Concepts of Thermodynamics
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Lecture – 30
First Law for Unsteady Problems - Examples (Contd.)

So, we have been discussing about problems concerning First Law of Thermodynamics, where the situation demands addressing unsteady state problems. We have worked out two problems, so for and we will continue with the next problem.

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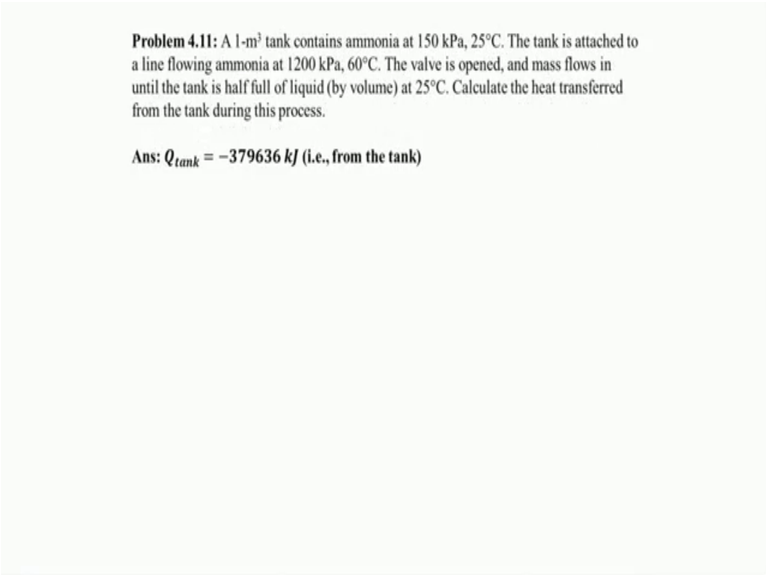

So, this problem is a 1 meter cube tank contains ammonia at 150 kilo Pascal 25 degree centigrade, ok. The tank is attached to a line flowing ammonia at 1200 kilo Pascal and 60 degree centigrade. The valve is opened and mass flows in until the tank is half full of liquid by volume, at 25 degree centigrade. Calculate the heat transferred from the tank during the process.

Now, this is also a tank filling problem. We had solved one tank filling problem earlier. The basic difference between that problem and this problem is that that problem was pertaining to an ideal gas, and now we are trying to workout a problem which for a substance which is a phase changing substance. So, you know the methodology in which we solve the problem although the concept remains very similar, but the methodology will be a little bit different.

And I want to impose on you the very striking difference of solving an ideal gas problem versus a phase changing substance problem, because you know many times students who are confused between these two and typically in the school level you have done mostly ideal gas problems. So, you have a tendency to use ideal gas concepts even for substances that are you know phase changing substances and so on. So, that should not be done. And this is an example where in such problems how do you solve. So, let me go to the board.

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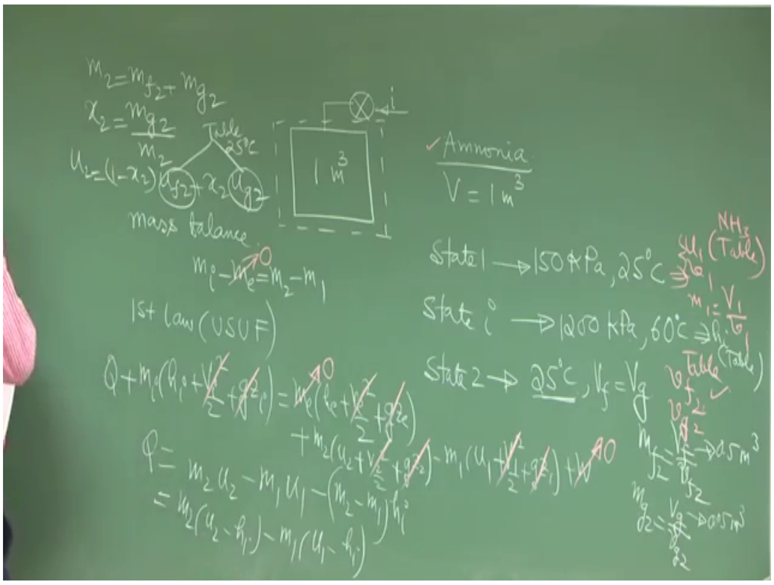

So, you have a 1 meter cube tank it contains ammonia V is equal to 1 meter cube. State 1, 150 kPa 25 degree centigrade, ok. So, this is connected to a supply line. So, there is a supply i, state i 1200 kilo Pascal, 60 degree centigrade. State 2, 25 degree centigrade and V f is equal to V g, ok. So, that is I know the tank is half full of liquid; that means, remaining half is vapor, so volume of fluid and sorry volume of liquid and volume of vapor are the same. So, and temperature is 20 degree centigrade.

So, you have to find out the heat transfer, right. So, you write first of all mass balance. So, in this mass balance what you require is to use this equation. There is no exit right it is a tank filling problem, but there is m 2 and m 1 right, the tank was not initially evacuated. So, m 2 minus m 1 is equal to m i. Then the first law for USUF Q, ok. So, I have just written the full equation because you know if you start with the full equation and then put your constraints given data in the problem that gives you a clarity of what you know, what you do not know, what you need to find out and all these things.

So, first of all there is no work done, work done remain 0. Then you do not have any exit state therefore this is 0. You will have a change negligible changes in kinetic energy and potential energy, you know for most of the problems it is like that, but I tell you, you know sometimes your examiner tries to make sure whether you are very alert. In some problems kinetic and potential energy changes may be important. So, you look into the problem statement first and see whether there is any hint that you know some of those terms may be important check it very clearly, if there is no hint like that you can safely neglect changes in kinetic energy and potential energy.

So, you will have Q is equal to m 2 u 2 minus m 1 u 1 minus m i h i, m i is m 2 minus m 1, ok. So, this is m 2 into u 2 minus h i minus m 1 into u 1 minus h i right. So, let us see what we know out of this. So, at state 1 temperature pressure both are given. So, from here you can find out at state 1 what is required u 1 from the table you can get ammonia table right ammonia table, prop fluid is ammonia.

So, do not you know this is again a very common tendency because most of the times you are working with water you have a tendency to jump into the steam table although you know the fluid is not water. So, look into what is the fluid? Enter into the corresponding table to you know get this. So, identify the state get u 1 and you also require specific volume at state 1 because you require mass. So, these two you get from table. So, mass is volume by specific volume, right.

State 2, state 2 clearly you have a liquid vapor mixture; that means, in the it is in the two phase region. So, you find out what is v f at state 2, v f at 25 degree centigrade again from table. You also find out what is v g. What is the mass of the vapor? See here you have to use the basic definition of specific volume. So, mass of vapor is V f by, so V f by v f 2. What is this V f? See it is half liquid and half vapor. So, if total is 1 meter cube this is half a meter cube, right.

And this is m f 2 and what is m g 2 this is vg by v g 2. So, this is and v g 2 is you know you get from the table. So, you know what is m f 2 and m g 2. So, what is m 2? Right. Not only that you can find out what is the quality at state 2. What is that? Mass of vapor by total mass, right. How do you, why do you require quality? You require quality because you have to know what is u 2. So, u 2 is 1 minus h 2 u f 2 plus x 2 into u g 2 these u f 2 and u g 2 are from table properties of ammonia at 25 degree centigrade, ok. h i in this equation state i is given in terms of pressure and temperature. So, you get a h i from a 1200 kPa 60 degree centigrade, ok.

So, with all these if you substitute you will get the total heat transfer. And this is the answer to this problem is minus 379.636 kilo Joule, ok.

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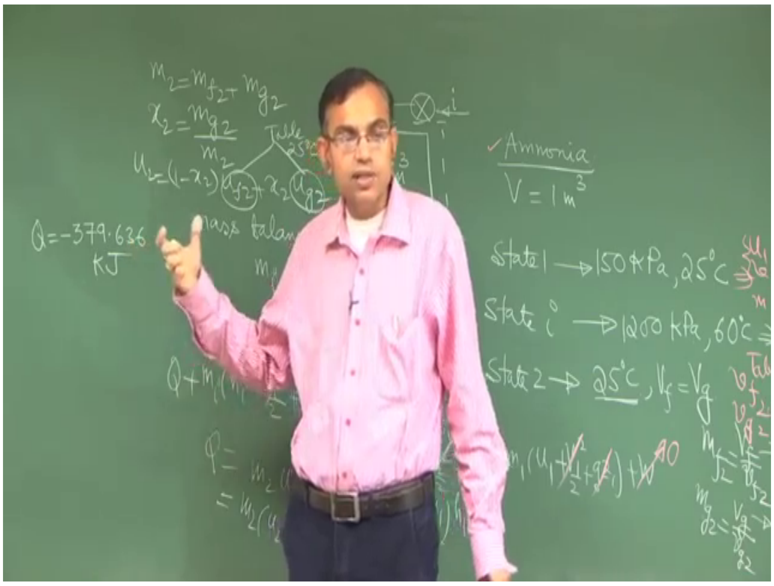

So, again you will see that there is a heat transfer which is required from the control volume to the surrounding because you are energizing the fluid more by supplying the flow energy or flow wall. So, that energy somehow has to be dissipated through heat transfer to the surrounding, that is why you know this is a negative heat transfer; so, all these are very important.

So, why you can say that well the answer is coming negative, so I understand this. Why this understanding is required? These understanding is required because say you are solving a problem somehow the sign of this has not come correctly, that will give you a first check that you know the sign of either heat or work is not coming consistent with the physics of the problem that should give you an alert.

If you do not get that alert; that means, you are dumb you are just you know putting values and whatever is coming you are accepting it, so you get an alert and based on that alert you figure out that you know whether it is consistent with the physical situation or not. If it is consistent with the physical situation that does not essentially mean that you know your problem solving is correct, but if it is not consistent with the physical situation it is definitely true that your problem solving is not correct. So, I would say that always be driven by this you know physics based considerations to put some basic checks on your answer, ok.

So, we will work out another problem. Let me erase the board; so the next problem, problem number 12.

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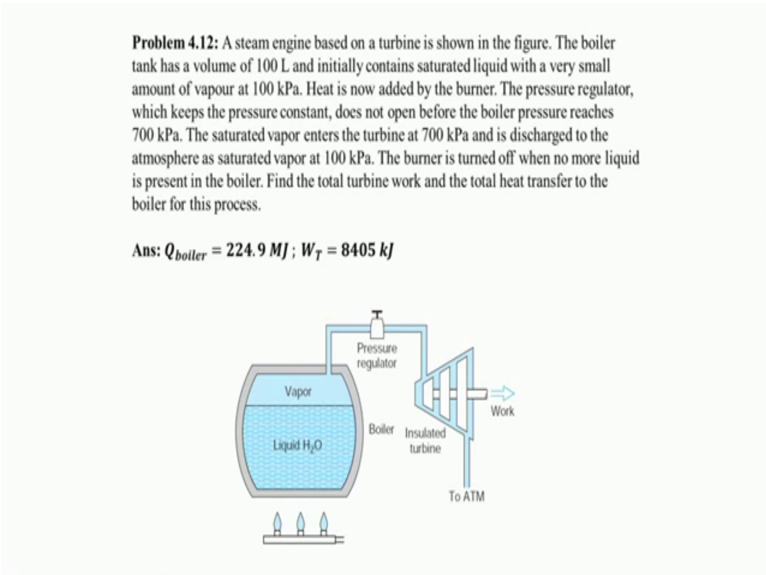

So, this is a bit involved problem for the beginners I would try to go through the problem very carefully a steam engine based on a turbine is shown in the figure. So, what is happening is that there is a boiler, in the boiler liquid water is converted into water vapor and then the water vapor is supplied to a turbine.

So, the water vapor has high thermal energy, in the turbine that thermal energy is utilized to do some work, ok. So, this is the basic arrangement. So, you can see that in the schematic there is a boiler and there is a turbine and there is a pressure regulating valve that controls the flow from the boiler to the turbine. The boiler has a tank of volume 100 litre and initially contain saturated liquid with a very small amount of vapor at 100 k Pa.

Heat is now added by the burner. The pressure regulator which keeps the pressure constant does not open before the boiler pressure reaches 700 kilo Pascal. So, the when the pressure regulator opens the pressure is already 700 kilo Pascal in the boiler. The saturated vapor at 700 kilo Pascal, enters the turbine and is discharged to the atmosphere as saturated vapor at 100 kilo Pascal. The burner is turned off when no more liquid is present in the boiler, ok. Find the total turbine work and the total heat transferred to the boiler for this process, ok. So, let me draw the schematic of this problem in the board.

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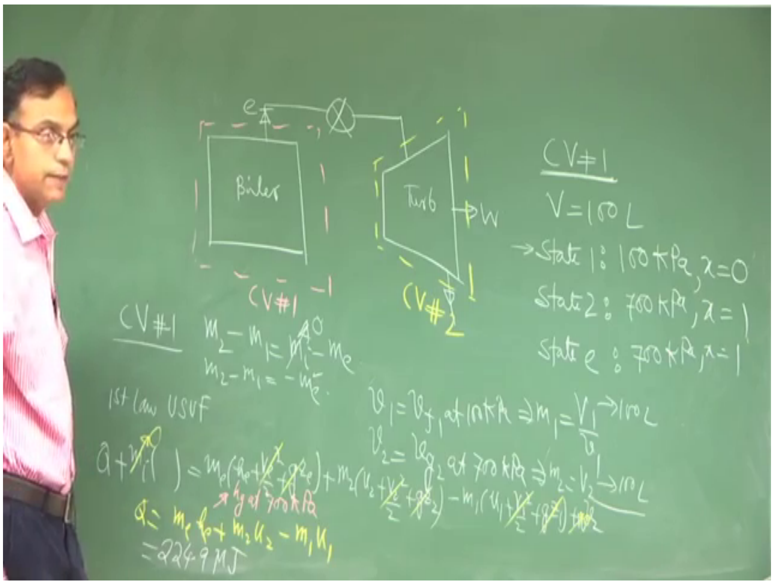

So, this boiler I am just drawing a block there is a valve here and then it enters the turbine, ok, this is turbine. So, to workout this problem I would prefer to break it into two simple simpler problems, one is a control volume one which is around the boiler, this is control volume number one, and another control volume number two which is the around the turbine. So, we will see what is happening around the control volume one first.

The control volume one has volume equal to 100 litre, state 1 100 kilo Pascal saturated liquid quality equal to 0, ok. State 2, 700 kilo Pascal quality equal to 1 saturated vapor right. Then state e, what is state e? This is the exit state e. State e 700 kilo Pascal quality equal to 1, because now everything is saturated vapor and that only gets transmitted through the line. So, this is from the physical understanding of the problem, ok.

Now, for the control volume 1, let us apply mass balance or energy balance. So, m 2 minus m 1 is equal to m i minus m e. So, here there is no inlet and there is exit. So, m 2 minus m 1 is minus m e. So, if we know what is m 2 and what is m 1 you can calculate what is m e. So, how do you calculate what is m 1? So, state 1 specific volume is v f 1 at 100 kPa, m 1 is V 1 by v 1; v 1 is this 100 meter this is same a v 2. What is v 2, small v 3? This is v g at 700 kilo Pascal, ok. So, m 2 is equal to v 2 which is again 100 litre. So, remember from litre, 1 litre is 10 to the power minus 3 meter cube. So, you have to convert that to meter cube by v 2, ok. So, you can calculate what is m e? Now, you apply the first law for USUF, ok.

So, now, let us see what are the values. So, m i this is 0, again you know for boiler, kinetic energy and potential energy changes are not negligible thermal are negligible and thermal energy changes are more important. There is no work done for boiler. So, Q becomes m e, h e plus m 2, u 2 minus m 1 u 1 right. h e is what? h e is h g at 700 kilo Pascal, ok.

So, if you substitute all those values Q will be 224.9 megajoule, ok. So, this heat transfer is required for many things, one is converting the water to liquid water to vapor water, next is supplying additional energy, so that there is a flow energy that is created and that vapor flows across this. So, these two forms of energy that energization is reflected by this heat transfer.

So, the next is the turbine work that we need to convert.

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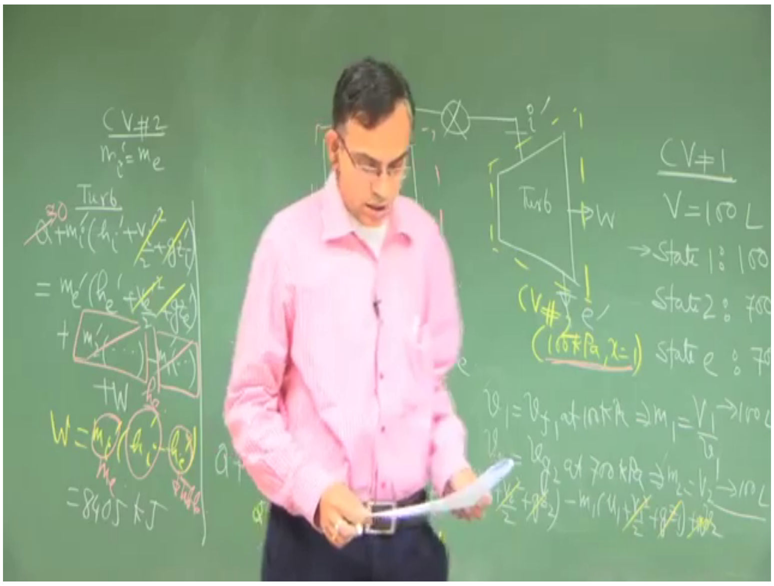

So, we will next consider the control volume 2, which is the turbine. So, for the control volume 2 let this i dash is the new inlet state which is same as e, at least for enthalpy, not for everything else but we require only the enthalpy. So, for. So, m i dash will be equal to m e right.

For the turbine, let us write this. So, this is a general law you know you can apply it for steady unsteady whatever. So, let us apply this. Q plus m i prime new state i prime into h i prime plus v i prime square by 2 plus gz i prime is equal to m e prime h this is e prime, h e prime plus v e prime square by 2 plus gz prime plus m 2 into something minus m 1 into something m 2 prime m 1 prime plus W, very important; this is the purpose of the turbine to get work done.

So, now one physical understanding that you have that you must have is that the turbine is a steady state device. So, because turbine is a steady state device the state of the fluid in the turbine does not change with time. So, this these state and these state, these two energies are the same. This is a physical understanding about the operation of the turbine you must have you know to solve this problem. So, this change is 0. Turbine is primarily for work done heat transfer is neglected until and unless. So, this is approximately 0, not really but you know as compared to this is not very significant. You can neglect the changes in kinetic and potential energy, if you do that then W will be m i prime into h i, so prime minus h e prime

So, state e prime is given. So, e prime is 100 kilo Pascal and quality equal to 1, saturated vapor, ok. So, from. So, m i prime is me for control volume 1, this you know and h i prime is he for control volume 1, that also you know. So, if you know these two and these you get from the table 100 kPa quality equal to 1, so table. So, that makes you a have all the data that is required to calculate the work done and this is a 8405 kilojoule, ok. So, this is the total turbine work for the heat that is supplied by the boiler.

Thank you very much. We will continue again in the next lecture.