Engineering Thermodynamics
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Lecture – 36
Applications. Problem Solving: Turbines

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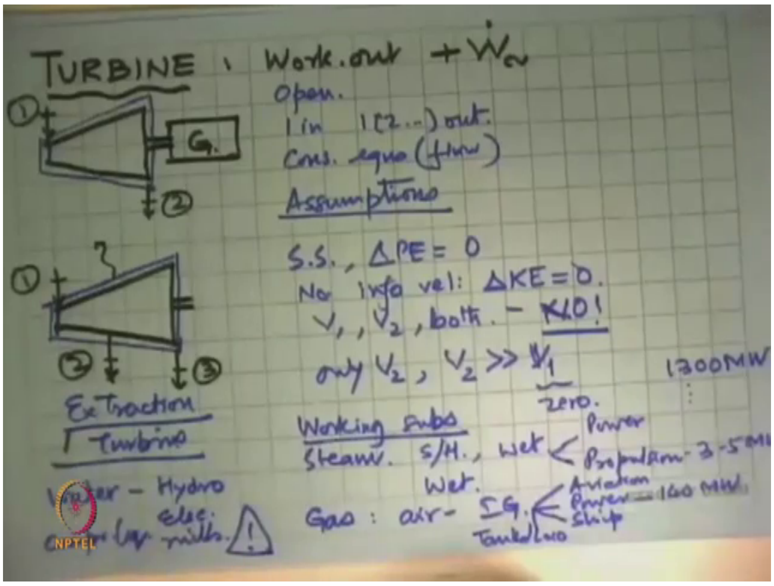

And the next thing we look at is a turbine. These turbine, steam turbines are used largely for power generation and also in the case of ships and submarines for propo the (Refer Time: 00:41) nuclear submarine or a nuclear aircraft carrier which have the nuclear reactor which produces steam and steam runs a steam turbine gas turbines also stationary like power generation gas turbines are also (Refer Time: 01:05).

When ships (Refer Time: 01:07) not so, a. Traditionally, we do not look at in a in this course, the working substance is water as different from steam (Refer Time: 01:36), this is water that where in a river or in a dam this gives you the idea (Refer Time: 01:41) of a hydroturbine and especially we use their although they came from fluid mechanics the basic idea about that it did satisfy (Refer Time: 01:53) the laws of thermodynamics.

We call it hydroturbines and they are used for producing electric power and in some cases, you know may be some turbines. So, working substances it will be steam we have to take it as from the property tables data, where we assume it to be an ideal gas. Hydro we assume it to be a compressed gas. And here we have to worry about what I mentioned in the case of pumps you have to take care of calibration. So, that is one thing to worry about.

So, give some idea what are the (Refer Time: 02:38) of machines the biggest turbines that are there are steam turbines which have gone in power up to 1300 megawatts and then what is the power generation devices and there are smaller machines a propulsion turbine could be like 3 megawatts to 5 megawatts. Gas turbines the biggest stationary gas turbines are of the order of 130, 140, 160 megawatts. Aviation turbines we do not talk of power it will look at what sort of a (Refer Time: 03:07). Time (Refer Time: 03:13) there are about 1 to 2 megawatts.

We will draw back on. So, what are the assumptions we have seen there? What equations we have, that we have looked at.

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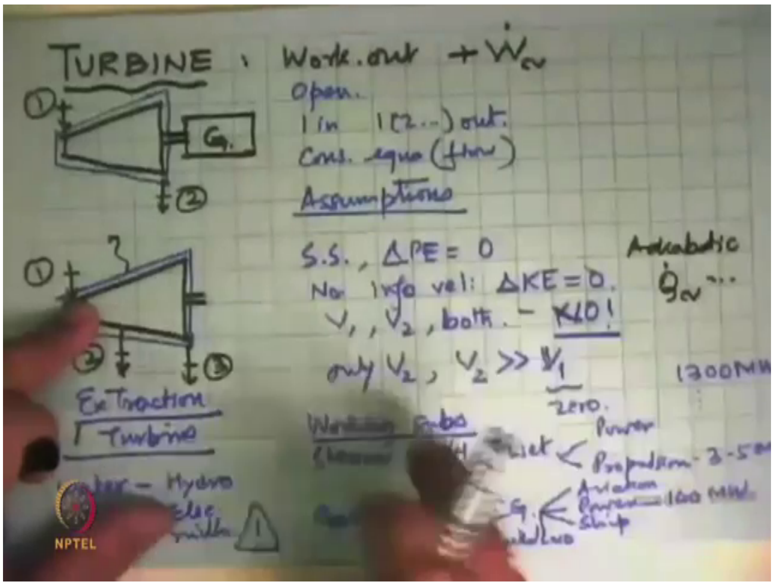

We assume that is there no other information get on about this thing. We say that this is adiabatic, if it is specifically mentioned that it there is some heat some Q dot cv is there then we take that value in the sec first law of motion. Otherwise, if there is no mention, we can assume that the turbine is adiabatic.

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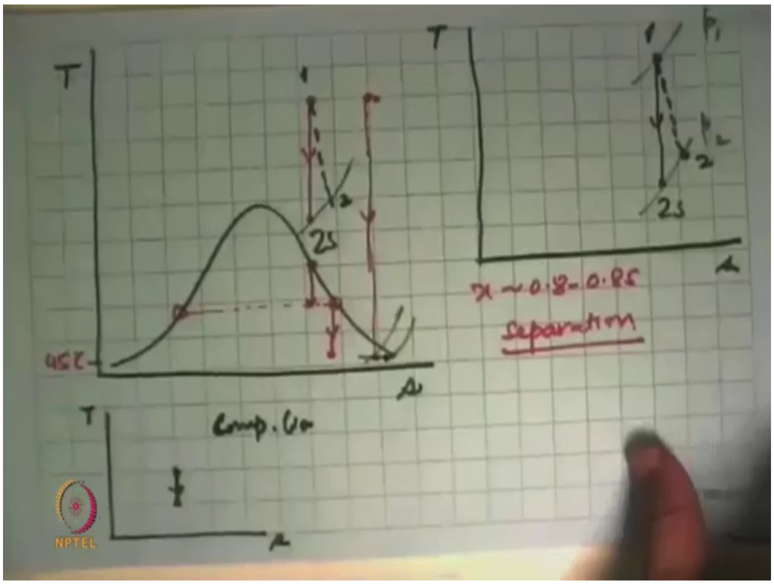

Now, you see what it looks like on property diagram. It is a T s diagram it is a looking at steam turbines, we have to show the dome, and in this case the mentioned in the what you like to do is avoid a two phase mixture inside those machine like the turbine.

So, in power station we start off with superheated steams at their expanded up to this point in one turbine, and then we take the steam out send it back to the boiler for heating it again and then bring it back almost at the constant pressure with same temperature and then we start expanding it in not just one turbine, but multiple turbine until it gets the temperature that is there for us 45 degree Celsius or so. Slightly wet steam in the end of the turbine that is where we need to be careful about the engineering part. So, that is what power steam turbines will do.

Nuclear turbines with a pressure somewhere say about there that one is dry saturated vapour from the nuclear reactor and this is expanded. And as you keep expanding the quality keeps going down. So, the engineering with keeps getting complicated so, we say that, I will come to a point where x is of the order of say 0.8 or 0.85 and then I cannot tolerate too much of liquid in the turbine it will break my turbine. So, what we will do is we will take this steam out and physically separate the liquid from the vapour because as a big density else.

So, the vapour state when they separated from here, we will come over here, the liquid state from here we will come over there and then we put it into another turbine and expanded until the cooling temperature is there. So, this is the physical separation device. We will look at this a later on case when we look at inner type of an application, but that is what happens in nuclear turbine and including nuclear turbines on ships and submarines. We are always dealing with the wet substance, and you have to always be very very worried vary about it, ok. So, that is it and there more about gas turbines.

So, gas turbines, we do not show the dome. We assume that we are far away from this dome way at the top somewhere about there much beyond this. So, very near to gas turbines diagram we will put this as T and s we want show that dome at all and we say that the gas turbine expansion is from say there, there in the ideal case and in all cases if it is an anisotropic turbine. The specific entropy we will increase, but the discharge pressure remains the same like this and this case the constant pressure lines are like that. So, this is p 1, p 2.

And the anisotropic turbine in this case it is starts from here, but it will end up over there this is 2 s, this is 2, this is 1, this is 2 s, this is 2 and in this case the totaling if it is an isentropic turbine the quality we will straightly improve. So, here is one practical advantage is that of throttling of say friction or irreversibility, but it most to were advantage as for even engineer is concerned, thermodynamically it goes the (Refer Time: 07:18) ok.

So, this these are the type of turbines that are there. If it is a hydro turbine well on the same diagram it will be completely on this type, but it will be too small. So, it will blow it up and we say that forget about that they are only looking at compressed liquid s and T then the hydro turbine will be like this, ok. So, that is how we show the process for the steam turbine and all type of turbines. This happen to be except may be sophisticated machine they are rotating with very fine clearances and this temperatures we are mentioned the continuously trying to increase this temperature look at better and to the thermal efficiency. That is about the turbine.

Now, let us take a few questions that are there and then then we will continue here.

Student: Good morning, sir. My name is Rajith Singh and I want to ask the question that is a what is the difference between classical and statistical thermodynamics.

So, we will take that up, ok.

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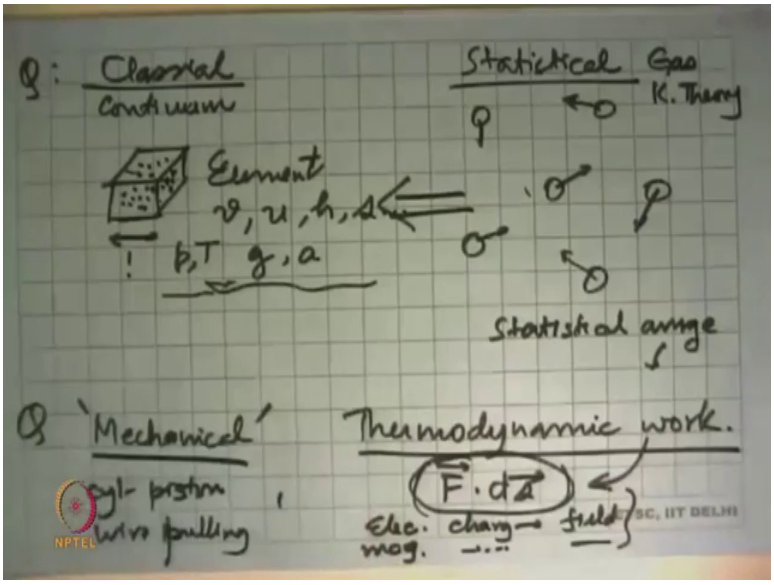

So, the question is what is the difference between classical thermodynamics and statistical thermodynamics. I start from two way basic any different concepts here, but at some point under some assumptions classical statistical thermodynamics becomes classical. In statistical thermodynamics we look at every atom or every molecule and some some properties to it, irrespective of the phase.

Most notably if it is in the gas phase then we apply the kinetic theory of gases. We assign some properties to every molecule and then we look at the statistical average because there are too many of these molecules, we cannot talk about each and every one of them. So, we look at the statistical average and start developing every from back bound.

So, we look at all molecules take a very large ensemble and say now what is the average look like and from there what do I get in terms of a pressure, in terms of the energy, in terms of various other things that is there. In classical thermodynamics which have been we are not going to look at each and every molecule, we will make the assumption that we are looking at a continuum which means that the smallest element of the substance that we consider and this one can approximate this say as the cube, I have got enough molecules or atoms in it that the statisticals average of this is good enough to tell what the entire element is all about.

So, whether it is pressure, temperature, enthalpy all of that we can get by looking at sort of an average of along these and we this is not worry about where that average came from, but we start off by saying that this is the smallest elementary we have. Some size we can put on it, this is of the order of angstroms fraction of an angstrom this is much much bigger hundred times bigger than this intermolecular distance.

And so, we take all of these in an element take the average properties of this and start talking about all the laws and everything as that we have learnt in this course. So, whether it is talking of specific volume specific a nu, h, s or a, g and a and all those properties including pressure and temperature. They are assuming that it is a minimum size of an element is this much and which is because of that we are able to assign properties to that. We cannot assign individual properties to each and every molecule and hope to track every one of them in a problem. So, that is the difference between statistical and continuum mechanics.

Some aspects of this can come from knowledge of statistical mechanics, but not the opposite. So, that is the difference between classical thermodynamics and statistical thermodynamics. If you want to look at since this reactions and mixtures in a very very fundamental sense one has to go to the statistical thermodynamics and that is not the subject or undergraduate thermodynamics courses, we will do that typically at post graduate level and at distance levels. So, that you have to learn statistical thermodynamics.

Student: Good morning, sir.

Good morning, yeah.

Student: Question is, what is the difference between mechanical and thermodynamic work?

Mechanical and?

Student: Thermodynamic work? And which devices are used for means in these devices mechanical work takes place and thermodynamic to work takes place?

So, exactly if we look at what we have learnt in this course while in the beginning we defined what was thermodynamic work. That when a force causes a displacement or of a system boundary this we said is work, and we said this is a thermodynamic definition of work. Now, this includes everything. It includes a mass being pushed and taken through a distance or a shaft turning around and giving a torque at a certain speed and doing work on something. So, this could all of that would be then classic classified as what we have got and mechanical work.

But this includes electrical work; that means, current flowing through a device, conductor or a heater in the current flows through it there is work in flow into that system. So, current is because we have a charge going across a field, they could have magnetic work, magnetic therefore, going in a field or we could even have that that the cylinder piston, piston arrangement.

This dash pushing against the piston and doing work, yes push that we will call as mechanical work, or say the pulling of a wire or increasing the surface area of say for device say surface tension working to produce work. So, strictly if you look at mechanical work, they have got F dot ds primarily as force on the rigid body causing a displacement that may say that it is mechanical work, but thermodynamic definition of work includes everything that includes F dot ds. So, charge moving in electric field in a fuel cell or in a battery is still work, but we do not call it mechanically work.

So, this is the much broader over (Refer Time: 14:05) definition of all types of things where F dot ds takes place mechanical work will look at largely only as a rigid body being acted upon and a displacement taken place, ok. So, that is a difference. So, mechanical work in the subset of thermodynamic work.

Student: Good morning, sir.

Yeah.

Student: I am Gokul from PSG tech and I have the doubt that in a refrigerant R 134 a, what does 134 signifies?

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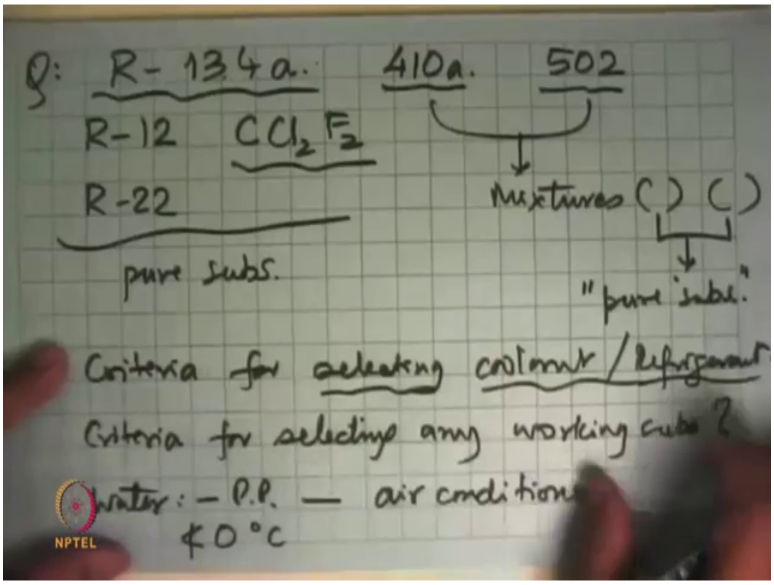

The question is in many problems I have put down refrigerant in R 134 a what is the meaning of 134a. So, very quickly to tell you all history of these things. He is started off with various refrigerant like R 2 in which is now brand this is C Cl 2 F 2, then you got R 22, like something else.

So, there is a one rule by which we convert this molecular structure into this part. So, from there you can look up there about literature anywhere and you can figure out what is the molecular structure of R 134 a or R 410 a R things like that, ok. 410 and 5 series like R 500 or R 502 these are slightly different from these because all of these are pure substances whereas, these are mixtures for which we have chosen two different mix molecules, mix then in the certain way then they are property is sort of a pure substance.

So, that that is what it is, I do not in the nodes I have put down that, this is I do not remember the exact formula of this C Cl, C Cl C F 2 or something like that is formula but then the very small method by which you develop these numbers. We can look up on the web or the book, ok. I do not remember it exactly that.

Student: And is.

Student: Good morning.

Yeah.

Student: Arun Akash, Arun Akash. My question is what is the criteria to select any refrigerant to refrigerant for a?

So, the question is what is the criteria?

Student: Yeah, what is the criteria to select a coolant or refrigerant for a system?

Ok. I have said it broad base this question this is a very important and a fundamental question, ok. So, what is the criteria for selecting any working substance for a cycle or a system or a process? So, what happens is this is the extent the case of refrigerants, in the case of power plants almost always we use only want to do and a reason for using water is firstly, it is abundantly available, second its properties are such that they are usably good for doing the engineering of it and the troll is if I can use water in a power plant I cannot here use water in an air conditioner.

And this is a issue that in should why majority of the air conditioner that you see do not have water as the working substance in an air conditioner. There are some air conditioners where water is the working substance, and if you want to see the exact numbers that are coming out of this I suggest you look up the module 3 assignment I think it is the last of the second last question I do not remember which one, there are was exactly the same question, that I want a certain heat transfer rate and I have a refrigerant which I say R 134 a or refrigerant like R 22 or refrigerant like what.

Now, problem is what are as a refrigerant is that you cannot go below 0 degree Celsius. So, you cannot use it in a refrigerator to get minus 10 degree Celsius and keep ice cream whereas, on the other materials are good. So, they can do the job. So, water for the freezer not possible for air conditioning where you want temperatures at 10, 12, 15, 16 degree Celsius water can be used it is used. The trouble is that there are many criteria which go in deciding how you select these things, besides the first comes of course, the thermodynamic criteria.

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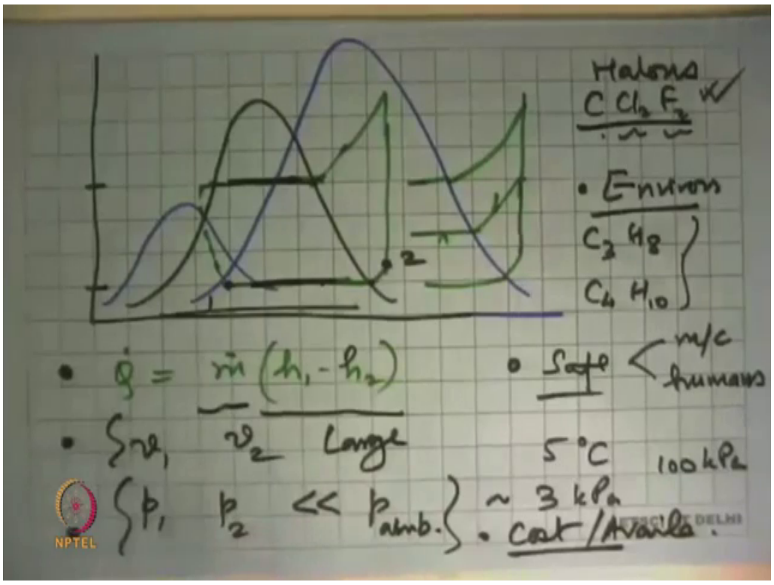

So, you should look at the thermodynamics of these and said what is the cycle in which I will operate and you say that here is my T s diagram and I am going to operate it between these two temperatures. So, for some substance this could be the saturation dome, for some substance this could be the saturation dome, some substance this could be the saturation dome.

So, what happens is that in this case you would never get a condensation if I have use this with this condition these two conditions this and this are both ok. So, in this case what will happen is that the cycle will become like that, there condensation will be there and then the throttling will happen over there with this temperature, then there and then goes over there. In this case it will be something like that, but here it will come over there like this, like this and like that, sorry here.

Now, what is happening is you look at these two states and you say first of all my cooling rate will be m dot into the change in the specific enthalpy say, h 1 minus h 2 was whatever may be these. Now, do I get a sufficiently large delta h from this state to this state. And if you see that problem in the assignment you will find that for some refrigerant this value is the few 100s, for water this value is a couple of 1000. So, it is a good grade. For water this is very big, so and is a very small flow rate water is a nice surface.

But look at the other properties now. So, you ask that this is my the first part how big will be my equipment and say what is the specific volume at these two state this is one this is two and you go back and pull out v 1 and v 2. And you will see therefore, water at 60 degree Celsius or 5 degree Celsius dry saturated vapour here v 2 is huge. That means specific volume has become so big that I need a very very big pipe to make this thing flow and that becomes impractical unless we are able to control it and redesign the machine to take care of that then we can do it. So, whichever water is not very good.

Then coming to all the other substances which are possible we say that we were all the C Cl 2 F 2, C Cl H F 2 all these type of families are there, but why did they couple off because the properties of C 3 H 8, C 4 H 10 these are also very suitable as refrigerants. And usually when ozone layer depletion get other problem we have to replace R 12 and some of the things that we have talked off was propane butane or mixtures of propane and butane. This is well the first criteria would be that is it safe, safe for the machine that which you should not react with the machine only why and safe for humans what it with links out.

And the nice thing about all these halons was that they were nontoxic. They did not react with the oil, they did not react with the components and the materials of which you make the component aluminum, brass or copper and all those things, and so they were became very very popular and they are very nice thermodynamic properties. The specific volume increase was also not very large. So, they were great chemicals of the industrial revolution. But in 20 years we saw that they were causing ozone layer depletion and now they have to throw them out.

So, they started looking at different things which are less of chlorine, maybe less of chlorine and start coming to other substances, but then these would also be, ok. So, but then these are not very safe, they are combustible if they recount you could have our possibility of an exposure. Inside the system there this only this substance then nobody exact there will be a exposure.

Specific volume is one concentration, then you look at the pressures that you get, the pressure here and the pressure here. For water if I would 5 kPa there and say 80 kPa over 8 80 degree C here and 5 degree C here the pressure here is very very small. So, this pressure p 1, p 2 they are very much less than ambient pressure. Now, this is of the order of I think 3 kPa at 5 degree Celsius. Ambient pressure it is 100 kPa. What it means is that your entire piping and all the joints that you made connections that you made with the pipes they have to be very very good, otherwise air will leak into the system the moment air leaks into the system the working the performance deteriorate very rapidly and you have a big problem.

So, you like that the pressure should be just above atmosphere, so that air does not get into the device. So, that is another criteria; that the pressure at this should be not just about atmospheric pressure and this should not be very very high not 60, 80, 100, bar every 20 bar 50 bar 30 bar something like that. So, that is the second criteria.

Specific volume of another criteria, when you got heat transfer rate safety and then of course, as an engineer you always have to worry about the cost and availability and these days like we started off this whole thing environmental in that. So, these are many issues that decide which substance we will use in the is the refrigerant cycle, but the starting point is like to say when the thermodynamics makes sense, the thermodynamics makes sense at the engineering is doable then that becomes the candidate material for the next step of consideration. If the thermodynamics does not make sense then we are in trouble, might does not forget that material and go to something else.

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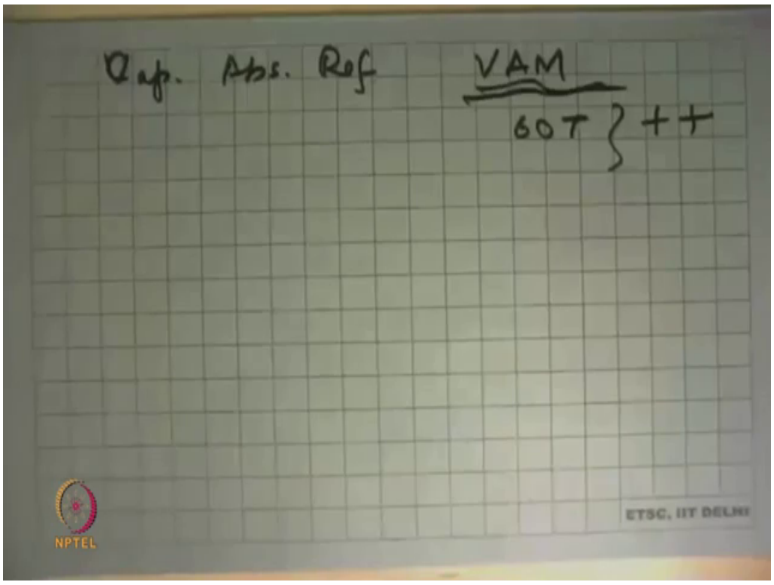

So, before I give this let me tell you that water is used as a working substance, you know refrigeration machine called vapour absorption, refrigeration system or vapour absorption machine VAM. We cannot make very small window AC type of things with VAM, but large things like 60 tones refrigeration or bigger 300 type we are very much there and if you had best heat source, they are very very good options because the electric part consumption is one-tenth or one-twentieth the power consumption of a vapour compression system.

So, energy efficiency wise carbon footprint wise these are the great stuff, but the engineering is not at all using in these case. We do not use conventional ret cycles, we take water and then we dissolve it in a salt and then we pump to the salt, so the work produced for pump required for pumping is very small and then we heat it to get the high pressure vapour back condense it and use it for the refrigerant. So, do keep in mind look up the website or and see vapour absorption machines there are 3-4 Indian companies that make it, they are used in many places and they are a very attractive options because they are very very energy efficient, ok.

So, we will conclude here and we have some more devices to look at, we will look at tomorrow. I will solve a few problems then we will go and we spend some time looking at vapour power cycles, the engine cycles and see how to do the analysis of that.

So, with that we will stop here.