MARINE ENGINEERING

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Lecture34

Steam Turbine

Good morning, today I will start the topic steam turbine but some calculations. Previous lecture also we have done some calculation, today also we will do some calculation. Let us recap little bit. So, Rankine cycle is started. Rankine cycle will have one boiler, boiler will be giving superheated steam to turbine.

Turbine I am drawing in specific way you should not draw in opposite way I already told so if you are drawing like this so it is okay but if you are drawing opposite way like this it is wrong. So this will be compressor later we will discuss about compressor. Now this turbine output will be going to one condenser so condenser purpose is to release and boiler purpose is to give heat to water so Q1 and there will be one pump actually pump will be working in the liquid zone so pump normally we draw like this ok and if I draw in TS diagram it will be first you have to draw vapor envelope then in boiler this is boiler So you have to put the number properly.

Already you have seen. It can be inside, outside, everywhere possible but ideally we will be assuming this after boiler let us see 1, 2, 3, 4. 1 to 2 is your condenser, 2 to 3 your pump, 3 to 4 your boiler. So 3 to 4 boiler is adding heat to fluid. So, first your sensible heating, then phase change will be occurring, then last part will be your super heating.

After super heating your turbine will be working. So, turbine will be extracting energy, power will be extracted, power extraction. turbine is giving power and turbine ideally we are assuming this isentropic process, ideally isentropic. But practically if we consider then it will be like this. So, 1 dash and 2 2 1 1 dash is constant pressure line 4 2 1 dash it is irreversible process

That is why we are putting dotted lines irreversible process and energy will be lost. we expected energy 4 to 1 but actually we are getting 4 to 1 dash. So we are getting little bit lower amount of energy. But same thing is happening in pump side 2 to 3 is your ideal case but practically it will be like 3 dash. 2 to 3 ideal process but 2 to 3 dash is practical.

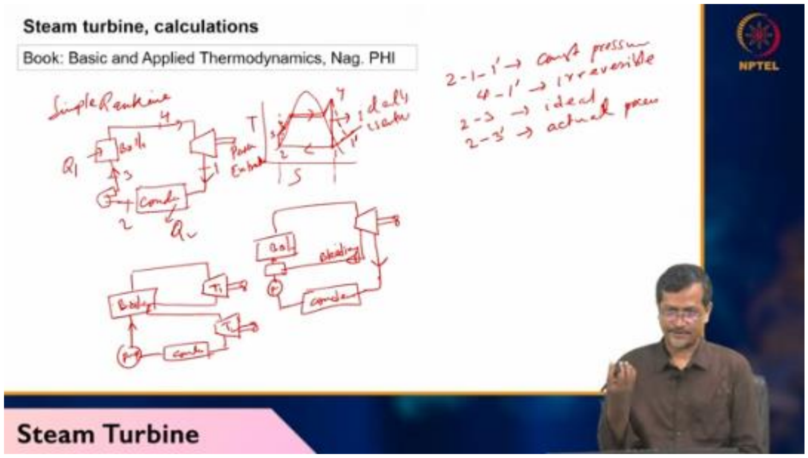
or actual process. So what is happening? 2 to 3 dash you see line is longer. Longer means you are giving actually more energy. Pump will be taking more energy than whatever you calculated for ideal case.

In turbine you are getting little bit less energy. So actual cycle actually will be giving little bit lower energy whatever you are calculating. But first you have to assume everything ideal and you have to calculate. And you are assuming also for ideal case that there is no heat transfer in other pipeline in other places. All the heat whatever boiler is giving turbine is getting same amount of heat.

And some amount they are extracting and some amount is going to condenser. So condenser purpose is to release only heat. it is not giving any other pressure drop or pressure increase. It is only changing phase and releasing heat. In boiler phase change occurring and increasing pressure.

Now this is a simple Rankine cycle. Simple I can say simple Rankine cycle but we discuss regenerative reheat also. Reheat like I have one turbine. I have boiler, so from turbine steam will be going to boiler, it will be reheated again, again it will be going to another turbine. turbine 1, turbine 2, then it is going to your condenser, then condenser to pump, pump to boiler.

you are taking two times energy, but you are having condenser one time means you are releasing less amount of heat actually okay so you are you improving performance of your system so maybe two three stages possible and another is regenerative system regenerative system what you do you have turbine then you have boiler now turbine will have condenser after turbine condenser then there will be pump then boiler it will go so after pump actually water temperature is lower now what they do they will take some amount of steam and they will be giving here okay then you are pumping to boiler so this is bleed we call bleeding okay some small amount of steam they will take and that will be put after pump okay so that temperature will be going up so boiler will be giving less amount of heat because already you got some heat from a turbine okay so this is the regenerative system and this is called reheat system so you may have complex regenerative plus reheating system also okay so if i have regenerative and reheat how it will look like regenerative Now, regenerative plus reheat system we have then how it look like.



So, I have one boiler first draw this boiler from boiler it will go to turbine 1. turbine 1 will be giving power. So, boiler is giving this much of energy to this turbine 1 then turbine 1 some after turbine one the steam will be going back to boiler again to get reheated it will move to another turbine okay turbine can be on same shaft because you have different many many shafts then controlling power will be difficult so normally they will be attached on a same shaft and they will be managing okay so then it will be giving exhaust steam it will go to boiler again so it is getting reheated so reheating is happening Then reheating steam coming to another turbine, turbine 1, turbine 2.

Then turbine 2, steam will be going to your condenser. So, turbine 1, steam did not go to condenser, rather it went to boiler. So, from boiler it went to turbine 2, turbine 2 to condenser it is coming, condenser 2 again pump. so pump then what is happening you take some amount of steam as a bleeding steam then you mix here okay this is regenerative part okay so bleeding is happening then again you put another pump and here also you take small bleeding amount you mix it here again pump then you put in boiler okay so you see this several steps are happening here uh so i can put numbering here number they have put like one here two after pump then three then after pump four then mixture five okay this after pump they did not put any pump actually here so we can remove it

You can put pump also or we may ignore also. Now this is 6, this is 7, this is 8, this is 9 and this one A, this one B. So now draw the TS diagram. So TS diagram when you are drawing, first you draw the vapor envelope, now you draw you see 5 to 6 5 after before boiler and after boiler you see so 5 means you have to come here 5 to 6 here 6 to 7 6 to 7 happening like this 6 and after turbine so 7 7 then 7 to 8 8 again increasing temperature Increasing temperature again going down 8 to 9.

So after 9 it is going to 1. You see these points 5 to 6. So after 5 the line is crossing and touching the saturation line. So we will not put any number because it is within boiler. So we are not putting any number.

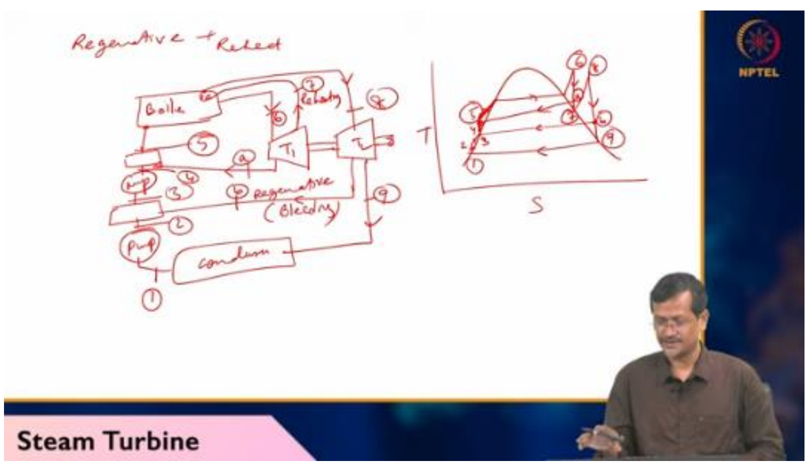
now 2 to 3 1 to 2 is pump then 2 to 3 what is happening 2 to 3 actually heat increasing so 2 to 3 is like this you are taking bleeding amount B 2 3 then 3 to 4 3 to 4 you see pump again working so 4 two five so four to five pump increasing temp three to four three to four four to five okay so you see four to five where is four four after pump then five five before five one mixing is happening so this is mixing point then four to Boiler is increasing temperature 5 to 6. And A is here I think. A is here.

From here. I will put here. A is here. Because this is 7. This point.

This is B point. This is 6, 7, 8, 9. 9 to 1. 1 to 2. 2 to 3.

3 to 4. 4 to 5. So, this way you can draw the T-S diagram. This is very complex actually. So, every turbine is giving some bleeding steam to increase temperature of feed water.

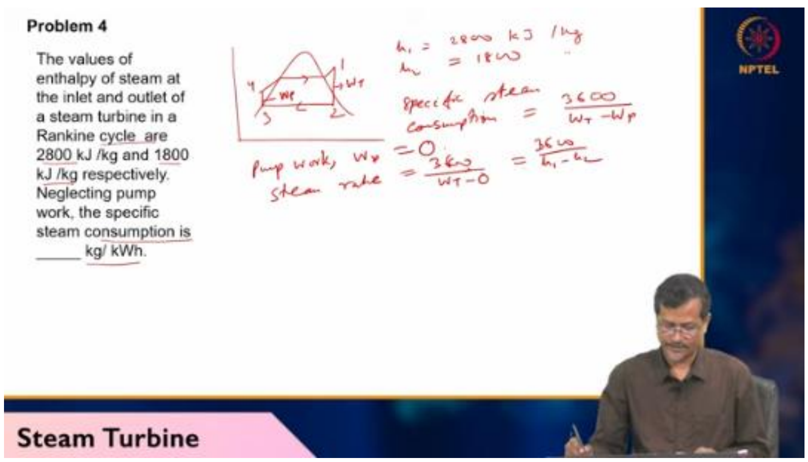
Feed water means the water going to boiler from condenser to boiler when you are supplying that steam. So, you are increasing temperature using your bleeding steam. So, whenever you are drawing this sort of diagram, you just put proper arrow diagram, proper numbering, matching numbering, left side, right side, whatever line diagram I have drawn, whatever TS diagram is there, the numbers must be matching. If there is any mistake in number, then you will not get marks. So, we will go to the problem 4.



The value of enthalpy of steam at inlet and outlet steam turbine in Rankine cycle, 2800 and 1800 kilojoule per kg. neglecting pump work so they are asking to neglect pump work so first you draw steam cycle ts diagram right so one two three four So, I am giving number randomly sometime I am starting one after boiler sometime before boiler. So, you can use your own notation there is no specific hard and fixed but everything must be correct whatever notation you use. So, H1 is given 2800 kilo joule per kg and H2 is given 1800 kilo joule per kg.

Steam rate or specific steam consumption specific steam consumption equals 3600 you can see 3600 divided by Wt minus Wp. So, specific steam consumption 3600 Wt minus Wp, Wt means this turbine work, Wp is your pump work. So, 3600 is coming for your time change. pump work Wp equals 0 it is given that we have to neglect the pump work.

Now steam rate equals 3600 divided by Wt because Wp is 0. So, it is coming 3600 and turbine work H1 minus H2. So, this is giving 3.6 kg per kilowatt hour. So, we will see next problem. So, this is from gate exam one problem was there not in your marine engineering other issues mechanical engineering gate problem.

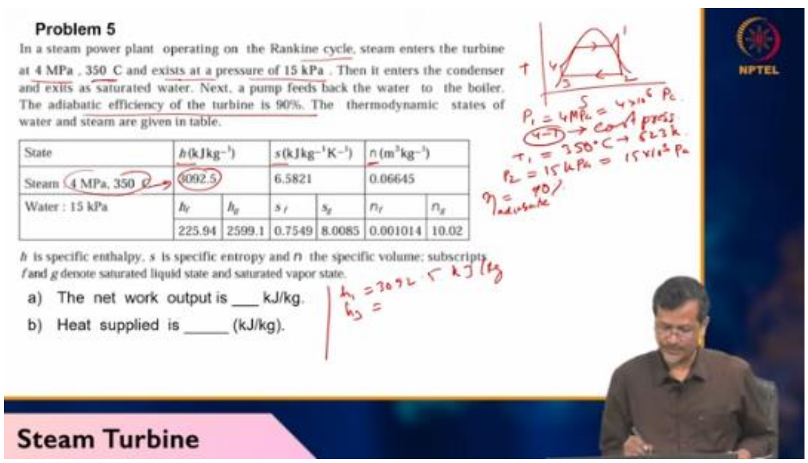


So, steam power plant operating Rankine cycle the steam enters turbine 4 MPa. at 350 degree centigrade in the steam top operand operating on the Rankine cycle steam enters turbine at 4 MPa 350 degree centigrade and exits at pressure 15 kPa so first you have to draw your steam cycle so TS diagram draw steam cycle here pump here So again numbering you put your own numbering 2, 3, 4 you put arrow symbol TS diagram. Now P1 is given 4 MPa they are saying 4 MPa steam entering the turbine. So P1 this actually 4, 2, 1 this is the same constant pressure line.

inside boiler pressure will not be changing. It will be fixed within the boiler. so this is 4 into 10 power 6 Pascal. So temperature 350 degree centigrade is given. So 623 K, 273 plus 6350, it will be coming 623.

P2 equals 15 KPa. So 15 into 10 power 3 Pascal. now adiabatic efficiency also given you can read the problem the adiabatic efficiency is 90% eta adiabatic 90% is given the thermodynamic states of water steam table actually small steam table is given here instead of giving full steam table so from there you can select the data and you can calculate so H specific enthalpy S entropy and N is the specific volume okay small n they are using for specific volume. So, we have to calculate net work output and heat supplied.

So, from this steam table you are getting H1 equals 3092.5 kg per kg this one and H3 Because you see this 4 MP and 350 degree centigrade temperature it is there. So, you are getting this one. So, H3, H3 means this condition in TS diagram you see 0.3. So, this value is coming 2 to 5, 2 to 5.94 kg per kg or you can say this one H fluid.



And Hg equals to 599.1 kg per kg. S1 equals S2 because entropy constant, S1 and S2 entropy same and Sf plus Xsg minus Sf, so it is coming from dryness fraction. x equals s2 minus sf divided by sg minus sf this is giving 6.5821 minus 0.7594 8.0058 minus 0.7549 so this is given 0.8033 Now H2. H2 equals HF again.

The same formula coming. HG minus HF. This is phase change occurring. That is why HG minus HF. HG will be having more energy because phase change occurred.

HF is fluid. Fluid will have less energy. So H2 value will be coming like this. 225.94 plus 0.8033. It is coming from here. 225.94

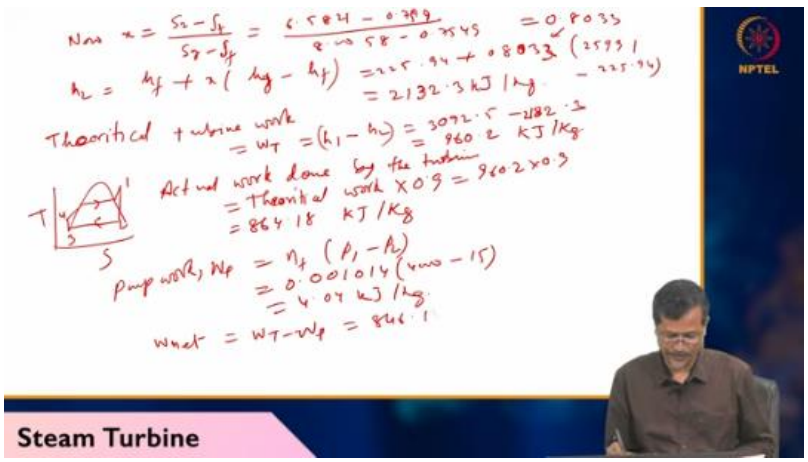
five nine nine point one minus two to five point nine four so this value will be coming to one three two point three K J per kg now theoretical turbine work theoretical turbine work equals W T equals H 1 minus H 2 Actually you should have your TS diagram every time in front of you. And we started this one 1, 1, 2, 3, 4. So I am getting H1 minus H2 turbine work. So it is giving 3092.5 minus 2132.3.

So this is giving 960.2 kg per kg. Now actual work done by the turbine. So theoretical work into theoretical work cross 0.9. Actually here some energy is lost because we are assuming theoretical means ideal one and practically we are getting little bit less. So 90% we are assuming we are getting.

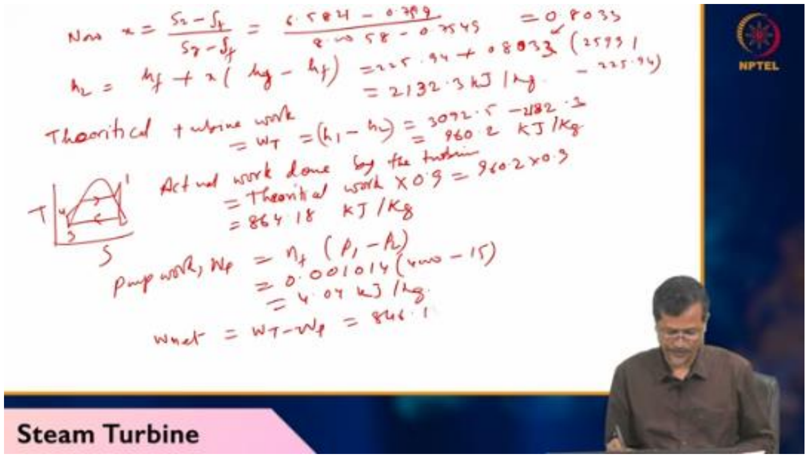
That is why 0.9 is coming and this is giving the problem actually. Adiabatic efficiency given 90%. So actually we can harness, actually we can get 90% power from turbine. So, 864.18 kg per kg. This is coming from this 960.2 into 0.9.

So, this is giving 864 kg per kg. Now, pump work. WP equals NF P1 minus P2. specific volume is given actually. 0.001014 and P1, P2 you can get from the table.

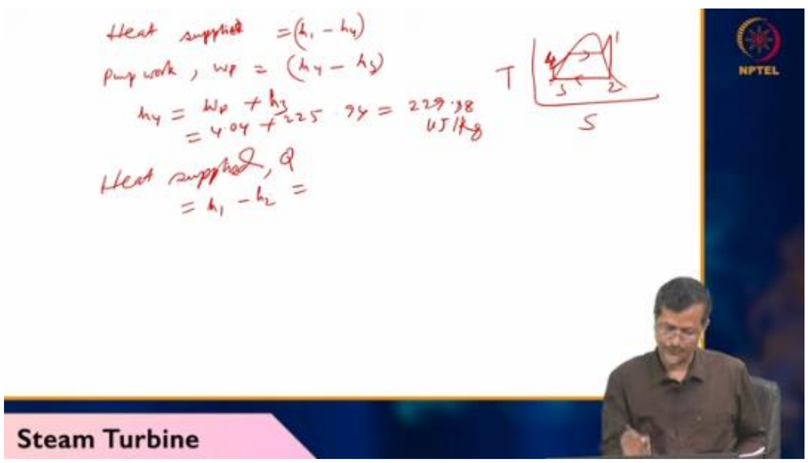
it is coming 4, 0, minus 1, 5. So, it is coming 4.04 kg per kg. W network we are getting Wt minus Wp. 864.18 minus 4.04 so it is giving 860.14 kg per kg so heat supplied heat supplied equals again TS diagram we have to draw TS 1 2 3 4 heat supplied is 4 to 1.



H1 minus H4 because H1 will have more energy than H4. So from pump work WP equals H4 minus H3. You can see this pump work H4 minus H3. This is 4. Now H4 equals WP plus H3.



equals 4.04 plus 225.94 so this is giving 229.98 kj per kg now heat supplied equals q equals h1 minus h2 Wait, why H1 minus H2? H4, H1 minus H4. So, H1 is 3092.50 minus H4 is 229.98. this is giving 2863 kg per kg.



Now, if I give mass flow rate then actually you can get total energy how much you are supplying or how much you are getting because mass flow is not given. So, thus we are calculating based on per kg of mass or steam. so yes another problem is a little bit different a coal fired steam power plant so it may be for example your steam system in your marine marine boiler heating purpose so that can be coal fired that can be liquid fired liquid fuel fire so coal fired maximum coal fired systems are replaced actually this is diesel based systems are coming up so basically maximum steam Turbines are replaced already. Okay.

Let us assume it is still coal fired is there. So coal fired steam power plant operating on a simple ideal Rankine cycle. So first Rankine cycle when I am talking. So TS diagram. Okay.

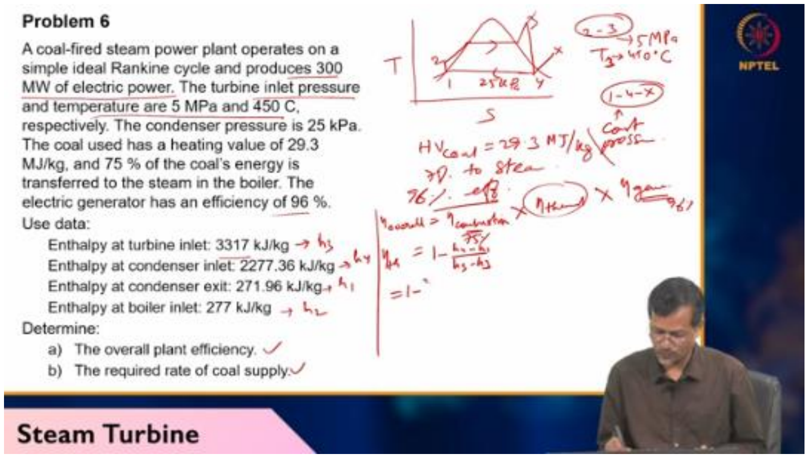
And your envelope. Now and produce 300 megawatt electric power. So how much electric power it is producing is given. Turbine inlet pressure and temperature is given. Inlet pressure and temperature is given.

okay so again numbering here one two three four you can see again i'm changing the numbering and this pressure is given because two to three pressure is same so this pressure is given five mpa okay and pressure temperature also given four five zero degree centigrade for point turbine inlet pressure that is that means T3 is given temperature at 3 is given maximum temperature the consider pressure 25 kPa condenser pressure so this pressure this is 1 okay so this 1 to 4 maybe 4 I can say Yes, I can put X. So, 1, 4, X. This is actually constant pressure line. Constant pressure. So, pressure is given 25 kPa.

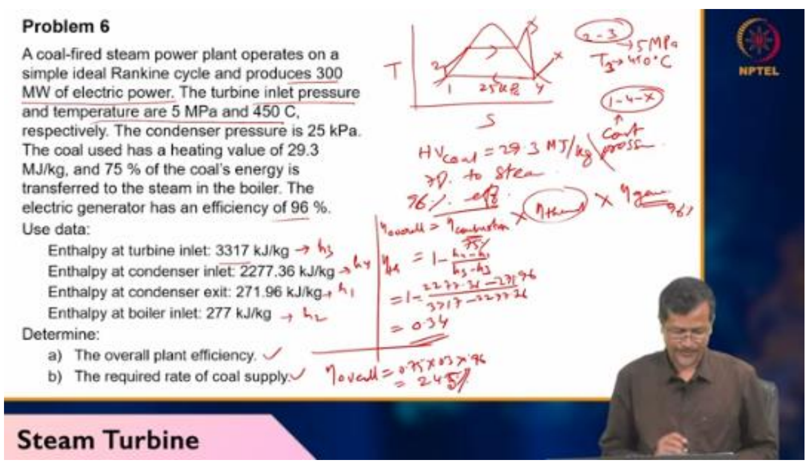
25 kPa. This one. And the coal uses heating value HCV. Coal heating value. So, I can write C heating value HV coal.

Okay. Heating value of coal is given 29.3 megajoule per kg and 75% coal energy is transferred to steam. 75% goes to steam. so some energy lost okay because flue gas will take 25 only 75 energy going to steam okay the electric generator has an efficiency 96 so electric generator you're using that is having 96 percent efficiency okay so you have to use the data enthalpy turbine inlet so h3 is given enthalpy condenser inlet condenser inlet means h4 is given enthalpy condenser exit h1 is given enthalpy boiler inlet h2 is given determine overall plant efficiency required rate of coal supply okay so eta overall eta overall equals eta

combustion efficiency combustion efficiency is the 75 percent and eta thermal efficiency eta thermal into eta generator efficiency so overall efficiency means like how much total fuel to your electric supply that much of power so combustion is having certain losses your thermal efficiency some losses in turbine and your generator also having some losses so all losses you are multiplying then you are getting overall efficiency now combustion efficiency given 75 percent generator efficiency 96 percent but thermal efficiency not given so thermal efficiency how to calculate so thermal efficiency actually you will get from turbine power and divided by your heat supplied in the boiler okay so 1 minus h4 minus h1 h3 minus h2 if you put all the values 1 minus h4 h4 is given two two seven seven point three six minus h1 h1 is given two seven one two seven one point nine six divided by h3 minus h4 h3 three three one seven minus two uh h4 two two seven seven point three six so this is giving value 0.34 percent so 34 efficiency you are getting thermal efficiency now overall efficiency eta overall So, you multiply all the terms 0.75 into 0.34 into 0.96. So, this will be giving 24.5 percent.



So, you see so low efficiency you get because of so many losses will be there. So, you are getting only 25 percent. There will be many other losses also. So, actual efficiency will be further lower because piping loss and other losses also not considered. Now, next part is there.



How much coal is supplied? m coal m dot coal coal supplied electric power output output divided by hv coal heating value of coal into eta overall efficiency overall so electric power output is given in your data so it is giving 30 mega 300 mega joule 300 30 kilojoule per second okay and your heating value is given 293 29 9300 kg per kg coal into your overall efficiency we already calculated 24.5 so this is giving 41.97 kg coal per second okay so this is your answer

Reheat cycle

$$\dot{m}_{coal} = \frac{\text{Electric power o/p}}{HV_{coal} \times \eta_{overall}}$$

$$= \frac{300\,000\ (kJ/s)}{29300\ (kJ/kg_{coal}) \times 24.5}$$

$$= 41.77\ \text{[illegible]}$$

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