Concepts of Thermodynamics

Prof. Suman Chakraborty
Department of Mechanical Engineering
Indian Institute of Technology Kharagpur

Lecture - 24
First Law For SSSF Process: Example Problem (Contd.)

We have been discussing on the steady state steady flow energy equation and some problems related to that.

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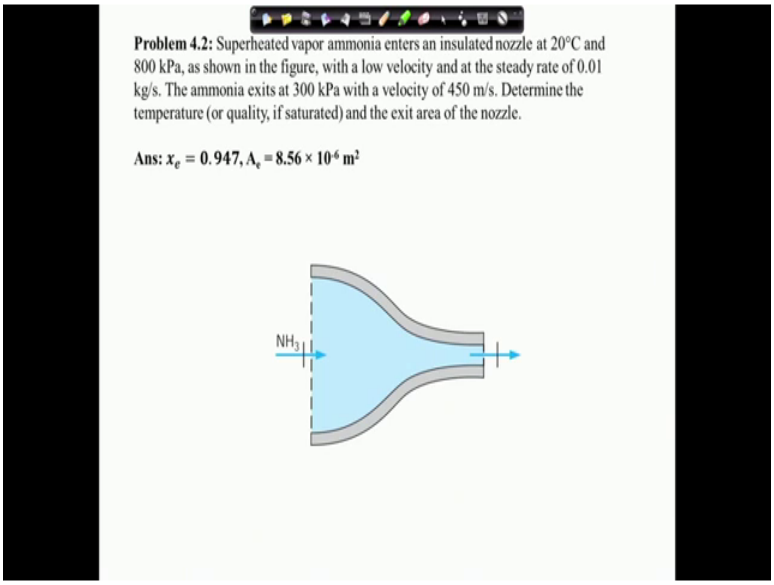

So, we will continue with that. The problem that we are now going to consider is problem 4.2 which is given in the slide here, let me read the problem out. Superheated vapor ammonia enters an insulated nozzle at 20 degree centigrade and 100 kPa, as shown in the figure with a low velocity and a steady rate of 0.01 kg per second. The ammonia exits at 300 kPa with a velocity of 450 meter per second. Determine the temperature or quality if saturated and the exit area of the nozzle.

So, let me explain a little bit what is a nozzle before you know trying to solve this problem. So, nozzle is all about converting the energy in a given flow to kinetic energy of the fluid. So, here you can see if you look into the figure the area of cross section in this case is reducing.

So, because the area of cross section is reducing what is happening is that the velocity here is increasing and of course you have to keep in mind that area decreasing means velocity increasing this is not really an obvious fact, because what remains constant between sections 1 and 2 is the mass flow rate which is density into area into velocity.

So, density also plays it is own part in this case the density plays it is parts in such a way that eventually the velocity increases and that is the purpose of the nozzle solved in this case. So, let us go to the board and try to solve this problem.

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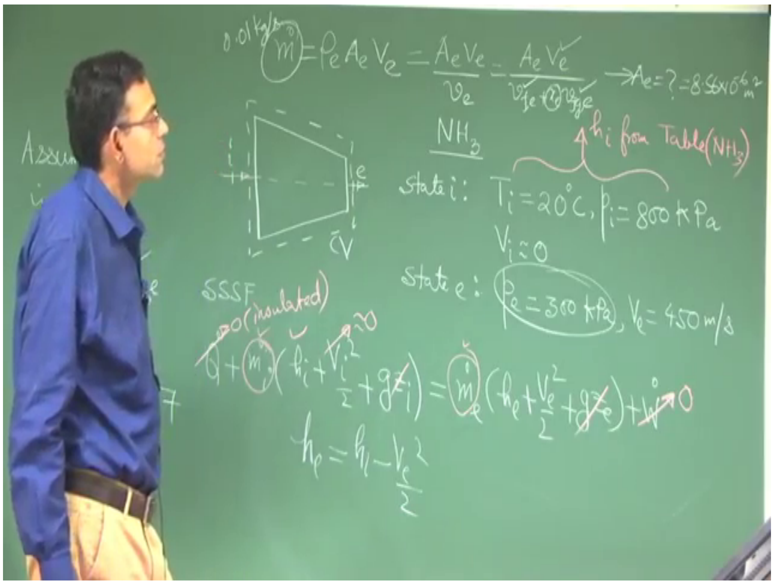

So, this nozzle has inlet state i exit state e, the fluid is ammonia state i is Ti equal to 20 degree centigrade p i equal to 800 kPa and Vi is small. So, when we write this Vi is small or approximately 0 it is not literally to be taken as 0, what is essential implies that this is much less as compared to Ve the velocity at the exit. So, this has to be interpreted properly rather than literally thinking it as 0 state e ok.

Now what we will do is we will apply the steady state steady flow energy equation between the states i and e for this control volume. So, you have so let us now see how we can get the different values you know Ti and pi, so from the property table of ammonia you can get what is a hi, so hi you know. What you know about Vi this is and for such a problems nozzle is not a very long device so inlet and exit their differences in height are such that these 2 are almost the same.

Nozzle is normally considered to be adiabatic in this case it is given in the problem definition that the nozzle is insulated, so because it is insulated this is 0 and the purpose of the nozzle is to not to get any work but just get kinetic energy out of the fluid. So, this is equal to 0 also m dot i is equal to m dot e equal. Therefore, you will get from here remember when you write this V square by 2 to convert joule to kilo joule unit you have to divide by 1000 one of the previous problems we have already told this, but just to recapitulate that that is very important.

So, once you do this, you will get he. So state e it is not given that what is where it is it is told that find the temperature or quality is saturated. So, let us assume that it is at in a 2-phase region. So, assume state e in 2-phase region. If state e is there in the 2 phase region then you have h e.

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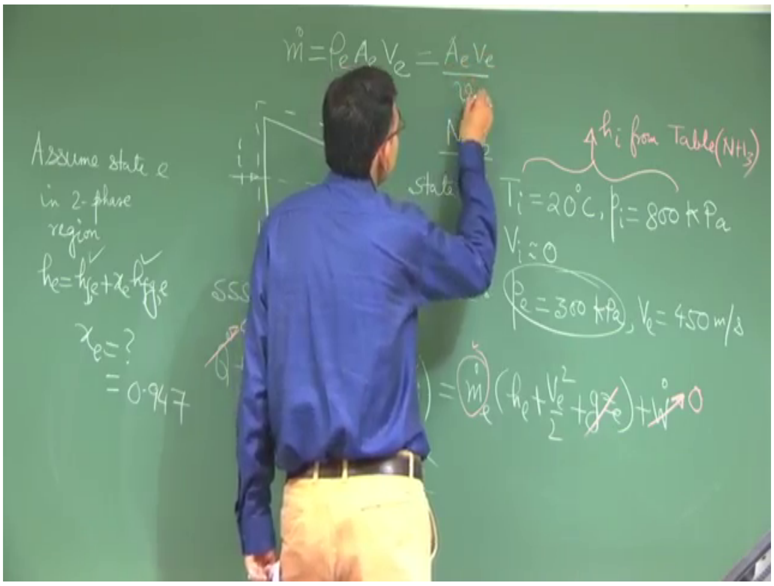

So, now at 300 kPa you know what is hf you know what is hfg therefore from here so these are from the table of ammonia at 300 kPa, so you will get what is xe. So, in this problem you will get if you calculate this xe will be 0.947 any value of quality between 0 to 1 is acceptable.

So, because this is between 0 to 1 this is acceptable that means it is in the 2 phase region had it not been between 0 to 1 that means it is not in the saturated or 2 phase region. You also have to find out what is the exit area of the nozzle. Now you can write the mass flow rate as this density into area into velocity this is the average velocity at section e, because density is 1 by specific volume you can write it in this way.

So, now you know what is vf at the exit state 300 kPa you know what is vfg and you know what is xe and then the mass flow rate is given this is 0.01 kg per second, Ve is already know which is 450 meter per second. So, from here you will get what is Ae this answer to this is 8.56 into 10 to the power minus 6 meter square.

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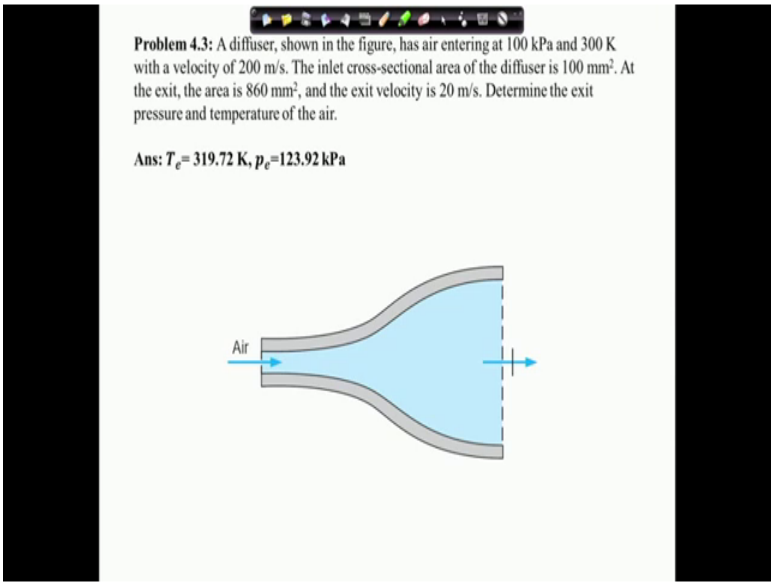

So, we will go to the next problem the next problem 4.3 a diffuser which for all practical purposes you may think of like inverse of a nozzle. So, a diffuser has air entering at 100 kPa and 300 Kelvin with a velocity of 200 meter per second. The inlet cross sectional area of the diffuser is 100 millimeter square, at the exit the area is 860 millimeter square and the velocity is 20 meter per second. Determine the exit pressure and temperature of the air. So, let us draw the schematic and then we will solve the problem.

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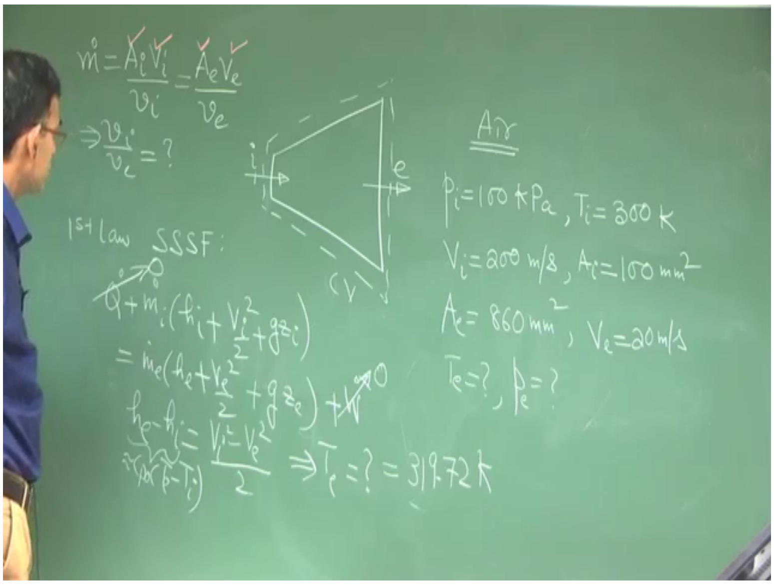

The substance air is there so you can use the ideal gas properties here, so you have pi 100 kPa. So, now what is to be obtained is what is T e and what is pe. So, we will apply the first law steady state steady flow for the diffuser controlled volume.

So, the diffuser here it is let us see whether it is told that it is insulated or not it is not told that it is insulated, but the other modes of transfer of energy are much more significant than heat and here there is no work transfer. So, this practical outlook that you have to keep in mind it is not told that is it is insulated, but you know the other modes of transfer of energy which are appearing here are much more significant as compared to this.

So, then what you can do is because m dot i equal to m dot e and if we assume Ai to be a perfect gas over this range then this is what we can arrive at. So, from here you can get what is Te again a caution, if you use kilo joule best unit on c p you have to divide by 1000 here. So, this Te is sorry yes this Te is then you also have to find out p e.

Now what you have fixed across the sections, so Ai is given Vi is given then Ae is given Ve is given. So, from here you will get this.

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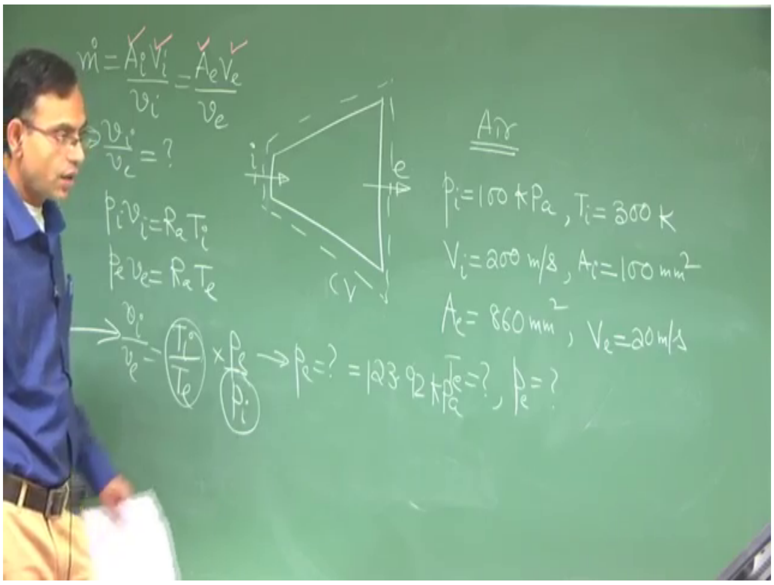

Now, you know so vi by ve, so if you substitute this here and you know already what is Ti by Te you already know what is pi. So, this will give you what is pe pe is 123.92 kPa. So, we have worked out 2 important problems in this class one is a problem related to a nozzle and another a problem related to a diffuser, they are very similar in terms of approach and the purpose of these 2 devices are just inverse of each other. In the next lecture we will continue with more problems.

Thank you very much.