Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Engineering Thermodynamics

Lecture – 18
First Law of Thermodynamics for Unsteady Flow Processes

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So let us start this lecture with a thought process for Marcel Proust.

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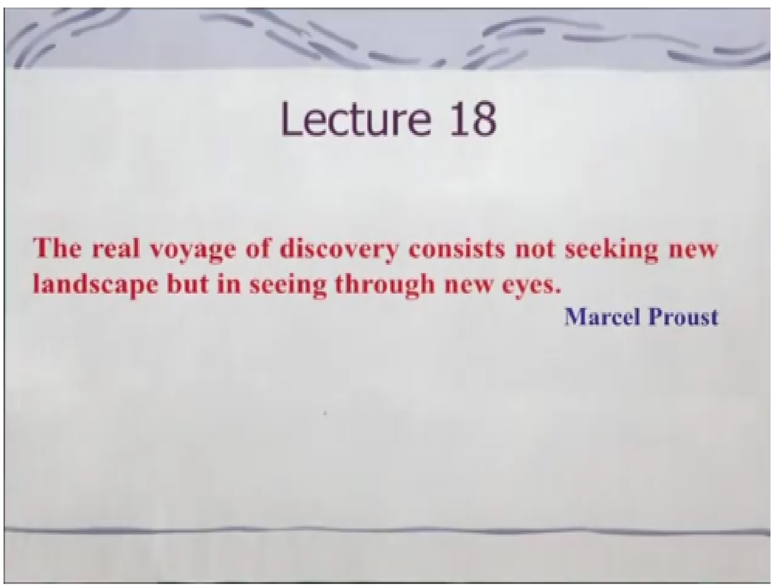

The real voice of discovery consists not seeking new landscape but in seeing through new eyes, so we will do as usual like will recall what we learnt in the last lecture we basically looked at how one can derive you know the first law of thermodynamics for a for an open system and then we have to also looked at the steady-state problems and how one can apply this first law of thermodynamics and we took also an example in the last lecture for turbine and where we had seen that that if you neglect the kinetic energy and potential in terms I mean you would not really commit much error in that because very negligibly small and what we will do today we will be looking at basically unsteady flow process right.

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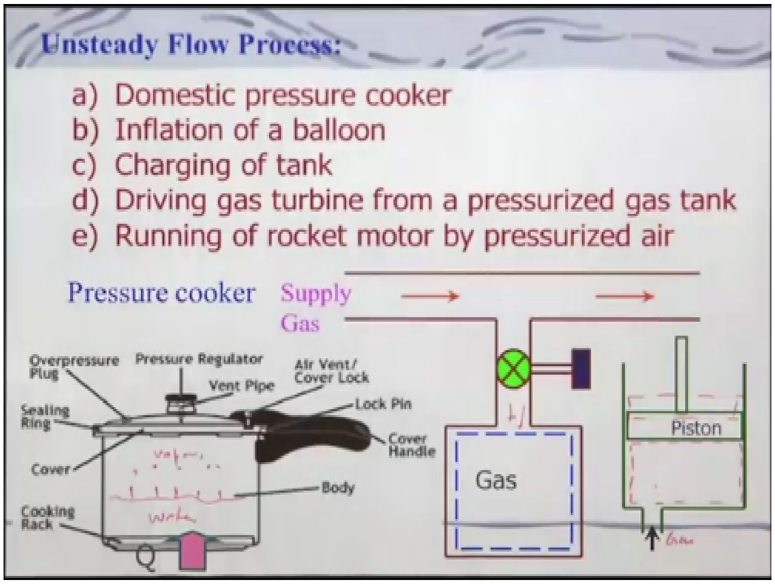

Because in the last lecture we have dealt with the steady flow process of course it occurs but there are several unsteady flow processes we which are very common in you know in engineering applications and also day-to-day life, so how we will apply that that is the question will be so what are the examples you know you are away about unsteady flow process can anybody tell me. Which will be unsteady that means you cannot afford to apply you know say that look the process is steady you must be knowing I am like you know I am I right.

For example like you might have seen that you want to inflate a valium or you want to inflate your tire or study tube you want to inflate your tube with the air right high pressure so that is a steady process or unsteady process that will be cannot be considered as a steady process because it will be go on changing right and there are any other examples comes to your mind, so if you look at like your pressure cooker let us say right in the pressure cooker when you heat I mean you boil some vegetables and other things what will happen they it will be pressure will be goes on building up.

And then some mass will be going out and till it reaches certain pressure right, so there are several example one can think of as a told domestic pressure cooker inflation of a balloon charging of tank and we can think of you know like driving a gas turbine from a pressurized tank right or any other you know kind of we you can also drive a piston engine you know or a some other kind of system, for example we are having power cut.

Now you can think of using you know some kind of stored energy and then use that like I can charge there some high temperature gas or the you know a high temperature and pressure gas in a tank and then allow it to flow through some device and which can give me some generate some electricity think of and of course the running of rocket motors by the pressurized air and several other of them one can think of, so if you look at this is a typical pressure cooker what I have shown here right and as some it being heated with some it right and then if you look at this is your pressure regulating valve right.

Which you might have seemed in your home what happens whenever this pressure is build up because heat is there let us say this some kind of man water you are boiling with a vegetable then you know it will be vaporizing, so these are basically vapors right and then you know the pressure will build up and when it will be reach the you know more than the weight which will be you know like you put a weight basically you know and that weight if the pressure the you know applied by the vapor is will be applying a force and that will be higher than the weight then the that what we call it basically petcock or the pressure regulator is a weight one.

And then it will go up and then some amount of steam which will be released and again it will come back and again it will build up, so this is basically unsteady by now this kind of you know things we can apply in several other places, so you might be aware like you know like we are having let us say biogas plant you have seen any of you have seen by biogas plant what we call goober gas you know plant in village rural areas suppose I want to generate some gas what I will have to do and it should be at high pressure right.

How I well make pressure then what we will do there will be dome on that I will put some weight and the gas will be collected pressure will increase I can use that one right, so there might be several application one can think of and let us say we want to charging you know a what a cylinder and you know like there might be you know charging of your nitrogen gas cylinder hydrogen gas cylinder even in your LPG gas cylinder what you get LPG you will be knowing like liquid petroleum gas right.

Is it a gas or is it in the cylinder what it will be containing in LPG cylinder it is basically liquid but when it will be released to atmospheric pressure then it will be a gas converter gasps right, so right that suppose you want to you to be collecting from somewhere, so you will have to charge those cylinders and for that let us say there is a supply gas and you are having evolved over here and if it is there then it will be coming over to this cylinder this is basically a gas cylinder and in the beginning of course it will be evacuated right you should not have anything in principle or you will have to or it will be at a very low pressure.

So that this pressure will be higher gas will become and fill it up and then it will be till it attained some equilibrium pressure then you will remove and that will be some mass is changing in this gas all the time right and so also the pressure temperature in this cylinder will be changing now you need to analyze this problems right, so where and there will be several other problems unsteady problems phenomena which we need to analyze and how we will do that we are going to see.

And there is another this thing what it will becoming is basically the you know piston cylinder arrangement, so in that suppose there is a piston here and you are putting some gas kind of things right and in this case what is happening if you take this you know control volume here right and this control volume is changing its position as the gas being filled and the pressure being higher right.

So that piston will be moving right, so this is also another unsteady phenomena which will be occurring most of your you know automobile engines right is not it gas will be our air will be entering and then you know it will be going out, so that how we are going to model is one question which we need to address.

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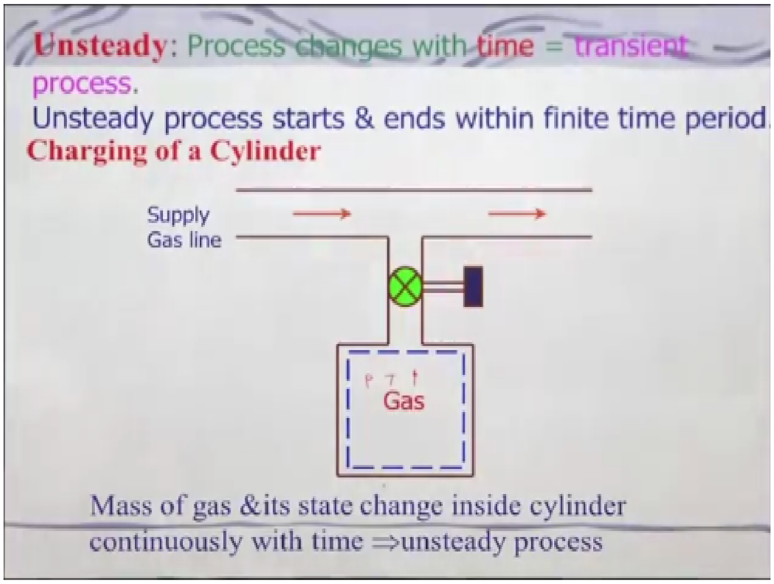

So see unsteady process means basically process which changes with time we call it also transient process and this unsteady process will be starting you know and ending within certain finite time right it may be few second it may be a few hours or in maybe a few minutes you know that way it will be and as I told the charging of a cylinder like you know one has to look at it is one of the examples and in this case what is happening the mass of the gas like which will be entering into this and the gas mass you know will be changing.

So also the pressure you know if I say pressure and temperature it will be changing you know like okay you could look at pressure will increase is if the temperature will increase or not that one has to see okay, so basically the properties and the mass of the gas inside this cylinder will be changing continuously you know with time, so therefore we call it as an unsteady process.

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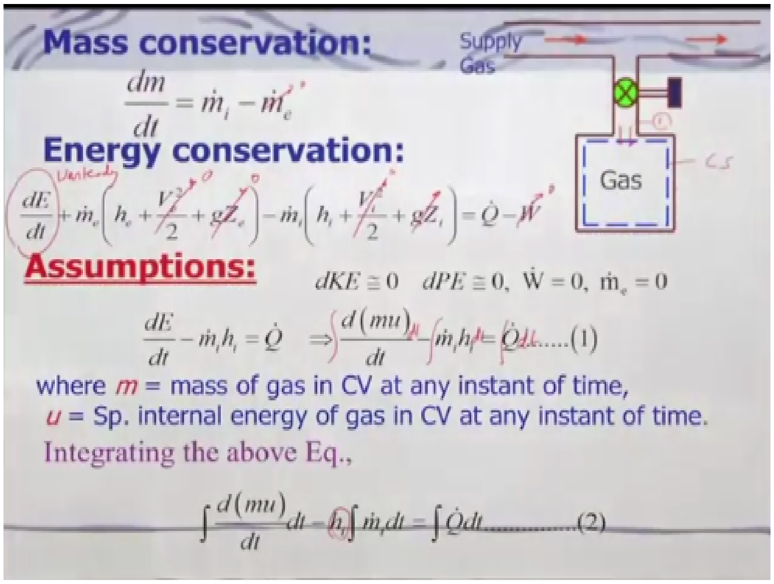

So what we'll do we will have to now apply basically mass conservation equation and in this case in this example of basically charging up a cylinder if we consider I can take this as a basically control surface and this is my control volume right the mass will be entering here and it is not going out, so if you look at this is my Inlet right and there is no exit so if I will have to look at the mass conservation and this there is no exit right, so therefore this will be 0 right this will be 0.

So now we similarly will apply the energy conservation equation right which is unsteady state and if you look at this term in the steady state we had neglected this is your unsteady term right this we are neglected in case of steady state we are saying it is 0 but here we cannot afford to say it is to be 0 or neglected right here we will have to consider that and of course if we consider in this case is there any work done in this case there is no work done it is a you know charging, so this will be 0.

And we can assume to be adiabatic or we need not to assume the process to be adiabatic, so right and the what we will do we will assume that you know change in potential energy this is equal to 0 for example you know the site is not really much having any effect right, so this potential energy this will be 0 change and we are saying that you know like the velocity with which it is entering into this chamber is very small of course it will be finite it cannot be 0 it will be fine it but this is small.

So therefore the change in kinetic energy is 0 basically right and then we can write down the you know first law of the thermodynamic for an open system becomes right de /dt – m. hr = Q. and here we are saying that it need not to be adiabatic but in some problem we may assume to be adiabatic depending on the boundary here we have kept that term you know with us, now if you look at we need to integrate this equation basically to find out right and then if I integrate this over here dt and similarly dt here.

So we can integrate between time 0 to t and we will see how we can and keep in mind that m is the mass of the gas in the control volume at any instant of time and of course u is the specific internal energy of the gas in the control volume at any instant of time that already we have defined, so by integrating this equation 1 we can get this right now we will have to see how we are going to you know like integrate this that is the important point one has to see.

Keep in mind that in this term like here I have taken the h you know this term i, have taken the hi out that means we are saying that whatever enthalpy with which it is entering into this control volume is not changing with time okay, is it a good assumption or a bad assumption because you know we are having it say you can say the supply is having a constant enthalpy you know kind of things and which is not changing and this is you can say that heat loss is not really much so and there is not much change so therefore I can take a J out and we will look at each of this you know each term of these terms and then see how we can integrate.

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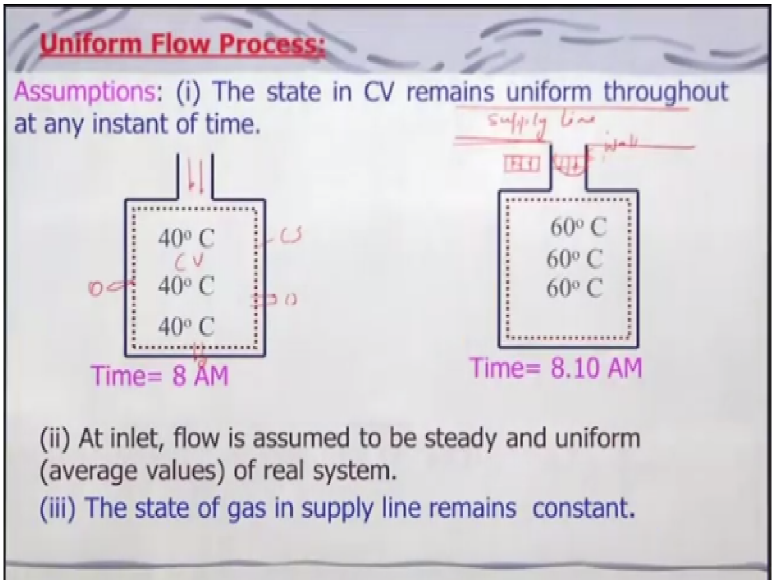

And before that we will do that you know like something uniform flow processes because if you look at like flow need not to be uniform but here we will be considering in this case that we are assuming the uniform flow process and the state in the control volume remains uniform throughout any instant of time right for example like if you look at if the sub mass is entering here with certain thing and then it will be having and there is a heat transfer taking place because not adiabatic you know some heat will be going out you know all the side so what will happen?

The temperature may change right but however we are assuming that throughout this series control volume right this is control surface this is my control volume that you know is not changing that is the assumption may be therefore we are calling it uniform but in actual situation it owned me so of course so as with time you know it becomes 60 degree Celsius now question arises will it increase or will it decrease right but I have just given so you think about it you may solve some problem and look at it and you know whether it will be increasing or decreasing.

I have just taken some example here so if the inlet flow is assumed to be steady and uniform right that is the point for example in a flow if it is coming over here you know let us say the flow profile it can be like this right yes or no because a boundary layer will be there is a pipe is here there will be boundary layer mention kind of things so this is a wall surface wall, wall of the pipe but however what will be assuming will be assuming as a uniform velocity profile that means the profile will be uniform.

Is all same velocity and if it is let us say parabolic profile this is the parabolic profile then we will say average velocity and then we can say work it out and we are assuming that uniform velocity at the inlet and uniform in the screw out keep in mind that in thermodynamics most of the time we will be looking at uniform velocity profile and temperature profile other thing at the inlet and exit and like in fluid mechanics where you will have to you cannot afford put consider uniform okay.

So anyway in thermodynamics we will be doing but unless otherwise it is given so if it is given non-uniform then you will have to handle how you know in a little different way so the state of the gas in supply rhyme remain constant there is a supply line here which is not shown you know this is your supply line right and this remains constant that we are assuming.

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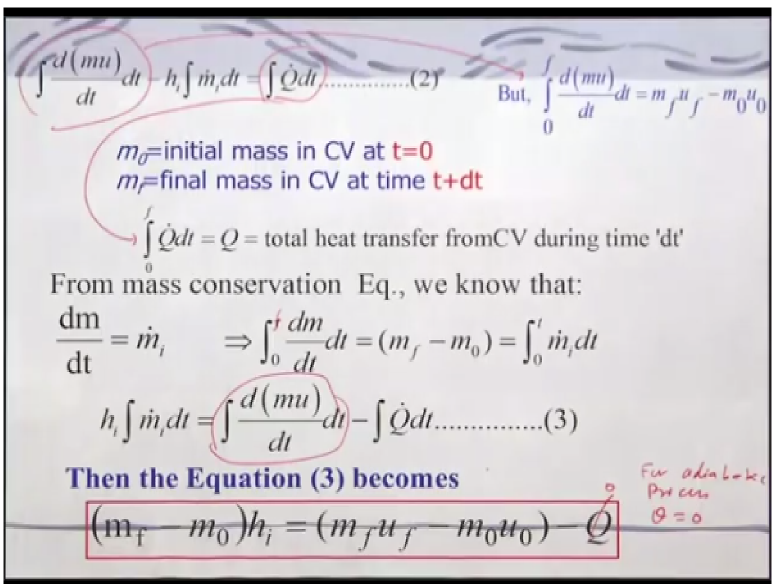

And let us look at each term and if I consider this term like this if you consider this term and then write down here we will get basically the what you call between 0 to in initial state to the final step that will be MF u F- M_0 U_0 right that is the thing by integration will get and where the M_0 is the initial mass in the control volume at time t is equal to 0 MF is the final mass in the control volume at time T + DT and similarly the internal energy u f & Q0 right.

So if you look at this term right Q0 this term I can take this out and this is Q.dt 0 to final become Q we are saying total heat transfer from control volume during time DT so and we will have to look at the last term from the mass conservation we know DM /DT = m. I and who if you can integrate this thing I mean this is basically you can say 0 to F right I mean you can say T or you can say F final you know F here and then we will find out this MF – M0 that is right.

So this portion will be like that so what we will do we will substitute these values in equation to all this thing and we will get that this H M IDT nothing but MF- M0 H I is equal to change in your internal energy terms right this term so this term is basically MF EF – M0 u0 and then Q dot DT basically q, so what he says is basically that changing what you call the amount of mass whatever is changing in the cylinder into the enthalpy is equal to the change in internal energy right.

A final and initial right and minus Q naught if was the adiabatic process you know you can make it zero for adiabatic process right, the Q will be 0 so this term will be 0 basically and you will find out is nothing but your you know enthalpy change in the water column in the cylinder is equal to change in internal energy kind of things one can think of.

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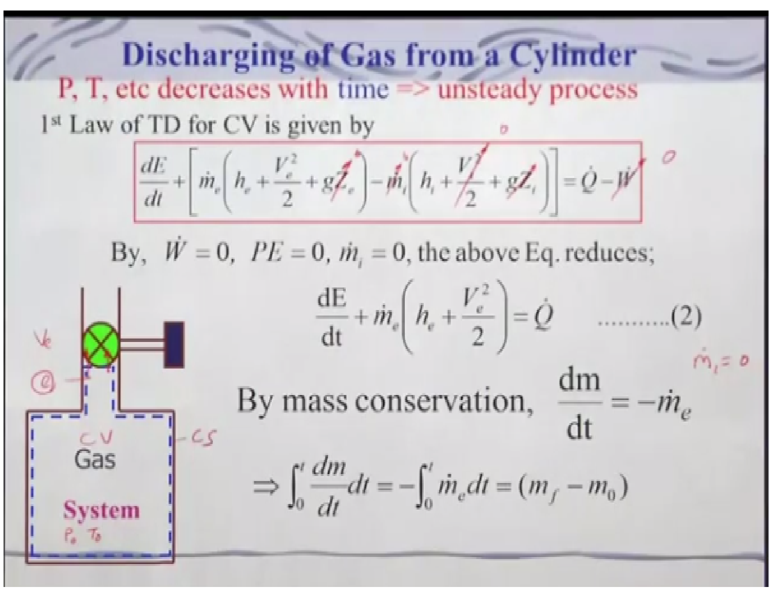

So now let us look at the discharging of gas from a cylinder right the earlier we have seen the charging of a cylinder now we will be looking at discharging of the cylinder and in this case we will consider that a gas which is there at certain pressure you know let us say initial pressure of P0 and let us say T0 right and it is going out by this wall right and this is your control volume and this is your control surface and this is your control volume I have taken and it is going out with certain velocity of course will be right.

And this is your you can say exit right it will be you can say with certain velocity it will be going Ve and as the gas is going out you will see that pressure and temperature of this gas in this cylinder will be decreasing with time right yes or no and so also the mass, mass whatever containing in this cylinder will be decreasing is therefore it is an unsteady process. Now we need to apply we will take a control volume as I told and we will apply the first law of thermodynamics in this case.

And of course we have already know that there is no work being done during this passes or on the system or by the you know system so therefore the work done will be definitely 0 and the change in potential energy you know will be 0 in this case right and there is no inlet so therefore this kind this portion will be 0 and here of course if you look at the Mi mass also this will be 0 I mean this is 0 so this term would not be there.

So however we are saying that it is will be having certain amount of velocity with which it will be going right, so then the energy equation becomes d/dt x m.e(he) that is enthalpy which is which it is exiting and with the v^2 /2 = Q. so we will have to integrate this equation right and before that we will have to look at mass conservation that is DM/DT = - M.e because m. I is basically zero right m. I is 0. So therefore you know it became DM /DT = - M.e and if we integrate this equation 0 to T I am that you will get Mf – M0 right.

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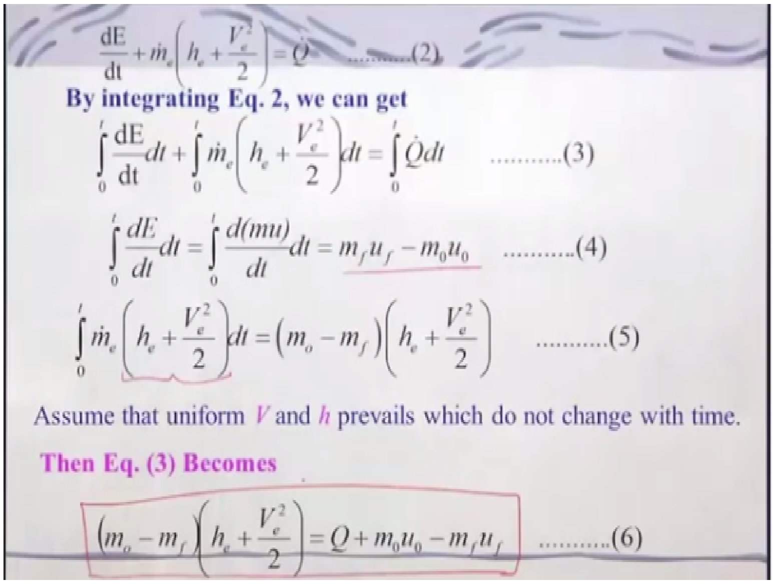

So now we will try to integrate the energy equation right and integrating this will basically between the 0 x 0 to certain time T and we look at each term already we have done it will be similar to that like d/ dt is nothing but your m-f and uf- M0 U0 and in the similar way we can also integrate M.e He + v^2/ 2 this into dt and we are assuming that this is not changing right this is constant you know not changing this term right He + V^2/ 2 is not changing with respect to time right.

Therefore I will take it out and then we will get M0 – Mf x He + Ve^2/2 right, keep in mind that here I have taken a you know -m because the mass is going out and then rather in other words the mass of the cylinder is decreasing right therefore the negative sign is taken so it became positive kind of thing here so this is assumption if you look at is not really right unless otherwise you are taking out very small amount of mass from the cylinder which is at a very high pressure and you know high-temperature high-pressure rather amount of mass in the cylinder is very high and you are taking very small amount so that velocity would not be changing.

Because pressure is not falling so drastically right then only otherwise velocity will be changing because the it is going to let the ambient pressure let us say for example right then the pressure of the cylinder is changing and at ambient will be remaining same so therefore the pressure gradient changing velocity has to change but we are assuming it is not changing with respect time for simplification right so that you should keep in mind.

So and equation 5 becomes right M0 – Mf sorry equation 3 becomes M0 – ff x He + $Ve^2/2$ = Q + M0 U0 – M0 Mf Uf right, so this is the things equation what you will get for the discharging of a cylinder right so it is similar to that right except that we are considering little kinetic energy or the exit velocity here that is all right not really much and right so this way you can handle this problems let me tell you like suppose here we have assume a control volume approach.

For charging and discharging of cylinder unsteady process suppose I want to use the control mass you know system or a closed system and I want to analyze this problem is it possible or not can I arrived at same equation or not it is possible you can do that and I would suggest you do it yourself and have a feel because you know it is important to appreciate that any approach you can do like either control volume or control mass system for any thermodynamic problem.

But however one has to be little careful and sometimes one will be you know convenient for a certain kind of a for example for flow problems you know control volume approach is convenient that does not mean you cannot apply the control mass system there right so that you should keep in mind.

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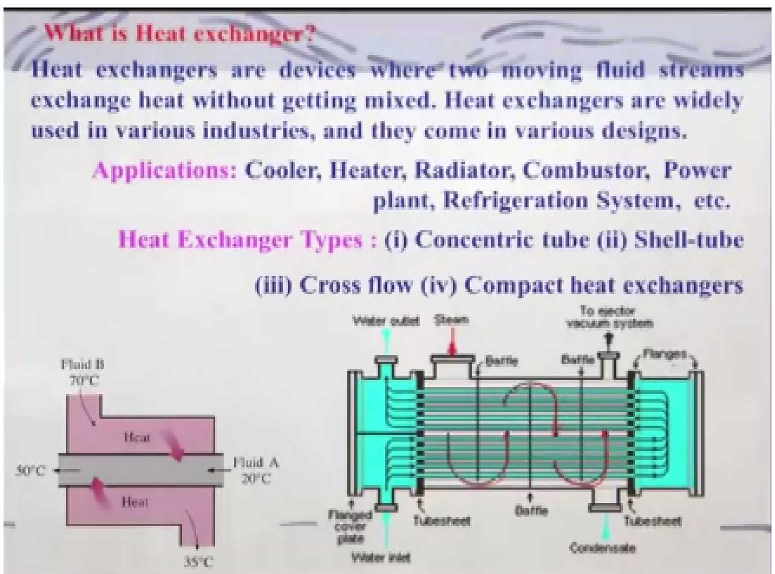

And let us see that another you know application of this open flow problems that is the heat exchanger you know like heat exchanger is being used routinely in industries to have a heat exchange you know between two fluids or maybe you know and without really getting mixed that is the thing but there might be another place where the fluid will be mixed together right it is like a mixture. What we do in yours our you know like whenever you take bath in the winter season that you know hot water and cold water with the help of a tea something you will be mixing and then getting a temperature water which is moderate enough for the for your body.

This thing otherwise if you take a you know directly the water from the, your geezer then it will be having problem is not unless otherwise it is controlled properly. So heat exchangers are widely used in various industries and they are also you know various kinds depending upon the application and also the depending upon the designer what they can think of. So if you look at application wise there are several like your cooler like.

What we use the desert cooler you know like can you think of desert cooler is a heat exchanger can you come in this definition it is not really right it will be rather comes under a mixture and like heater you know radiators in the car that is a very good you know heat exchanger and in the recuperative kind of combustors we do exchange the heat and so that you can what you call pre-heat your air and other things.

Of course power plant refuge system several I mean heat exchanger is a very you know what you call important component what people use in industries and other places so heat exchangers can be several type concentrated tube type cell tube type cross flow type compact heat exchanger. I mean several of them one can think of those people who are in mechanical engineering you know they will be learning this about eat exchanges in detail.

So let us consider that a heat exchanger a cell and you know a tube type kind of X heat exchangers like you can say that concentrating tube type heat exchanger in which case the fluid a is you know coming with 20 degree Celsius and leaving with 50 degree Celsius because the fluid be which is entering into this which will be come in contact with the cold fluid which is at 70 degree Celsius and it is leaving at 35 degree because there is a heat exchange which is taking place without really getting mixed right they say not and there will be.

Now if you want to analyze this problem right so you will have to you know like take care of how to take a control volume are there so this is a simply simpler kind of system so the let us look at the another kind of heat exchanger in which if you look at the your old or the water is coming over here and it is going you know kind of things to the tube right it is going through these tubes right again it is coming to another chamber and it is again going back.

You know and then the steam which is at high temperature to becoming these are the baffle so that will give more resistance again path pass through this way you know like if you look at it will be passing through this way and this way again these three. So that you know more contact more residence time will be given and heat exchange will be and this is basically you know kind of a complex you know heat exchanger kind of things and you want to analyze this kind of problem will have to simplify.

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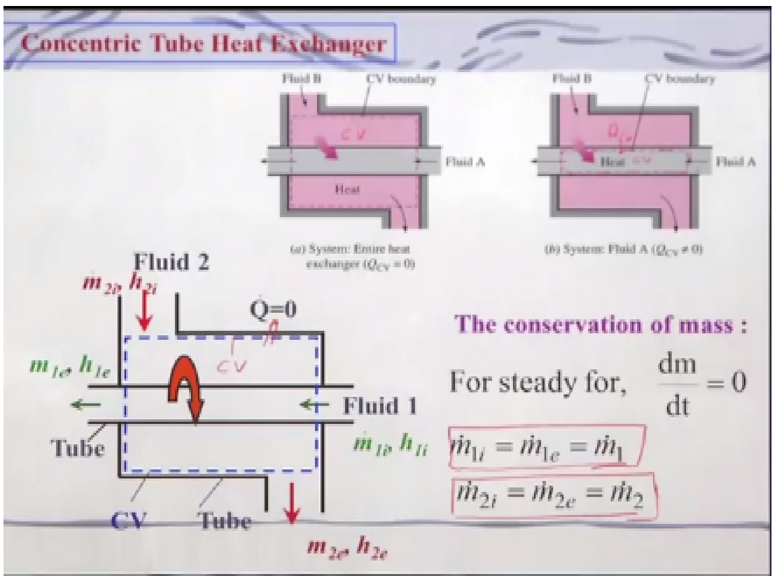

The things and we will see now look at a concentrated to heat exchanger and one can think of using you know to a control volume like if I put it this way that in this case this is your control volume boundary like this as the control volume and which include both the old fluid pipe and also the heart feed pipe. And in this case if I take this as a system will consider the heat exchange you know in this control volume is 0.

But if I take the other example like the say example but I will choose this control volume here right this is my control volume so then you know like you will have to consider how much heat is passing through this surface you know there will be some kind of a you know heat which is passing through this control volume. Right and this here you know you will have to take care so what I am trying to emphasize here that whenever you choose a control volume for a particular analysis you will have to be very careful to handle the things right.

Otherwise you will be in trouble so let us consider this thing how we are going to that like weed one is passing through this and which is having what you call m dot IV the inlet right and this is with enthalpy at the further the one enthalpy at the inlet for this tweed1 and similarly it is the fluid to it is entering with certain mass flow rate and the enthalpy and it is being cooled down and then this heat being transferred to the cold fluid and then become the fluid you know temperature increases.

So if you look at we are taking this as a control volume as a result there is no heat being transfer you know like Q dot is basically zero equal to zero because all the heat is the exchange of the fluid from the 232 to the fluid one. So mass conservation equation you know we can get because it is a steady flow process so DM DT is equal to zero so therefore you will get basically mass flow rate at the inlet for the fluid 1 is equal to mass flow rate at the exit for the fluid1 is equal to M one. Similarly for the fluid to that is m.i =m e =m2.

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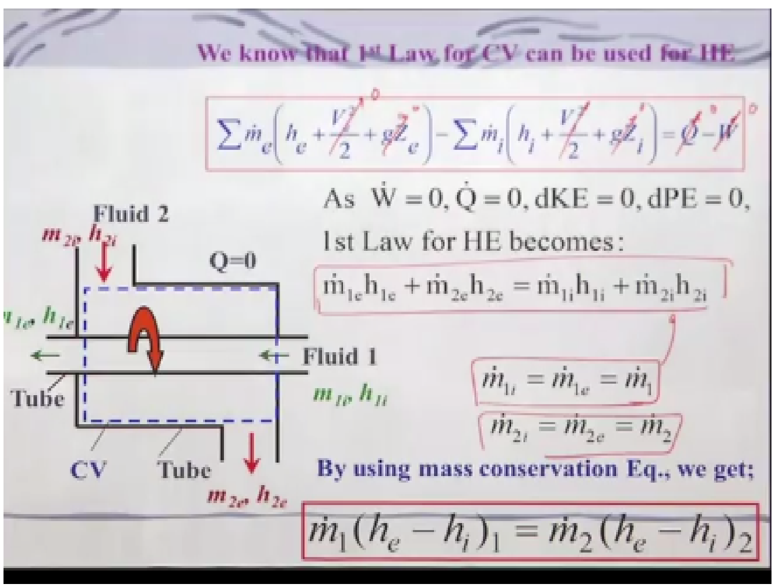

So and what we will do now we will basically apply this first law of thermodynamics for this control volume and if you look at in this term what we are doing we are basically making these assumptions that is the change in potential energy is zero right and there is no work done here and what about heat it also is there is no heat exchange right between the control volume because control volume in that control volume both the you know fluid are embedded.

So therefore that will be zero and change in the kinetic energy also is equal to zero. So therefore you can get the first law of thermo dynamics very simple that is enthalpy balance and that is the total enthalpy at the what you call for the fluid one at the exit plus the total enthalpy for the fluid to at the exit is equal to total enthalpy at the inlet for the fluid one and for the free to that is all basically enthalpy balance nothing else.

And from the mass conservation equation we already know this right that is this thing so that what we will do we will basically put this equation over here and then simplify and then we can write down as m dot one into a chi minus H I at the what you have read 1 that means whatever the total enthalpy of a fluid is equal to total enthalpy for the fluid to that means total enthalpy for the fluid one is equal to total enthalpy for the fluid

To the very simple way of you know looking at it I mean you need not to really do this you know equation to look at it but if you just keep it and does that balance then it will be good enough.

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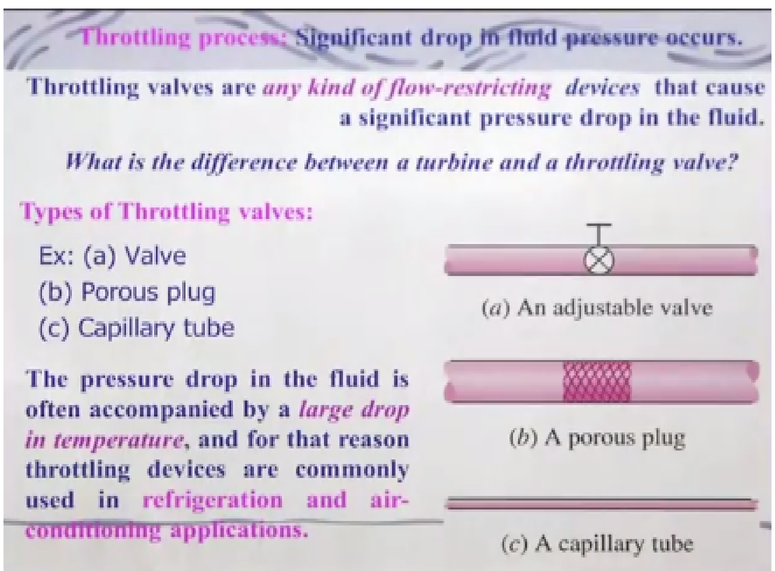

So let us look at another process what we call is a throttling process in this case the there will be significant drop in fluid pressure where these processes will be occurring in are you know this thing any idea. Because there will be significant pressure drop for example you have already seen the turbine right in the turbine or in the compressor there will be significant pressure draw right yes or no yes or no.

See if you look at fan the pressure you know will be increasing little bit the pressure drop means basically pressure will be decreasing in this case you can say so it will be in the case of turbine there will be significant drop in the pressure because the right and but however we are not discussing about that here we are discussing about a wall like suppose you are having a we have seen that there is a discharge kind of a you know from a high pressure gas cylinder.

And that wall when I open there is a lot of pressure difference like way in cylinder of let us say let us say nitrogen gas cylinder or hydrogen gas cylinder it will be late say 100atmospheric pressure or maybe 500 atmospheric pressure it is there and then you know the change it to the one atmosphere is a very significant drop chick. You know from let us say 500atmospheric to the one atmospheric pressure so that drop you know with it will be occurring across evolve because there will be a control wall which will be controlling thing.

So the throttling valves are any kind of flow restriction it will be restricting the flow device that causes significant pressure drop in the fluid and as I told that that what is the difference between a turbine and hurtling ball the turbine if there is a pressure drop there will be work done right that means work mechanical work being done but in this case there is no work done as such because if the if you look at there is a discharging of a cylinder or a gas from a high pressure cylinder is going out.

There will not be any work done as such right so there are various kinds of throttling valves which you will be knowing but let me just tell you few of them the one is the wall like when it is open or a half open or you know kind of things there will be a threatening process there will be significant change in pressure drop there is a porous plug you know and there will be capillary tube you might be knowing what is the capillary tube.

Right you are aware it is a very thin you know too thin you know and a small diameter tube thin wall like your hypodermic needle whatever use for unmixed that can be used as a capillary tubas such. So if you look at these are the diagram what you can keep in mind this is a adjustable valve and there is porous plug and the capillary tube which is very small kind of things returned a small diameter tube and this pressure drop in the fluid is often accompanied by the laws drop in temperature.

Right and for that reason the throttling devices are commonly used in refrigeration air conditioning system did you observe any time maybe in your chemistry lab or some other things you might have opened a high pressure cylinder gas and then you will find that you know Lily in the winter season like you will find some condensation is occurring across that tube you have observed any of you have observed or not have not seen? Please see it whenever you do some experiments like why it is happening because the temperature is coming down very low and the moisture is there in the atmospheric air it will condense on the top of it and you can see that.

So therefore that is why it is being used of course you must not have seen your refrigerator there will be something you know throttling valve will be there and you see there is a tube which the capillary tube being used you know to reduce the pressure so that you will get the cooling effect.

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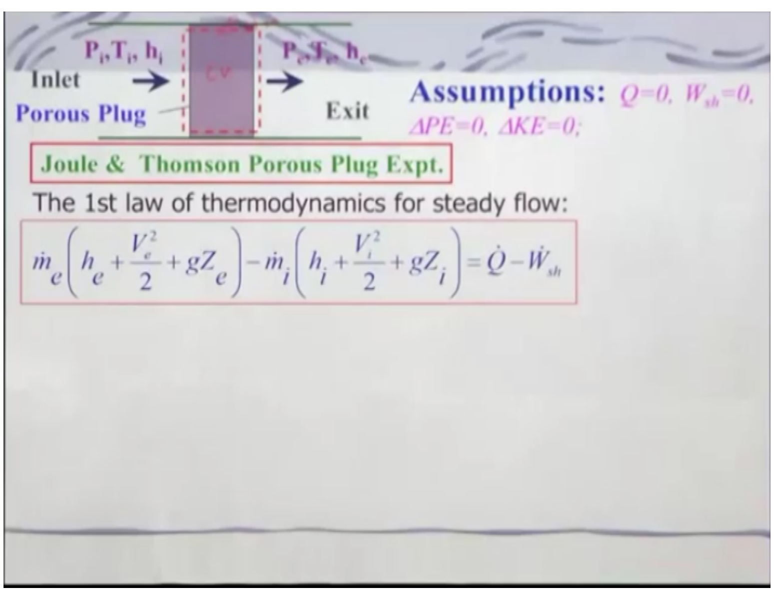

They actually this experiment basically done by the first by the jewels and also some sense so what they did like there is a forest plot one can think of and taking and then there is a pressure high pressure Pat the inlet p I and temperature T I of course it will be having some enthalpy of the fluid and when it pass through that pressure PE you know will be reduced and temperature te it may you know change it will be changing it may be reduced or in maybe enhance.

And then enthalpy also will be changing at the exit so this assumption let us say we can say there is no if I take this control volume right for the porous block here this is my control volume so what will happen is there any heat will be going through so if you look at these are very small kind of this thing the heat is very you know it transfer will be zero there would not be any heat transfers such and there is no work done.

So therefore the shaft work will be zero and we are saying that the change in kinetic energy is zero because there won’t be any much velocity change will be occurring and so also the change in potential energy is equal to zero and we can assume this process to be steady right and there is no unsteadiness as such is there we are considering.

And then with this assumption one can really you know use this equation and then make this is basically zero and this change in potential in a zero change in kinetic energy is a zero what it amounts to be among to be that the enthalpy at HI is equal to H E and we have also from the what you call from the mass conservation equation we can write down that m dot E is equal to m dot I is equal to m dot so therefore the either the specific enthalpy or the total enthalpy is remaining constant we have seen similar thing in your heat exchanger and this process is known as isenthalpic process right throttling is basically is an isenthalpic process.

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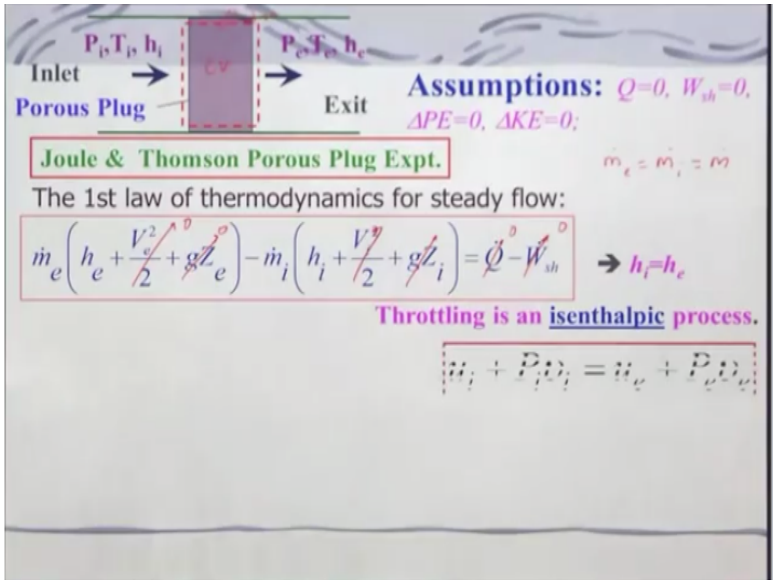

And so if I just rewrite this you know enthalpy in terms of the internal energy you can say that internal energy this is basically internal energy and this is what this is your flow works and that is at the inlet and equal tote again internal energy and the flow work at the exit so if you consider that EV that is the flow walk right this is the flow work is at the exit is greater than the flow work at the inlet then you that is internally the exit will belles than eye and if you assume that you know co is not really changing much with this temperature change .

Then you can happily say that 2 is less than T I kind similarly if the flow work at the exit is less than the flow work at the inlet this other way around that internal energy at the exit greater than the internet as a at the inlet and Exit temperature will be greater than Ti right so is it really will be occurring this kind of thing that means you know that it will be higher than that right suppose you take a nitrogen gas cylinder and you open the wall from high pressure.

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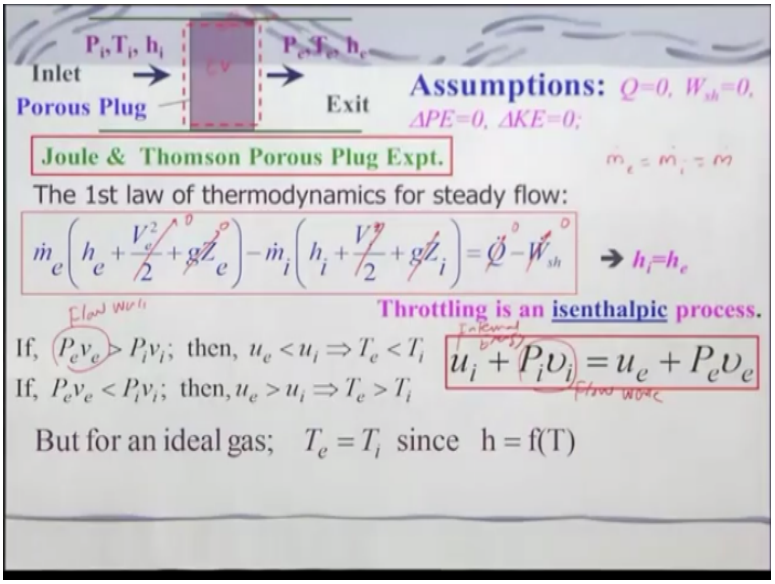

The gas will be going and take a hydrogen cylinder and open a ball and the you know and then there will be throttling process will be taking place what will happen there right you think about that we will come to this so but for an ideal gas the enthalpy you know we know that T E is equal to t I that means you know right because enthalpy is a function of temperature only type and for as I told that that they have conducted experiment by keeping this what you call pit constant and then varying the PE by the throttling wall

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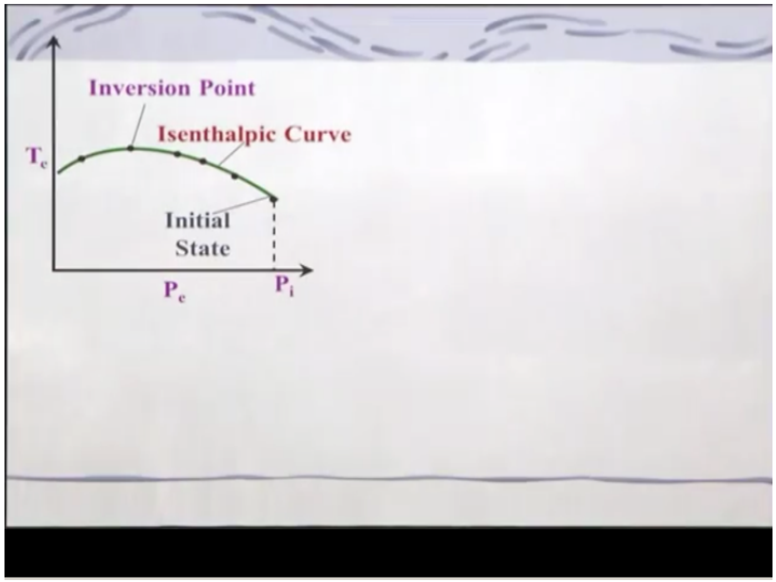

And you can changes if you conduct these experiments like you take this p I and then goes unchanging the PE and then you will get different temperature you will get that it is you know increasing then it is remained a you know reaching almost you know there is no change here and then again it is decreasing and this is the inverse point because the slopes changing you know from the what you call right hand side to the left hand side if you conduct this experiment several of them and of different inlet conditions.

You will get you know various curves like that you know and if I joint his inverse and point like where the slope is 0 right then what will happen this curve is known as inversion curve right and in this region like what you call we call it a region of cooling and in this region we call it as a region of heating so then we can define a term the joule- Thomson coefficient is where mu Otis do T by do P and H is enthalpies remaining constant and this is a you know property of the system which will be will be being used.

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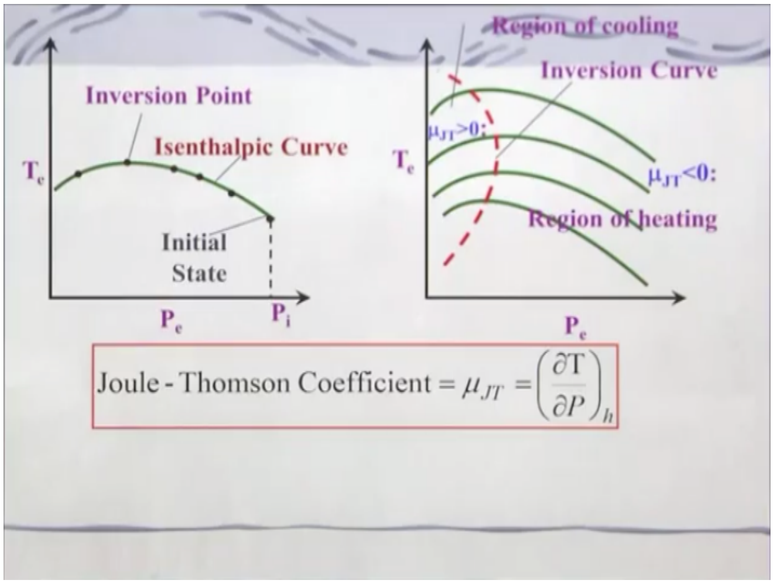

And we will also be discussing this about whenever we will go for how to evaluate this in terms of measurable properties like we will discuss that and so this if you look at this point is joining if you look at this is a maximum inversion point if we join over here that is the temperature corresponding and if you consider theism je t is equal to basically e minus TI/ PE minus P I when mu je T is greater than 0 right that is in this region what will happen pen is less than P I all the time because you know pressure will bellower p/e less then what happened to is less than T Therefore this is cooling regime right this will be cooling me and when mu je Its less than zero this region right when PE is less than P I and T is greater than T I heating region

Right so as I told like particularly you know when you handle this hydrogen kind of gas you know there you will get this heating up therefore one has to be careful when you are handling the hydrogen cylinder kind of things for almost all gases at ambient temperature mu je T is greater than zero that is cooling right and exceptionally hydrogen helium Nina you know these gases one has to be until of course helium and neon is inert gases so therefore no problem but hydrogen is Avery reactive gas so therefore one has two and four hydrogen the inverse centimeter two.

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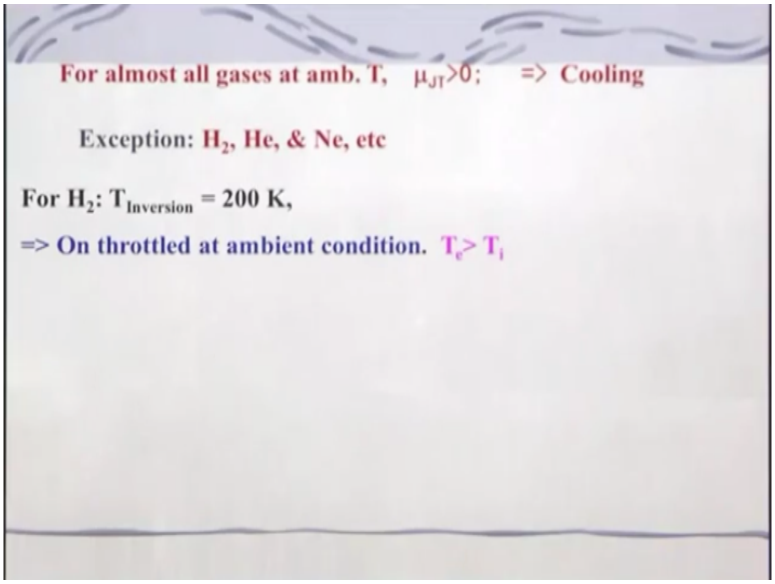

Thousand Kelvin kind of thing so on turtle at the ambient temperature T is greater than T I you know if it is higher temperature then you know if there is a leakage then it may you know ignite the mixture around that place so there will be explosive kind of things so therefore one has to be very careful handle the hydrogen cylinder for avoiding the exposure so acknowledge of inversion curve for real gases essential to design refrigeration liquefaction systems kind of things therefore one has to understand these properties of the joule-Thomson coefficient.

And which will be also discussing and expressing in terms of measurable properties whenever we are talking about how to handle various properties kind of thing so for an ideal gas shuttling process.

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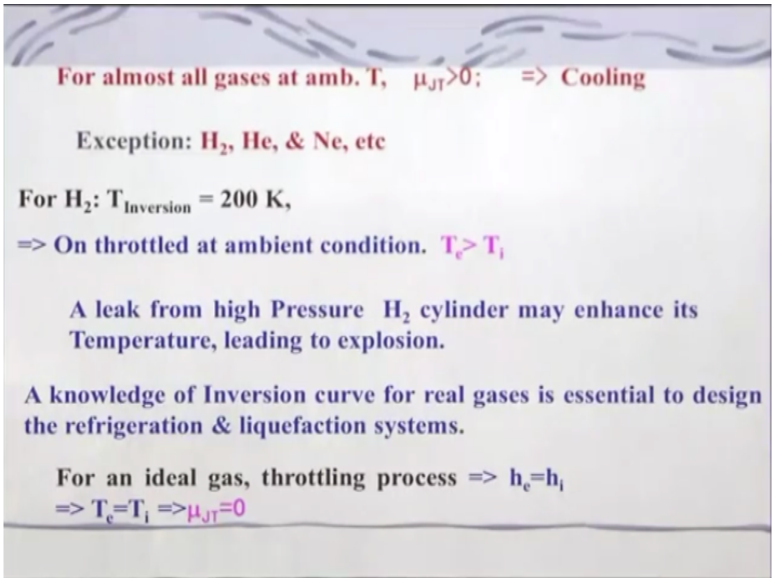

the what you call E is equal to t I that means basically the jewel comes in coefficient is equal to 0 so if you look at we have seen this thing how you can apply the first law of thermodynamics and in this case there is no reacting you know or you know flow this is not a reacting flow no reactions are going on in the next lecture what we'll be doing will be learning how to handle the reacting to write in this case a heat exchanger.

And then you what you call compressor and then turbine another problems what we have seen in case of unsteady will there is no reaction going on you know there is no reheat release no chemical reaction going on so these are the simpler fluid we will have to see how we can apply this first Locker Medina reacting flows in the next lecture thank you.

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