# Materials and Energy Balance in Metallurgical Processes

**Prof. S. C. Koria**

**Department of Materials Science and Engineering**

**Indian Institute of Technology, Kanpur**

**Module No. # 01**

**Lecture No. # 27**

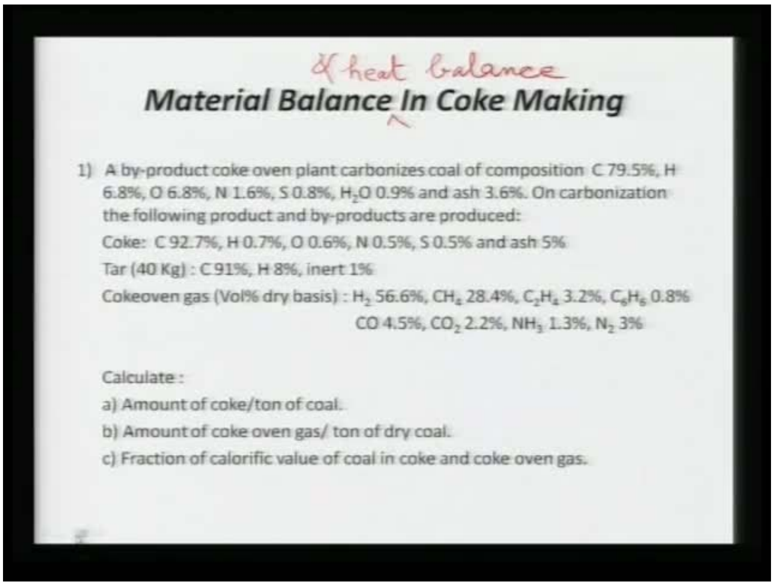
**Coke Making**

(Refer Slide Time: 00:21)


We will be discussing in this lecture material balance and heat balance in coke making. The basics of coke making, the raw materials input and product output have already been discussed in an earlier lecture.

Now, here I am giving you few problems. You may also consider they are the self assessment exercise. Out of the three, I will try to see how much problem I am going to take. Maybe I will taking one of the problem and rest you can solve yourself. So, here we go with the problem number 1.

(Refer Slide Time: 00:49)




Typically, in the coke making industry, a byproduct coke oven is used to produce coke from coal and all of you know that coal is heated out of contact of air. You can also call this process as carbonization.

A byproduct coke oven plant carbonizes coal of composition and this is given to you as carbon, hydrogen, oxygen, nitrogen, sulphur and so on.

On carbonization, the following product and byproducts are produced. I am considering coke as a product because that is what is required from coke oven and rest all I am considering as a byproduct.

So, coke composition is given. You should also note this problem as information about the various compositions that enter typically in the coke making process. Coal composition you should also note and coke composition you should also note. You should also see the analysis of coke. It contains typically sulphur also and you should see that when this coke is used in the blast furnace, the sulphur from coke is one of the sources of sulphur in pig iron.

So, one has to control the sulphur also. However, this sulphur you can only control by controlling the amount of sulphur in the coal.

That is what we should see in the analysis which is given here. You should also see ash. Though in this particular problem, the ash content of the coke is extremely low - 5 percent ash is a very wonderful coke to be used in the blast furnace because the ash which is produced during combustion of coke in the blast furnace directly enters into the slag and it increases the volume.

So, lower the amount of ash better is the operational features of the blast furnace iron making.

It is in this perspective you should also look at the various compositions, input and outputs of the problem. Do not think that it is mainly to solve the problem. You should also see all those important points and make a feel about the various inputs and outputs and their effect.

Normally, the ash in the coke is 10 to 12 percent or Indian coke still has a higher content of ash. Ash also contains Si O 2, Al 2 O 3, calcium oxide, magnesium oxide, all inorganic oxides are present. Most of the oxides are present in the ash. So, it increases the volume of the slag.

Tar, I will consider as a byproduct; its composition is also given. You can see from your carbon and hydrogen, it is also a byproduct which can be used for production of energy because it contains the combustible component that is carbon and hydrogen.

It is a very good fuel. It can be a very good fuel provided you think of its use in the subsequent processes.

You see the composition of the coke oven gas. If you look very seriously over here, you will find that hydrogen, methane are in main proportion around 56.6 percent and 28 point some percent.

Hydrogen and methane, they are highly combustible component and if used properly, you can generate a large amount of energy from the coke oven gas which is coming out of the byproduct coke oven.

You should also see that this amount that you will be producing on per day basis because you will be using around 10000 tons of coke or more than that.

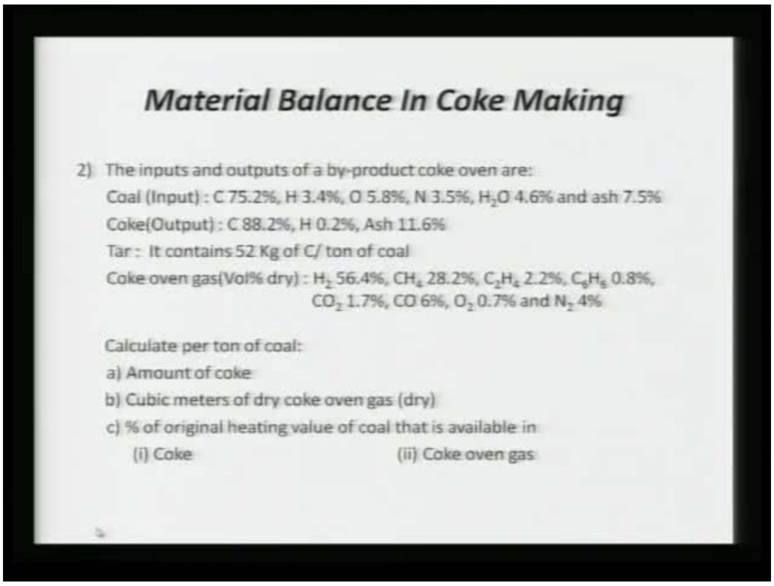
So, that much amount of coal and that much amount of coke oven gas will be produced. Accordingly, I wanted to say that those aspects of the problem should also hit your mind to see what one can do from the byproduct also.

The product coke is used because that is for this purpose we have implied the process. Coke has to be used, but then the byproduct; what is to be done? Byproduct may contain a huge amount of energy as in case of coke oven gas, as in case of tar it contains huge amount of energy; what is to be done?

As an engineer, you should also give a thought to the byproduct when you look for the conservation of natural resources and clean environment because these are the issues that also should hit your mind after reading this problem.

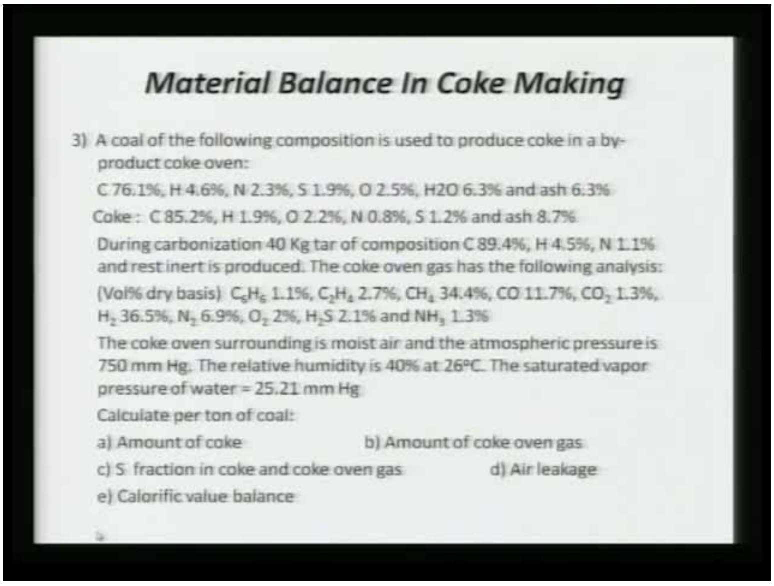
I will address when I will solve this problem. As a result you have to calculate amount of coke per ton, of course, coke oven gas and the fraction of calorific value of coal that is present in the coke and coke oven gas.

(Refer Slide Time: 05:39)




Now, problem number 2: it is also on the same line. All that here little bit changes in the inputs and outputs are given and some conditions are given; some conditions are not given. Again you have to calculate amount of coke cubic meters of dry coke oven gas (dry) and percentage of original heating value of coal that is available in coke and coke oven gas. This problem is just for your practice so that you can see whether you can do this problem or not.

(Refer Slide Time: 06:09)




Here, let us go for the problem number 3. Problem number 3 is typically because you put your byproduct coke oven in an atmosphere.

Now, the atmosphere may be dry or it may be humid; in days of rainy season, the atmosphere becomes humid and air is also humid.

It is quite possible that there could be an air leakage into the byproduct coke oven. It is very difficult to make an air tight compartment of the coke oven. Little bit amount of leakage of air is quite possible during the processing of coal to coke. So, this particular problem addresses about that particular aspect.

Coal of the composition is given say carbon, hydrogen, nitrogen, sulphur, oxygen, H 2 O and all are given. Similarly, coke which is produced is also given. Here also, ash is at 8.7 percent. Now, during carbonization 40 kg tar is produced and tar composition is also given; the coke oven gas composition is also given.

In addition to this, what the problem says is moist air is surrounding the coke oven and the atmospheric pressure is 750 millimeter mercury; the relative humidity is 40 percent at 26 degree celsius.

The saturated pressure of water is 25.21 millimeter of mercury at this particular temperature and pressure.

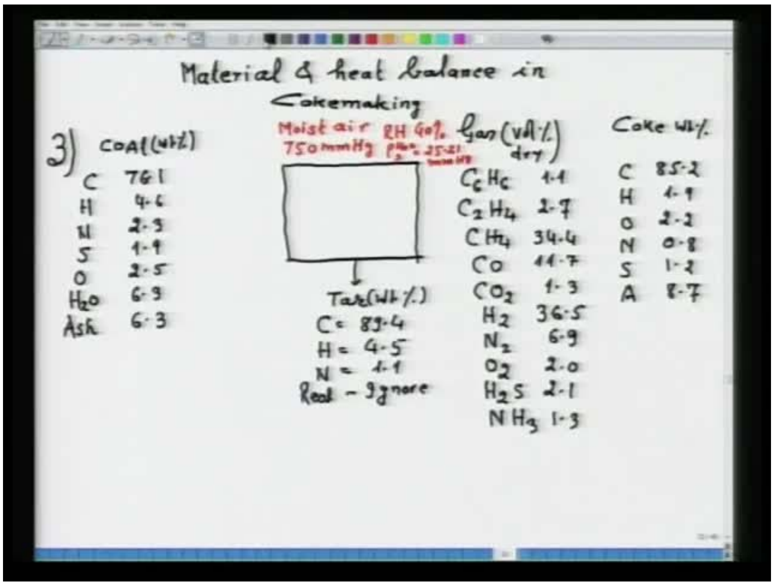
Here, you have to calculate amount of coke oven gas, coke, fraction of sulphur and so on. Air leakage and calorific value balance that means the input of the calorie and output of the calorie that is typical of the heat balance also.

In this particular problem, what should hit your mind is that because the coke oven is surrounded by the moist air, air leakage is possible.

In an attempt to calculate the air leakage, you should know the composition of air. Remember 79 percent nitrogen and 20 percent oxygen is the composition of dry air. When the air is moist then the composition of the air is bound to change.

So, here one has to recalculate those compositions also. These are the 3 problems which I have thought in this particular lecture. I will first of all try problem number 3. Let me go to the solution of problem number 3. So, let us take the problem number 3.

(Refer Slide Time: 08:32)




Problem number 3 says: Here, I will just draw a block diagram for the material balance and heat balance exercise. Here, I am introducing coal and its composition: it has carbon: it has hydrogen: it has nitrogen: it has sulphur: it has oxygen: it has H 2 O: it has ash.

As I said, there is no need to write this is in weight percent because the composition of all solids normally it is given in weight percent unless otherwise stated.

So, this is in weight percent. Even if I write or if I forget to write that is in weight percent. That is here is 76.1, hydrogen 4.6, nitrogen 2.3, sulphur 1.9, oxygen 2.5 and ash 6.3.

As a result of carbonization, we will be producing tar and tar composition is given to us say carbon 89.4, again it is on weight percent, hydrogen 4.5, nitrogen 1.1 and rest ignore for the present calculation.

As a result of carbonization, we look at the composition of the gas. The composition of gas is always given on say volume percent. This gas composition is given volume percent dry.

I am giving the composition. You should also understand that and realize the importance of this byproduct. You may consider byproduct is a waste, but it contains a huge amount of energy that we will see in the course of the problem.

So, it has $C_6H_6$, $C_2H_4$, $CH_4$, CO, $CO_2$, $H_2$, $N_2$, $O_2$, $H_2S$ and $NH_3$.

You must be wondering how it is forming. It lies in the process of carbonization of the coal because coal contains all organic matter carbon, hydrogen, nitrogen, oxygen, sulphur they are all say, organically combined in a bond formation. Bonds are broken; so, which one reacts with what a probability of reaction and availability of the concentration of various elements accordingly, the formation of this dry coke oven gas form. So, $C_6H_6$ is 1.1, $C_2H_4$ 2.7, note methane 34.4 percent, carbon monoxide is 11.7 percent, $CO_2$ is 1.3 percent and note hydrogen is 36.5 percent.

Even just seeing the analysis, you can imagine that the coke oven gas has a very high calorific value, only if you consider $CH_4$ and hydrogen. They are in very large amount and besides, well $C_6H_6$, $C_2H_4$ they also are the combustible component, but their percentage is very less.

$CH_4$ and hydrogen are in very high percent. So, it has a calorific value. While seeing this, the problem should also hit you or should force you to think that the conservation of natural resources energy resources is also possible by considering the calorific value of the coke oven gas. That point should not be forgotten. It is that I am trying to stress upon nitrogen 6.9, oxygen 2, $H_2S$ 2.1, $NH_3$ 1.3.

However, now in the byproduct $C_6H_6$ may not be used; it can be sold in the market as benzene. Similarly, $NH_3$ can also be converted to ammonium sulphate; it is a good fertilizer.

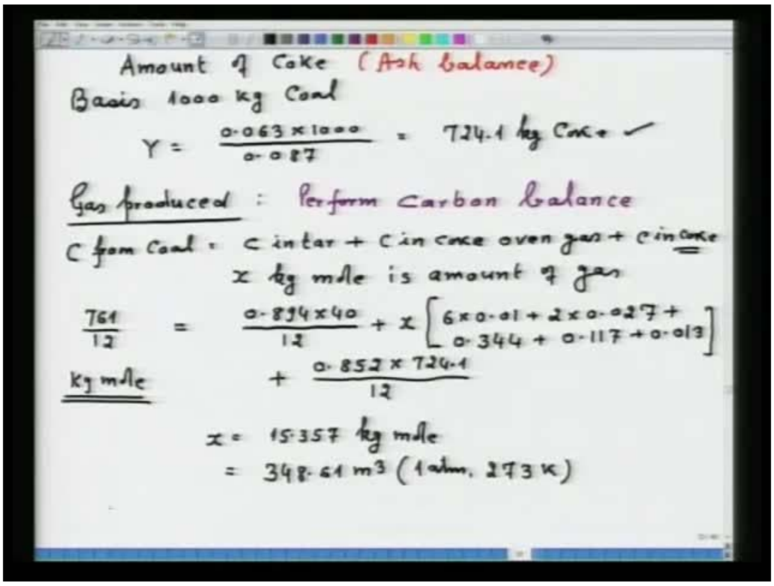
So, those aspects should also be coming in your mind by seeing the byproduct particularly when you are conscious enough for the environment cleanliness and conservation of energy resources. These two things must also be given due consideration while solving the problem. Now, coke of course, analysis is on weight percent; it has carbon, it has hydrogen, it has oxygen, it has nitrogen, it has sulphur and it has ash.

Carbon 85.2, hydrogen 1.9, oxygen 2.2, nitrogen 0.8, 1.2 and 8.7 and of course, the coke oven is surrounded by moist air, the pressure is 750 millimeter mercury, by pressure I mean atmospheric pressure, relative humidity is given 40 percent, temperature 26 degree celsius and saturated vapour pressure $P_{s\,H_2O}$ that is given to you 25.21 millimeter mercury.

So, that rather transfers the qualitative statement of the problem into a block diagram where it is perceivable from here what the inputs are, what are their composition and how to begin to solve the problem.

Now, the first thing you have to calculate the amount of coke. I will briefly also give how to calculate.

(Refer Slide Time: 15:13)




Now, in calculating amount of coke, one has to do ash balance because you have to search that component or that part of the composition which directly enters without undergoing any change.

Since it is destructive distillation, whatever ash is in the coal, it will be present in the coke. If you do the ash balance, you will be able to calculate the amount of coke. Here of course, you have to take the basis and let us take the basis. Already it is said you have to calculate per ton of the coal. Basis is let us say, 1000 kg coal of composition as it is given. If you do the ash balance It is very simple to do ash balance and if I consider Y is the amount of coke and if I do simple ash balance, I will be getting 0.063 into 1000 0.087 and I simply make this solution this comes as 724.1 kg coke. 0.1 - if you wish, you can discard it. This is straight away the answer of the problem.

In all the two problems that are given to you, you have to perform ash balance and straight away by performing the ash balance, you will be able to calculate the amount of coke.

Next, we have to calculate the coke oven gas produced. In order to calculate the gas produced, again you have to select an element which can be seen in the balancing and which is not lost anywhere. If you select hydrogen, it can be lost; select oxygen, it can be lost here and there it can combine and so on.

Here, if you see the carbon and if you do the carbon balance, if you charge x kg of carbon then x kg of carbon should be available to you in the product and byproduct.

The key to know the amount of gas produced is to perform carbon balance and rest no other balance can give you the answer for gas produced to my knowledge.

However, if you discover some innovative method I do not know, but so far I see into this problem and all of the two problems, it is only the carbon balance that can give you the amount of gas that is produced.

You have to perform carbon balance; it is very simple. You have to put now carbon from all sources. The input is only carbon from coal and it is distributed where it enters carbon in tar plus carbon in coke oven gas plus carbon in coke and nowhere carbon is being lost. You can see the problem, you can see the material balance block diagram that I have given to you; you will find that carbon is being distributed in all these 3 compounds tar, coke oven gas and coke.

Now you should also see that Now, we have 1, 2, 3 and 4 variables; amount should be known. Carbon coal amount we know, tar amount we know, coke amount we know, percentage is also known to us. The fourth amount that is carbon coke oven gas we do not know, but the percentage carbon that is there we know. So, we can calculate; it is very simple, as simple as that.

So, we have to perform this balance. Balance performing is again an exercise that has to be done. Take kg mole or kg or whichever way you like; choice is yours, but at the end while doing the balance the unit should be same on both sides. You cannot compare 1 rupee with 1 dollar.

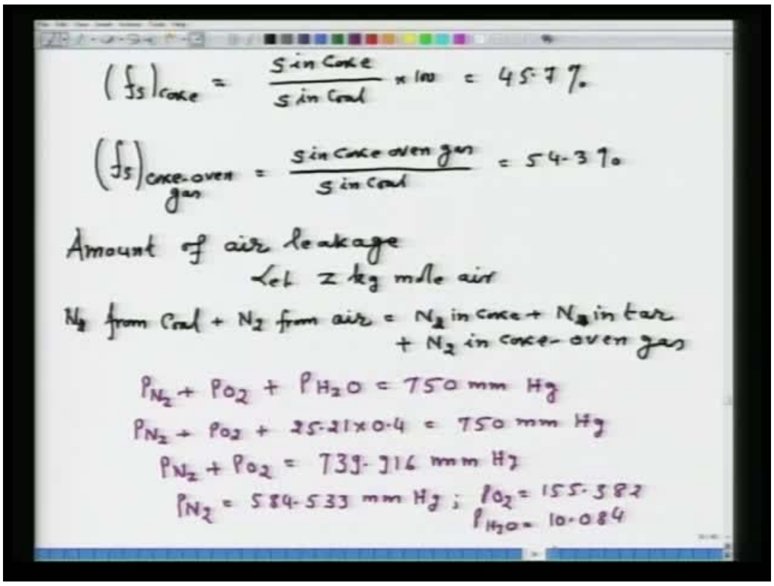
If left hand side is kg mole, right hand side should also be kg mole. Choice is yours; you do the way it suits you, the way you like it.

I will do the kg mole balance. Let us consider x kg mole is amount of gas. You may also consider x meter cube is the amount of gas; then you should do meter cube balance. See this is all that Now, you can straight away write. It will be 761 by 12, carbon in tar 0.894 into 40 upon 12 plus x 6 into 0.01 that is the benzene, plus 2 into 0.027 that is C 2 H 4 plus 0.344 plus 0.117 plus 0.013. This is all the carbon which is present in the coke oven gas and plus carbon in coke here that is 0.852 into 724.1 divided by 12, 12 is the molecular weight or atomic weight of carbon. Remember this is all in kg mole. The only unknown is x. So, I can very easily find out x that is equal to 15.357 kg mole.

Now, you can express in meter cube. That will be meter cube that will be 348.61 meter cube at 1 atmosphere and 273 kelvin.

Again think of the answer that you have gotten in terms of conservation of energy and in terms of energy that you are going to produce. You are producing 15 kg mole of gas per ton of coal. If on per day basis, you are converting 10000 tons of coal to sustain the production of pig iron then you can imagine how much amount of coke oven gas will be producing. It will be 15 into 10000 and accordingly, you can calculate the calorific value and so on and so forth. So, that is as important thing that should come into your mind.

(Refer Slide Time: 23:43)




Now. the next thing that you have to calculate is fraction of sulphur that is present in coke and coke oven gas. now say fraction of coke it is very simple now Fraction of sulphur in coke obviously that will be equal to sulphur in coke upon sulphur in coal.

You can just calculate and also into 100 if you do, it will be 45.7 percent. Similarly, I can calculate now fraction of sulphur in coke oven gas, again I have to calculate sulphur in coke oven gas upon sulphur in coal. You have to calculate the sources from your sulphur is in. That will be 54.3 percent. So, that takes care of the problem of the solution of this.

You have to calculate amount of air leakage. To calculate the amount of air which is leaked, can you think of an element which does not react anywhere or which is always inert?

Here, nitrogen is one such element that may react internally; say nitrogen may react with hydrogen, but N H 3 amount is available to you in the output.

So, if you do the nitrogen balance then probably you can calculate the amount of air leakage because you do the nitrogen balance that is input of nitrogen should be equal to the output of nitrogen and there is no other source of nitrogen, expect coal.

Nitrogen is not coming anywhere had there been no leakage, but if you do input of nitrogen and output of nitrogen, you find some excess and this excess has to be come from the leakage of air into the coke oven.

We have to perform the nitrogen balance and in order to perform the nitrogen balance, I will write down again let us consider say z kg mole here. Mind you, we do not know the composition of air and that has to be calculated.

Nitrogen from coal and input side will also have nitrogen from air that will be equal to nitrogen in coke plus nitrogen in tar plus nitrogen in coke oven gas.

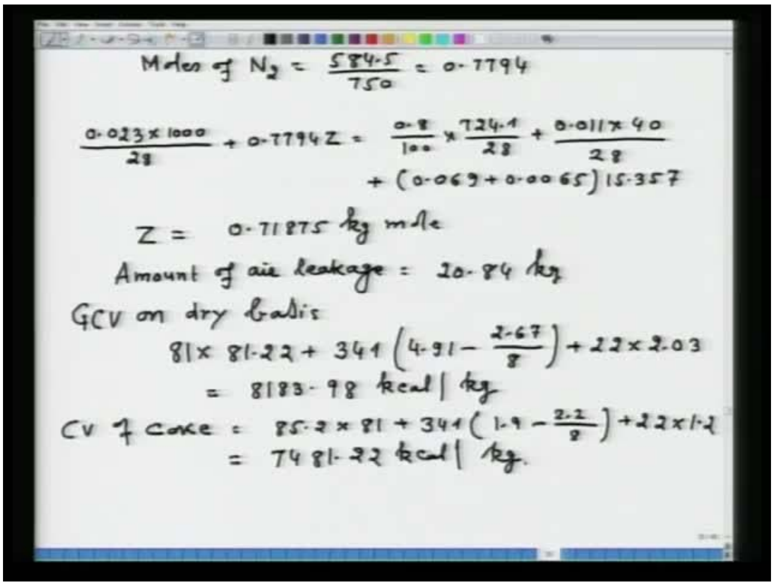
Essentially the N 2 symbol is for gas, but in coal it is present only as N. So, I will put nitrogen from coal it is N. Similarly, nitrogen in coke is N, tar also it is N and N 2 is present as a gas in the coke oven gas because in coke and tar nitrogen is present in the elemental form and gases it is as N 2. (Refer Slide Time: 27:28) That is why I deleted this N 2 and this N. So, that is what the balance you have to do, but since we are doing in kg mole that part is to be remembered; that is in coal, all the elements are present as N, O, H; they are not present as N 2, O 2 in coal, coke and tar, but in gases they are present as N 2, O 2 and so on.

Before this, you have to find out the composition of air. You see we are given say P N 2 plus P O 2 plus P H 2 O that is equal to 750 millimeter of mercury; that is what we are given.

Now, P H 2 O we can find out. So, P N 2 plus P O 2 plus 25.21, it is the saturated vapour pressure into relative humidity is 0.4 that is equal to 750 millimeter of mercury.

If I write now, P N 2 plus P O 2 will be equal to 739.916 millimeter mercury. This has become as if the gas has become dry. Here, I can find out P N 2 is 79 percent of this that is equal to 584.533 millimeter mercury, P O 2 we are not interested that will be 155.382 that is 0.21 of 739.916. Of course, P H 2 O will be 10 point something. I will write down just for completion - P H 2 O will be 10.084.

(Refer Slide Time: 29:39)




Now, I can do the nitrogen balance. The moles of nitrogen in moist air now would be 584.5 upon 750 that will be 0.7794. Now, I can do the nitrogen balance.

So, I am just writing down the value say 0.023 into 1000 upon 28 plus 0.7794 Z. It is not 0.79 because 0.79 is the proportion of nitrogen or fraction of nitrogen in dry air; this is in the moist air.

Had there been the temperature changes, this value will also change. That will be equal to 0.8 upon 100 into 724.1 upon 28 plus 0.011 into 40 upon 28 that is the nitrogen in tar plus 0.069 plus 0.0065 that is N H 3 and N 2 into 15.357 that is the amount of gas that is determined. If you solve this particular thing, we will be getting the value of Z that will come out to be equal to 0.71875. However, there is no need to have such a thing, but since I have written kg mole.

So amount of air leaked amount of air leakage now since it a kg mole. Now, I can access meter cube when I specify the temperature and pressure.

So amount of air leakage that is equal to 20.84 kg. You have to multiply by its molecular weight or if you want to find out in meter cube you multiply by 22.4 then it will be one atmosphere and 273 kelvin. You can also find out at 750 millimeter atmosphere in 26 degree celsius as the temperature is given in the problem, but then you have to find out one kg mole corresponding to meter cube at this temperature and pressure. Anyway you can find out the (( ))

Now, we have to find out the fraction of original heating value of coal that is available and so on.

First of all, you have to find out the gross calorific value because calorific value of the coal is not given. So, we will find out gross calorific value on dry basis. The concept of it I had already given to you in the earlier lecture. Now, GCV on dry basis, why I am calculating is because of as follows.

Coke is given on dry basis; there is no moisture in this. Volume of gas is also given on dry basis; there is no moisture. So, as such you have to calculate gross calorific value on the dry basis.

That means, first we will convert the composition of coal which is given on wet basis to dry basis that means the relevant elements carbon, hydrogen, nitrogen, sulphur and so on; we have to modify them.

That is, we have to multiply by 100 upon 100 minus percentage moisture. If I multiply say for example, percentage carbon by 100 upon 100 minus moisture then I will be getting its composition on dry basis.

You can do this exercise and then you will be getting and the formula to calculate gross calorific value I have given in just an earlier lecture.

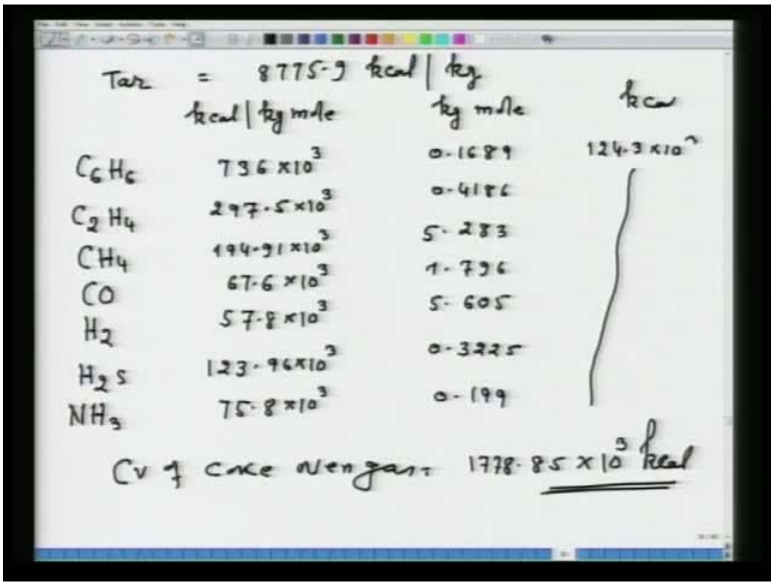
So, GCV on dry basis will be 81 into 81.22. Now, 81.22 is composition of coal on dry basis, its composition on wet basis was 76.3 percent.

You multiply by 100 divide by 100 minus percent moisture plus 341 4.91 minus 2.67 upon 8 plus 22 into 2.03.

This gross calorific value is coming to be equal to 8183.98 kilo calorie per kg.

Similarly, I can calculate the calorific value of coke. The calorific value of coke will be equal to 85.2 into 81 plus 341 1.9 minus 2.2 upon 8 plus 22 into 1.2. So, calorific value of coke that is equal to 7481.22 kilo calorie per kg.

(Refer Slide Time: 35:51)




Then I can find out tar same way. So, tar calorific value will be 8775.9 kilo calorie per kg.

Now, we have to find out the calorific value of coke oven gas. Earlier lecture, I had already said how to find out the calorific value. So, the gases which are there we have C 6 H 6.

We have to consider only those compositions which contribute to calorific value. Nitrogen, it does not contribute to calorific value; CO 2 is inert, when you combust them. You have to consider all combustible components and calculate their calorific value when they are completely combusted.

The values are C 6 H 6, then you have C 2 H 4; they are combustible hydrocarbons; CH 4 is also combustible; CO is also combustible, H 2, H 2 S and NH 3. They are all combustible components of the gas.

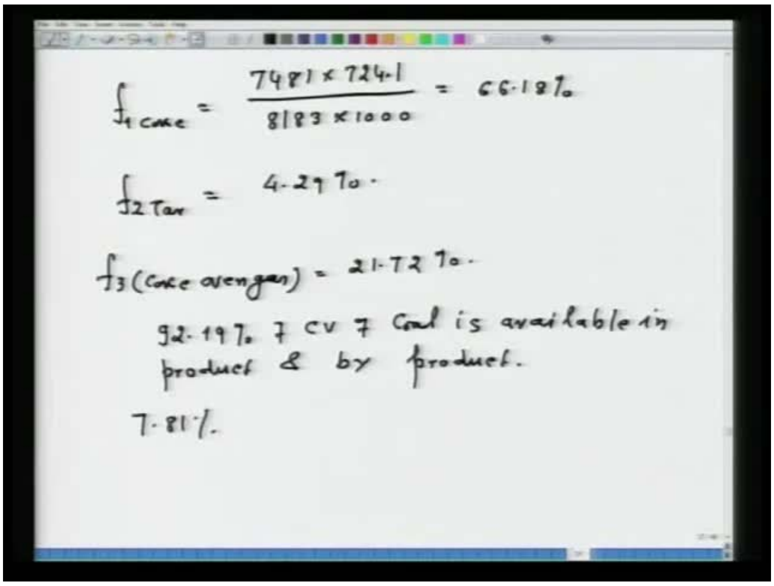
The values are in kilo calorie per kg mole. Some value I have given in earlier lecture. Here, it is 736 into 10 to the power 3, 297.5 into 10 to the power 3, 194.91 into 10 to the power 3, 67.6 into 10 to the power 3, 57.8 into ten to the power 3, 123.96 into 10 to the power 3 and 75.8 into 10 to the power 3.

Now, what I have to do? I have to multiply by their respective kg moles. Here, if I write kg mole then C 6 H 6 is 0.1689, 0.4186, 5.283, 1.796, hydrogen 5.605, 0.3225 and here it is 0.199.

(Refer Time Slide: 38:44) So, I have to now multiply this value with this to get the kilo calorie. If I do all then I will be getting the calorific value of coke oven gas. What you have to do? So, you get here kilo calorie you multiply this value by 0.1689 for example, you will get here on124.3 into 10 to the power 3.

Similarly, you will get for all and if you add them together, this will be 1778.85 into 10 to the power 3 kilo calorie - that is what the caloric value of coke oven gas.

(Refer Slide Time: 39:35)



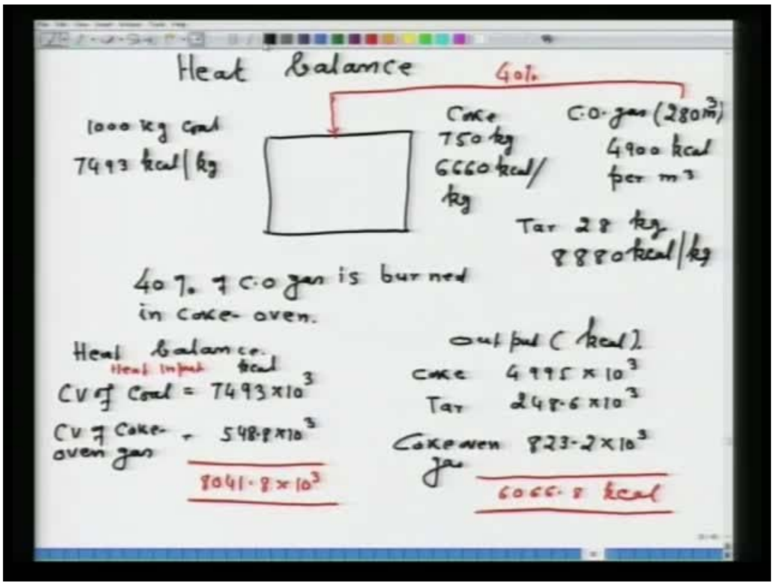

Now, it is easy to find out the fraction. say for fraction I will say for coke fraction for caloric value f 1 in coke, that will be caloric value of coke, you have 7481 into 724.1 divided by 8183 into 1000. The coke contains around 66.18 percent of the calorific value of coal. Similarly f 2 tar, you can also find out the same way, that will be 4.29 percent and f 3 say coke oven gas that will be equal to 21.72 percent.

Now, if I add all these percent together then I will be getting that 92.19 percent of calorific value of coal is available in product and byproduct.

That means, 7.81 percent of the calorific value of the coal is unaccounted according to both of us, but the 7.8 percent calorific value of the coal has been lost as the sensible heat of coke oven gas, coke and tar.

It is because in our calculation the products are also discharged, for example, at 1000 degree celsius. So, the 7.81 percent of the calorific value of the coal is being available in the form of sensible heat of coke oven gas, coke, tar and also if some heat losses occur from the oven. That makes the complete analysis and about this I am illustrating another problem for the heat balance. Let us make the heat balance of the problem.

(Refer Slide Time: 41:57)




Let us consider a process, again a coke oven and what I have done here. I am supplying here 1000 kg coal whose calorific value is 7493 kilo calorie per kg. I am producing here coke, its amount is 750 kg and calorific value is 6660 kilo calorie per kg. Then I am producing coke oven gas; this amount is 280 meter cube. The calorific value is 4900 kilo calorie per meter cube. I am producing tar which is 28 kg and calorific value is 8880 kilo calorie per kg. Now, note the calorific value and accordingly, the energy which is available to you. The problem is that 40 percent of the coke oven gas is burnt in coke oven. That means this coke oven gas say 40 percent, it is sent back; 60 percent is going out. 40 percent is burnt and 60 percent is going into the atmosphere. First you have to perform the heat balance; so, set up heat balance. What will be heat balance? There will be heat input. So, heat input would be C V of coal and C V of coal will be 7493 into 10 to the power 3 of course, that is in kilo calorie.

The next would be say, C V of coke oven gas because forty percent of the gas is being sent back to the oven. That means 40 percent of this that will be 112 meter cube multiplied by 4900 that makes 548.8 into 10 to the power 3.

This is my heat input. So, that makes total 8041.8 into 10 to the power 3.

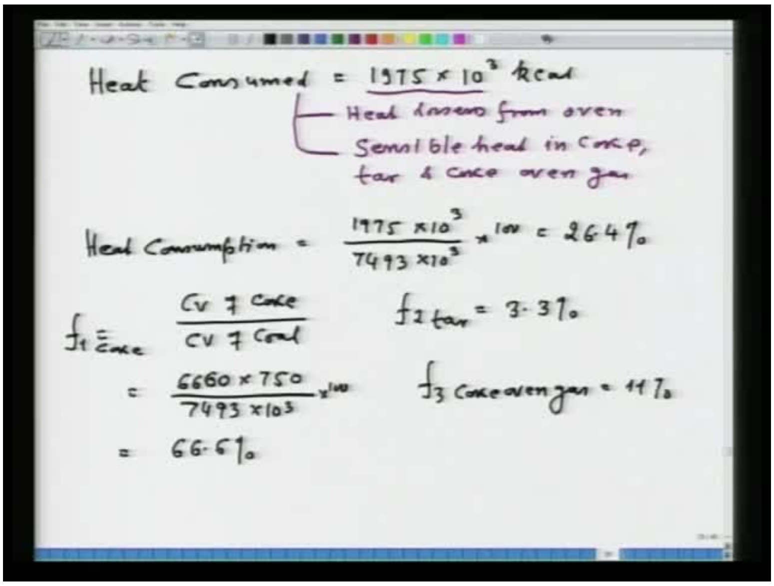
Now, let us do output again in kilo calorie. One output is your coke that is 4995 into 10 to the power 3, tar 248.6 into 10 to the power 3.

Coke oven gas you know now, 40 percent is recycled and 60 percent will go into the atmosphere; that will be 823.2 into 10 to the power 3.

Now, output here is equal to 6066.8 kilo calorie. The difference between the input and output; what is that difference? Can you think of a difference? You have heat input 8041 and output you could get only 6066.

The balance of the heat is, heat consumed. Where is the heat that is consumed? Part of the heat is consumed as losses from the oven and from where it will come? It will come from the calorific value of the coal. The products are raised to a temperature of 298 to 1273 kelvin from where this heat will come. It will also come from the calorific value of the coal. So, the difference between the two, we can write as the heat consumed.

(Refer Slide Time: 46:50)




This heat consumed in this particular problem will be 1975, not the year; it is 1975 into 10 to the power 3 kilo calorie.

This heat consumed consists of heat losses from oven. We have not accounted in our balance. This also accounts for the sensible heat in coke, tar and coke oven gas because all this will be heated up to a discharge temperature of 1273 or 1373 kelvin. So, that is what this means that around 1975 into 10 to the power kilo calorie per ton of coal; our basis was 1000 kg. So, that much of heat is consumed or is lost and should not be surprised if the heat input is not equal to heat output. If in the heat output term, we consider all - sensible heat of coke, sensible heat of coke oven gas, sensible heat of tar, heat losses everything then probably the balance will be there.

So, that is what the important thing one should know that they are not equal because these things are not considered. We can say for understanding, what we can do now? We can refer this heat consumption to the original calorific value of coal. This will be 1975 into 10 to the power 3 upon 7493 into 10 to the power 3 into 100 that will be around 26.4 percent. That means, 26.4 percent of the calorific value of the coal is lost in heat losses from oven and sensible heat and so on.

Now, we can calculate for example, friction of the calorific value of coal that is available in coke. So, f 1 coke will be equal to C V of coke upon C V of coal. We have to multiply accordingly; 6660 into 750 upon 7493 into 10 to the power 3 and if I multiply by 100, I will be getting in percent. That will be 66.6 percent that means 66.6 percent calorific value of the coal will be available in the form of coke. I can have f 2 that is tar; similarly, we can calculate and that will be 3.3 percent. I can calculate f 3 that is fraction that is available in coke oven gas and that will be equal to 11 percent.

What this analysis suggests? This analysis suggests you that look, here a certain amount of energy are available for its use for example, coke oven gas 11 percent and tar though it is small, but it has a high caloric fuel.

So, those personalities which are environmental conscious and energy resources conscious that is conservation of energy resources conscious, they must think to reuse the energy of the byproduct that is available to us in some form. Do not forget, here we have not considered the sensible heat that is at 26 percent. We can also consider the utilization of sensible heat of coke because coke will be discharged at around 1000 degree celsius or 1100 degree celsius. Look at the very large amount of sensible heat that will be available. All these are the issues that results after performing the heat balance because when you perform the heat balance, then you come to know, that much amount of energy is going there, that much amount is coming over here. I should think some of its reuse.

Now, some of the issues I will be addressing when I will take lecture on say, heat balance and its connection with the conservation of energy and environment.

Thank you