Engineering Thermodynamics
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Lecture – 08
Thermodynamic Concepts: Thermal reservoirs

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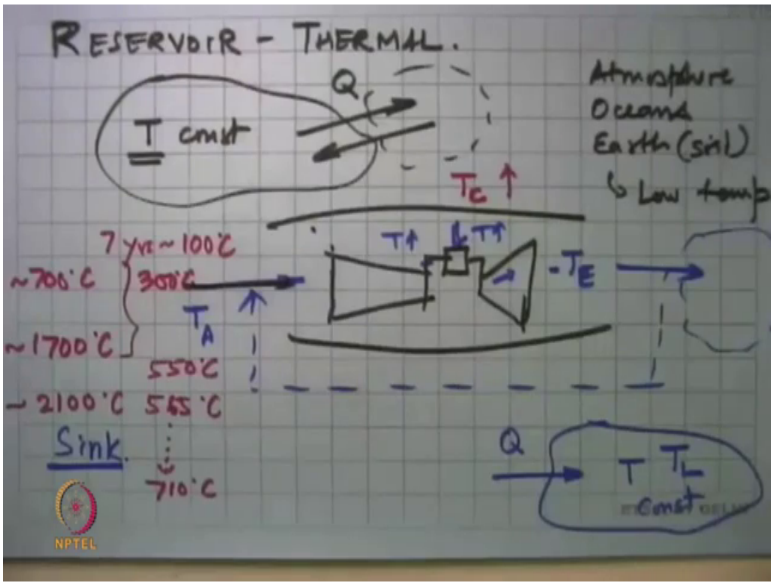

Is the concept of a thermal reservoir, it is a concept it is hypothetical and we say that reservoir is a system, a space or a body or an ultimately it is a material somewhere which can have as much heat transfer to or from into it. And that will of course, go to another system and in this process its temperature will remain constant. Whatever its temperature was you can take out as much heat as you want you can pump in as much heat as you want its temperature does not change. In nature we have a few things like this and the two biggest ones: one is a atmosphere and the other are the oceans.

Some people would think that even the earth itself the soil can be considered to be a reservoir. And the idea that these two are at the lowest possible natural temperature, that we get where ever it maybe; these are reservoirs that are used to dump heat dump energy from cycles ok. So, that air craft engine that is operating that is of pictures are is throwing exhaust gases into the atmosphere. And, when we do the analysis we take that into account that it gone out into the atmosphere. We did not cool that gas to bring it in, but what we did was that the compressor of the engine took ambient air, compressed it, sent it to a combustor which expanded in a turbine. And finally, this whole thing came out and we put this whole thing in a (Refer Time: 02:29).

So, what it did was this air went in at same temperature which was ambient temperature, it got compressed. So, its temperature went up pressure went up then we burnt fuel into it its temperature went up further. Then we expanded it here and here it came to some other temperature exhaust temperature T E which we threw it out atmosphere. To develop the analysis of this what we assume is that we have a gas or a substance which is going through this, it gets heated up here comes out and then that gas got cooled and came back here. So, we now have a close system a cycle and you can do the analysis as well (Refer Time: 03:08) and what you are assuming there is that the atmosphere is the dump.

So, there are two types of reservoirs would have one in which there is heat transfer into it that is called a sink. So, reservoir at the temperature into which you can dump energy in a heat, there is heat transfer to it and its temperature remains constant ok.

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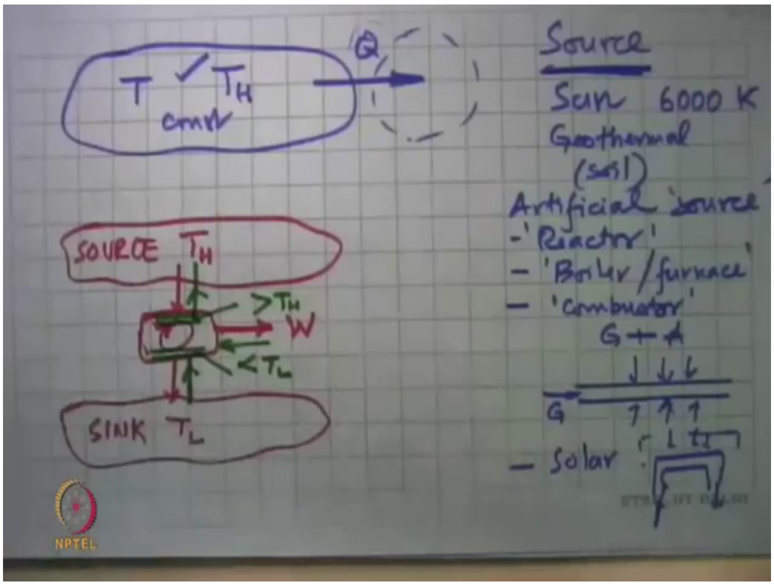

So, if this is the sink and the second type of a reservoir is measured at the temperature from, where one draws heat into another system and its temperature remains constant. And, these two this is the source and that is a earlier we look at was a sink. And we need these concepts to fully understand any of this process, that are around us whether it is a petrol engine or a diesel engine or the power plant or nuclear power plant. Because, in all those cases we get energy from a high temperature source convert part of the, to work and dump the remaining into the lower temperature sink.

This will become more clear when you look at the laws and, but the issue is how do I create a source. Sink is easy you can say look I have oceans in the atmosphere if I happen to be in Siberia where, the temperature is very low. My sink is at a low temperature I can do many things with it. If I happen to be on India in summer temperatures of 40 degree Celsius, there is nothing you can do nature is like that and that is the temperature at which you have a sink. And, we always work with that only in designing all these systems ok.

So, how do I make a source especially a high temperature source and nature gives only one source; and that is the sun. So, sun we say is a source at a temperature of about 6000 Kelvin and this is sending us energy. So, you can think of this as sun energy coming here then that we can do various things we did on earth, only a fraction of its total energy that the sun give out ends up at the earth surface. Beyond this we can say well ok, if I go deep into the earth or where did the volcano I have hot coarse and that is the source. So, I can put water into it get steam and then a power plant and generate electricity. So, you can say that I have a geothermal source of the earth itself on the soil and that I can us as a source. And, this is the basis of geothermal power plants ok.

So, beyond that there is very little by way of a natural source that we have and so, we create our own source and we say what is an artificial source. And, is all the application that we have seen so, far in the case of a nuclear reactor yesterday; we say that the reactor can be modeled as sort of a source. It is continuously generating heat internally; it maintains its temperature even while you take heat out of it. And, that is why we say that the reactor is a source. In a coal fired power plant we say that the boiler or its furnace is a big entity into which we keep firing fuel coal oil or gas or may be even waste gas or garbage. It burns, generate heat, it maintain its temperature and we keep taking some energy out of it to heat water and then make steam out of it.

So, that is an artificial thing that we created and we model that as that thus water is getting energy or this heat transfer to the water from a source which is the furnace, where you burned the fuel continually. And, you are burning in such a way that it even give this and at the same time maintain its temperature at value that you want it. So, that becomes an example of a another example of an artificial source and then the air craft engine that I just showed, the combustor can be taken as the source where it again doing the same thing continuously pumping an fuel generating high temperature and take taking up the gas.

So, that way energy is taken away from the gas. Well, difference in that is that while this two case, in this two cases the water did not mix or have any action to do with the high temperature part in the fluid. Here the gas and air actually is an (Refer Time: 08:24) and so, it is strictly a process where the air got heated by something burning in it. Ideally one can model it as the gas going in this or air going in this and this being heated by the source. So, that is another example of a source and this example that I showed you day before yesterday; in the solar thermal concentrating solar thermal plants we use the sun, but as our analysis of the cycle was concerned that type where the water was going in and coming out a steam this was getting heated by the sun.

So, you can say that this particular thing was the source and if you store that energy then that device would be a source or as long as the point where, you are drawing energy out of it ok. So, that were the examples of a source and the two sinks that we have a with us and we would like to go with the lowest temperature sink; we will see why is the atmosphere and the oceans. So, we are or whenever we make work we are always dumping heat into the, you drive a car you have very small fraction of the energy coming out of from the fuel is converted into work. The rest is dump in the atmosphere and when you brake the car of the remaining work that accelerated the vehicle that is also dumped into the atmospheric heat. So, ultimately all of that ends up in the sink which is the atmosphere ok.

So, that was that, the next thing I want to take up now is two things yeah, what is that questions.

Yeah.

Is heat always transferred from source to sink? The question is do we always transfer heat from source to sink, but directly no, but what we do and we can make a sketch of that. Is that we have a source at temperature a high temperature and from there we transfer heat to a system. And, from there if the system is operating in a cycle the symbol for that is this and then we due dump some of that into a sink and the balance comes out the work.

So, this is of a system working in a cycle. On a continuous basis this will happen and that is all we continuously (Refer Time: 11:08). The opposite is also possible and that is what a refrigerator does. You have a sink which is your refrigerator inside or in the case of an air conditioner, it is the inside of the room which is the low temperature body which is the sink. We put work into this which is what your driving the compressor with, we extract heat is transferred from this to this to system and then all of that is dumped into the surrounding which is the source.

So, how does this heat transfer take place where inside this what one does (Refer Time: 11:49) air, but inside this you make a tube where the temperature is lower than this temperature. And, then it goes out its temperate and dump that heat to the source after it is compressed. So, for this heat transfer to take place in the system the temperature here must be less than T L, the temperature here must be greater than T H only then this system will work ok.

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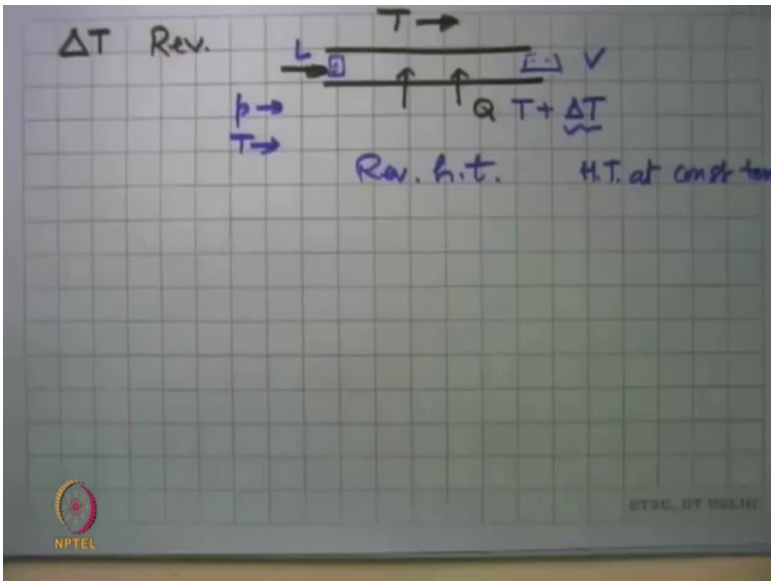

So, we have at that we can look at one more thing which is that if I want heat transfer to take place over a very small temperature difference in a reversible way; in the closest that one can get is to say that look I have a material flowing in this. And, as we add heat to this its temperature does not change and intuitively one would say no, this is not possible if I heat something its temperature got to go up. But, we have one thing which we exploit very very heavily which is that is a substance here what you see in everyday life say like water is going here you heat it and it comes out as well.

And, during this process the pressure is same then the evaporation process the temperature is same; that means, anywhere at this point wherever we were adding heat the temperature was also the same of the substance. And, now we get one control that the systems temperature is very much constant. To make the process externally reversible we select that this heat transfer is taking place from surroundings whose temperature is say T plus delta T and as we make delta T very very small we are getting the closest we can to reversible heat transfer. And so, in many many applications we try to exploit this fact that if I can get evaporation or the opposite which is quantum section, I can have heat transfer at constant temperature.

So, this is heat transfer at constant temperature and that is a thing we will exploit very heavily. And, that is what I came to this point because here that what happens in your air conditional and refrigerators; there is phase change taking place in both of this. So, they are this is at a low temperature taking heat from here, this is at a high temperature taking transferring heat there. So, the question here so; that means, that means answer. So, directly putting heat from source to sink, it does not give us any advantage at all. Of course, if our objective is to cool something say we have a microprocessor that is operating which is generate heat and you want to cool it. So, you can say that the micro processor is the source on that you put a heat sink and you put a air blowing on it actually we are cooling it.

So, that micro processor in the source surrounding air is sink and we are deathly dumping it from source to sink. And, the objective there is not to make power or anything, but the objective there was to keep the temperature of the chip below a certain temperature. So, that its life is so long and it does not be at least survives that much long and by the way that is the very very hot research area. Because, the whole technology that you see around you everyday new cell, new mobile phones with all sort of things coming into it this is this was completely unimaginably years back. Now, we are not just able to make chips and drive them fast and software and hardware for it, but the most precious thing is we are able to cool them, that is very that is where the break through are still coming.

And it is go happen for the another 20 years and this idea also tells you that if we are (Refer Time: 15:54) like the air craft engine picture that I made; this also tells us and that then we look at the (Refer Time: 15:58) it will become much more clearer. That is this is the peak temperature we got say with this (Refer Time: 16:05) was generated the peak temperature and say this is the team T combustor at T C. And, thermodynamics will tell us that if I keep increasing this their efficiency keep only one something with the power point bulb.

So, I show you some data day before yesterday to show you that when the first turbines where made this temperature was all the order of 700 degree Celsius. I mentioned that now we are already working with 1700 degree Celsius and in the next 20 years we have probably, let me to see this go up may be 2100 degree Celsius. And, because of this airplane engine and stationery gas turbines which are generally electricity, they all becoming more and more efficient. The same amount of fuel being burned, more electricity being more work being produced.

So, historical what has happened here is that about every 7 years that this temperature goes up by 100 degree Celsius, that is some lot of research that goes on your tips of few 100 people working on it; many of them with doctorates. A lot of money is required to do this, the corporations have equipment that we will do and they are the leaders in making this engines. Same thing happen with coal burning power plants, starting early on the temperatures of 300 degrees Celsius about in the forties and fifties. We now have reached we reached 550 degree 25 years ago. Then after a lot of R and D, were able to extend this to 565 degree Celsius and now this climate change being a major issues there is a lot of R and D now going on to push this to 700 and 10 degree Celsius.

This is a great research challenge; we have to look at completely new sets of materials, new machinery; new ways of manufacturing and be able to predict how this will work. And, all these things is not something that works for a few days when we say that the technology has matured and come into a market; it makes resource went on for 7 years or 10 years. And, much it comes into the market as we use (Refer Time: 18:22) you can use this nonstop for 1000s of hours, you want to make a power plant with this thing which will run nonstop for 1 year at least. And, we do make them (Refer Time: 18:32) it and burn it for 25 years; that is also which where technology becomes the challenge.

But, the point of talking about this is that the motivation for newer engines that you see coming around you, motivation for you power plants coming around you the air conditioner, refrigerator is coming around you. And, probably everything else coming; in somewhere the other comes from this motivation of thermodynamics. So, which one the starting point after that there is a lot more from different knowledge things that happens to make the products.