Applied Thermodynamics for Marine Systems

Prof. P. K. Das

Department of Mechanical Engineering

Indian Institute of Technology, Kharagpur

Lecture - 8

Introduction to Vapour Power Cycle

Today, we will continue with the topic which we have started in our last class. That is different reversible processes where the working medium is an ideal gas. If you recall we were doing or discussing the constant pressure process.

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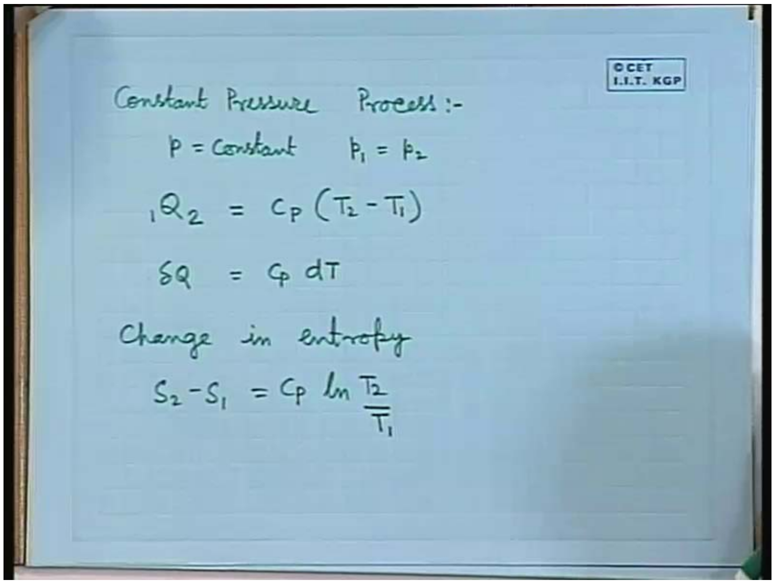

Constant Pressure Process :-

$p = \text{Constant} \quad p_1 = p_2$

$${}_1Q_2 = C_P (T_2 - T_1)$$

$$\delta Q = C_p \, dT$$

Change in entropy

$$S_2 - S_1 = C_p \ln \frac{T_2}{T_1}$$

This has got another name. It is also called the isobaric process. In this process we have p is equal to constant; that means p_1 is equal to p_2. We have derived the expression for work done during this process and heat transfer during this process. If we recall, we have ${}_1Q_2$ that can be expressed in terms of a specific heat for constant pressure into T_2 minus T_1. That means, a differential heat transfer is C_p dT and from this, one can readily get the expression for change in entropy. Change in entropy, S_2 minus S_1 is equal to C_p ln T_2 by T_1. We have different expressions like the expression for work done, the expression for heat transfer, the expression for change in entropy and specific heat in this case is C_p. Similarly, we can think of another reversible process, let us say a reversible isothermal process.

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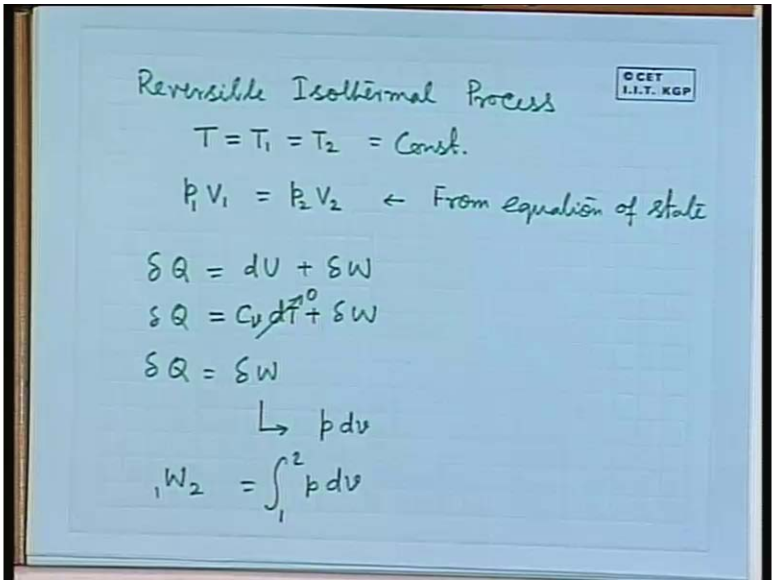

Reversible Isothermal Process

$T = T_1 = T_2 = \text{Const.}$

$p_1 V_1 = p_2 V_2$ ← From equation of state

$\delta Q = dU + \delta W$

$\delta Q = C_v \cancel{dT}^{0} + \delta W$

$\delta Q = \delta W$

↳ $p\,dv$

$_1W_2 = \int_1^2 p\,dv$

In a reversible isothermal process, the temperature remains a constant. T is equal to T_1 is equal to T_2 is equal to constant. If we have that then, we will have p_1v_1 is equal to p_2v_2 from the equation of state or ideal gas law. This is from the equation of state for ideal gas. Once we have this one, we can take care of the other property changes. With the help of first law of thermodynamics one can write dQ is equal to dU plus dW. dU for an ideal gas or for that matter any other compressible fluid, we can write Cv dT plus dW. There is no change in temperature. The change in temperature is equal to 0. So this is equal to 0 and there is no change in internal energy. We can get dQ is equal to dW and as it is a reversible process and the fluid involved in this process is a compressible fluid, dW can be expressed as pdv and we can write $_1W_2$ is equal to integration 1 to 2 pdv. There is a relationship between p and v; so that relationship can be used for determining the work done.

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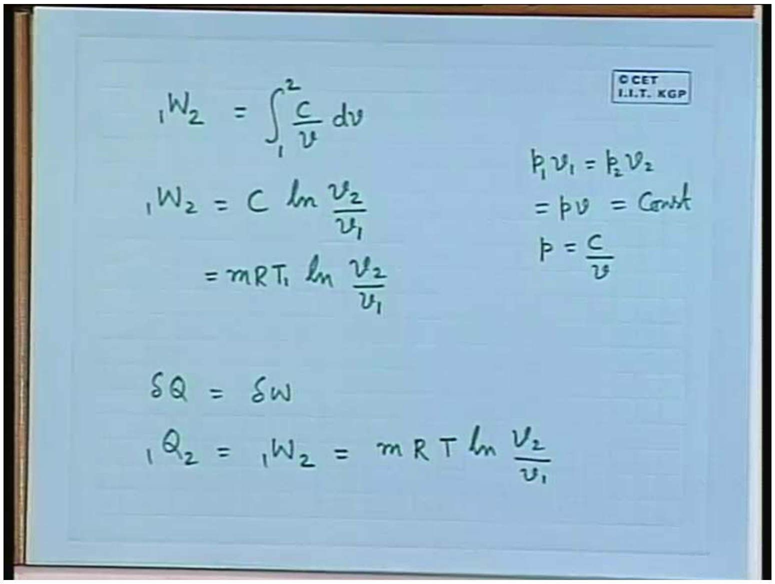

$$_1W_2 = \int_1^2 \frac{C}{v}\,dv$$

$$p_1 v_1 = p_2 v_2$$

$$= pv = Const$$

$$p = \frac{C}{v}$$

$$_1W_2 = C \ln \frac{v_2}{v_1}$$

$$= mRT_1 \ln \frac{v_2}{v_1}$$

$$\delta Q = \delta W$$

$$_1Q_2 = {}_1W_2 = mRT \ln \frac{v_2}{v_1}$$

$_1W_2$ that is equal to 1 to 2, p we have to express in terms of v. How can we express it? We have got p_1v_1 is equal to p_2v_2 is equal to pv is equal to constant. Let us say this constant is equal to C. We have p is equal to C by v. This we can put here and C by v dv we can put. $_1W_2$ is equal to, one can take C outside, and then it will be ln v_2 by v_1. That is what we will get as the expression for work done. This C is nothing but p_1v_1 or p_2v_2, so we can express it as mRT_1 or mRT_2 as we like it. We can put it as mRT_1 ln v_2 by v_1. That means in an isothermal process if we know the initial volume and the final volume, then we can find out what is the work done. Similarly, if we know the initial pressure and final pressure, we can determine the work done. The heat transfer in this process, we have got dQ is equal to dW for this isothermal process or $_1Q_2$ is equal to $_1W_2$. Once we have calculated $_1W_2$ we can calculate $_1Q_2$ also or we can write this is mRT_1 or T_2 or T in v_2 by v_1. Again, from here, we can calculate the change in entropy.

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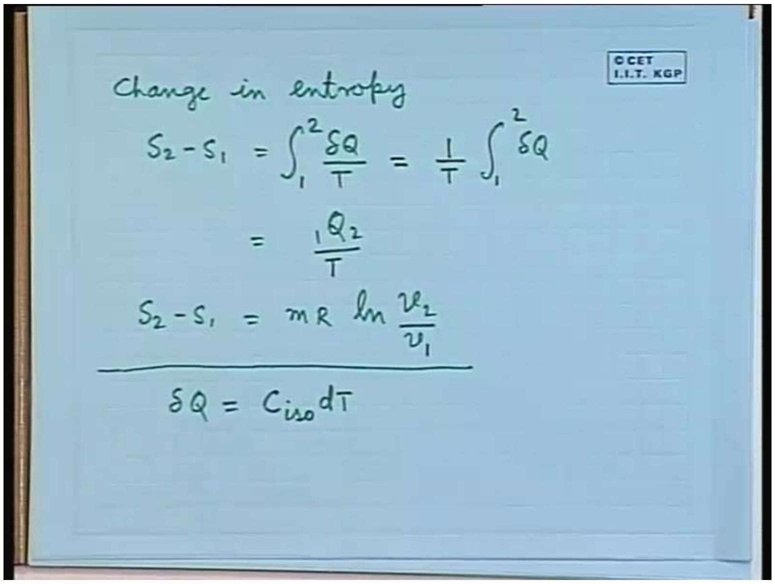

Change in entropy

$$S_2 - S_1 = \int_1^2 \frac{\delta Q}{T} = \frac{1}{T}\int_1^2 \delta Q$$

$$= \frac{{}_1Q_2}{T}$$

$$S_2 - S_1 = mR \ln \frac{v_2}{v_1}$$

$$\delta Q = C_{iso}\, dT$$

During this process, the change in entropy, S_2 minus S_1 is equal to integration 1 to 2 dQ by T and one can take T outside as it is a constant; so 1 by T integration 1 to 2 dQ, this will be ${}_1Q_2$ by T. S_2 minus S_1 will be mR ln v_2 by v_1. This is the change in entropy during this process. Let us use for the calculation of heat transfer or for the estimation of heat transfer a different kind of a relationship. Let us say dQ is equal to C isothermal into dT. This is the specific heat during isothermal process multiplied by change in temperature. We know that heat transfer is equal to specific heat into change in temperature. That is what I have written here, dQ is specific heat multiplied by change in temperature. dQ, we are getting some sort of a finite quantity or if we integrate it ${}_1Q_2$ that is a finite quantity whereas dT is equal to 0 or there is no change in temperature during this processes.

What does it mean? The product of two quantities is giving a finite result or finite value but one of them is 0; then either of this should be infinity. So C isothermal will be either plus infinity or minus infinity depending on the direction of the transfer, depending on whether it is heat addition or heat rejection. Probably I have mentioned it earlier that for a compressible fluid there is no fixed specific heat; the specific heat depends on the type of process. The value of the specific heat varies from plus infinity to minus infinity. It can even become 0. Here, we are getting the example where the specific heat value is equal to infinity. We are getting the other expressions like the expression for heat transfer, expression for work transfer and expression for change in entropy. Not only that, in this process we can see that the change in internal energy is equal to 0 as there is no change in temperature.

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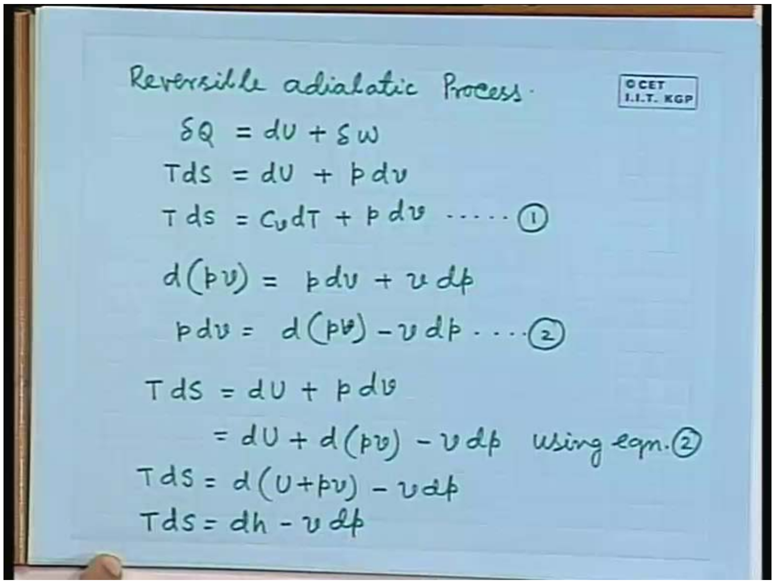

Reversible adiabatic Process.

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$\delta Q = dU + \delta W$

$Tds = dU + pdv$

$Tds = C_v dT + pdv$ ..... ①

$d(pv) = pdv + vdp$

$pdv = d(pv) - vdp$ .... ②

$Tds = dU + pdv$

$= dU + d(pv) - vdp$ using eqn. ②

$Tds = d(U + pv) - vdp$

$Tds = dh - vdp$

Next, we will go to the reversible adiabatic process. Whatever process we have taken so far, some property was constant like we have constant pressure process or isobaric process where pressure remains constant; we can get a relationship between other properties like volume and temperature from the equation of state. In the constant volume process or isochoric process, the volume remains constant and one can get a relationship between pressure and temperature. Similarly, in the isothermal process the temperature remains constant; again one can get a relationship between p and v, pressure and volume. But, here in the reversible adiabatic process, we know that there will not be any heat transfer. But what will be the relationship between pressure volume and temperature that is not apparent from the verbal description of the process. If we say that dQ is equal to 0 or 1, Q_2 is equal to 0, readily we cannot say what type of process it is. That means, what relationship between pressure, volume and temperature is there, that we cannot readily say.

Let us derive what type of process it is. We know that the first law says dQ is equal to dU plus dW. If it is a reversible process and if a compressible fluid is involved, then instead of dQ, one can write Tds, dU remains as it is and this is pdv. As it is a compressible fluid the mode of work transfer I have taken as the pv mode of work transfer; pressure, volume mode of work transfer. Again, I can write Tds is equal to C_v dT plus pdv. This is what I can write. Let us say that this is one relationship I am getting and I am giving a number to this equation. This is equation number 1.

Let us say I want to determine this quantity d of pv. This can be written as pdv plus vdp and then pdv I can write pdv is equal to d of pv minus v of dp. Let us say this is another equation I am getting. If we use one of the previous relationship that is Tds is equal to dU plus pdv we can write, this is dU plus d of pv minus v of dp using equation 2. Using equation number 2, we can write this. Tds can be again written as d of U plus pv minus vdp or finally we can write Tds is equal to dh minus vdp.

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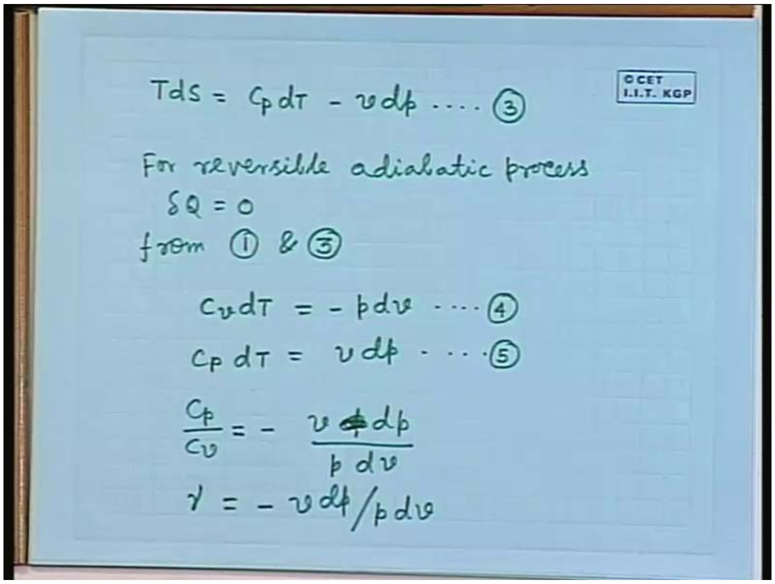

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$Tds = C_p dT - v dp \; .... ③$

For reversible adiabatic process

$\delta Q = 0$

from ① & ③

$C_v dT = - p dv \; .... ④$

$C_p dT = v dp \; .... ⑤$

$$\frac{C_p}{C_v} = - \frac{v \cancel{p} dp}{p\,dv}$$

$$\gamma = - v dp / p dv$$

In the next place I can write, Tds is equal to C_pdT minus vdp. Let say, this is our equation number 3. We are interested in reversible adiabatic process. For the reversible adiabatic process, dQ is equal to 0; heat transfer is equal to 0. Tds we can write as equal to 0, putting Tds is equal to 0 in 1 and 3. From 1 and 3 what we can get? From 1 we can get C_vdT is equal to minus pdv. This is what we can get and from 3 we can get C_pdT is equal to vdp. Let us say these are called 4 and 5. Using 5 and 4 or dividing 5 by 4, one can get Cp by Cv that is equal to minus vdp divided by pdv. This is what we get. Now Cp by Cv is specific heat at constant pressure, specific heat at constant volume. This ratio we can replace by another number. Let us call it gamma. Gamma is equal to minus vdp by pdv. We need to do some more simplification.

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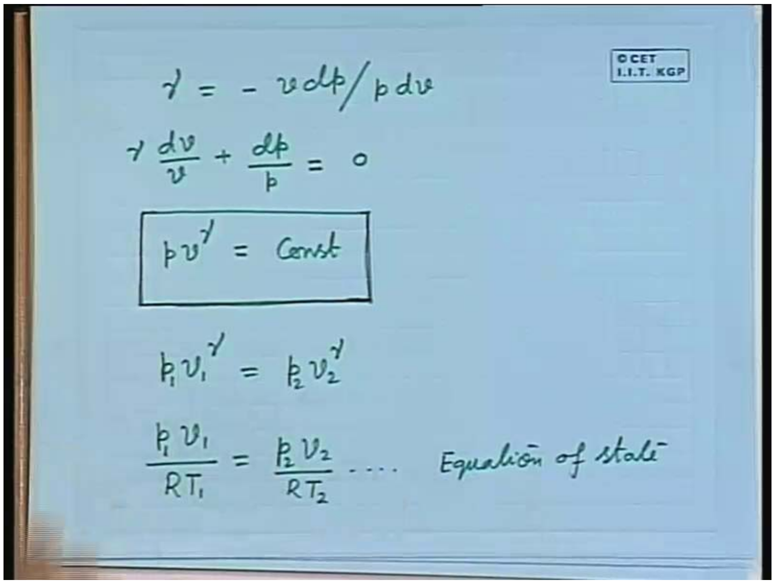

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$$\gamma = -vdp/pdv$$

$$\gamma \frac{dv}{v} + \frac{dp}{p} = 0$$

$$\boxed{pv^{\gamma} = Const}$$

$$p_1 v_1^{\gamma} = p_2 v_2^{\gamma}$$

$$\frac{p_1 v_1}{RT_1} = \frac{p_2 V_2}{RT_2} \ldots\ldots \text{ Equation of state}$$

If we go about it like this, gamma is equal to minus vdp divided by pdv then we can write it like this. Gamma dv by v plus dp by p that is equal to 0. This we can write and by some more simplification, we can write ultimately from this pv to the power gamma is equal to constant. This is the relationship we will get for a reversible adiabatic process. Unlike other processes, which we have seen earlier the relationship between pressure, volume and temperature is not explicit from the verbal description of the process that it is a reversible adiabatic process. But if you follow the logic, apply the combined first law and the second law then we can see that we get the relationship between pressure and volume in terms of the specific heat, that is Cp and Cv or in other words in terms of the ratio of the specific heat which is gamma. This is a very well known expression for the thermal engineers and we will see in number of places we will idealize the process to be a reversible adiabatic process.

In many cases the expansion process and compression process will be idealized as a reversible adiabatic process. Generally, if the process takes place in some sort of a container or cylinder which is well insulated, then the heat transfer is very less and the process also takes place very fast, so there is not much scope for transferring heat with the surroundings. That is why the process becomes adiabatic. However there are some dissipative effects. This process cannot be made ideally reversible process, but we simplify the process to be a reversible adiabatic process. Once we have this, one can have p_1v_1 to the power gamma is equal to p_2v_2 to the power gamma. Again one can have this relationship p_1v_1 by RT_1 is equal to p_2v_2 by RT_2 this is from the equation of state. If you use these two equations then the relationship between pressure, volume and temperature, in explicit form you can get. Basically there are different forms of relationships but some forms can be written like this.

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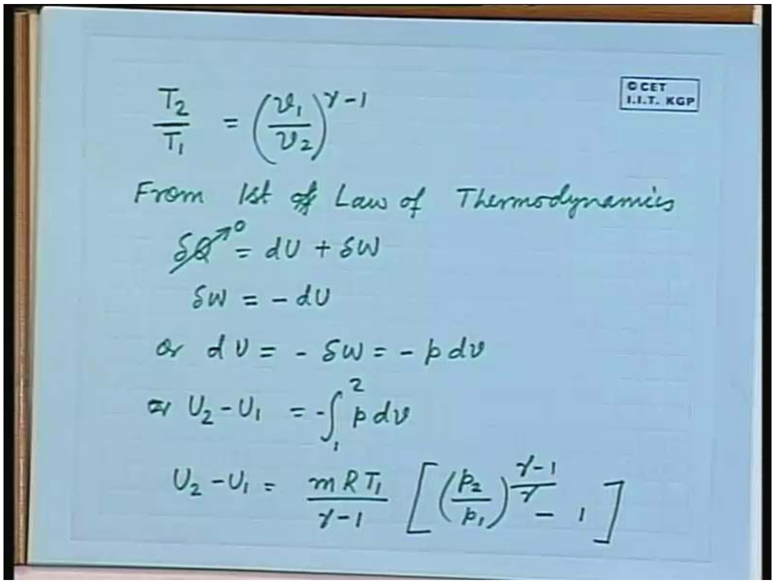

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$$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{\gamma-1}$$

From 1st ~~of~~ Law of Thermodynamics

$$\cancelto{0}{\delta Q} = dU + \delta W$$

$$\delta W = -dU$$

$$\text{or } dU = -\delta W = -p\,dv$$

$$\text{or } U_2 - U_1 = -\int_1^2 p\,dv$$

$$U_2 - U_1 = \frac{mRT_1}{\gamma-1}\left[\left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$$

T_2 by T_1 is equal to v_1 by v_2 to the power gamma minus 1. This is what one can write or one can again get a relationship between temperature and pressure. This is a relationship between temperature and volume but one can get a relationship between temperature and pressure. Those are not difficult to derive. After that, we are interested to determine the other changes in properties or heat transfer and work transfer. Basically, we can apply the first law of thermodynamics. From the first law of thermodynamics one can write dQ is equal to dU plus dw. In this case, dQ is equal to 0; dW is equal to minus dU or dU is equal to minus dW is equal to minus pdv.

As it is a compressible fluid, again the mode of work transfer is the pv mode of work transfer; that is why we have written it. U_2 minus U_1 that is the change in internal energy is equal to integration 1 to 2 minus p into dv. If we do the simplification, again just like before what we have to do is, we have to replace p by v using the relationships which we have derived earlier. You will get U_2 minus U_1 is equal to mRT_1 by gamma minus 1 that is equal to p_2 by p_1 to the power gamma minus 1 by gamma minus 1. This is the relationship for change in internal energy. This is the relationship or this is the expression for work done also if we put a minus sign in front of it. We can get both change in internal energy and work transfer from the same expression, only the signs are different.

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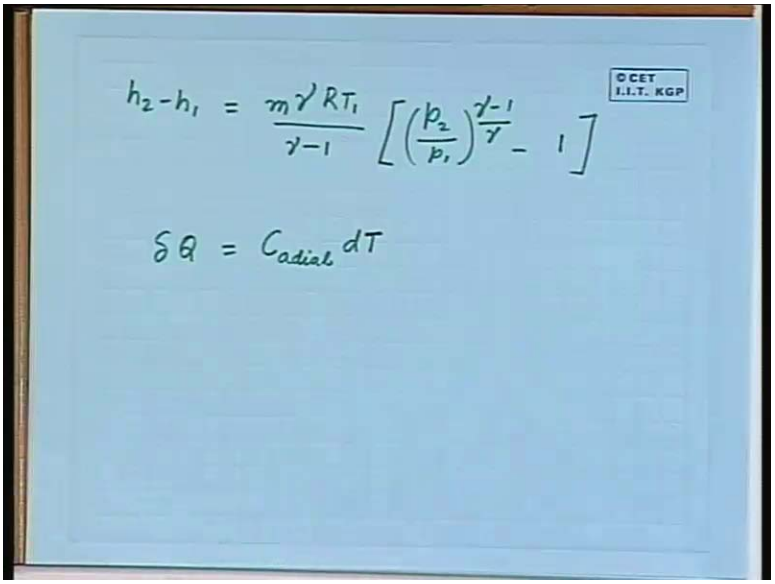

$$h_2 - h_1 = \frac{m\gamma R T_1}{\gamma - 1}\left[\left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$$

$$\delta Q = C_{adiab}\, dT$$

If we are interested in determining the change in enthalpy, h_2 minus h_1 you can derive it readily. The result will be p_2 minus p_1 whole to the power gamma minus 1 by gamma minus 1. This is the change in enthalpy during this process. Again, if we write dQ that is the heat transfer is equal to let us say some adiabatic into dT. What we know is that dQ is equal to 0 but we have seen that there is a finite change in temperature. If dQ is 0 and it is a product of these two quantities then C adiabatic must be 0. The specific heat during adiabatic process is equal to 0. Again I will remind you what I have said earlier that specific heat can have any value, even 0. In this case, we are getting specific heat is equal to 0. Though there is change in temperature there is no heat transfer. Then lastly what we want to do is, we can think of a process which is a general process.

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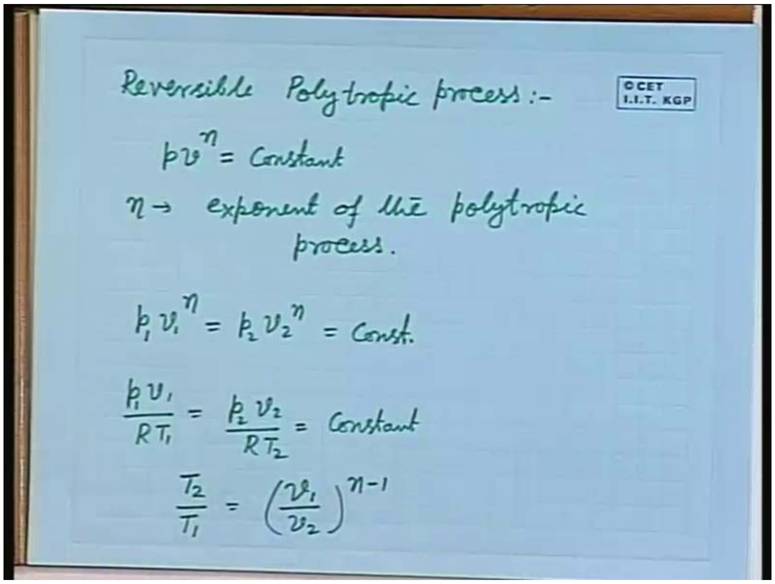

Reversible Polytropic process :-

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pv^n = Constant

$n \rightarrow$ exponent of the polytropic process.

$p_1 v_1^n = p_2 v_2^n$ = Const.

$\frac{p_1 v_1}{RT_1} = \frac{p_2 v_2}{RT_2}$ = Constant

$$\frac{T_2}{T_1} = \left(\frac{v_1}{v_2}\right)^{n-1}$$

We can call it a reversible polytrophic process. This process is denoted as pv to the power n is equal to constant. n is called exponent of the polytrophic process exponent of the polytrophic process. Then, we can get the relationship p_1v_1 to the power n is equal to p_2v_2 to the power n is equal to constant and again p_1v_1 by RT_1 is equal to p_2v_2 by RT_2 that is also another constant. Using these two relationships, one can derive the relationship between either pressure and temperature or volume and temperature. The expressions will be much similar to what we have done in case of our adiabatic process and that means one can get T_2 by T_1 that is equal to v_1 by v_2 to the power n minus 1. This relationship one can get using the above two expressions.

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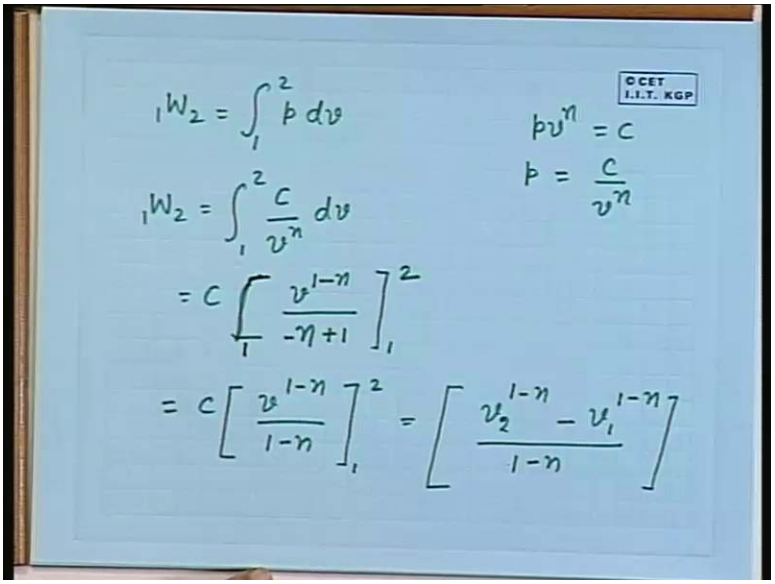

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$${}_1W_2 = \int_1^2 p\,dv$$

$$pv^n = C$$

$$p = \frac{C}{v^n}$$

$${}_1W_2 = \int_1^2 \frac{C}{v^n}\,dv$$

$$= C\left[\frac{v^{1-n}}{-n+1}\right]_1^2$$

$$= C\left[\frac{v^{1-n}}{1-n}\right]_1^2 = \left[\frac{v_2^{1-n} - v_1^{1-n}}{1-n}\right]$$

Here, one can have dw or ${}_1W_2$ that is equal to 1 to 2 pdv and what one can do is, one can use this relationship; that means, pv to the power n is equal to C, p is equal to C by v to the power n. Putting this, ${}_1W_2$ that is equal to 1 to 2 C by v to the power n dv and then one can take C outside; this is 1 to 2 or let us do the integration. This will be 1 by minus n plus 1 and at the top v to the power, again same thing will come, 1 minus n v to the power v to the power v to the power to the power and again same thing will come 1 minus n and then this is 1 to 2. Basically I can write C v to the power 1 minus n by 1 minus n and again C can be replaced, 1 to 2 or this is v_2 to the power 1 minus n minus v_1 to the power 1 minus n by 1 minus n into C. Next C can be replaced p_1v_1 to the power n or p_2v_2 to the power n.

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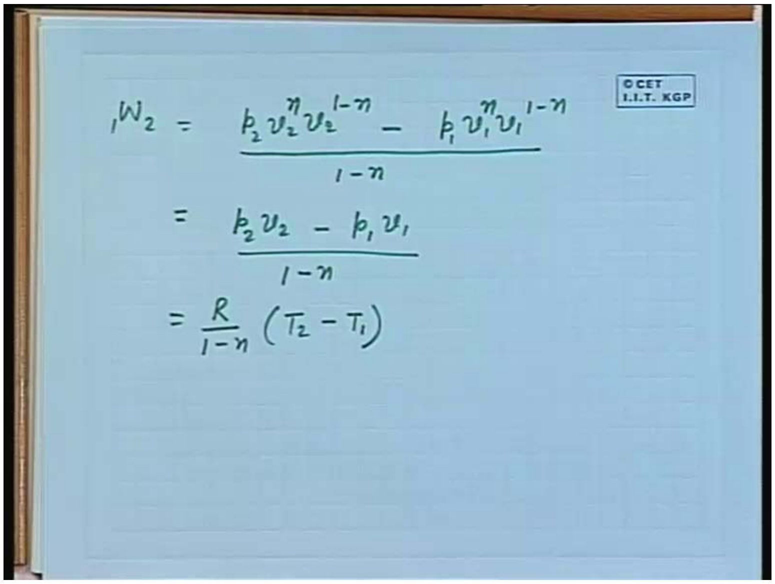

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$${}_1W_2 = \frac{p_2 v_2^{n} v_2^{1-n} - p_1 v_1^{n} v_1^{1-n}}{1-n}$$

$$= \frac{p_2 v_2 - p_1 v_1}{1-n}$$

$$= \frac{R}{1-n}(T_2 - T_1)$$

If we do that, $_1W_2$ will be p_2v_2 to the power n then v_2 to the power 1 minus n minus p_1v_1 to the power n v_1 to the power 1 minus n divided by 1 minus n. Then, we will have p_2v_2 minus p_1v_1 divided by 1 minus n and again as p_2v_2 is equal to RT_2 and p_1v_1 is equal to RT_1, we can replace it like this; R by 1 minus n then T_2 minus T_1. This also we can write either in terms of pressure and volume or in terms of temperature we can express it. Similarly, if we want to determine the heat transfer, in that case, I will use the first law of thermodynamics.

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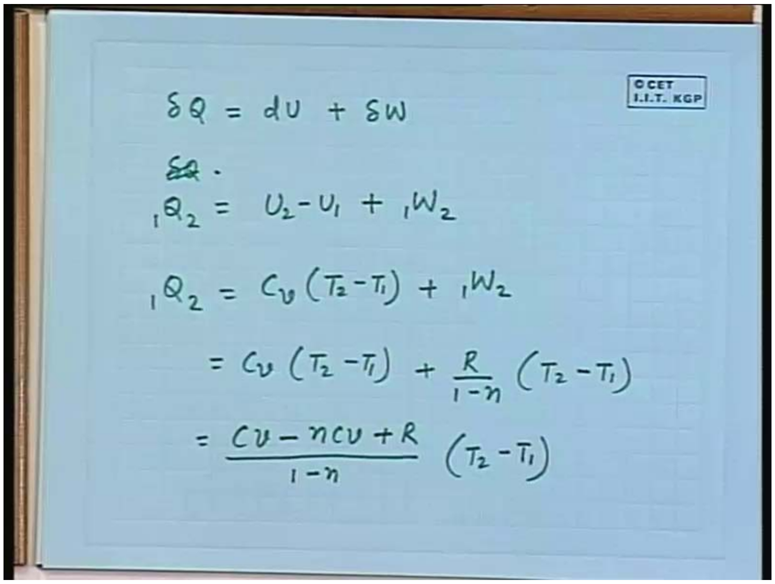

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$$\delta Q = dU + \delta W$$

$$\cancel{\delta Q} \cdot$$

$${}_1Q_2 = U_2 - U_1 + {}_1W_2$$

$${}_1Q_2 = C_v(T_2 - T_1) + {}_1W_2$$

$$= C_v(T_2 - T_1) + \frac{R}{1-n}(T_2 - T_1)$$

$$= \frac{cv - ncv + R}{1-n}(T_2 - T_1)$$

dQ is equal to dU plus dW; this, I will use. If I do that, I am getting dQ is equal to or let us say $_1Q_2$ I am getting as U_2 minus U_1 plus $_1W_2$. I have already got the expression for $_1W_2$. So, $_1Q_2$ is equal to C_v T_2 minus T_1 plus $_1W_2$. That means this will be C_v T_2 minus T_1 plus R by 1 minus n T_2 minus T_1. Then, we can write it like this. T_2 minus T_1 can be taken as common. So, C_v minus nC_v plus R by 1 minus n T_2 minus T_1; this we can write. Now, what is R? C_p minus C_v is equal to R. So, we can replace this as C_p minus C_v. If we do that just 1 step ahead, $_1Q_2$ that is equal to C_v minus nC_v plus Cp minus C_v by 1 minus n and T_2 minus T_1.

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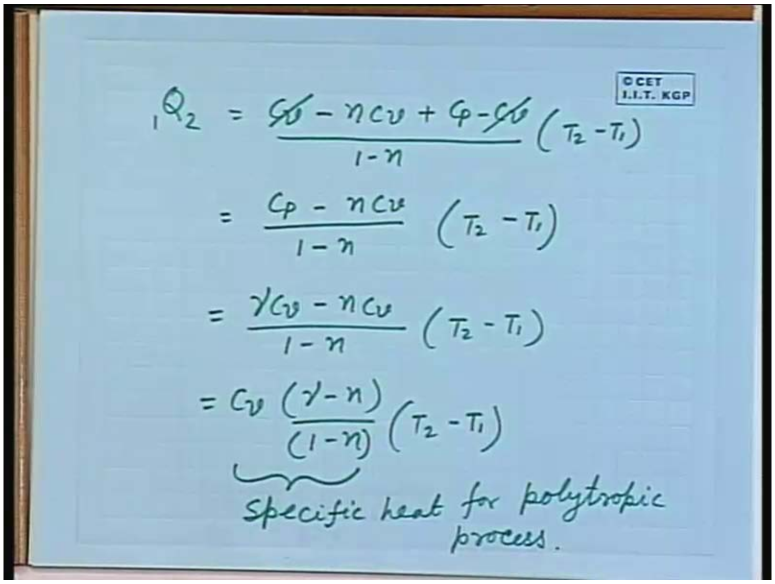

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$$_1Q_2 = \frac{\cancel{C_v} - nC_v + C_p - \cancel{C_v}}{1-n}(T_2 - T_1)$$

$$= \frac{C_p - nC_v}{1-n}(T_2 - T_1)$$

$$= \frac{\gamma C_v - nC_v}{1-n}(T_2 - T_1)$$

$$= \underbrace{C_v\frac{(\gamma - n)}{(1-n)}}(T_2 - T_1)$$

Specific heat for polytropic process.

This and this cancel; so, one can have C_p minus nC_v by 1 minus n T_2 minus T_1. Again C_p by C_v is equal to gamma. C_p by C_v is equal to gamma or C_p is equal to gamma into C_v. That is what we can write. Gamma C_v minus nCV by 1 minus n that is T_2 minus T_1. This is equal to C_v gamma minus n by 1 minus n into T_2 minus T_1. We know $_1Q_2$ is some specific heat multiplied by the change in temperature. This becomes specific heat for polytropic process; this is the specific heat for the polytropic process. That means we can write for a polytropic process, dQ is equal to C_v gamma minus n by 1 minus n into dT; this we can write.

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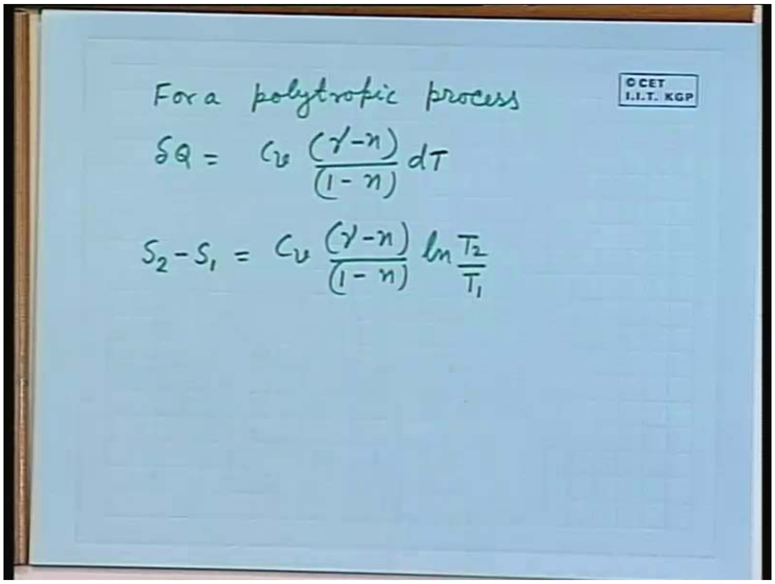

For a polytropic process

$$\delta Q = C_v \frac{(\gamma - n)}{(1-n)} dT$$

$$S_2 - S_1 = C_v \frac{(\gamma - n)}{(1-n)} \ln \frac{T_2}{T_1}$$

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Once we write this then, the change in entropy can be determined very easily. S_2 minus S_1 is equal to this specific heat gamma minus n by 1 minus n ln T_2 by T_1. Once we have expressed the rate of heat transfer in terms of specific heat and change in temperature, next we can write down the change in entropy like this and this is the change in entropy for the polytropic process. Basically, what we need to know here is the index of the polytropic process and the specific heat at constant pressure and constant volume. That is what we need to know for knowing the specific heat for any process. It is interesting to note that all the processes whichever we have discussed so far, all are some special cases of the polytropic process.

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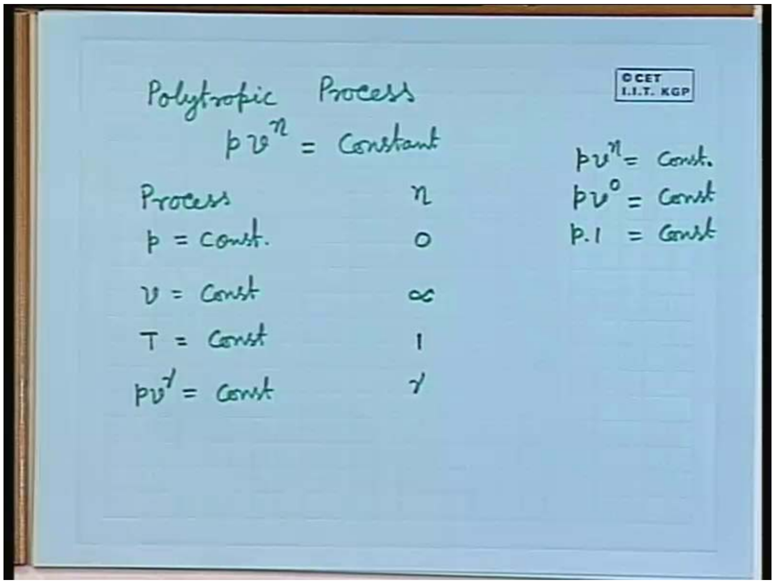

Polytropic Process

pv^n = Constant

Process	n
p = const.	0
v = Const	∞
T = Const	1
pv^γ = Const	γ

pv^n = Const.

pv^0 = Const

$p.1$ = Const

A polytropic process is expressed as pv to the power n is equal to constant. If we think of different processes, let us say p is equal to constant. That means it is a constant pressure process or isobaric process. What I like to show you is the expression for polytropic process pv to the power n is equal to constant. Whatever processes we have discussed so far, that means constant pressure process or the constant volume process or isothermal process, all are some special cases of polytropic process. Let us start with a constant pressure process or isobaric process. In this process p is equal to constant. p is equal to constant how can we derive it? Let us see that.

pv to the power n is equal to constant. If we put n is equal to 0 then it becomes p into v to the power 0 that is equal to constant. Then p into 1 that is equal to constant and then the required value of n we are getting as 0. In an isobaric process we will have the exponent of the polytroph that is equal to 0. We can think that v is equal to constant. In that case we will see that the n value which is required to satisfy this equation that becomes infinity. Let us say that temperature is equal to constant. This is easy; so, the value of n becomes 1 and then pv to the power gamma that is equal to constant and in that case n value becomes gamma. We are seeing that all the processes which we have discussed separately all are the special cases of any polytropic process. Again, it is left to you the expression for specific heat, what we have got for the polytropic process, there if you put the respective values of n you will get the specific heats which we have got for the special cases. That also you can check.

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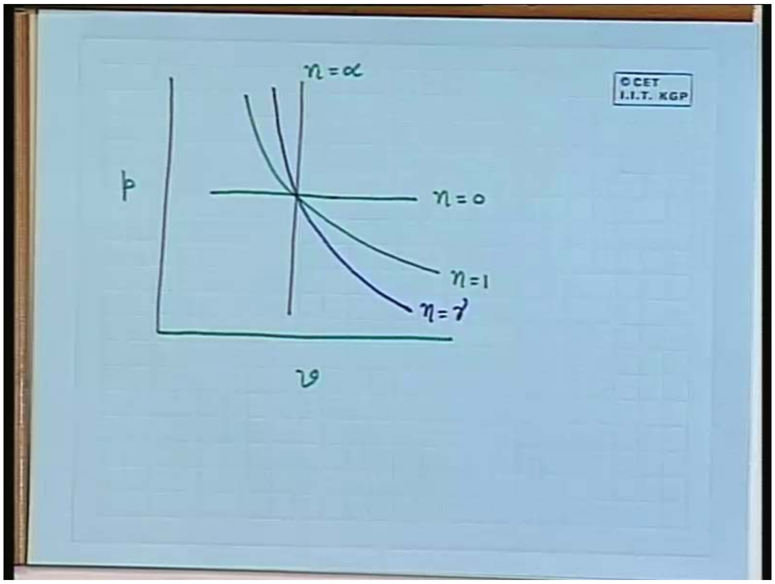

Lastly, I will just plot all these processes on the pv plane. This is a pv plane. This is your constant volume process and this is your constant pressure process. The constant pressure process n is equal to 0; constant volume process n is equal to infinity. You will have t is equal to constant. That means, n is equal to 1. Let us use another color. This will be clear, this is n is equal to gamma. If it is a diatomic gas or air, you know that we take 1.4 to be the value of gamma. These are the representations of your different processes on the pv diagram.

This is what I wanted to convey to you. Here, we can see that if we think of two different pressures, let us see from here, let us say this is the initial point and let us say the gas is expanding like this. Initially, the gas is at some pressure and then the gas is expanding to some other pressure and this is the isothermal path and this is the adiabatic path. From this it is clear that the work done if the gas is expanding then the isothermal work done will be more than the adiabatic work done. This concept is important, if we are considering a compressor. What amount of work is required for compressing the gas, this concept is important. I think here we can stop our discussion regarding the different reversible processes, where the ideal gas is working fluid.

After this, we will start a new topic and that is steam cycles or steam power cycle.

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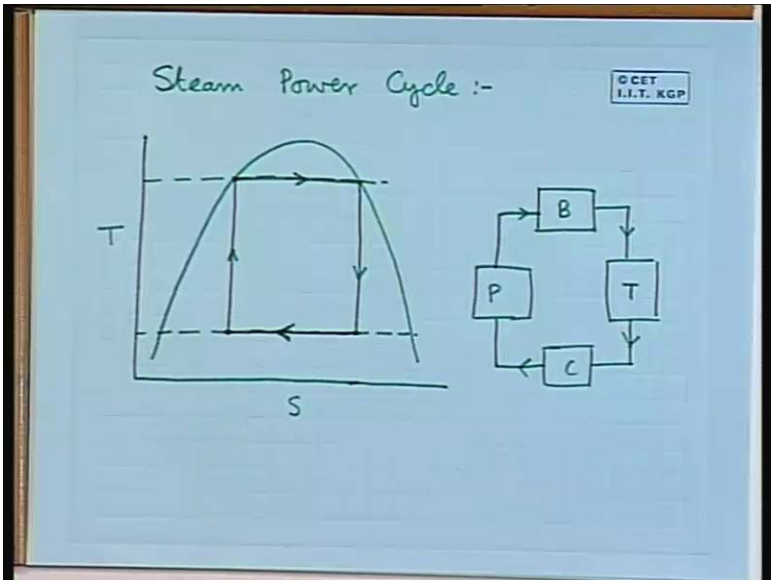

Steam Power Cycle :-

Basically, steam is used as the working fluid for steam power cycle. A steam cycle is basically a heat engine cycle and for any heat engine cycle the motto of the engineer will be to have the maximum efficiency. We know if the source temperature and the sink temperature are fixed, then the maximum amount of efficiency that can be derived from the source and sink is also fixed. That is the Carnot principle. We will get the maximum possible efficiency if we use a reversible engine or a Carnot engine between the source and sink. In case of a steam power plant, the ultimate sink is the atmosphere where the heat has to be rejected and source that is the temperature which we get from combustion, the temperature of flew gas that is the source temperature; that can be taken as the source temperature.

As the sink temperature is limited by whatever is available in our surrounding or environment, the source temperature is also limited because we cannot arbitrarily increase the temperature as we have got certain materials, engineering materials, which has to withstand the high temperature. Basically from the restrained form of the material we have to limit the source temperature. We can take this as granted that our source temperature is the highest temperature that is limited and the sink temperature that is also limited. Between these two temperature limits, we have to get the maximum output or at least we should try to get the maximum output. We have learnt that a Carnot engine or a Carnot cycle will be able to give that amount of or that maximum performance of the cycle. Using steam as the working substance, let us have a Carnot cycle. I am using the TS diagram. This is T and this is S. Let us say this is the source temperature. Due to material restrains or constraints from the material point of view, we should not go above this. Let us say this is the temperature of the sink which is available to me.

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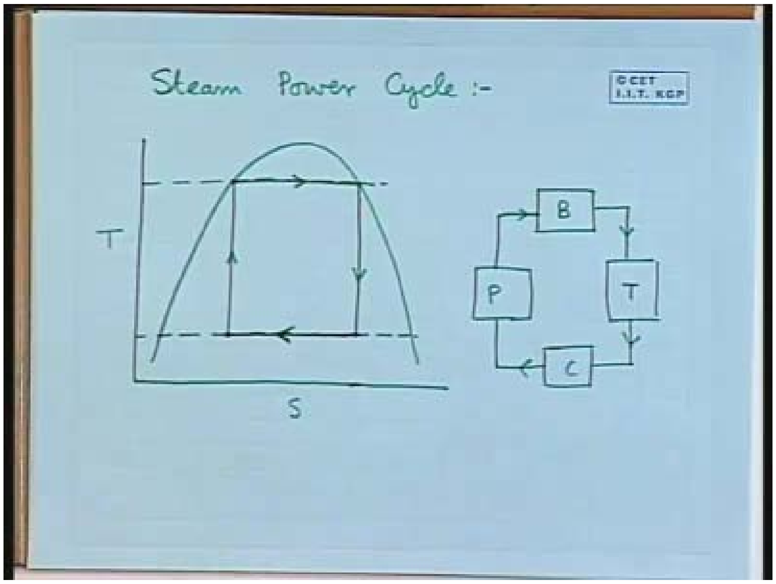

These two temperatures are there and the Carnot cycle constitutes four processes. Two of them are isothermal processes, isothermal heat addition and isothermal heat rejection. Then there is one adiabatic expansion and one reversible adiabatic compression. Basically, my Carnot cycle using steam as the working fluid will be something like this. This is what I will have, a Carnot cycle using steam as the working fluid. Here, steam will be generated at a constant pressure and a constant temperature, because it is in the two phase region. If it is at constant temperature it will be also be at constant pressure in the boiler. Then, adiabatically and reversibly it will expand through the turbine then it will condense in the condenser. This is a constant temperature process and as it is within the two phase dome, it will be a constant pressure process also. Here, at this point, I will get a mixture of steam and water. That has to be compressed reversibly and adiabatically to the point where it has to be again heated in the boiler to produce the steam.

This is what I will get if I use a Carnot cycle. Basically, this Carnot cycle will have four components: one boiler, one turbine, then there will be one condenser and then there will be one pumping device, which will pump it back to the boiler. These are the four components which are there in a steam power plant. But, in a steam power plant, we do not use the cycle as it is shown in this diagram or we do not use a Carnot cycle in practical steam power plant because there are number of difficulties. I think we will stop here and in the next class we will start from this point.