trunk line gas and then distribution plant stations is a pump gas from holder supply to medium or high pressure distribution lines. We about 20 to 100 psig or and or up to 2500 psig for storage.

So, we see that different stations are working at different levels of station.

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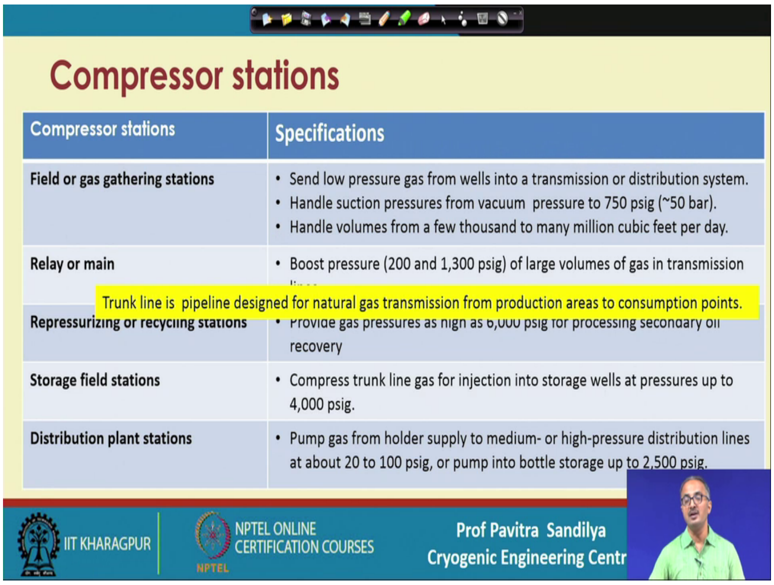

And the trunk line is in the pipeline designed for natural gas transmission from production areas to consumption points. So, all these lines required different levels of pressure. So, we need different types of compressor and compression stations.

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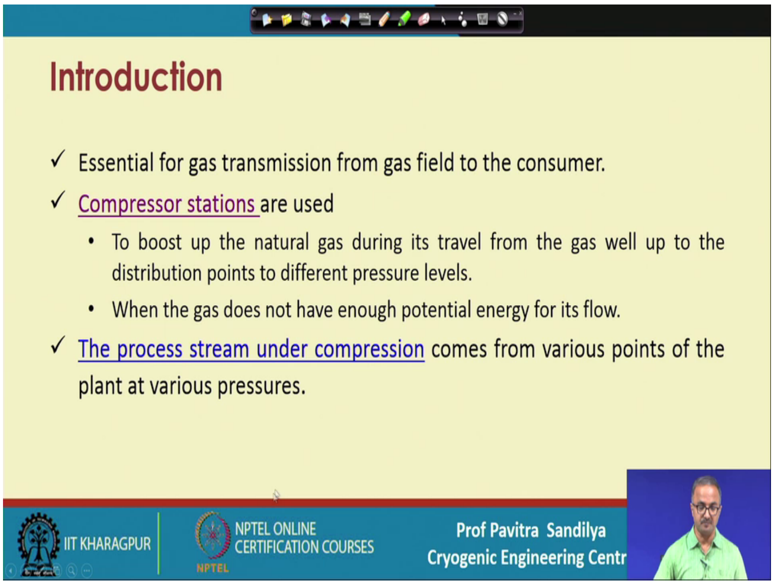

The process stream under compression comes in various points. So, we can have the various types of process streams in this and we find that these things may be coming from differentprocesses.

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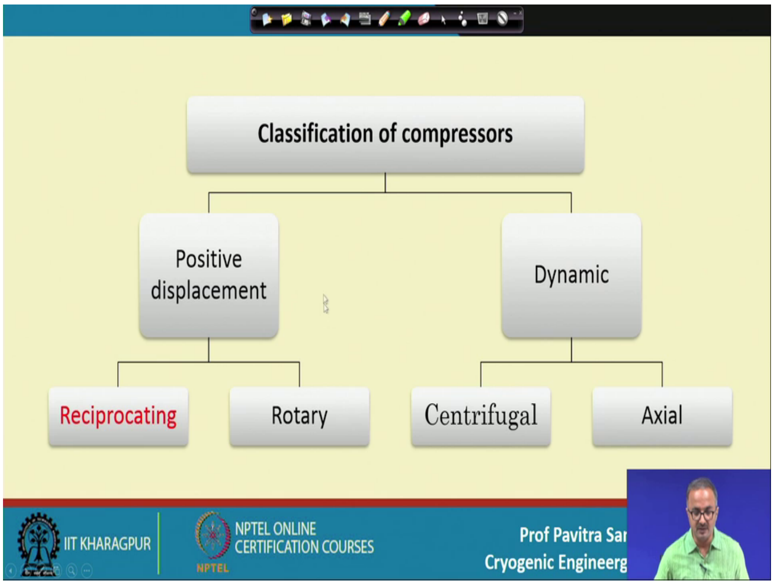

And then we have the classifications of the compressor at in this we find here positive displacement and dynamic compressors under positive displacement here reciprocating compressor, rotary compressor and under dynamic we have the centrifugal compressor and axial compressor; now this particular reciprocating compressor, we the most widely used compressing system for the natural gas industry.

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Now, let us go to some fundaments of the compression before we go to compressors. So, first we go for this compression of ideal gas.

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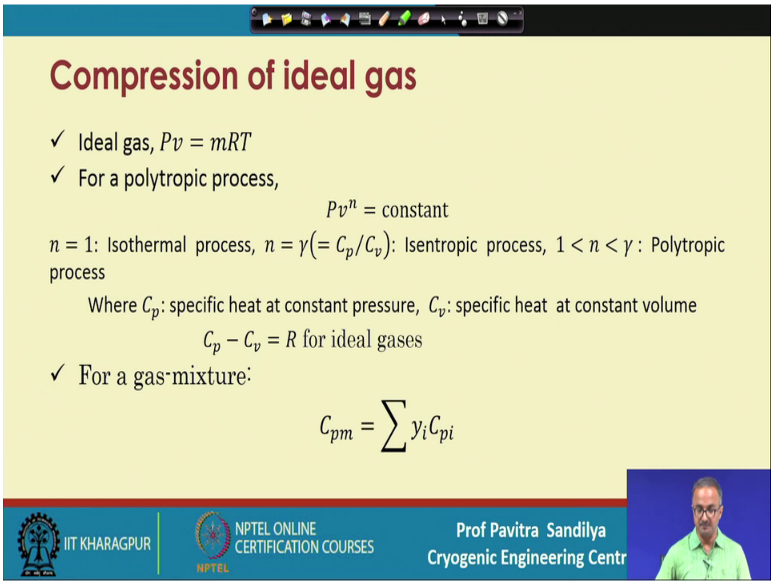

And here we find that for ideal gas we know that Pv equal to mRT; this m is the mass and R is the gas constant. Understand this if you are writing in terms of number of molten then we are we shall be using the universal gas constant.

Now we have for polytropic process we have Pv to the power n equals to constant. And this n is equal to 1 that is for isothermal process and for isentropic process we have n equals to gamma and that equals to Cp by Cv that is the ratio of the specific heat at constant pressure and the specific heat at constant volume. And is n is different unity and gamma then we have polytropic process, where because Cp is always more than Cv; so, gamma will always be more than 1.

And we also know that for ideal gases is different between the specific heats at the constant pressure and constant volume is equal to R. So, for a gas mixture if you are apply is equation then we have to rule some mixing rule to find out the average specific heat and this is one of the way that we are taking the summation of the product of the mole fraction and the individual specific peaks. So, that is how we get the average specific of the gas mixture.

Now, next we come to the theoretical work of compression.

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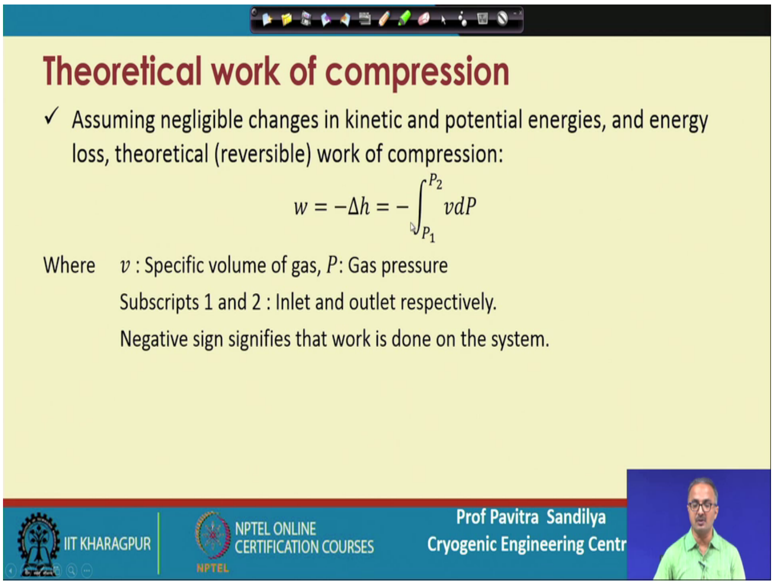

In this we have that we assume that there is insignificant changes in a kinetic and potential energies and there are no energy loses. Then we will discuss if you apply the first law of thermodynamics; we get the work is equal to the minus the same in the enthalpy and this is given by this particular equation.

That from integral we are going from P 1 to P 2 in this case 1 and 2 below the inlet and outlet votes v is the specific volume and P is the pressure of the gas. And the negative sign we are taking because we know that work has to be imputed to the compressor to make it work; so, we are putting it negative.

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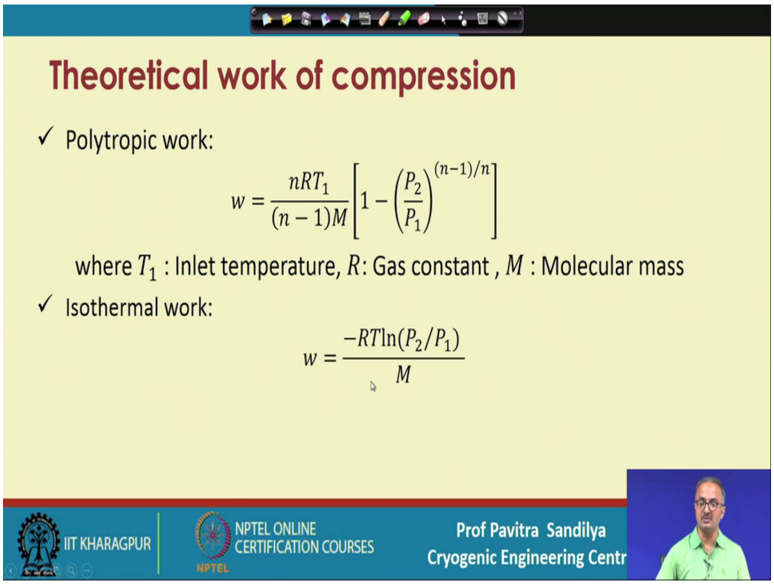

The theoretical work of compression for polytropic work is given by this particular equation which is obtained by integration of the equation shown earlier. And we get this particular equation we find here that this P 2 by P 1 is the compression ratio; that means, to what level we are compressing from the inlet to outlet; they and the temperature at the inlet.

And n is the molecular mass of the gas and if we put n equals to 1; then we cannot solve this different directly; we have to solve it separately. And then we solve it separately, we get this has a expression or the work for isothermal compression.

Next we go to the compressor efficiency in this case we have different types of efficiency overall efficiency, isentropic efficiency, polytropic efficiency, volumetric efficiency.

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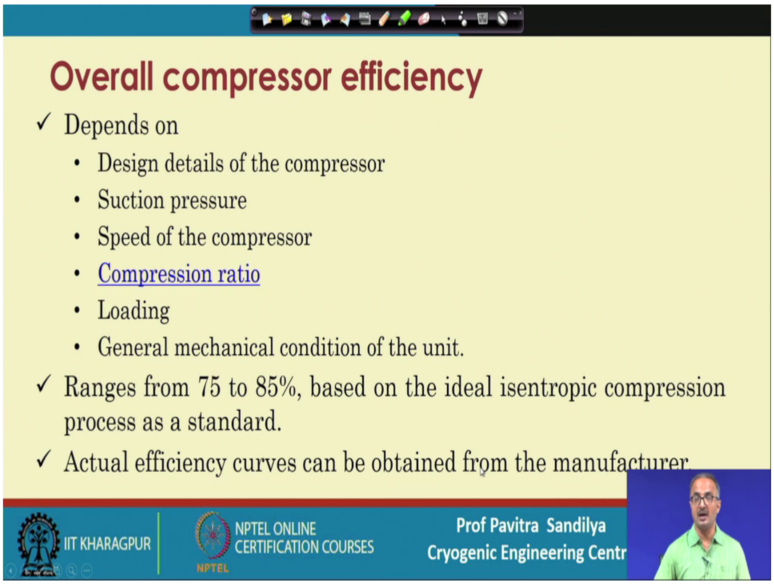

Now, here we see that the overall efficiency of a compressor depends on these factors by the design details of the compressor suction pressure that is the P 1. Then the speed of the compressor, the compression ratio the loading of the compressor the mechanical condition that ways is the compressor running for long time if there are any wear and tear of the compressor unit.

So, and then we find that the ranges of these overall efficiency varied between about 75 to 85 percent based on the ideal isentropic compression process as a standard and actual efficiency curve are given by the manufacturer.

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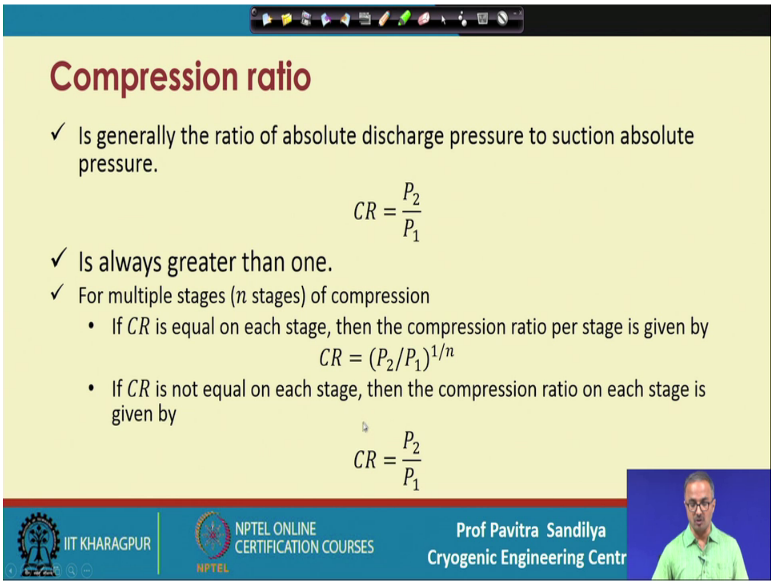

Here we see the compression ratio is determine like this that from the ratio of the absolute discharge pressure to the absolute suction pressure. And it is always greater than 1 because P 2 is always more than P 1. And when we have multiple stages, suppose we have n number of stages then we find that if CR is equal to on each stage then we find the compression ratio for each of the stages is P 2 by P 1; it will be power 1 by n whereas, if CR is not equal to for in on the stages then we have to find out the to this compression ratio for each of the stages; separately.

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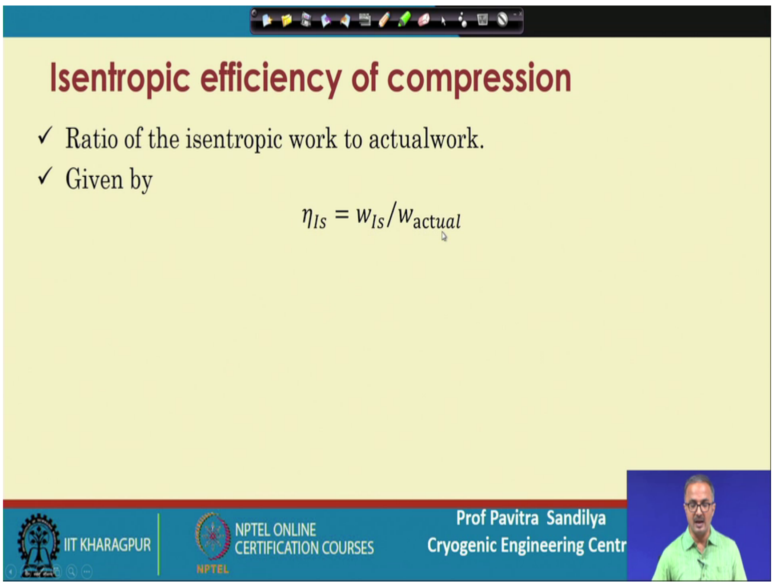

Next we come to isentropic efficiency of the compression and this is to the ratio of the isentropic work to the actual work, and it is given by this particular expression; in this case this is signifies isotropic and this is the actual.

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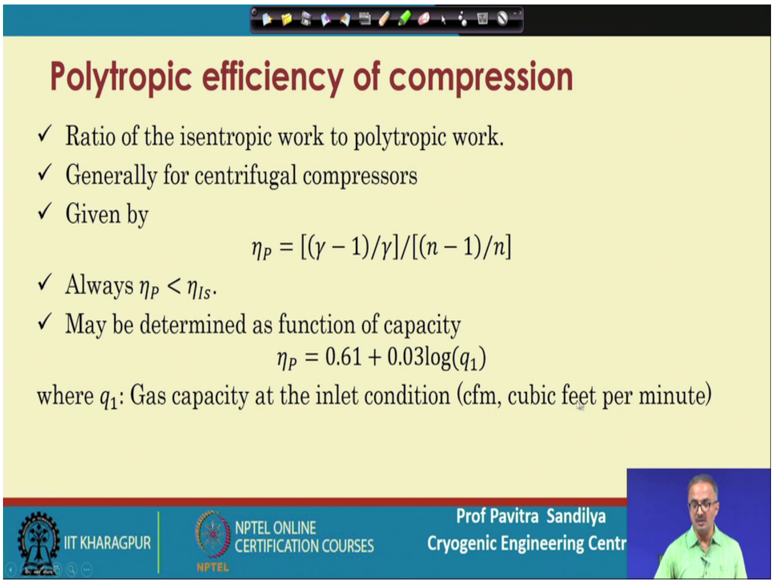

Next we come to the polytropic efficiency of compression and this is the ratio of the isentropic work to the polytrophic work. And it is generally use for the centrifugal compressors and is given by this particular expression that this is the gamma gamma minus 1 minus by gamma; this is of the isentropic process and n minus 1 by n and this is of the polytrophic process.

And we find that the polytropic efficiency is always less than the isentropic efficiency. And this may be also determine or some empirical correlation based on the capacity of the particular gas. So, this may correlation may be also used to find out the polytrophic efficiency. So, in this particular expression the gas capacity is given by the cfm that is the cubic feet per minute.

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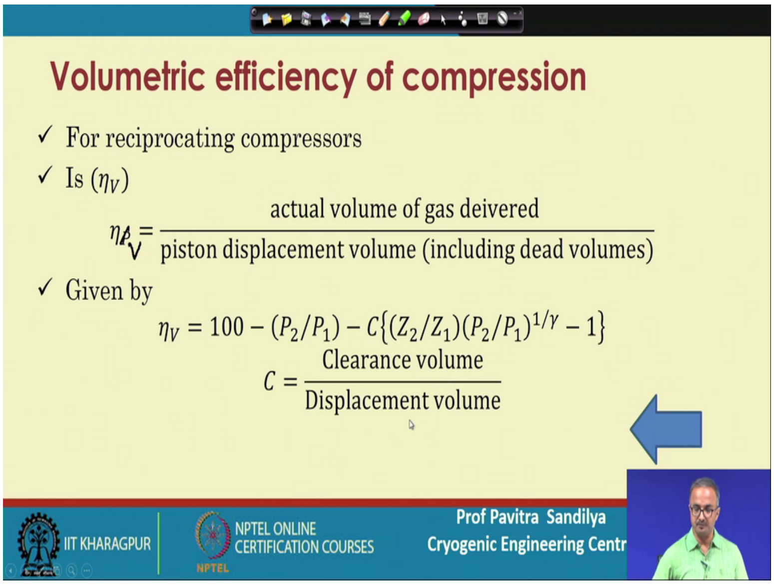

Next we come to volumetric efficiency which is generally used for the reciprocating compressor. And in this case it is defined as the actual volume of the gas delivered to the this will be eta v. So, this is the expression for this for the volumetric efficiency that is the actual volume of the gas delivered to the piston displacement volume including the dead volumes we shall be looking into this a bit later.

And we find that this particular expression is given from is given some this equations that this volumetric efficiency depends on again the pressure ratio. And also the ratio of the competitive factor of the gases and at the independent outlet conditions and the value of the gamma, and we see here is the clearance volume to the displacement volume.

Next we come to outlet temperature of the gas after compression.

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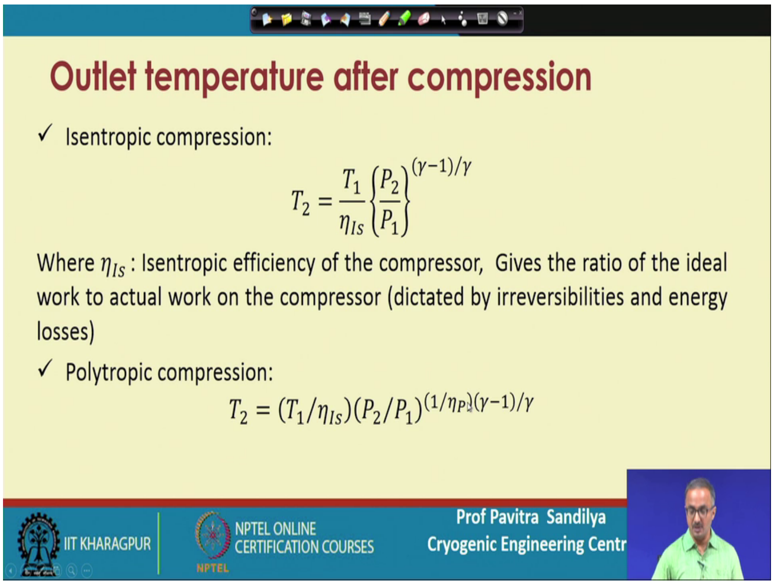

You know that whenever we are compression any gas; there will be some a heating of the a gas. So, the temperature increases it will have its own effect on the compression efficiency because the volume of the gas will change due to the change in the temperature.

So, it is important for us to know the outlet temperature of the gas. So, here we have for isentropic compression; this is the expression to find out the outlet temperature in terms of the inlet temperature, the compression ratio and the isentropic efficiency. And for the polytropic compression; we have a singular expression, but in this case we have deriving it from the isentropic in change in the temperature and we are taking that from the definition.

So, relationship of this polytropic efficiency we are replacing the n by these expression of the polytropic process. Next we come to the capacity of compressor.

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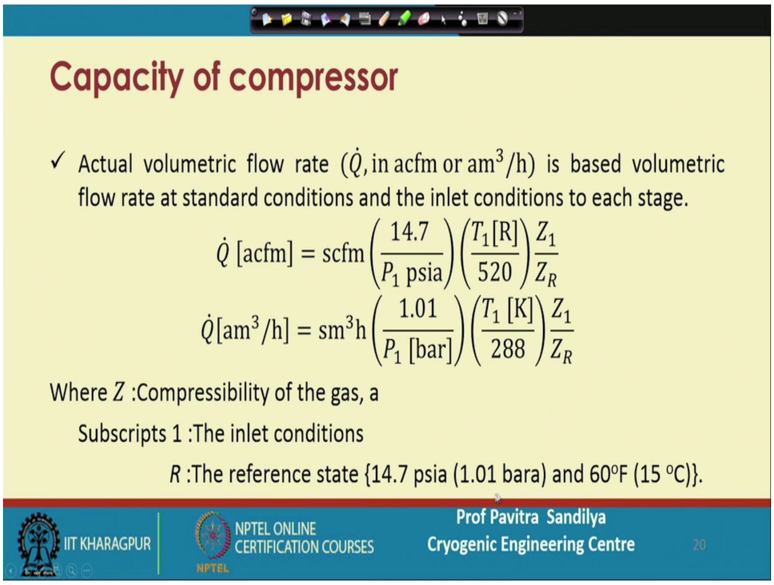

In this case it is the defined at the actual volumetric rate and that is given in acfm this a stands for actual, but it can be even in terms of actual cubic feet for minute and it could be actual cubic meter per hour. And it is based on the volumetric rate at standard conditions and inlet conditions to each stage. So, here we have the expressions this is this can be derived easily from the gas law and we find to find out the actual capacity which is a standard value or standard value is 14.7 psia and 520 ranking.

So, with this we can find out the actual capacity in terms of the cubic feet terminate and in terms of the meter cube per hour we take the standard cubic meter per hour value. And again if you the pressure in terms of bar and temperature in terms of Kelvin and is Z 1 and Z R are the compressibility at the inlet condition and some reference condition respectively. These reference condition is taken has the 14.5 7 psia and 60 degree Fahrenheit or about 1 bar and 15 degree centigrade.

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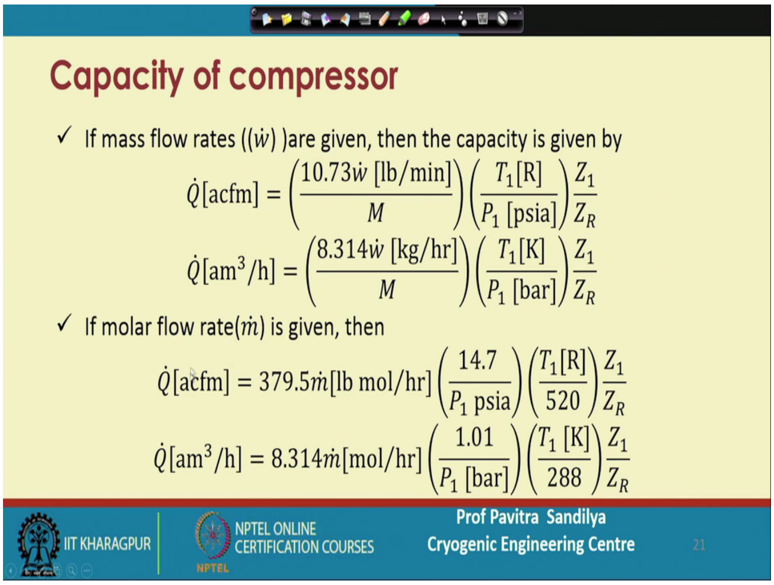

Then if we are given the mass flow rates; then also we can find out the capacities in terms of the volumetric flow rate from this expression if it is in spf system and this form this expression; if it is in the Si units. So, this is we have using the gas law to find out due to correlate the mass flow rate give the volumetric flow rate of the gas and in this case we are having the flow rate in terms of mole. So, this is for the mass and this is some to mole; in terms of mole also we can correlate the gas flow rate mass flow rate with the volumetric flow rate.

Next we come to the power requirement.

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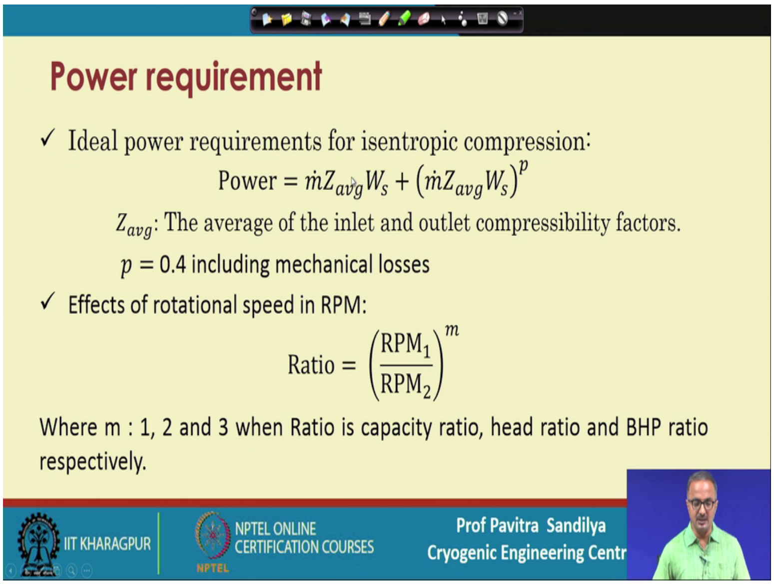

And in this case we find the power requirement is given for this processes like this is this particular thing is the isentropic and if it is not isentropic; then we use another factor for some mechanical loses. So, this particular expression we find the this is used for the to find out the power and this W stand for the work for the short work that is the work we have calculated so far. And this is the effect of the RPM on this compressor if compressor efficient performance and in this case we find that some ratio is equal to 2 RPM ratio to the power m.

Now, this m is taken to the one if you cannot capacity ratio; that means, the capacity's are linearly baring with the RPM. And if you talk of the head ratio; that means, how the head ratio change then we take this m to be 2 and; that means, there the head is varying with square of the rotational speed. And then lastly of the BHP ratio that is the power consume that is BHP that is that is going to the cubic power of the rotational speed.

Next we come to the multistaging.

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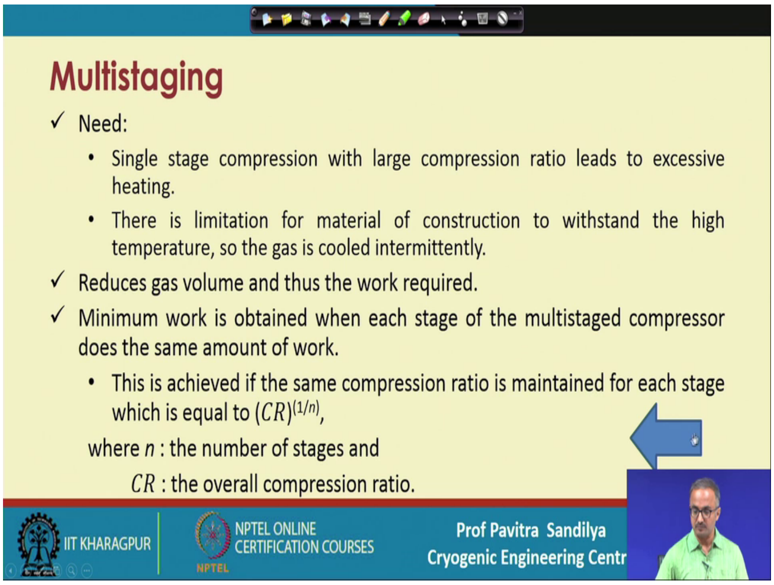

In the multistaging, we have the, what a need be what a need multistaging because single stage compression if you go for a very large compression ratio; we find it will lead to excessive heating and if there excessive heating we a find the particular material construction we not be able to withstand the high temperature.

So, the gas has to be cooled intermittently intermittently and for that we need you might be studying and it does another advantage is this the when we cooled down and what happens that the gas volume comes down. And the when the gas volume comes down we find the work requirement also comes down.

So, minimum work is obtained when each stage of the multistage compressor does the same amount of work is can be derived some theory. And in that case if same ratio compression is maintained for each stage that is the total compression ratio from the inlet to outlet is the total compression ratio. And if you divide along across each of the stages; n is the number of the stages. So, if you divide this total compression ratio in each of the stages and if you put the same ratio for each stage that will lead to the minimum amount of the work.

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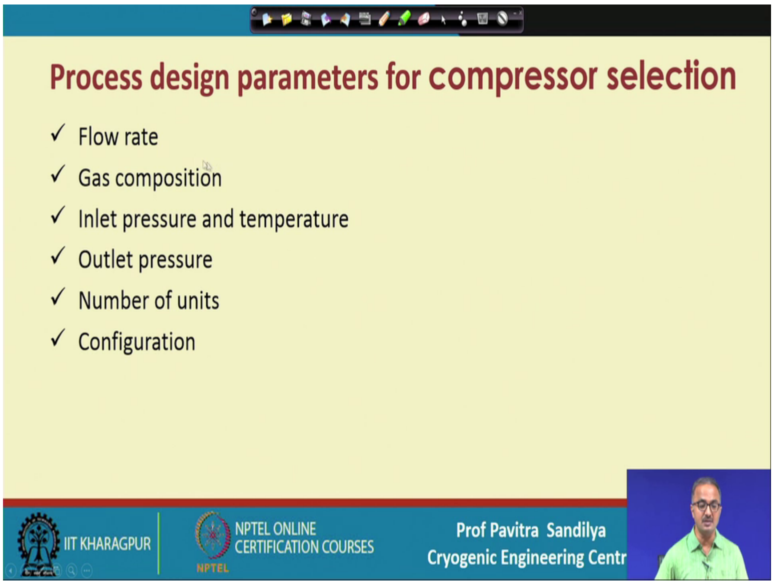

Lastly, we come to the radius process design parameter for selection of the compressor. Here we have the flow rate the gas composition because the gas composition determines the various properties of the gas. Then we have the inlet pressure and temperature, the outlet pressure, number of units and the configuration.

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And here are some of these references which give the detail about the compression in the natural gas systems.

Thank you.