Materials and Energy Balance in Metallurgical Processes

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Module No. # 01

Lecture No. # 39

Energy Balance in Industrial Furnaces

This lecture is in continuation of the lecture of additional topics, Industrial Furnaces. Why I selected this lecture is, simply to illustrate the various concepts which I have delivered in earlier lecture on Industrial Furnace. Now, here, I will be illustrating those concepts by solving few examples. Here is the example number one.

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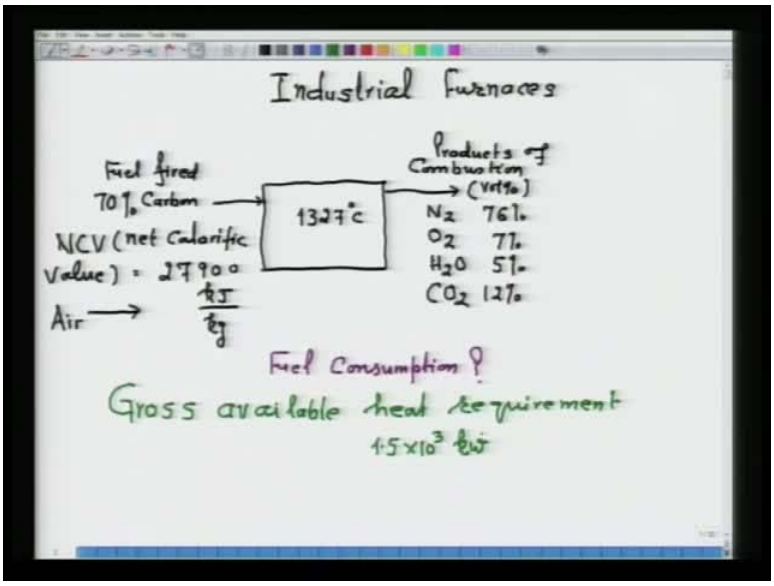

Now, in this particular example, what have I done? Let us consider a fuel fired furnace which is maintained at the temperature 1327 degree Celsius. Now, this furnace is fuel fired, having 70 percent Carbon. This is solid fuel fired or Coal fired furnace; it is given that, it has 70 percent Carbon. Here, the calorific value of this fuel that is Net calorific value - NCV of this fuel is given - 27900 kilojoule per kg.

Then, of course, for combustion, air is also passed along with the fuel so that combustion occurs inside the furnace. The products of combustion that is POC - they consist of Nitrogen, Oxygen, H 2 O and CO 2. Now, their volume percent is given - the composition is given: say Nitrogen is 76 percent, Oxygen is 7 percent, H 2 O is 5 percent and CO 2 is 12 percent; they are all in percent.

Now, what we have to find out? We have to find out, for this particular situation, what is the fuel consumption? Also, it is given that the gross available heat requirement of the furnace is 1.5 into 10 to the power 3 kilowatt - that is what is given to us.

Now, under this condition, we are required to find out what is the fuel consumption. Now, here, it is also given. If it is not given, as I have said in my earlier lecture, that when temperature or products of combustion is not given, then you can assume that the products of combustion will discharge at least at the temperature of the furnace; It cannot be discharged below the temperature; of course, not above also, but we can assume safely that it discharges, let us say in this particular problem, at the temperature 1327 degree Celsius. This is the temperature of POC. In this particular problem, air is supplied at 25 degree Celsius. Of course, fuel is also supplied at 25 degree Celsius. So, we are required to find out the fuel consumption.

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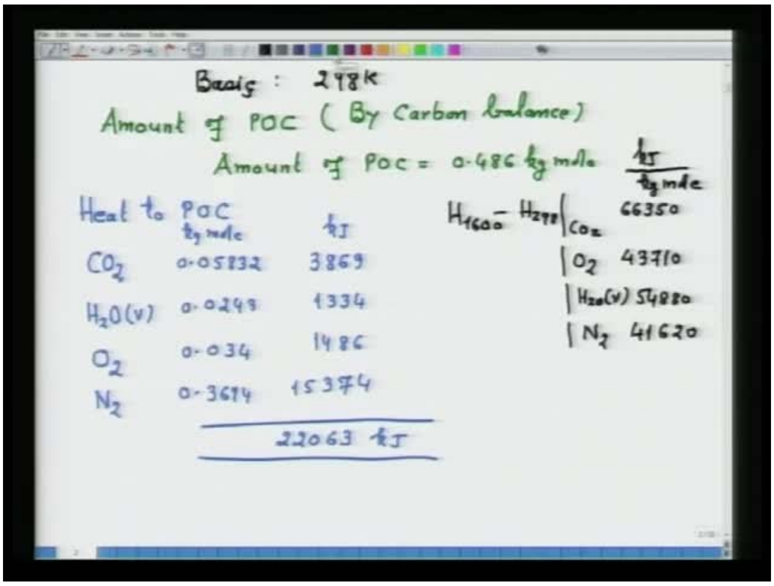

So, let us proceed now. We will select now, first of all, the basis of calculation. As I said, in all thermo dynamic calculation, consider, it is a basis is at 298 Kelvin. That is, at this temperature, the heat content value should be known to us. Now, first of all, in order to calculate the fuel consumption, we have to know - what is the amount of heat that is carried away by POC. If we know that amount of heat which is carried away by POC and if we know the calorific value, then we can calculate gross available heat per kg of the fuel. We are already given with the gross available heat requirement. If we divide both with the gross available heat per kg of the fuel, then we get the fuel consumption. So, just like that.

So, first of all, we have to calculate the amount of POC. Since I have calculated this on several occasions, you can to do the Carbon balance. You can assume that as, say Y kg mole of POC and you can do the Carbon balance. You cannot do anything else except Carbon balance because the Coal is having 70 percent Carbon and nothing else is given.

So, in this particular problem, the approach would be to go from the POC side and then to calculate. So, here, first we will calculate amount of POC, and this can be obtained by Carbon balance. So, if we do the Carbon balance, straightaway I will write down, the amount of POC for this particular problem - that will be equal to 0.486 kg mole per kg of Carbon. Now, since we know the amount of POC, we calculate the heat to POC. Now, we are in a position to calculate heat to POC.

In order to calculate heat to POC, we have to calculate the heat content of the various components of the POC - that is Nitrogen, Oxygen, H_2O and CO_2. Now, remember here, Net calorific value of the fuel is given. So, by definition in the calculation of net calorific value, the state of the product of combustion is chosen as vapor because the H_2O is in the vapor state. So, while calculating the heat carried by products of combustion, you should also select the reference state – gaseous, and their H_2O is in the vapor state.

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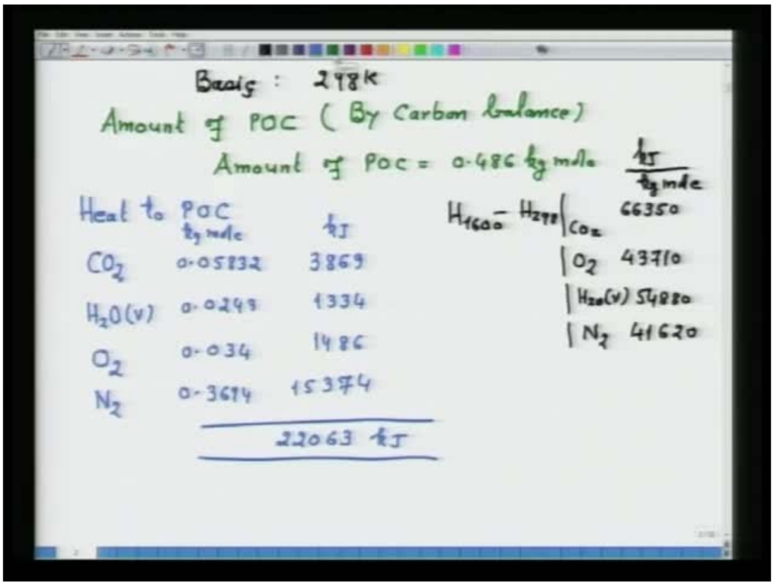

Now heat to POC: first of all, I give you the values of the heat content. The heat content of various components are H 1600 minus H 298 for CO 2, for O 2, for H 2 O vapor; mind you - these are at 298 Kelvin and of Nitrogen. For CO 2 this value is 66350; For O 2 – 43710; for H 2 O vapor – 54880; for Nitrogen – 41620. These values are given in kilojoule per kg mole. So, now, heat to POC is straightforward form to calculate. I will write down first of all CO 2, then H 2 O vapor, then Oxygen and then Nitrogen.

Now, I can calculate kg moles because I know the amount of POC. So, CO 2 will be 0.05832, H 2 O vapor is 0.0243, O 2 is 0.034 and Nitrogen is 0.3694. So, I can calculate now heat carried by each component of the flue gas or products or combustion in kilojoule. So, for CO 2 it is simply multiplied by CO 2 value, heat content CO 2 per kg mole with the kg mole. So, this will be 3869, I have rounded off, 13341486 and 15374. So, if you sum it, the heat to POC will be 22063 kilojoule.

Now, since we know heat to POC, we can calculate the gross available heat per kg of the fuel.

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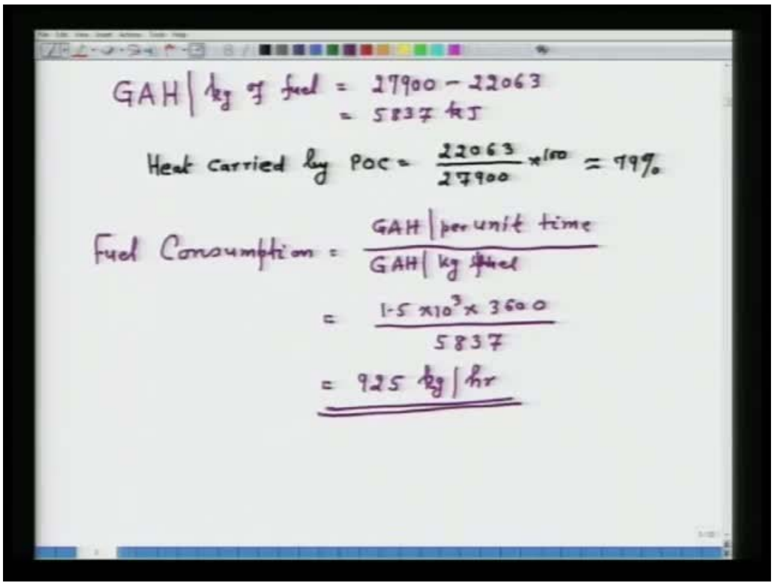

GAH - gross available heat per kg of fuel, as I have done in a previous problem that is equal to 27900 is the calorific value of fuel minus 22063. Heat to POC - that value is 5837; this is kilojoule. Now, you see that much amount of heat is available. If you just do a simple calculation, then you will note that, out of the calorific value of the fuel that is 27900, the heat carried by POC, if I just calculate in percent, heat carried by POC is equal to 22063 upon 27900 into 100. A simple calculation will give you - approximately 79 percent of the calorific value of the fuel is carried away by flue gases. That means in this particular problem, the 21 percent of the calorific value of the fuel is utilized by the useful part of the function, which is the heating air; 79 percent is carried away by the flue gases.

So, higher is the temperature, more percentage of the calorific value will be available to you in the products of combustion; of course, lower is the temperature, lower amount will be available. Now, this particular thing will constitute a different dimension of the capturing of the energy. You are seeing that a large portion of the energy is still available. 79 percent of the calorific value of the fuel which is still available to you, depends on what you do with that available heat in the products of combustion.

Now, before this, we can calculate fuel consumption. We can now calculate fuel consumption which is gross available heat required per unit of time divided by gross available heat per kg of the fuel; here, of course, per unit of time.

So, we know, the 1.5 into 10 to the power 3 is what it is joule per second; so, into 3600 divided by gross available heat per kg of the fuel. We have calculated 5837. So, you note that, the fuel consumption is 925 kilogram per hour. So, this is the fuel consumption when the furnace is operated by 70 percent Carbon of the fuel, and POC or the heat to POC is at 1327 degree Celsius. Now, the question before us is - can we cut down the fuel requirement? The answer is yes.

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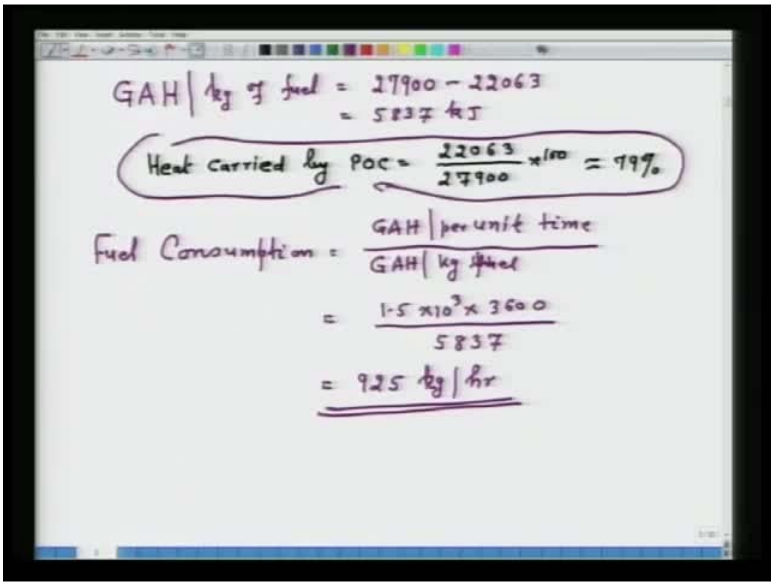

In the same process, we can do that. How will we do that if we analyze this problem? You note that the heat carried by the POC is of considerable amount that is of the order of 79 percent. What we can do with that?

We can let it go waste because it is joule; the 79 percent of the calorific value is in fact the fuel, where fuel is the calorific value. So, that means it is going to waste. So, the first thing that should come into your mind after this analysis is - you should think of the ways how can we use the sensible heat of products of combustion in order to cut down the fuel requirement? Now, by cutting down the fuel requirement, you are doing two functions simultaneously.

One - you are cutting down the fuel requirement as well as you are reducing the Carbon emission to the environment. This is what I am going to illustrate by the same problem. I am continuing and putting as part b.

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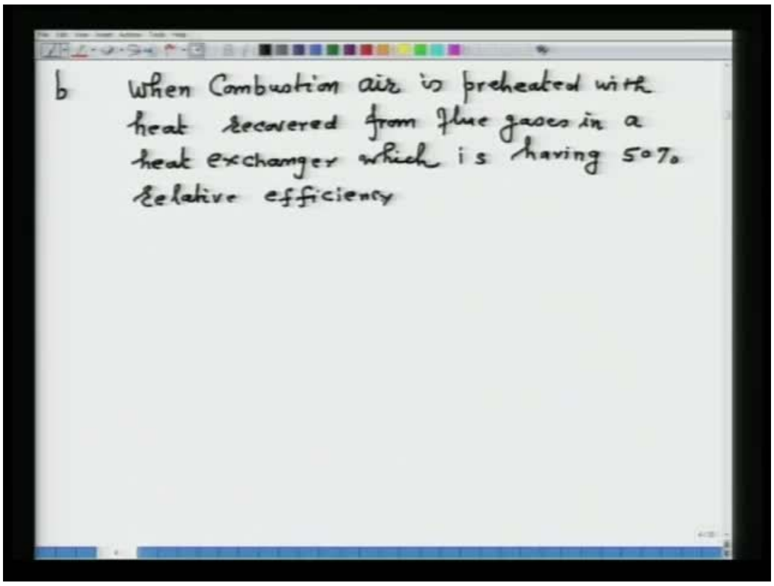

What I am telling is when combustion air is preheated. Now, important is, with heat recovered from flue gases, there is no point if you preheat the air by combusting extra amount of fuel; then you have not done a very intelligent job. The intelligent job that you have done is that, you are preheating air by recovering the heat which is going with the POC; that is the important thing, my dear friends.

So, it is preheated with heat recovered from flue gases, flue gases or products of combustion - one and the same, in a heat exchanger which is having 50 percent relative efficiency. This concept I already introduced to you in my earlier lecture on industrial furnace.

So, this is an intelligent way. You are capturing the heat and trying to reuse it. So, with that, you are reducing the fuel requirement; bound to reduce. Because of the amount of heat you are supplying now, fuel consumption will be reduced; so, fuel saving, contributing to the energy saving and also contributing to the environment cleanliness because then you will be discharging less Carbon into the atmosphere. That is what I am going to illustrate now.

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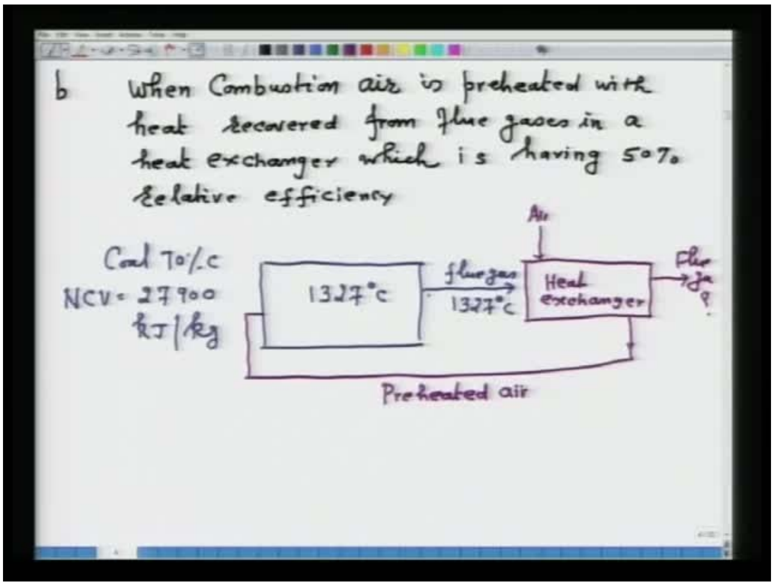

So, let me represent this particular problem. What have I done? I have done the same thing. This is my furnace, as usual operating at 1327 degree Celsius. Coal - 70 percent Carbon, NCV - 27900 kilojoule per kg. Now, this is a flue gas or products of combustion - one and the same thing. The composition is same as it was earlier; so, there is no need to write here. The temperature discharge is at again 1327 degree Celsius.

Now, what do I do? I teach now, a heat exchanger; so, I put a heat exchanger; this is heat exchanger. Now, the objective of heat exchanger is to extract the heat of POC and transfer it to the air, incoming air. So, here somewhere I put my air which I require for combustion. In (a) part, it was not preheated; now, the same air - I am preheating it. So, air and here is the outlet for air and here is the flue gas (Refer Slide Time: 19:08).

Of course, its temperature, you have to find out from heat balance. Presently, it is not our objective. So, what we are doing now? We are taking air from here and we supplying this air into this furnace. So, here we have a preheated air. Now, in the preheated air…, so, that is what now our loop is.

Now, what we have done in the furnace? We installed a heat exchanger; it extracted the heat, and heat the combustion air.

So, now we have to calculate back, the fuel consumption. Of course, we have installed a heat exchanger; we have invested certain amount of money; we want see what profit it brings; how much it can save? So, again, we have to calculate the so called heat to POC, then heat recovered, and again, we have to do the heat balance. So, let us do that.

Now, first of all, since we are preheating the air, we have to find out the amount of air. So, the first thing is that.

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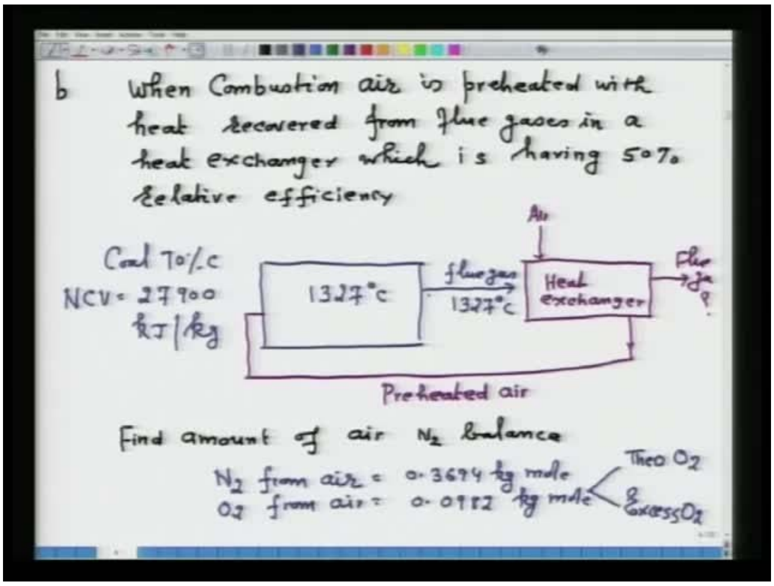

You have to find amount of air because we are preheating the air. Only heat is being put into the furnace through preheated air and nothing else. So, find amount of air - how can you find out amount of air? In several occasions, how have you done? You will do the Nitrogen balance; you will perform the Nitrogen balance. So, if you perform the Nitrogen balance, the Nitrogen from air - that is equal to 0.3694 kg mole because all Nitrogen of air goes into the products of combustion, provided the Coal does not contain any amount of Nitrogen because there is no composition given over here. So, you can do nothing from the Coal side; all that you can do from the products of combustion side.

Similarly, we can then find out Oxygen from air; say, 79 21 percent. So, that will be 0.0982 kg mole. Now, mind you, this air which you have calculated 0.092 - it consist of theoretical Oxygen as well as excess Oxygen as well as both; just for your information. So, now, we know the amount of air. So, next thing we can calculate now - the relative efficiency.

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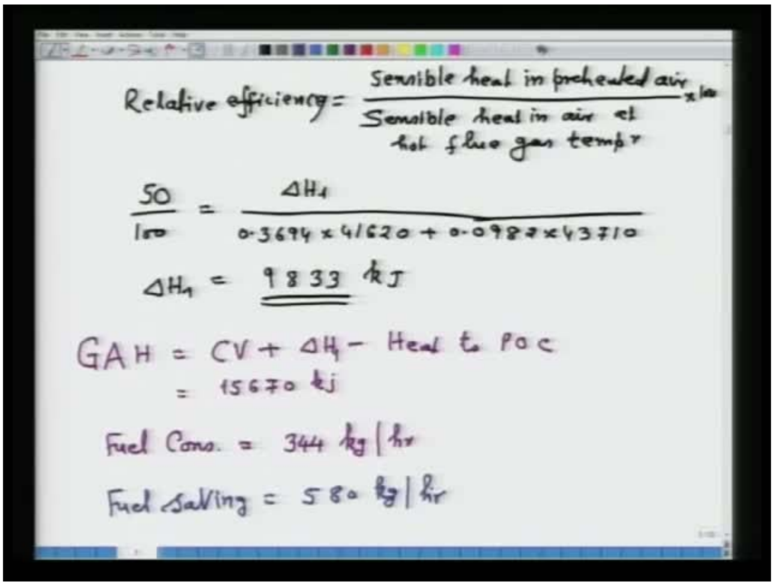

We can calculate relative efficiency. As already you know, that is equal to sensible heat in preheated air upon sensible heat in air at hot flue gas temperature; already, I have illustrated how to calculate this.

Now, here, relative efficiency is given. So, what we can calculate? Relative efficiency is given. So, we can calculate sensible heat in air at hot flue gas temperature. Hot flue gas temperature is 1327 degree Celsius. The heat content values are given. So, you can calculate both things. So relative efficiency let us take as 50; of course, it is multiplied by 100. So, when I do percent, that is fifty by hundred that is equal to preheated air is delta H 1. So, this will be equal to 0.3694 into 41620 plus 0.0982 into 43710 - that is what we will calculate. So, this calculation comes delta H 1 that is equal to 9833 kilojoule. That means that much amount of kilojoule you are able to recover from the heat which was taken away by products of combustion by installing a heat exchanger.

So, now the gross available heat would be - calorific value of this fuel plus sensible heat of air minus heat to POC, or let us put as delta H 1, heat to POC. So, everything is known. Now, this value will be equal to 15670 kilojoule.

Now, I can calculate. Fuel consumption heat requirement is the same – 1.5 into 10 to the power 3 kilowatt. I have illustrated through the earlier formula. So, this fuel consumption now will be coming 344 kilogram per hour.

What do you think now, my dear friends?

By installing a preheater, now you are consuming for the same heat requirement 344 kg per hour. So, what will be the fuel saving? Fuel saving by installing a preheater or exchanger - that will be equal to 580 kilogram per hour.

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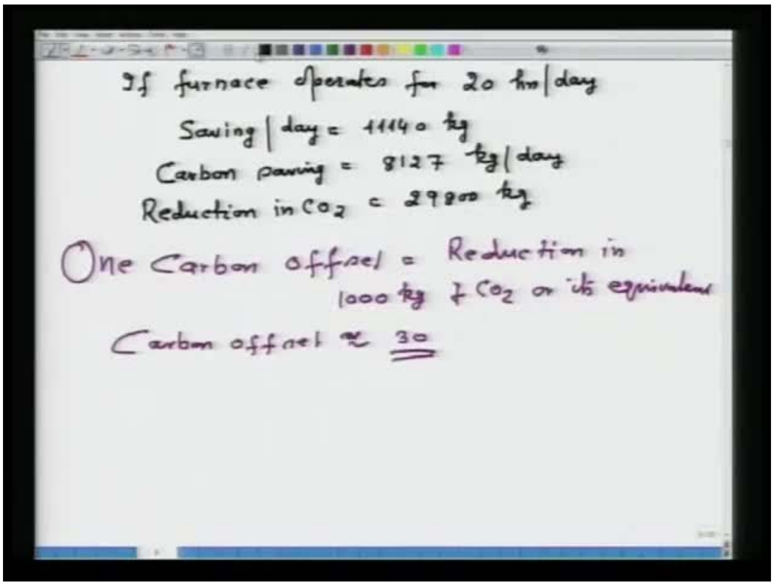

Now, extending this thing per (( )), let us say, if now furnace operates for 20 hours per day, then saving per day will be equal to 11140. So, this will be in kg. Now, the Carbon saving is the fuel. Carbon saving would be 70 percent of this; 8127 kilogram per day you are saving Carbon. Now, this is equivalent to reduction in CO 2; reduction in CO 2 - that will be equal to 29800 kg. How is it? C plus O 2 is CO 2. Same you have convert to kg mole; multiply by 44. So, you are reducing that much amount of Carbon dioxide.

Now, here comes the concept of motivation. The motivation is - you can earn this Carbon, that is so called Carbon oxide or Carbon credit, and that is available to you.

Whereas, to define a Carbon offset which is a financial instrument which is aimed at a reduction in greenhouse gas emissions, typically, it has come from the concept of Kyoto protocol and so on, to encourage the high temperature users based on the fossil fuel that well you earn Carbon credit or you Carbon oxide.

Now, how can we earn? Carbon oxides are measured in terms of metric tons of CO 2 equivalent. That means how much amount of CO 2 we are saving; that is your Carbon oxide. So, for this say one Carbon offset that is equal to reduction in 1000 kg of CO 2 or its equivalent; equivalent means, suppose we are reducing other NOX of water then it is 1000 kg CO 2.

So, in this case, Carbon offset or Carbon - they are same thing. We can call Carbon offset or Carbon credits are same thing. That will be approximately, 30 Carbon credits you are storing per day. So, we can imagine now per month or per year and so on. So, this is the illustration of this.

Further if you think, this is one way of reduction of the fuel.

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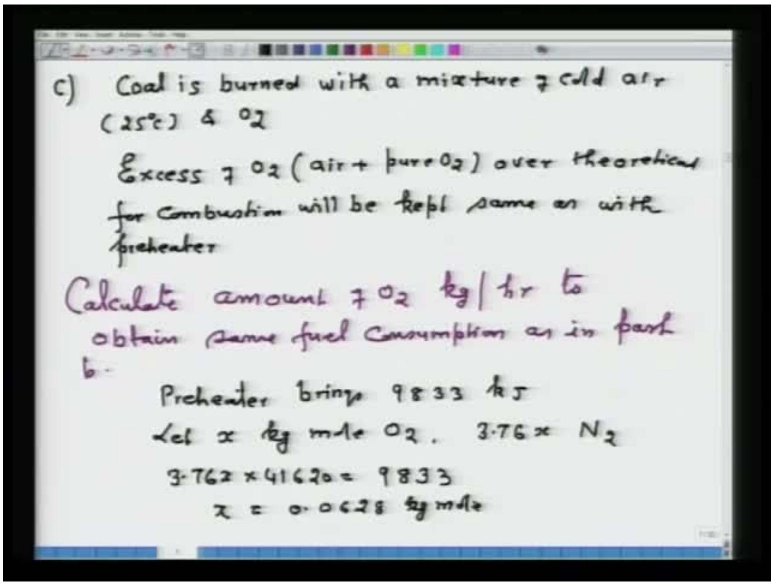

Now, suppose, if you do not have a heat exchanger, but Coal; Part (c) - there is no heat exchanger. Now, Coal is burnt with a mixture of cold air which is 25 degree Celsius and Oxygen; no heat exchanger - that is the condition.

Now, excess of Oxygen the condition is excess of Oxygen that is in air plus pure O 2 that you will be supplying over theoretical for combustion will be kept same as with preheater. That means whatever amount of heat that you added through the preheater that will not be added now, but then, that you have to compensate it somewhere by adding Oxygen.

Now, what we have to calculate? Calculate amount of Oxygen in kg per hour to obtain same fuel consumption as in part (b). So, now what is required to be done? That is, you have to obtain this same fuel consumption, but without preheater, as you got in part (b). Now, this objective can be attained because excess of Oxygen, you have to keep the same. How can you attain this particular objective? You have noted that, every last percentage of heat is carried away by Nitrogen. So, if I reduce the amount of Nitrogen, then I can do my job.

So, let us solve this particular problem. We note that preheater brings 9833 kilojoule of heat. When preheater is not used, then Nitrogen of the flue gas must be reduced corresponding to the amount of 9833 kilojoule; then my job is over.

So let us consider let x kg mole. O 2 is now required. Then 3.76 x will be the moles of N 2. So, that means 3.76 x into 41620 - that will be equal to 9833. So, the amount of x, that I can calculate is 0.0628 kg mole. That much amount of Oxygen if I add, then I will be removing Nitrogen and hence the less amount of heat will be carried away by Nitrogen. Hence, I equal into 9833.

So, whatever amount of heat which preheater was bringing, now, I have cut down that heat by reducing the amount of Nitrogen; that is the only trick.

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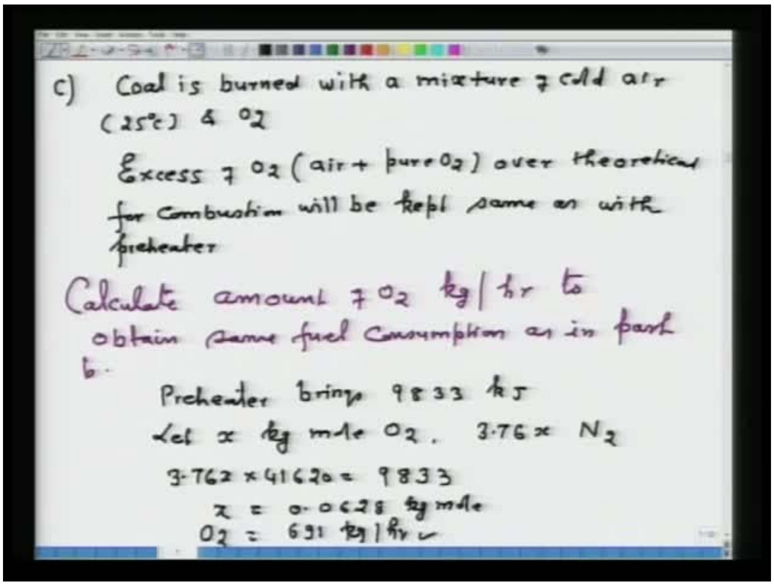

So, now Oxygen, I can calculate. The Oxygen will come 691 kilogram per hour because I know the fuel consumption already given to you. So, from that, you can get the amount of Oxygen; that is 691 kg per hour. So, what my objective of illustration of this particular problem is that, there are several ways in which one can cut down the fuel requirement and hence the concept of Carbon credit.

Now, I will give you another problem. So, you can think and you can do that.

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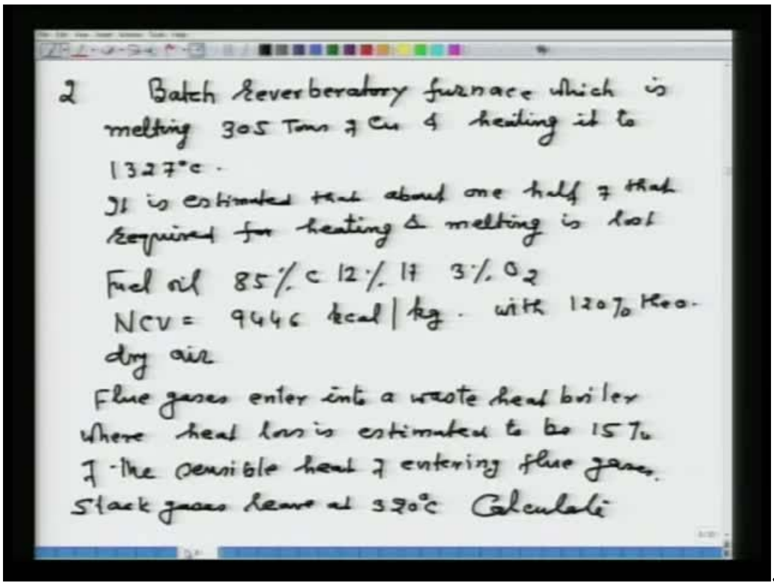

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Now, another problem is like this: the problem number 2. Let us consider a batch reverberatory furnace which is melting. I mind you, which is melting 305 tons of Copper and heating it to 1327 degree Celsius. Now, it is estimated that about one half of that required for heating and melting for heating and melting is lost. That means, the heat which is required for melting and heating - half of that is being lost.

Fuel oil is used whose composition is 85 percent Carbon, 12 percent Hydrogen and 3 percent Oxygen. Its NCV - that is equal to 9446 kilo calorie per kg, burnt with one 120 percent theoretical dry air. So, flue gases enter into a waste heat boiler. So, here instead of a heat exchanger, what we have done? We have installed a waste heat boiler.

Now, waste boiler is a typical appliance for heat recovery and converting water into a steam. It is very important heat recovery device. Where, in the heat boiler it is said that heat lost is estimated to be 15 percent of the sensible heat of entering flue gases. That is, only 85 percent of the heat is recovered and 15 percent is lost which is of only Stack gases. That means the gases from the boiler leave at 320 degree Celsius.

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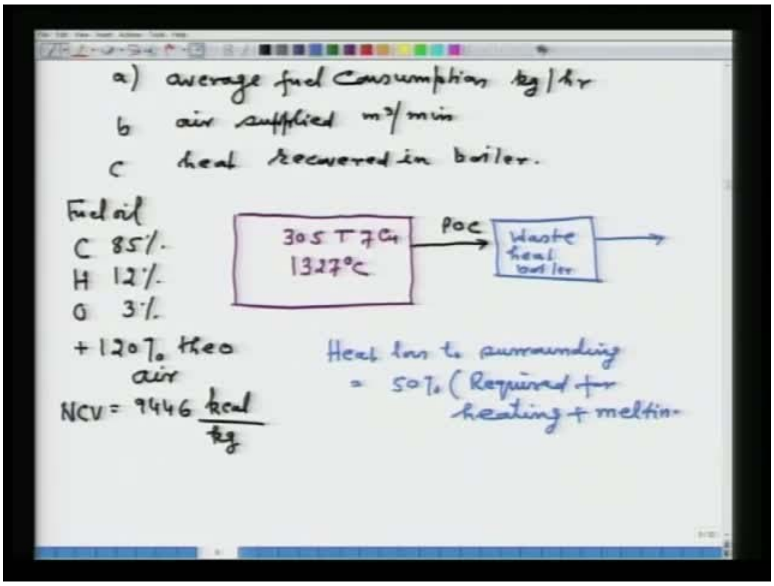

Now, you are required to calculate average fuel consumption, air supplied, and heat recovered in boiler. If you wish, you can also express that heat recovered in terms of calorific value or whichever ways you like do it.

So, I will just give you the hint to solve this particular problem. I will omit few steps so that you can fill in that blanks and you can solve the problem.

Now, first of all, I will illustrate. I will say just draw a line diagram. So, what this problem tells is that, we have say 305 tons of copper which is melting and its temperature is raised to 1327 degree Celsius. Now, this is an oil fired furnace; that is a fuel oil, and its composition - you have Carbon, you have Hydrogen, you have Oxygen; Carbon is 85 percent, hydrogen is 12 percent and Oxygen is 3 percent. It is burnt with plus 120 percent theoretical air.

Now, its NCV is also given; that is 9446; it is given in kilo calorie per kg. Now, the POC which is being discharged from here is taken to a waste heat boiler. Somewhere here (refer Slide Time: 37:37), we have a waste heat boiler and from the waste heat boiler, the gases are discharged at a particular temperature.

Now, here say heat loss is estimated to be 15 percent from the waste heat boiler. Heat loss to the surrounding is given; say, heat loss from the furnace part. Heat loss to surrounding - that is equal to 50 percent, that required for heating and melting, heating plus melting; that is all given to us. So, now we have to calculate the fuel consumption.

Now, as such, first of all, we have to calculate the material balance and then we have to do the heat balance.

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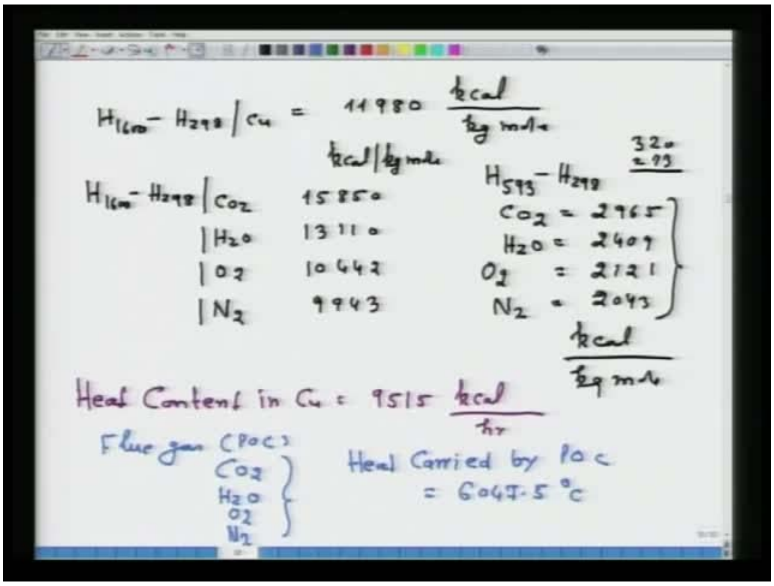

So, here, now let me give you some values that will be requiring say it is given say for example, the heat content that is H 600 minus H 298 for Copper. It is given 11980 kilo calorie per kg mole - that is given to you.

Now, say H 1600 minus H 298 - this is for CO 2, for H 2 O, for O 2 and for Nitrogen - that is given. 15850, 13110, 10442, and 9943 - this is given in kilo calorie per kg mole.

Now, the flue gases after the waste heat boiler have been discharging at 320 degree Celsius. So, these values are given, say H 320 plus 273 that is 593 minus H 298 - these values are given. Again, for CO 2 that is equal to O 2 – 965, for H 2 O, this value is 2409, for say O 2 this value is given 2121, and for Nitrogen, this value is 2043; again, all their units in kilo calorie per kg mole.

This value will be needed while doing other parts of the problem. So, first of all, you can calculate heat content in copper because you have to find out the losses. So, heat content in copper all the values are given; you can convert kg to kg mole, and so on. So, heat content in copper - that will be equal to 9515 kilo calorie per hour.

Now, again, I can find out the amount of flue gases. Take one kg of the fuel; compositions are given. So, we can find out the flue gases or products of combustion. So, we have CO 2, H 2 O, O 2 and Nitrogen. So, you can calculate their respective amount - kilo calorie per kg mole at the respective temperature of the discharge. The products of combustion are discharging at 1327 degree Celsius. So, you can calculate all and the heat carried by POC should come of the order of 6047.5 degree Celsius.

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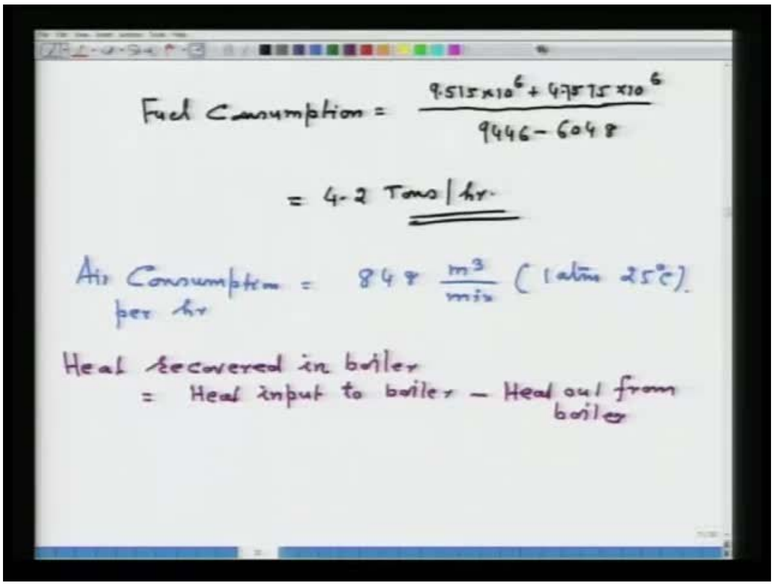

So, I can calculate now, the fuel consumption, that is, the heat required per unit of time.

You know the heat you will require for melting and heating of the Copper that 9.515 into 10 to the power 6 and plus half is being lost; so, plus 4.5 a sorry 4.7575 into 10 to the power 6. This is the heat required for melting and rising the temperature to 1327 or (( )) 1600 Kelvin and then half of it is being lost. So, that much amount of heat is required per unit of time. Available heat is only 7446 minus heat to POC 6048. So, fuel consumption is coming 4.2 tons per hour. That is a equal to 4.2 tons per hour; that is what is the answer for part (a).

We can now easily find out the air consumption. Of course, you have to do the Nitrogen balance and then you know the fuel consumption, and so on. So, if air consumption per hour we have to find out, that will come 8048 meter cube per minute. I hope you can calculate the tonnage is give and air amount is given. So, you can find out that is at one atmosphere and 25degree Celsius; this is the part (b).

Now, the next thing that comes is the heat recovered in boiler. We have to calculate heat recovered in boiler. What will be the heat recovered in boiler? Very simple; that is, heat input to boiler minus heat output from boiler. That is the heat that is stored in the boiler. Heat is being input at 1327 Kelvin of which 15 percent is lost. So, only 85 percent is recovered. The heat output from boiler - that is heat taken by POC after exiting from the boiler, that is at 327 degree Celsius. The amount remains the same. The amount is not being utilized anywhere; only heat being extracted.

So, amount is the same and the temperature is different. You can calculate heat output from the boiler from the sensible heat value which I have given to you; heat input to the boiler, we already calculated, and then 85 percent you take it. So, this value, heat recovered in the boiler - that will come 3928 kilo calorie per kg of fuel.

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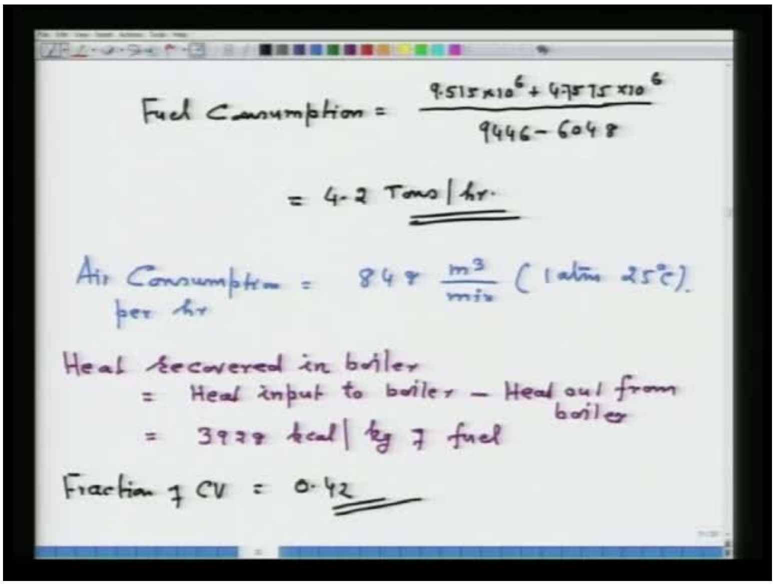

Right now, just for information, fraction of CV recovered, because we are always interested. All these - heat to POC, heat recovered, they are all a fraction of the calorific value of the fuel because the source of thermal energy is the calorific value of the fuel. So, it is always i mean to know what fraction you are able to recover that is the important thing.

So, fraction of calorific value of Coal that is recovered is equal to 0.42. Simply divide 3928 by the calorific value of fuel and you get this value. So, this is in short, for problem number 2.

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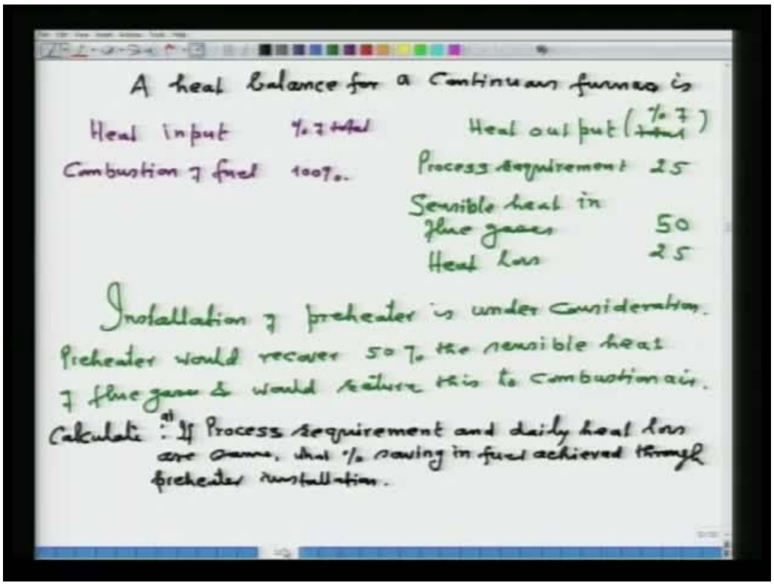

Now, let me see another problem. Now, this problem I have given. In case you are working on a shop floor for a long time on the furnaces, and all of a sudden your management has come, and asks you that – look, this is the heat balance for which you are operating for very very long years. I have got an idea that I can save the fuel because I have heard that, if I recovered the heat from the flue gases, I can save the fuel. That means I can reduce the fuel consumption.

So, my dear engineer, you are being here; a very simple problem is there; can you convince me, whether by installing a preheater, what advantage I am going get in my company?

So, here is the problem. You are simply given to heat balance of a continuous furnace. He has told you that heat input, slowly from combustion of the fuel that is 100 percent of the fuel. That is all. 100 percent of the total heat is being supplied by combustion of the fuel.

Now, heat output – again, percentage of total is given. Remember, the process requirement is 25 percent of the total, sensible heat in fuel gases is 50 percent and heat lost 25 percent.

Now, he tells you that, I am considering installation of a preheater.

What is given to you is that. Preheater would be able to recover 50 percent of the sensible heat of the flue gas and all that 50 percent you recovered - it would be available to you in the form of combustion air. That means 50 percent of the heat preheater will recover and the same 50 percent will be given to the air for preheating.

Under this condition, you let me know, what will be the percent saving in fuel through preheater installation, when the process requirement and daily heat lost are kept same. I think you understood the problem. He is very clear in his mind. I want to know from you, if I install a preheater because that involves a huge amount of investment, what percent saving in fuel I will get, if the process requirement and daily heat loss are same? This is his query number one.

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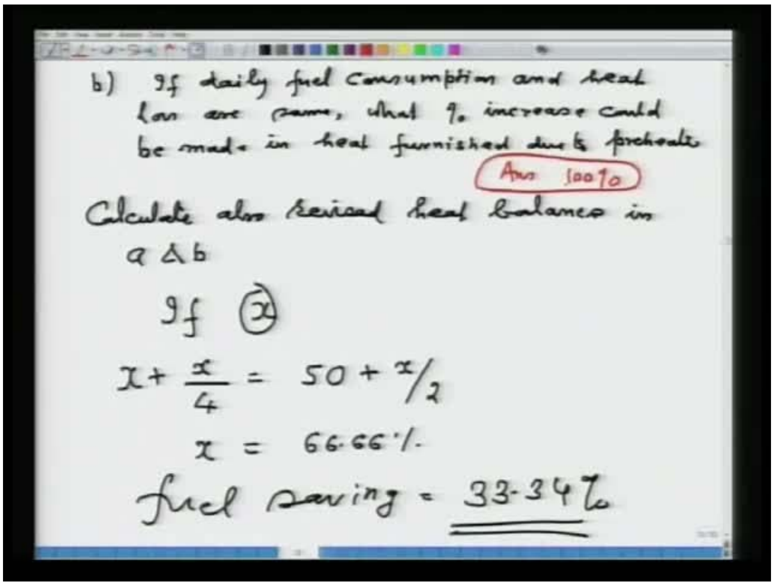

Now, his query number 2 is if the daily fuel consumption and heat loss are same.

Now, here, heats are different, he is telling. If the daily fuel consumption and heat loss are same, what percent increase could be made in heat furnished due to installation of preheater.

There are two things: I install a preheater, naturally I will cut down the fuel requirement; I install a preheater, I do not cut down the fuel requirement. Then, there will be excess heat in the furnace. What percent increase in the heat I will be getting?

So, take out your pen and pencil, and notebook. Convince your management that - look sir, if you install a preheater, that much amount of fuel you are going to save; if you do not want to save fuel, then you can increase the efficiency of the furnace. Here, since you are using for melting, you can tell him – sir, if you do not cut down your fuel, you will be increasing the efficiency of the furnace, that is more output will be there and more money will come into your pocket. So, that is what we have to tell him now.

I will just give you the hint. If suppose you are having what (a) is telling, the process requirement in daily heat loss is the same and what percent saving in fuel will be achieved. That means, now, the fuel will not be 100 percent; fuel will be some x percent because we are saving the fuel. So, if x is my percentage fuel through which I am supplying the heat of x, x by 2 will go in the flue gas because in the beginning, 100 percent, 50 percent was going into flue gas.

Now, x is the renewed fuel consumption; x by 2 will enter into the flue gas; out of x by 2, half will be recovered. So, I will be recovering x by 4.

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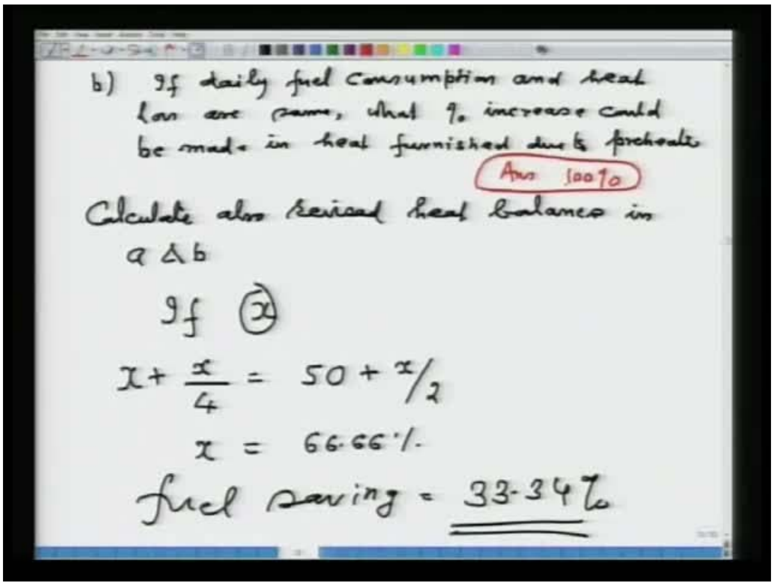

Now, my heat balance would be input x due fuel plus x by 4. That is coming by the preheater installation and that will be equal to 50 because I have to keep the process requirement, heat loss, are same. 50 plus x by 2 is the heat taken by the flue gas.

Now, look now, what I have done? x is the percentage of fuel. Now, you are required to burn of x. x by 2 will be carried by the flue gases from x by 2; half you will recover; so, x by 4 will be recovered. So, heat balance - x plus x by 4. 25 for the process requirement, 25 for the heat loss - that you to kept same plus x by 2 - that is a flue gas. So, I get the value of x. Very simple. 66.66 percent; so, the fuel saving now would be 33.34 percent. Look at how convincingly you can tell him that, you can save that much amount of fuel.

Now, the part (b), I leave it to you to think it over and to do it, and the answer part (b) will come that you can increase the efficiency. The answer for this is that, you can increase the efficiency of preheating if you do not cut down the fuel requirement 200 percent.

So, try to get this answer and feel happy that you have got the answer and you understood the problem.