Engineering Thermodynamics
Professor Jayant K Singh
Indian Institute of Technology Kanpur
Department of Chemical Engineering
Module 07
Lecture No 43
Gas Power cycle air standard assumptions value of Carnot cycle in engineering

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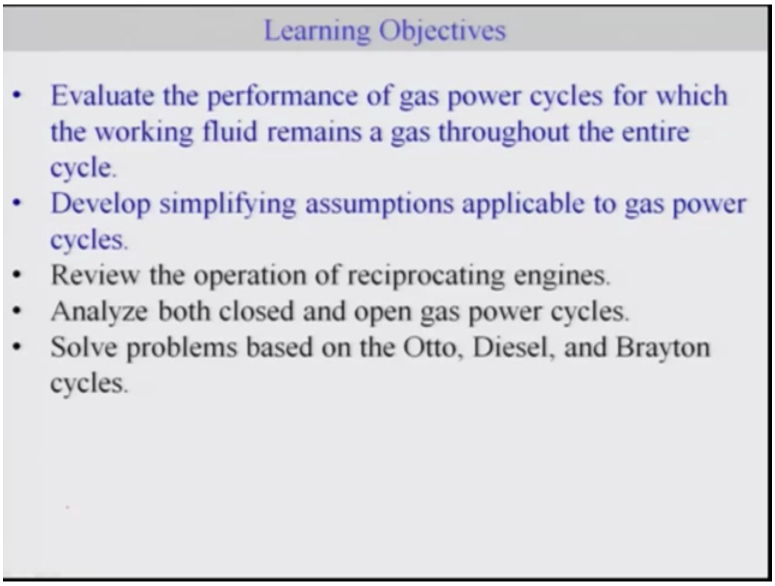

What we have covered up till now is understanding of first law of thermodynamics and as well as second law of thermodynamics. We are going to now start our new topic is going to be on the power cycles and in particular, we will start gas power cycle so we will be try to evaluate the performance of gas power cycle in this particular lecture, okay. Before we start, let us look at the definition or in general, different forms of thermodynamic cycle.

So thermodynamic cycle, let us say TC, you can have make use of it for power cycles okay and we are going to say power cycles for those where the cycles are used by net power output devices, so cycles used by net power output devices okay. So that would be your power cycle. The thermodynamic cycle can be used for refrigeration cycle, okay, where the cycles are used or cycle is used by devices to produce a refrigeration factor okay.

So these examples would be your AC, refrigerator okay or heat pump or here the example would be your automobile engine okay. Thermodynamic cycle, you need to have certain working fluid so based on the working fluid, we can have 2 different forms of cycles. It is one of the your let us say gas cycle so here the working fluid remains gas or remains in the gaseous states okay all the time and then you have this vapor cycle.

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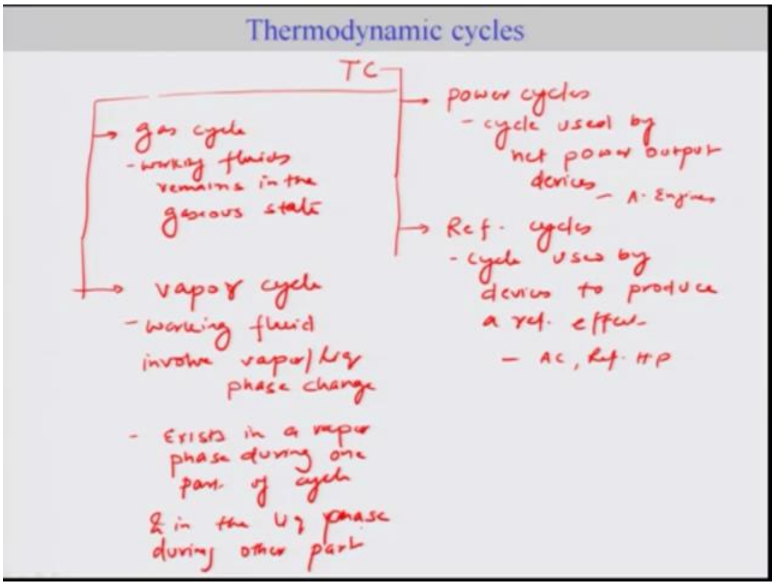

So, one way of making use of thermodynamic cycle is called gas cycle where the working fluid remains in the gaseous state and other would be your vapor cycle where the working fluid involves some kind of a vapor liquid phase transition and one part of the cycle would be, the working fluid would be in the vapor phase and other cycle would be in the liquid phase.

Okay, so thermodynamic cycle can be also categorized in 2 forms, one would your closed cycle, other could be your open cycle, so the definition would be for the closed cycle, your working fluid returns back to its initial state okay and for the open cycle, the working fluid will not return to its initial state, but rather it will be replenished that is the existing working fluid will be taken out from the system and the new one will be entered, so let me just describe it more.

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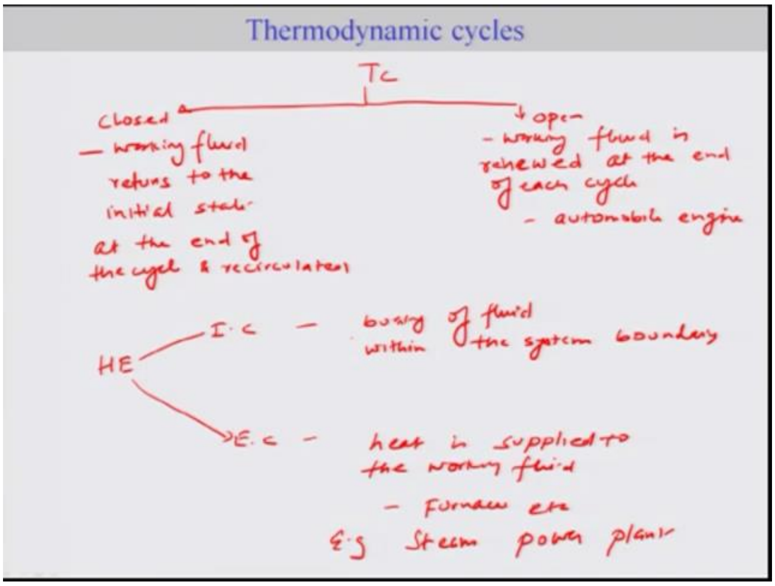

So for the case of closed cycle, you have working fluid returns to the initial state at the end of the cycle that is, it is recirculated, okay. For the case of open cycle, working fluid is renewed at the end of each cycle, okay. So the example of open thermodynamic cycle would be your automobile engine okay, so in this particular open thermodynamic cycle, the gas do not undergo a thermodynamic complete cycle.

Ideally we should say this is the fluid or the working fluid undergoes mechanical cycle okay so we will get an idea of this subtle difference in the later part of the lecture. Now if we discuss this heat engine, which basically make use of thermodynamic cycle, we can categorize the heat engine based on internal combustion or external combustion okay, where internal combustion would be your, for the case where you are burning up fluid occurs within the system, within the system boundary.

So this will be your automobile engine okay, where the external combustion would be the case where the heat is supplied to the working fluid okay externally or from the external source so the source would be something like furnace, your nuclear reactor, geo thermal well, so these are the different sources so the example of external combustion heat engine would be your steam power plant and for the case of IC, it would be your automobile engine, okay. So what we are going to do is, we will first look at our power cycle first and followed by refrigeration cycle okay.

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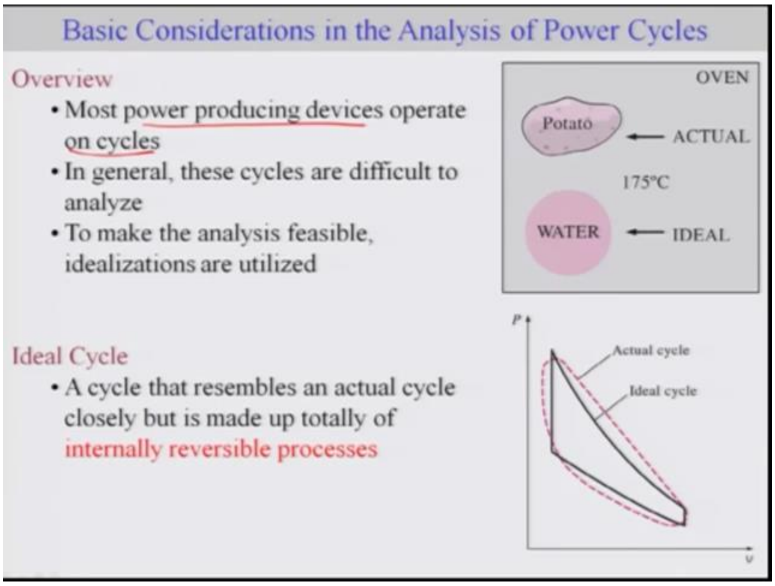

Uh Now let me just briefly give an overview of basic consideration which we need to undertake for the analysis of the power cycle, where the idealization would be done to simplify our analysis in order to solve the problem okay so let us take an overview so most power producing devices will be operated on the cycle and as I said in order to make this analysis easy, we need to consider idealization.

For example, the one can consider let us say a potato in a oven and it represents as a water body as an idealized model and of course, the results need to be taken very carefully that it should not be extended to many different systems because there are limitations as far as the modeling is concerned or idealization is concerned. For the case of a cycle which may be looking at this as a actual cycle in a dotted form, we can idealize this in terms of your this the one, considering that each of them are this internally reversible processes.

So the actual process may not be internally reversible process, but they can be considered or represented by an ideal cycle which consists of internally reversible process. So this is an example of taking converting the actual cycle to ideal cycle for the sake of analysis okay. So an ideal cycle would be a cycle that resembles in an actual cycle closely, but is made of totally internally reversible process.

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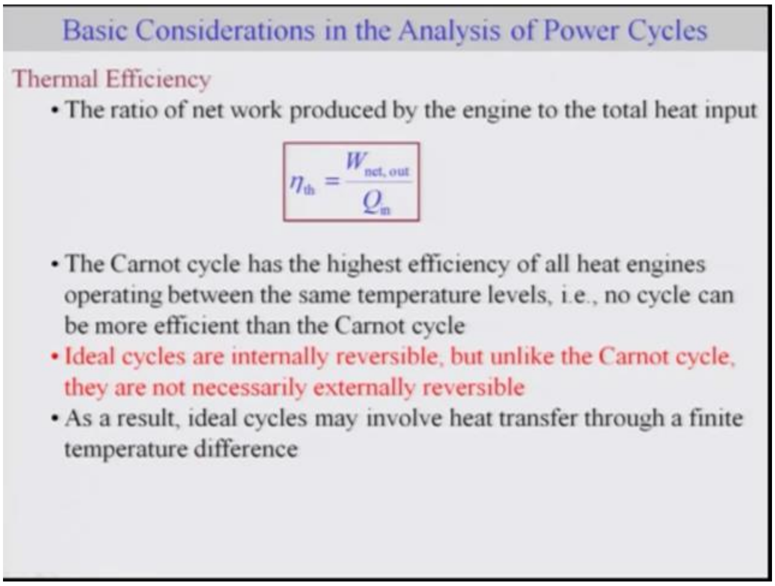

Now as we know from our and the earlier analysis for the case of the engine that the efficiency of engine is defined as W net divided by Q in and we know that for the case of Carnot cycle, which the efficiency is the highest so now we know that Carnot cycles are externally and internally both reversible. So ideal cycles are considered to be internal reversible, but they need not be necessarily external reversible, which essentially means that ideal cycle may involve certain heat transfer through a final temperature difference

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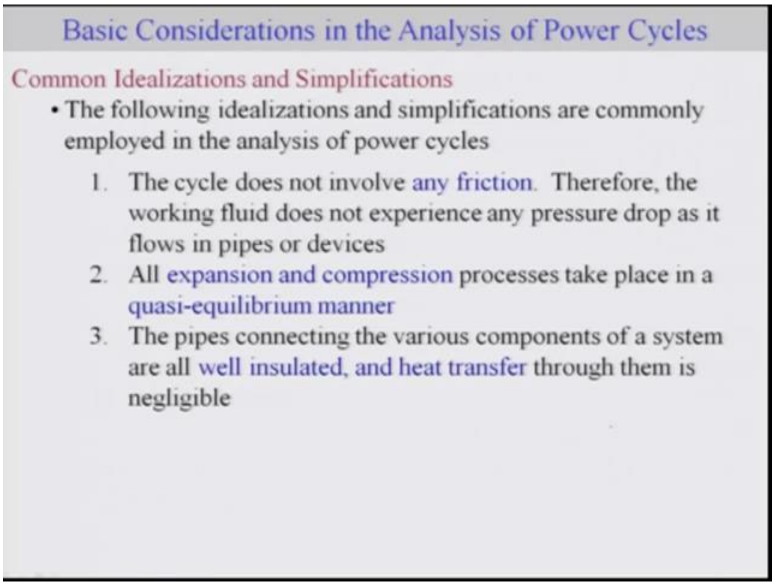

So what are the common idealization and simplification in the analysis of the power cycles that the cycle does not involve any friction okay, which essentially means there is no pressure drop through any pipe or devices? All expansion, compression processes are taken in a quasi equilibrium manner which essentially means that all the processes are internally reversible process. We will be considering all devices insulated or in other word, we will be considering that the pipe connecting the different components of the systems are well insulated in or heat transfer through them are negligible so this will make our analysis very simple.

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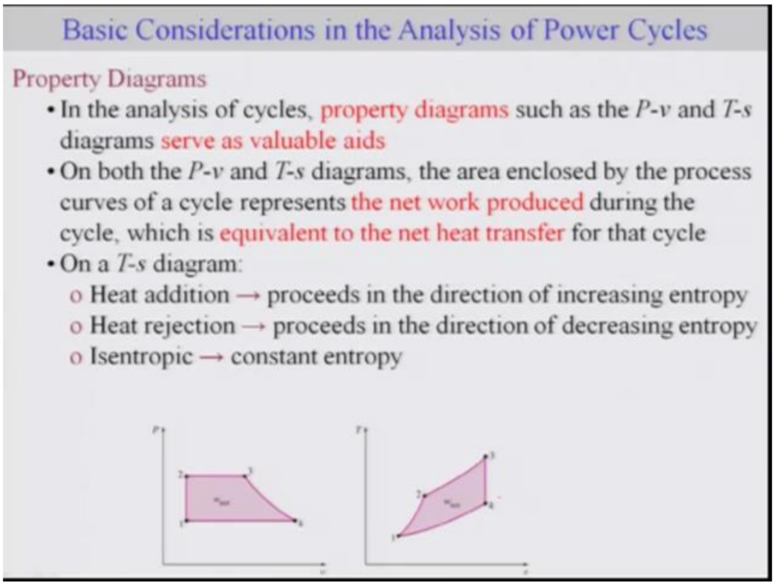

Now in the analysis of power cycles, the property diagram would become extremely useful diagram and for the analysis and as we have discussed earlier, the PV and TS diagram, the area enclosed by the process, such as described here, it represents the W net okay, and this is equivalent to the net transfer for the cycle for the idealized cycle okay. For the case of NS diagram, we are aware of the fact that heat addition would mean increase in the direction of the increasing entropy.

Or in other word, heat addition proceeds in the direction of increasing entropy. So essentially if you consider something like this, then it is very clear that this 1 and 2, 3 process involves heat addition and heat reduction would be proceeding in the direction of decreasing entropy and isentropy could be your constant entropy, so this is something which would be representative of changes in the entropy corresponding different you know heat addition or rejection or an adiabatic processes okay.

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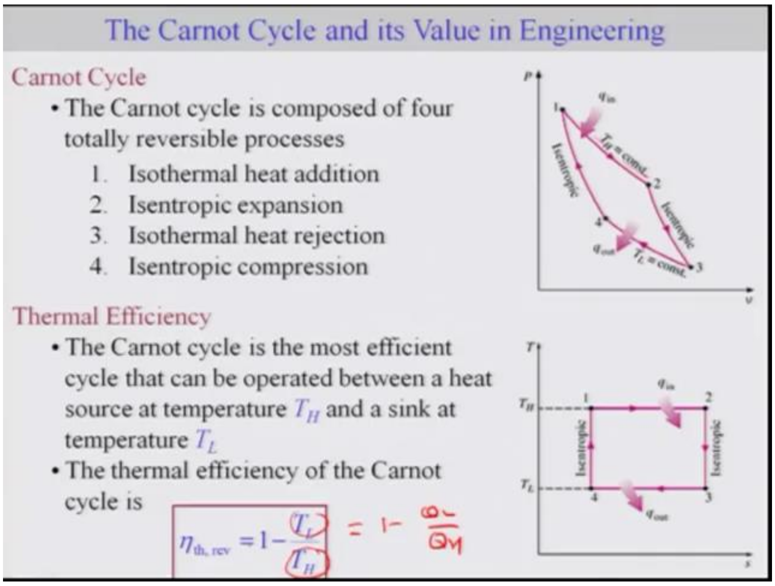

So this is something which is completely clear if you had used this Carnot cycle, which we have already discussed earlier that it consists of 4 reversible processes. It has quite a value for in our engineering application okay, it is something which we can clearly understand once we describe the different engines, so the Carnot cycle composed of your heat in at constant temperature, that is isothermal addition and then your isentropic expansion okay, which is nothing but adiabatic reversible expansion and then you have a constant temperature heat rejection that is isothermal heat rejection followed by isentropic compression okay.

And for the case of a Carnot cycle, we have already developed this relation that this can be written as simply the efficiency can be written as 1 - the ratio of TL and TH okay. Though Carnot cycle provides kind of a very simplified form of a cycle where one can produce network okay, it is difficult to implement such Carnot cycle practically okay because of the fact that reversible isothermal heat transfer is very difficult to achieve in reality.

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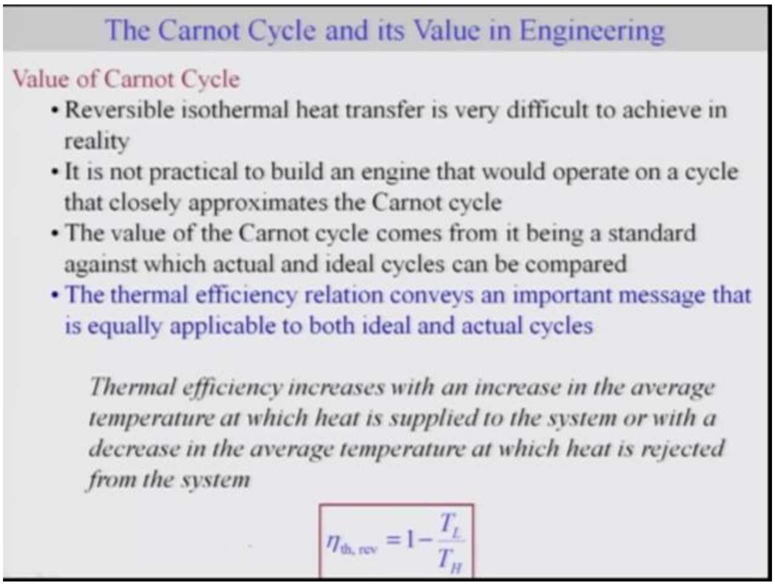

So the Carnot cycle does act as a standard against which we try to develop a gas or power cycles and thus we can compare the actual or ideal cycle against the Carnot cycle. One of the important thing with the Carnot cycle is that which provides an important message is that you can improve the thermal efficiency of the cycle by increasing the average temperature at which heat is supplied or by decreasing the average temperature at which heat is rejected okay, so that means if your TL or increase your TH, the Eta is going to increase, this is something, this is a message which you can take it from the Carnot cycle based efficiency.

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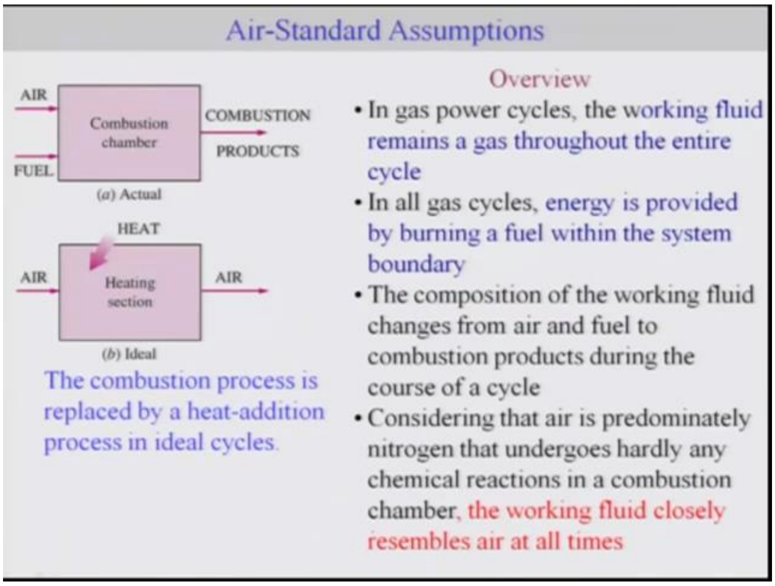

Okay so now in order to analyze the power cycle where we are going to make use of gas to start with, we are going to make certain assumptions which we call air standard assumptions, before we start listing down those assumptions so let us try to overview this particular combustion chamber which intakes are air and fuel and undergoes a combustion leading to combustion products.

Now it should be clear as we are aware of the fact that the air contains predominantly in that region and hence what we can do is, we can consider that the even combustion products are mainly composed of air and whatever the combustion energy is being generated, it can be idealized as a constant heat which is provided to the chamber or heating section, so this kind of idealized form where the in the in terms of representation.

So as I said that air + fuel compression goes to combustion product and there is heating. This can be idealized in the form of that you have simply air and the whatever the energy being generated can be represented as energy being provided to the heating section okay and that leading to air okay. So considering as I said, the air is predominantly nitrogen that undergoes hardly any reaction in a combustion chamber.

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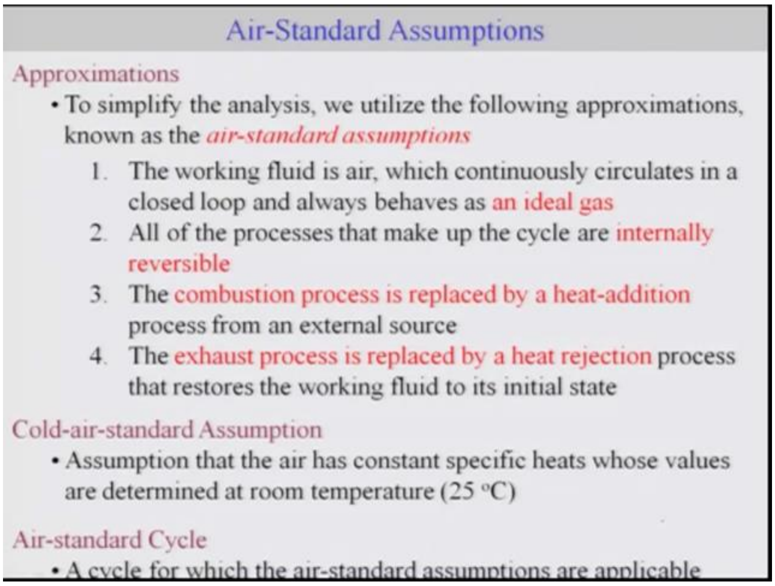

The working fluid which we are going to consider closely resembles air at all time okay. So this leads to the set of assumption which we call its air standard assumption and we are going to list down here that what we are going to consider for this case of a gas based power cycle is that the gas, that is your air which you if you are making use of air standard assumption then air is going to be considered as an ideal gas okay, so the working fluid for the air standard assumption is air which will be considered as an ideal gas.

All the processes which are involved in this particular cycle or all the processes that involves a mix of cycle are internally reversible. The combustion process is replaced by a heat addition process from an external source as I was mentioning in earlier slide and the exhaust process is replaced by heat rejection process that restores the working fluid to its initial state okay. So we will understand this combustion process and exhaust process for this particular cycle more clearly in the next lecture.

Okay so the other assumption we are going to make use is cold standard assumption, where we are going to, we will consider the air having a constant specific heat at room temperature for the analysis okay, so that means the CP or CV are going to be constant which we are going to fix it at 25 degree Celsius. So we are not going to consider the variation in the temperature in the analysis of specific heat and the cycle which we are going to apply, this air standard assumption would be called air standard cycle okay and that is something which will take up in our next lecture for further making use of this assumption.

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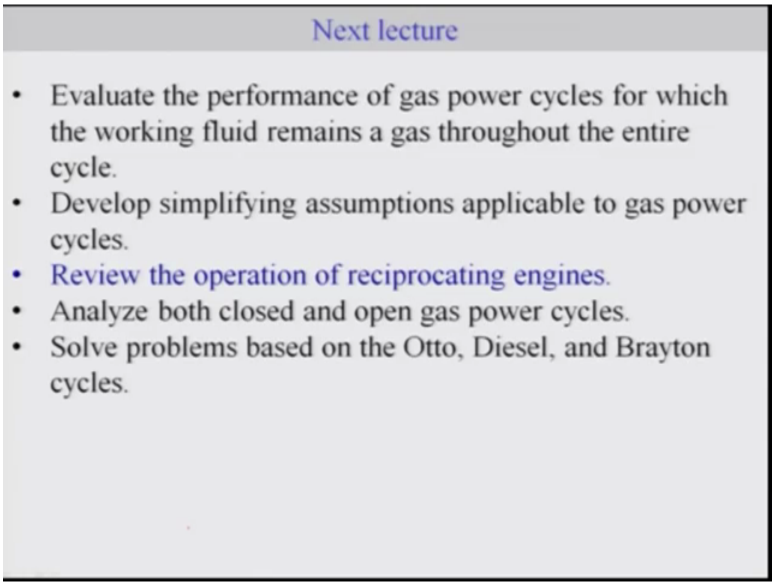

Okay so we will end this particular lecture. In the next lecture we will first review the operation of reciprocating engines okay and so hopefully this air standard assumption and its utility will become clear in the next lecture, so see you in the next lecture.