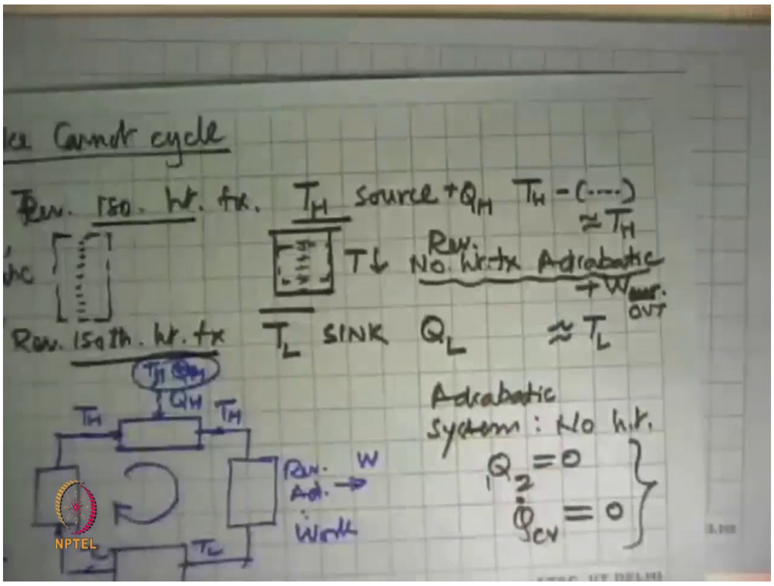
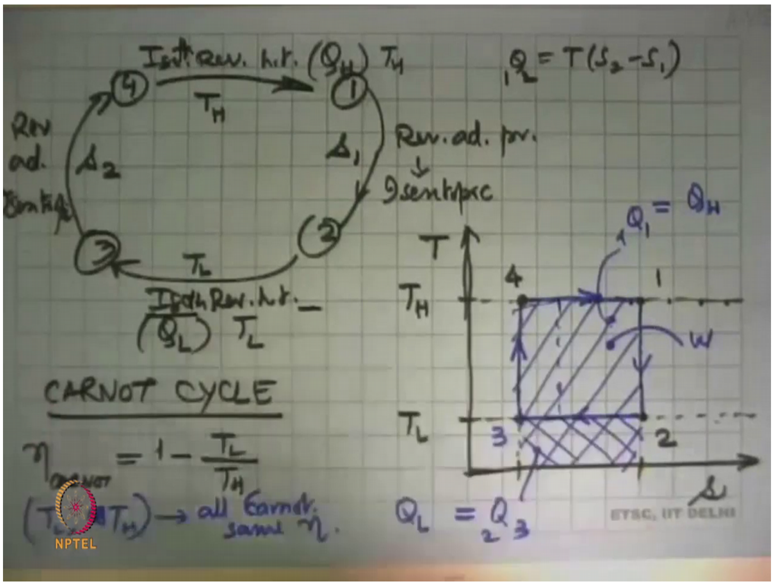
Engineering Thermodynamics
Prof. S. R. Kale
Department of Mechanical Engineering
Indian Institute of Technology, Delhi

Lecture – 31
Laws of Thermodynamics: Carnot Cycle Realization

(Refer Slide Time: 00:17)



(Refer Slide Time: 00:28)



How can I make a Carnot cycle? We have some more information, and we can try to put that whether you say that first process was isothermal, reversible, heat transfer from the source, this followed by a process. So, this took a two state 1, then it is going to state 2, this is a reversible adiabatic process. Then came to state 3, during which the isothermal reversible heat transferred from heat rejection to the sink at T L. And the 4th state, you come back reversible adiabatic work and then cycle.

So, these are the basic processes of a Carnot cycle, so this means that temperature is constant, this is isothermal process, this was also isothermal process. And this we just showed isentropic, this is also isentropic ok. So, to process the temperature is T H, in this process the substance temperature is T L, in this process the entropy of the substance is some value say s 1, and here the entropy of the value s 2.

And now we can see how we can put up this cycle, and for that we will invoke a property diagram. And say on the x-axis, I am plotting the entropy s. And on the y-axis, the temperature T, and I want to show this cycle. So, first is T H which is going to be here say, and T L which is going to be there. And what it is telling us is that I can have a cycle as long as it is (Refer Time: 02:59) this line I am ok. So, where we will go 4 to 1, only 4 were here, 1 could be the anywhere to the right of it.

The region you may look up that Q is T times s 2 minus s 1 or what the final minus initial. So, s 2 is greater than s 1, Q is positive which means there is heat transfer to the system, and which is what is happening here with the source. So, the straight point two has to be to the right, it can be here, there, there, anyway does not matter. So, let us take it somewhere there, so this is take point 1, this was 4 in our naming here. This has to be a reversible process, so we will show this by absolutely.

So, this is our point where there is heat transfer taking place. And if I want to calculate it, according to this one, the area under this is Q T into S 1 minus S 4 that is your heat transfer amount of heat transferred from the source into the system. Now, let us see what happens 1 to 2, reversible adiabatic process tells us that it has to be isentropic process that means, the entropy has to be the same. So, it has to be a vertical line there which comes, and intersects with the T L line and determines state 2, this is also a reversible process. So, we will put that by a solid line, and put an arrow on that.

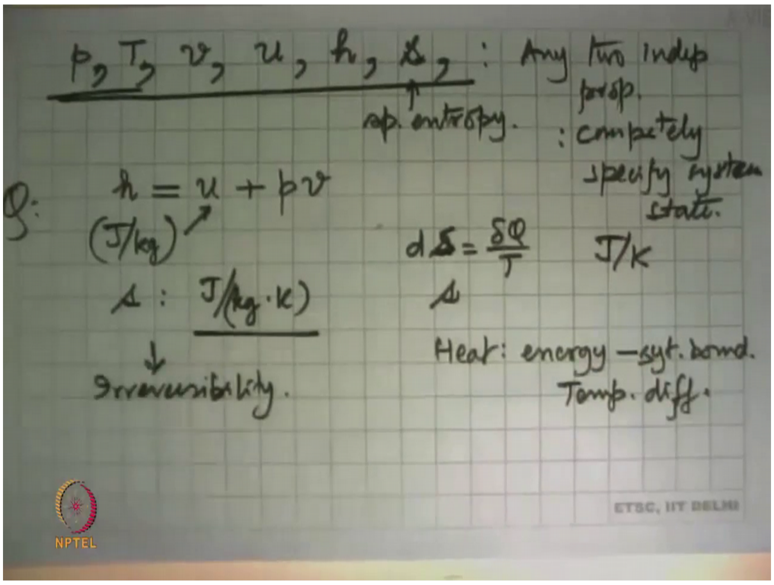
And to complete the cycle, it has to come back heat rejection minus this has to be now a negative term, so heat is going out. And you come up to a point, where the entropy at state 3 is equal to entropy at state 4, which means that it is to be on the vertical line, so that this process also becomes and isothermal process.

So, now we can see that this is the heat rejection process brings us to state 3, and finally this process isentropic process which brings us back to state 4, so that is the most general representation of a Carnot cycle on the temperature entropy diagram. There is no dependence on what substance it is, what state it is what shape on the machine it is, nothing of the sort.

Carnot cycle always has to be a rectangle and its same thing that the efficiency of this is going to be 1 minus T L upon T H. And it does not matter, whether the cycle was like this or the cycle was like this, this rectangle or it was this big rectangle like this. The efficiency is the same, what changes is that 4 to 1, the area under this is Q for this process 4 to 1. And area under this is Q 2 to 3, this Q 2 to 3 is heat loss to the sink, this is equal to heat input from the source, and the difference which is the area of this this is the work done by the cycle ok, so that is what we have.

And what it what other consequences of this definition are that between any two T L and T H pairs once this is defined, all Carnot cycles have same efficiency. And second any real cycle with any reversibility, they have an efficiency less than the Carnot cycle. So, are two things that come out about the Carnot cycle here, but what we have in the process is also done is defined this property, which is entropy ok. So, this is one important thing that has come out.

(Refer Slide Time: 08:16)



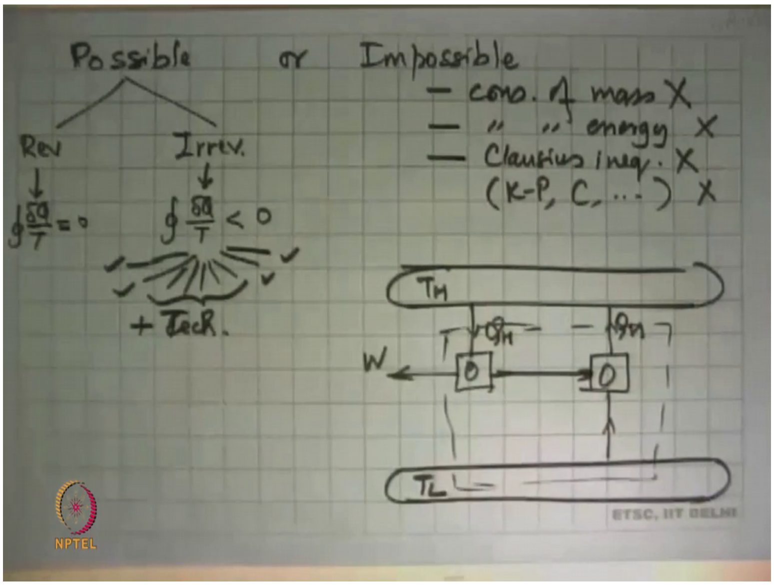
And yesterday, when we looked at the first law, he started off with properties that were p, T, and then we define the specific volume, we came with our specific internal energy, specific enthalpy, and now specific entropy. All these are properties of the substance, and any two independent properties, we will completely specify the system state. So, any combination of these two out of these four will always be two independent properties.

Any one of this and either one of this will also always be two independent properties. Only a certain restricted cases, these two will not be independent properties, and that we will learn about in the next module, right now it does not matter. So, this is what we got about entropy, we have defined what is the entropy and just some questions here.

Let us take first, there are two questions are somewhat similar; concept of enthalpy, and the other one is what is the difference between heat and entropy ok. Concept of enthalpy we looked at yesterday, and I just revised that for you; h is defined as u plus p v is a combination of properties, and the units of all of these are joules per kg ok. And entropy as we have just seen d s equal to delta Q by T, so the units of this are going to be if it is capital S, it will be joules or kelvin. If it is small s, this will be joules per kg per kelvin.

Units of specific entropy are different, some of the units of specific enthalpy which also were the units of specific internal energy. (Refer Time: 11:16) heat we have already defined in the previous module with that form of energy that is transferred across system boundary because of a temperature difference. So, these are two very very different things, heat is energy specific entropy or entropy is something which is an indicator of the amount of irreversibility that is there in a process ok. So, those are two questions that was there.

(Refer Slide Time: 12:30)



So, now we have this whole thing, and we can do a lot of solving of problems. It also about tells us that they are handled as to what process is possible, and what process is not possible. So, let us spend some time looking at that. So, either it is possible or impossible. Impossible means, either it violates the law of conservation of mass or conservation of energy, which is the first law of thermodynamics is that is violated not possible or it violets Clausius inequality, then also it is not possible. Such systems are should be rejected outright, there is no discussion debate on this.

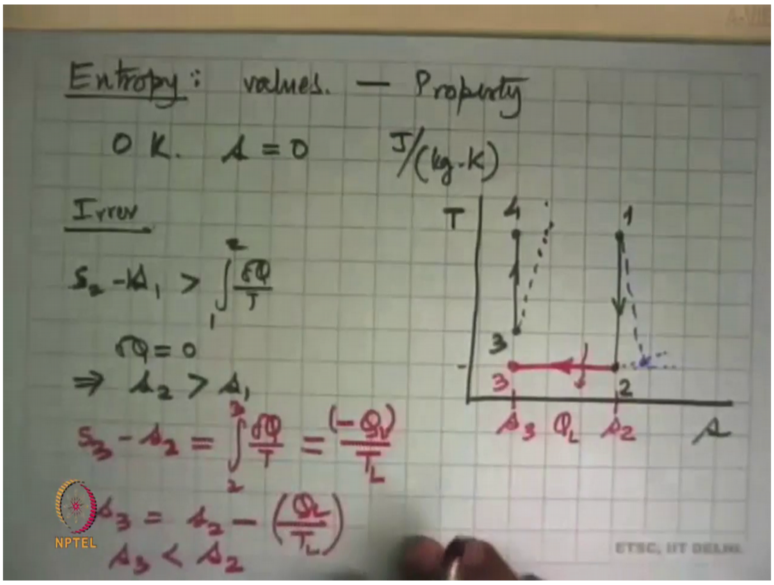
And of course, if it violates either the Kelvin Planck statement or the Clausius statement, then also it is out, so that it is something it is scientifically not possible. No matter what one does, you cannot get away from the reality that is this one possible. There are two things, it could be either reversible or irreversible. So, if it satisfies the first two, and cyclic integral of delta Q by T equal to 0, then the system is possible.

Although we know that practically, it is not realizable. And what a practically realizable is cyclic integral of delta Q by T is less than 0. Once you do that we have seen that there are many many possibilities of systems that can be made, and why do we not see them in the real world is because it is not that the science is not in place, it is that science plus everything else which is what becomes technology that is not favorable. Either you do not have the materials or it is countable too expensive, it will be too big or it is the cost is not worth it, any of those factors come into play, and that particular thing can be said to be ok. We know we can make it, but we are not going to make it. (Refer Time: 15:05) science tells us that it is possible to make it.

So, very large number of these will be there, but we will not be seeing them in our everyday life that is the difference. So, some of these technologies will become feasible and we see them all around us. So that is what I plan to cover today, there are more questions we can take up, because the question which as who the equivalency of Kelvin Planck and Clausius statement (Refer Time: 15:43) what you can do is even make that there are two reservoir. And we say there is one cycle which does this, so it is violating the Kelvin Planck statement.

And now we will put another cycle where this one is put into this, and it does this and now I can show that it violates the Clausius statement. So, I leave it to you to do the small exercise. Just redefine the system in a different way, and see what you get ok. So, this is Q H this is Q H, and this is what is happening. So that is that, anymore questions? Let us (Refer Time: 16:55).

(Refer Slide Time: 16:58)



(Refer Time: 16:56) time on that thing what is entropy, and how do we get the values for this. Now, first we have said that entropy is a property, which means that if I have two other independent properties defined, we can get the entropy. And the convention is that at 0 kelvin substances we have s equal to 0. So, some substances are done that way, say things like liquid hydrogen liquid nitrogen.

But, in some other cases like water, we will take s at the triple point to be 0, and then from this all the numbers work out ok. So, the units will be of course I have mentioned joules per kilogram per kelvin ok. Now, let us check some processes which are irreversible. And we said that in the Carnot cycle, we had a process that came from there to there, this was T, this one s, and isentropic process came like that.

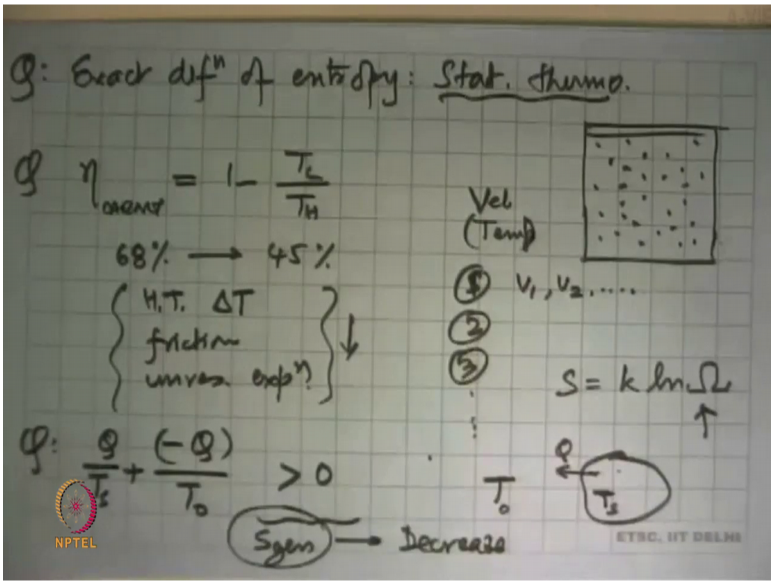
And we will ask the question, if this process were not isentropic, then what will happen ok, before that let us take questions here ok. What is the difference between perpetual motion machine of first kind and second kind ok? Perpetual motion machine, I will come back later on. What is the exact definition of entropy ok, why entropy of universe is continuously increasing, up to which limit, it will increase ok. There are couple of questions about entropy, I just finish this little discussion, and then I will come back to those questions ok.

So, in this process, what we have is that s 2 minus s 1 will be greater than delta Q by T. And if in an adiabatic process, this was an adiabatic process that means, delta Q equal to 0, then s 2 will be greater than s 1, which tells us that if this process were to be irreversible, then the final state 2 will lie to the right of this. So, this process can go somewhere there ok, this process cannot come back this way as long as it is adiabatic process that means, there is no heat transfer, we can go that way. And same is two of the other process also that you were looking at process that went from here to here, this was a reversible process. This tells us that if this process were irreversible, this will also go to the right. So, this state final state say 4, it will be lying somewhere over there that is one thing.

And now let us see, what happens through the process said that was 2 to 3. So, we have a process that came from there to there, and say this was 3 here. There were heat transfer taking place S 2 minus s 1 equal to delta Q by T, which has some heat loss took place Q upon the temperature which was there say T L. So, this is s 3 minus s 2. But, this heat transfer is out of the system, so this has a minus sign. So, what we are seeing is s 3 in s 2 minus Q L upon T L. Lot of these are positive numbers, which means that s 3 is less than s 2. And that is what this picture is also telling us; s 2 is over here, s 3 is over here, s 3 is less than s 2.

So, we have a process here, during which the entropy of the substance decreased. So, this is not something inconsistent with what we have been talking of if there, because there was heat transferred out of the system entropy of the substance has decreased, so that statement that entropy always increases is not entirely correct. They have to be much more specific and much more careful in making that statement ok.

(Refer Slide Time: 22:22)



Exact definition of entropy, for getting this answer, we have to go to statistical thermodynamics. And it is basically an indicator of the number of states that are possible for a given material. For instance, if we have in a system a certain number of molecules, and according to the kinetic theory of (Refer Time: 23:00), they all have a certain velocity distribution and a certain temperature with that. Then this velocity what is the probability that all of them have the same velocity that answer is 0, they all have a variation some molecules are faster, some are slower.

So, the extent of spread of this variability in their velocities can be mapped into saying that for each particular case, where I have velocity of each and every molecule, this is state 1. Then another combination of velocity is state 2, another is state 3, and like that we can have a very large number of states. And S is this is the number of possible states that the system can have, so it is an indicator of how many possible states that are possible, which the system can take. (Refer Time: 24:04) if there is only one state with the everything is at 0 kelvin, then of course S becomes that there is nothing else there is only one state, and that is the smallest value of entropy.

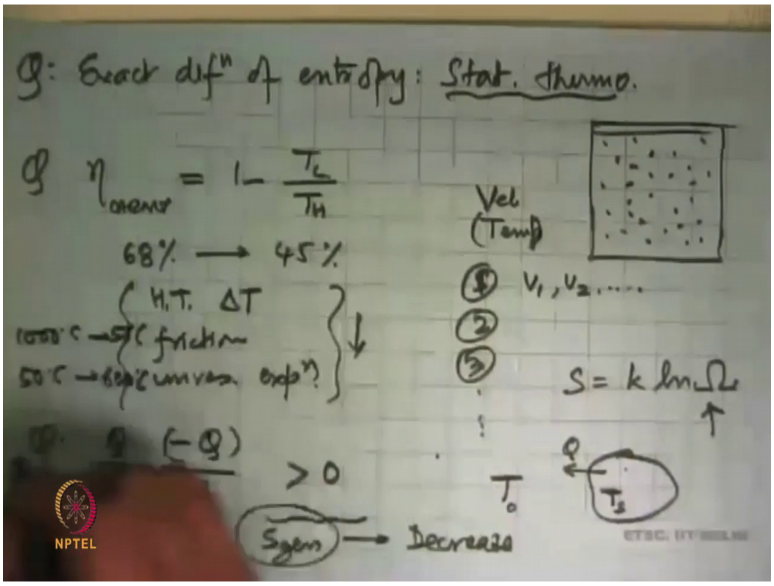
So, this is an indicator of the number of states that a particular system in a particular state can attain ok. Those were number then we say the irreversibility to this the number of states increases, so the entropy is increase. So, not in a very nutshell very briefly is what entropy tells us, it is not about just talking about randomness and things like that. It has how many what is the measure of states that a particular system can take at a microscopic level not a macroscopic level ok.

There is a question about why engine efficiency is limited to 45 percent ok. I just showed that the maximum possible efficiency with a Carnot cycle, this is 1 minus T L upon T H. And that gives an upper limit on what is the best possible number. So, in the real world that comes down, so whatever that number was say 68 percent, it came down to 45 percent, because there is heat transfer across finite temperature difference, there is friction, then there is some unrestrained expansion. And all of these put together bring the efficiency down from there to there. And the idea of doing research is try to minimize these minimize friction in the flow, you try to study the fluid mechanics more and more that way you reduce that, and make that think more efficient.

And so these are all the factors that bring down, what is practically possible to a much smaller number than what is physically, what science tells us is actually possible. So, there is a question about increase of entropy, why the entropy of universe is continuously increasing is simply, because you are always doing irreversible process. So, the entropy keeps increasing, but that apart one can look at it this way that there is a system at T s, and the surrounding at say T 0. And across this, they will say a finite temperature transfer from the system.

So, entropy change of the system will be that heat transfer divided by its temperature which was T s. Entropy change of the surroundings is minus Q divided by T 0. And if you look the net change of entropy, which will be the sum of these two, this will always be greater than 0. And that is what you normally know that entropy of the universe value increases that is not too much of a concern. But, the idea that there is entropy being generated that actually gives you an idea that is how can I decrease this, so that is the quantifiable way of trying to minimize irreversibility's in a cycle or in the process ok. How to achieve reversible process practically ok?

(Refer Slide Time: 27:57)



So, what reversible heat transfer try to minimize the temperature difference across which heat transfer takes place. And a good example of that we are running out of time, we will take it up when we look at applications. How many design a boiler that at one point, you have gases which are at 1000 degrees Celsius, and we will cool them down to 50 degrees Celsius.

And water at 50 degrees Celsius, which you want to heat to say 600 degrees Celsius. So, how do we design this, so that the irreversibility's are minimized that is what boiler designers will do, and practical boilers are actually done that. We will take up these examples later on. To what extent that disorder of the substance increases, where disorder of the substance increase, it just the number of states that the substance can take that increases ok, do not think of this as a disorder.

Why is the absolute value of internal energy not measurable ok? All of these properties, they are all we are looking at differences. And the only consistent way by which we can say that it is 0 at this particular value is either we randomly assign that value or on some basis they assign that value, it is what we do for water we do that for refrigerants. But, if you want to be strictly true to be consistent with physics, then we say that at 0 kelvin, the substance has no internal energy, it is in a maximum state of this, it is the order is perfect, so entropy is also 0, so that we can take why we do not do that for all substances.

We do it for some is that if we take that the reference state, and take values of internal energy, and entropy at conditions at which design machines that all the numbers will be very very large. And dealing with those numbers doing addition, subtraction, multiplication just gives becoming more and more of problem. And so what we do is we just shift the whole scale up to a nice convenient number. So, all the numbers are a few thousands, so that is what we have done, this that is what ok.

Here as the question, why Carnot cycle cannot be actualized in practice? What I have said that again that we cannot have reversible isothermal heat transfer, because we normally to have two substances, whose temperature difference is very small and remains constant, making such a thing is very very difficult. And if I have to heat do heat transfer over a very small temperature difference and which have very large area for heat transfer to take place. The machine size will become enormous that is one thing, we will always have friction in wherever the fluid is flowing.

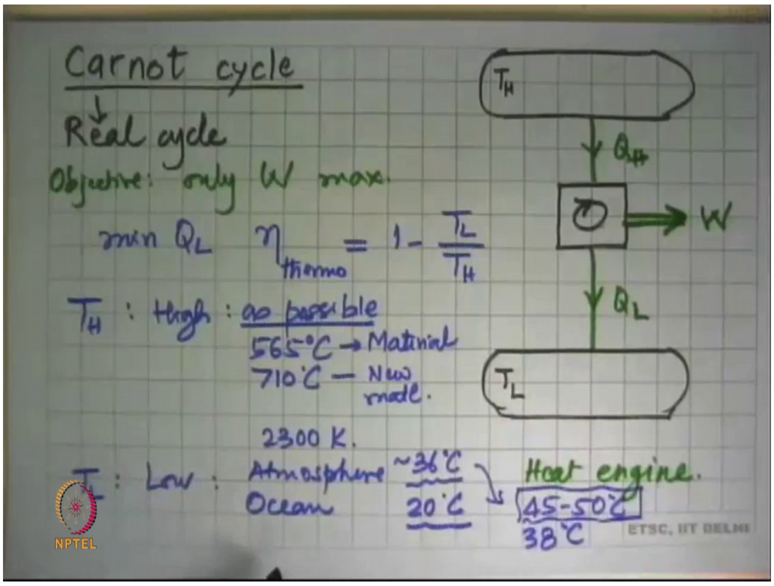
So, steam going through a pipe, oil be pump to this or a shaft rotate on a bearing, there is always friction there or say in a wind mill type of a thing air flowing through the blades, there will be friction over there that cannot be eliminated. We can try to minimize it, but we can never eliminate it. So, practically we cannot get the Carnot cycle in the real life, but it is good for one thing that it tells us that given what you have what is the highest cycle efficiency that you can even imagine; practically it will be on much less ok.

So, I have answered this one absolute value of internal energy not measurable, but we calculated from other properties like pressure, temperature, specific volume, and then we use it relations between properties of a substance to calculate internal energy, specific enthalpy, and specific entropy. This we will not go into the details of those equations in this course, but good to remember we will get some of those equations that is we make we measure some properties, and from there we are able to use equations. They are consistent with physics to compute internal energy, enthalpy, and entropy, and other properties also.

What is the physical significance of entropy, well in the case of a process that we have seen entropy change is an indicator of how much irreversibility is taking place ok. So, you can take it that way that is the physical significance of entropy; you can minimize that to whatever extent possible by designing it that is good. If you want to make it very very small, it theoretically may be possible, practically it may not be possible ok.

So, we will stop here. And what we are done now is we got an idea of second law of thermodynamics. And tomorrow, we will look at the implications of this. We will look at some more processes and conclude our discussion about the second one, we look at the second law for an open system. Then we look at some process, and say that if I have to analyze a process, I how do I go about applying the conservation of mass, conservation of energy, and the second law of thermodynamics and solve the problem. So, we will come into a position, where we will have all the tools required to formulate the equations that we need to solve to get the answer that we are seeking in the problem.

(Refer Slide Time: 32:43)



And now we go back and ask a question that has come up, and let us take some time on that. And the question is that why is Q 2, which is lost to the low temperature reservoir in a heat engine operation cannot be recovered completely or partially. So, here is what the question means, you have a high temperature reservoir, a low temperature reservoir, this took heat from here Q H. And dumped some heat into the low temperature reservoir Q L, and in the process gave us work.

So, this is the Carnot cycle for heat engine. And simple if we look on this paper, this is exactly what any of the big the power plant or the aircraft engines or a nuclear power point, they all do that it will basically this ok. Now, we said that my objective is only to produce work. If that is the objective, and I want maximum work that I can get from this, then the implication is that for is a given amount of Q H, I should get maximum here and minimum over here.

So, my objective now becomes minimize Q L or maximize the cycle efficiency, the thermodynamics cycle efficiency, and it tells us that this is 1 minus T L upon T H. And so look if you want to increase this maximize the cycle efficiency, take T H as high as possible and when I say as possible means, possible in an engineering sense or a techno economic sense.

Right now, when I mentioned that the temperature is 565 degrees Celsius in a qualified power plant, this is (Refer Time: 35:02) temperature. This is done, because the material from which we make the boiler tubes, and the turbine, and the pipes that cannot withstand higher temperatures for long periods of time, long period means 25 to 30 years. If we go to 600 degree Celsius or 700 degree Celsius with the same material, the power plant will (Refer Time: 35:25) deform, and very quickly we would not we will not be in a position to use that power station.

So, when we try to talk of 710 degrees Celsius, the idea is what new material can I use which will withstand this temperature or 25, 30 years, 2 year. We could go even higher, because in the furnace when we burn a fuel, we can get temperatures of the order of 2300 kelvin has a maximum temperature, when you burn a hydrocarbon fuel. So, theoretically we can go that high, and we attempt to do that in a gas turbine going higher and higher, but not in a stationary power generating system, so that is what I mean by as high as possible.

The second thing to do is take T L as low as possible. And what is the lowest that we can do that we dump heat into the atmosphere or into the ocean. So, how to dump heat into the atmosphere, we say that well in the summer time, it will be 45 degrees Celsius, in winter it will go down to 20, 22 degrees Celsius. In some cases maybe between 36 and 20, 20 the maximum temperature, the minimum would even go down further. So, we have to work with a varying atmospheric temperature, and we say that ok.

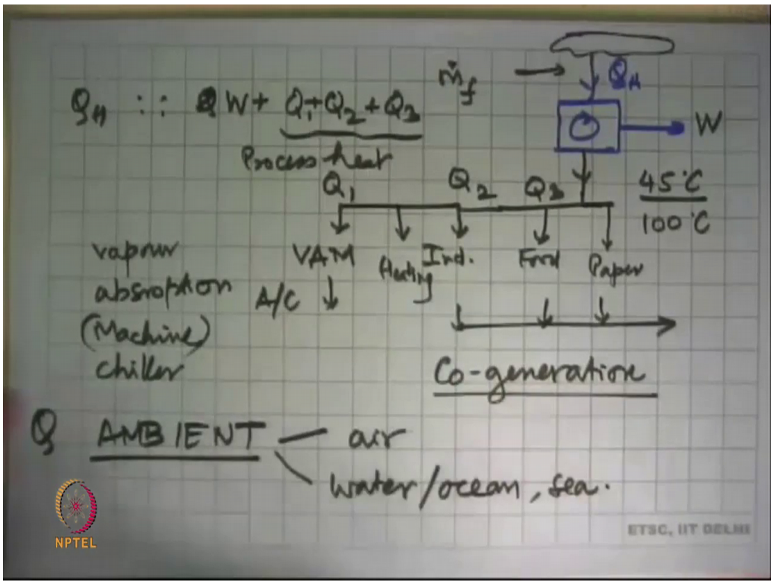
Let us say that 36 degrees Celsius is something for which my system should operate. If the ambient temperature goes down to 20 degree Celsius, my cycle will become a little more efficient, so that is what we do in the real engineering of these systems. So, when we decide this we said it, I would not reject heat to this thing. So, if I have to reject heat to air at 36 degrees Celsius, then it tells me that I cannot cool down the substance to say around 40, 45, 46, 50 degrees Celsius, so that the size of the heat exchanger is limited. One can argue that where if you want to reject at 36, why do not you take it at 38 degrees Celsius?

When you still as possible you can cool it to 36, yes, 2 degrees difference is there, but then the size of the equipment will become very very large. And that an engineering sense is not feasible ok, so that is what people leave a temperature differential of like 10 degrees, 12 degrees, 15 degrees Celsius or maybe 8 degrees, but not 2 degrees. So, we brought it down as far as possible, and said look I cannot cool it any further might as well less this energy, and let it go.

And that is the once you have done that what it means is that you had that substance at 45 to 50 degree Celsius. If somehow you can take that substance, and use it where you want to do something say steam of this temperature, I can heat water and raise its temperature by maybe 2, 3, 4 degrees Celsius that is about good enough for having a bath. But, then the amount of energy that you have is so huge that is practically not possible.

And second this is there in a power station, which may be many hundreds of kilometers away from that people living where the big demand is. So lame pipes and carrying this thing and using it there becomes very very impractical, so that is the reason, we cannot hope to go below what nature has given us. Our ocean temperature, our atmospheric temperature sets the lower limit. If they are in a very cooler climate, it works out even better. So, if you are in the temperate zones of the earth atmosphere that is nice you can get a little more efficiency from that cycle than what you will get in the tropics, but that does not mean that everything is lost.

(Refer Slide Time: 39:40)



There are other ways by which you can maximize the utilization of your Q H. So, I will take a few minutes to go into this. And what we will does, it says that look I when use the cycle and when I reject the energy, I get some work out some (Refer Time: 39:50) Q H, which is by burning of the fuel. But, now I would be at slightly different thing, I would not explained it, all the way down to 45 degree Celsius, I would not cool it down, but I will keep it at say 100 degrees Celsius.

And then, we said look with 100 degree Celsius, I can do a lot of things. I can run many industries, for example I can run a laundry. There cloths have to be washed, and laundry is mandatory in a 5 star hotel and as well 5 star hospital and but every hospital. When you have to wash the clothes and sterilize it, you need heat. So, either you use the electric heater or burn fuel to generate steam and then sterilized more cloths or if you have a way this energy is there, then you can directly use this, and get some benefit out of it or you can use it in some other process like say food processing or paper making that you need heat.

So, if you do that, and then collect whatever the outlet was there, whatever temperature it was you can then collect it, and send it back, heat it up, and again put it into your cycle. Now, what has happened is you are looking at the system, which is not purely a thermodynamic cycle ok. One more option, I will put out here. We can even take some of the steam saying this cycle which was there, and use it in a device called a vapour absorption machine. And this can be used for providing air conditioning.

So, this is entirely a possible idea that in the power station, we use some of the steam to generate chilled water, and we pump that chilled water to buildings and houses. So, instead of everybody putting a window AC or a split AC, you can have a centralized AC, where the chilled water is coming from the power plant. That way the overall utilization of the fuel, so that means this Q H came about by burning fuel at a certain rate that amount of energy which was there some came out as work. And we consumed some of that as heat in these different applications Q 1, Q 2, Q 3.

So, the total amount of energy that we put to use was some of these three, this tells us that the of all the Q H that we had, we are now able to get some work plus use Q 1 plus Q 2 plus Q 3 as process heat. And that way we are able to utilize a much larger amount of the fuel burned in our requirement, and that is more efficient than generating electricity, and using electricity to run all these things or separately burning more fuel to get steam for these industries. This idea is popular in many cases.

This in cold climates this steam is also used for heating. So, we take a steam pipe, and run it throughout the city and into everybody's house, one steam pipe comes in. There is a heater over there and that when you get heating of your house, you do not use an electric heater, but you end up using steam to get heating. And energy wise, it is much more efficient, and nowadays of course carbon footprint is much lower. This idea is called cogeneration many industry use it, but there are many more options still available. And we can in future these could be in use, where by burning fuel we are able to utilize a lot of that energy not 30 40 percent in a power plant.

But, if you put all of these maybe 60 percent, 70 percent, 80 percent also, but remember that is not a thermodynamic cycle, so Carnot cycle limitations do not apply to that, so that is an idea that I put out. By the way VAM means, Vapor Absorption Machine or vapor absorption chiller. And this can also work by taking, if you have heat, which you have to dump into the atmosphere. For example, from a diesel generator set from a typical engine one-third of the work come energy put into the fuel comes out that work one-third goes as lost through the radiator, one-third is lost through the exhaust.

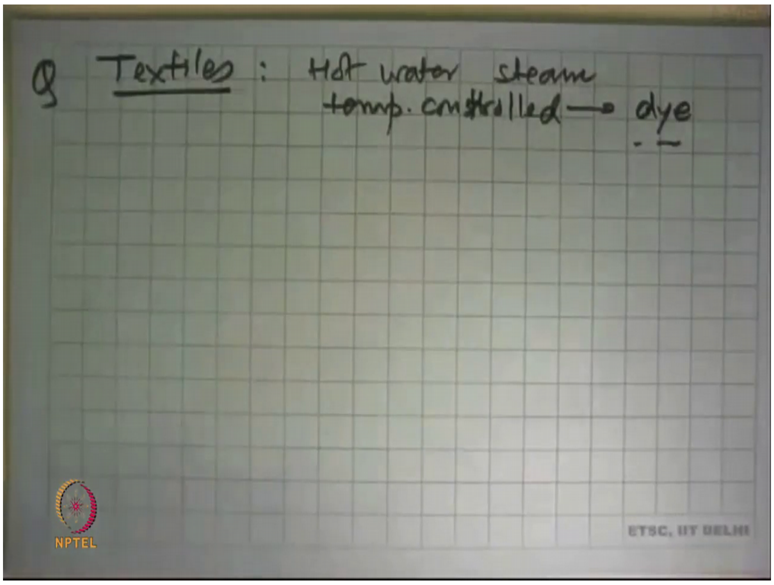
So, there is a two-third of the energy of an engine is actually wasted all the time. If in the stationary application which runs all the time, we can take that heat run a vapour absorption machine, and do air conditioning of another lot of buildings. So, over all the utilization of the energy of the fuel increases, and these type of systems will become very very attractive, but there is a lot of scope to actually go about to innovate lot of these things here.

It is a challenging book starts with thermodynamics, then goes into various things and ended up in economics and technical feasibility ok, so that takes care of the question which was there, and there is one more question ok. What does the term ambient mean? When we say ambient, it means what is around us. So, along this is the atmosphere which is air. So, the air in the room in which you are sitting that is the ambient or in a larger context, the area where you live that is your ambient. Somebody else is living in some other place, their ambient is different, so that the ambient air. And if you are near a sea, you have water, when we say ambient water it means, whatever that ocean was of the sea was this is ambient.

So, in the sense it is what is around you, which is what is naturally there. So, you can say that this is what naturally exists in our surroundings, you can take that way. So, when we talk of maximum temperature of the day, minimum temperature of the day, we are basically saying at that particular location, what was the highest ambient temperature, what are the lowest ambient temperature, if there are rainfall, then we say well what are the ambient rainfall at that point.

But, this is basically what it is. We can even use the work ambient in the context of air pollution, somebody will say that the ambient air quality here is so many micrograms per cubic meter of particulate matter, so that is what it means that in your vicinity in your surroundings, this is that particular parameter ok.

(Refer Slide Time: 47:05)



There is a question here, what are the applications of thermodynamics in textile field. One of the big applications of thermodynamics in textile field is that in many textile operations, we need either hot water or steam or a temperature controlled system for certain things to take place; for example, for say dye or for processing of yarn things like that.

So, what most textile industries will do is they will take a boiler, where they will burn diesel oil or some other fuel, it will generate steam. And this is relatively low pressure steam, and that steam will they will route it to all these processes that they have. So, how to design that how to get the maximum efficiency from it, how to reduce your fuel bill by optimally using that energy of steam that is one application of thermodynamics over there.

And it will also help you to decide, what is the way that I can collect some of the way steam is possible, and put it back or if there is say a hot water which has got chemicals in it, which is otherwise going to be wasted. Before, throwing it out, can we recover some of that energy and use it somewhere else in the process. So, thermodynamics self-person say that ok, this much energy is possible to be recovered from this waste, and that way your total energy bill goes down, it will become a little more eco-friendly.