Materials and Energy Balance in Metallurgical Processes

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Module No. # 01

Lecture No. # 24

Lead Smelting Material Balance

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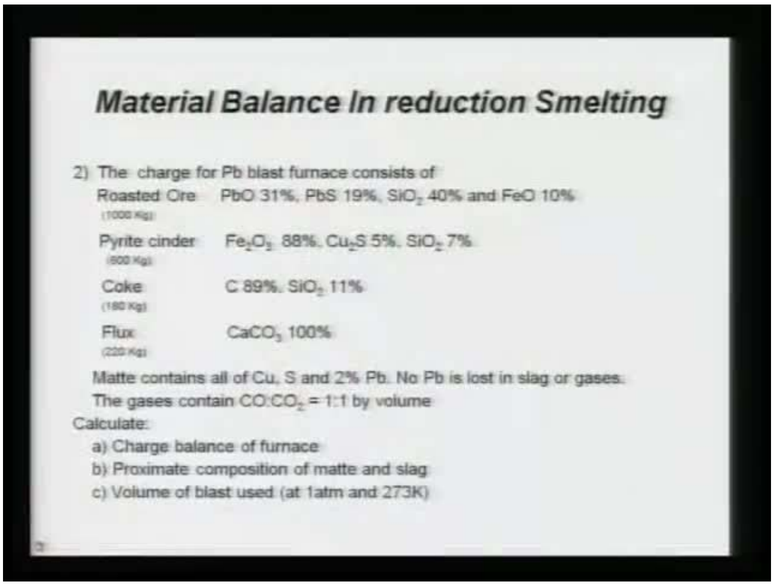

Let us see further the problems on material balance in reduction smelting. In an earlier lecture, I have given the introduction to reduction smelting and the relevant information to solve material balance problem in reduction smelting. In that lecture also, I have solved one problem on lead. Here, some more problems on reduction smelting. For example, production of lead in a lead blast furnace. Problem two: the charge for blast furnace or lead blast furnace is given. It consists of roasted ore, pyrites, cinder, coke and flux. All of you know flux is used to slag to remove the impurities.

As the result of smelting or reduction in smelting in blast furnace, matte of this composition is produced. It is said no lead is lost anywhere rather in slag or gases.

Normally, there may be some loss of lead in slag or gases. Depending on the problem, you have to consider, if it is given; if it is not, you can ignore it.

Now, the gases contained here in the ratio CO is to CO 2 is 1 is to 1 by volume. You have to calculate A, B and C. Now, in the B part, this is said - the proximate composition and as I have said at many occasions that proximate analysis consist of minerals. That means you have to report the presence of mineral not as individual elements. That is what the proximate analysis means. Volume of blast as such you have to deal.

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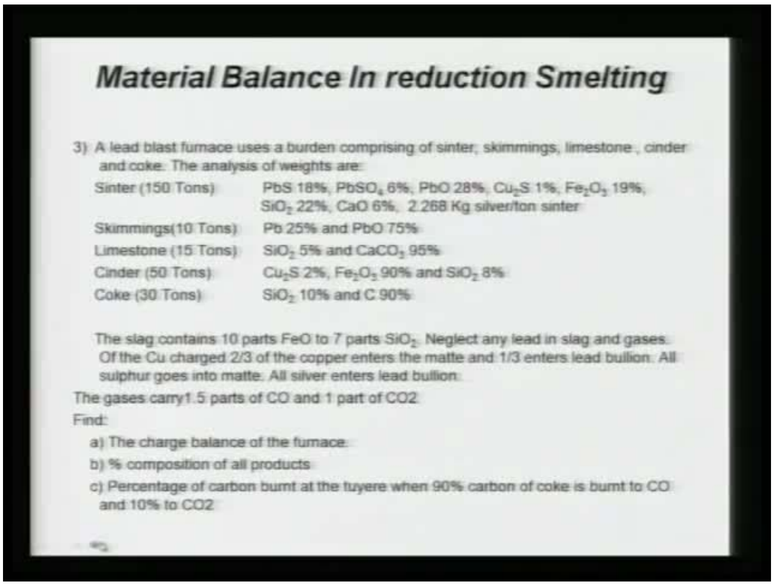

Now, the problem 3 - again there is a different type of problem here; some more complication has been introduced say the burden which consists of sinter, skimming, limestone, cinder and coke. Skimming in fact is the product of lead blast furnace which is again recycled in order to recover lead. As you see in this particular problem, skimming which is obtained contains significant amount of lead and lead oxide.

So, there is a huge loss of lead. So, many a times in the plant, to improve the economy of the blast furnace smelting of lead ore - the skimmings are recycled to recover lead. I mean you may recycle in the blast furnace as a feed or elsewhere. The whole idea is that you do not want to lose lead.

So, here sinter is a roasted 150 tons, then skimmings, limestone, cinder and coke - they are all the charge and all these 1 2 3 4 5 constitute and the term is called burden. Burden consists of all these things. Now, it is further said, the conditions of slag and the components which are there - it is given to some extent - it is said slag contains 10 parts Fe O to 7 parts Si O 2. It is also said, you neglect lead in slag and gases. Further conditions are imposed of the copper charged, two-third enters into matte and one-third into lead bullion.

Remember, you should also understand that the product of smelting of lead ore is not pure lead; it is an impure lead which is called lead bullion. When you say lead bullion, it contains several impurities: say copper is one impurity, silver is another impurity, antimony and so on, depending upon the elements which are present. These are all the impurities. It is called as lead bullion. It is said one-third enters into lead bullion; all sulphur goes into matte, all silver enters into lead bullion.

In order to get lead, you have to further refine and there is a very detailed refining sequence of production of refined lead from lead bullion. Several steps are involved for refining of lead bullion to get pure lead. Now, again here, the gases carry 1.5 parts of CO and 1 part of carbon dioxide. So, you have to make charge balance. With the term charge balance, you must be very clear what is being required here.

You have to calculate the input and output both; that is what the balance means. Then, percentage composition of all products and percentage of carbon burnt at the tuyere when 90 percent of carbon of coke is burnt to CO and 10 percent to CO 2. So, this point has to be kept in mind; under that condition you have to solve the problem.

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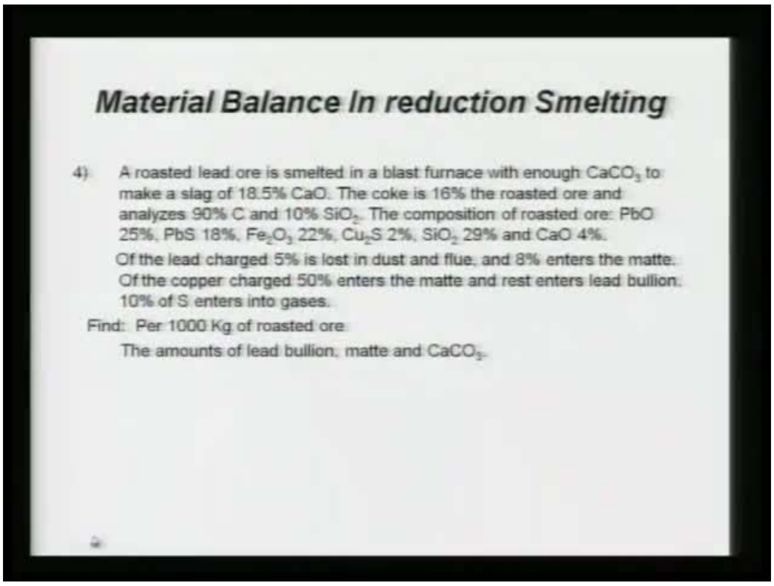

Now, problem 4 - a roasted lead ore is smelted in a blast furnace with enough calcium carbonate to make a slag of 18.5 percent calcium oxide, coke is 16 percent of the roasted ore and analyzes 90 percent carbon and 10 percent Si O 2. The composition of roasted ore is given; of the lead charge - 5 percent is lost in dust and flue. In earlier problem, we said no loss; now some losses are also there. So, this problem illustrates that and 8 percent enters into the matte. Of the copper charge, 50 percent enters into the matte and rest enters with lead bullion. 10 percent of sulphur enters into gases. Per thousand kg of roasted ore, you have to calculate amounts of lead bullion, matte and calcium carbonate.

These are the problems that I have read quite slowly so that you can read it and you can understand the problem. The answers are given as usual; you should not see the answers before you make a solution.

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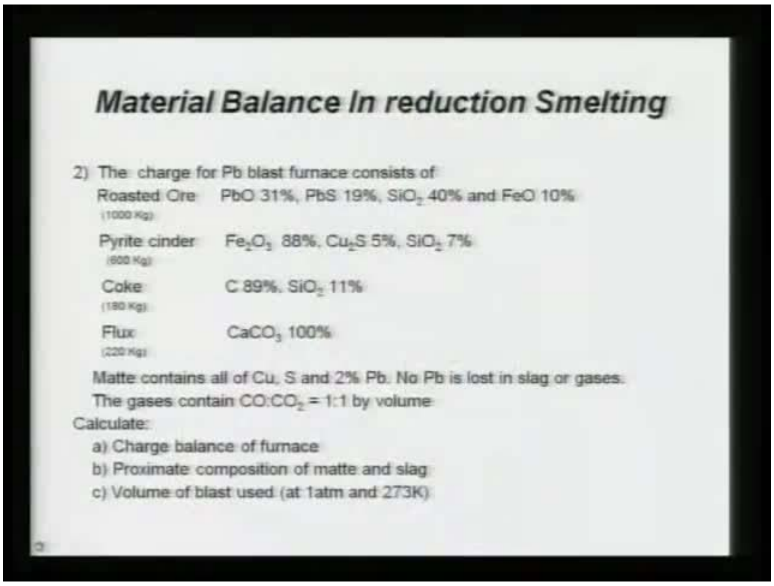

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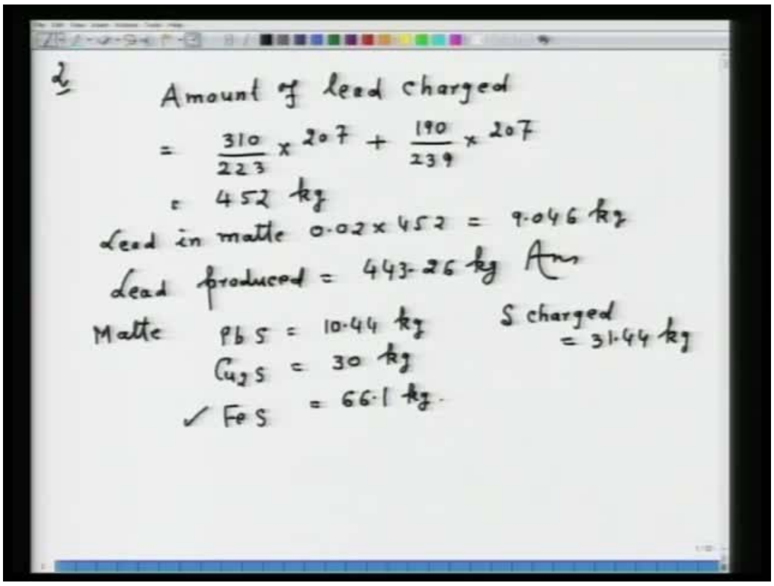

Here, I will proceed for the solution of these problems. Let us take problem number 2. I will first of all calculate amount of lead charge. I hope you must have read the problem. I am straight away proceeding with the solution. Amount of lead charged - that is you have to see from all sources. The source of lead, it is only the roasted ore from where your lead entering.

So, amount of lead charge that is equal to say -310 upon 223 into 207 plus -you have lead sulphide also, which is 19 percent; so, that is 190 upon 239 into 207. So, that makes around 452 kg of the lead which is being charged. Now, lead in matte as per the problem - lead in matte which is 0.02 into 452 is 9.046 kg as per the statement of the problem. So, the amount of lead produced – as there is no loss anywhere. So, the amount of lead produced will be 452 minus this, so, the answer would be 443.26 kg. That is the answer when it says that you have to calculate the amount of lead produced.

Now, calculate the matte. Matte contains a lead sulphide; it contains Cu 2 S and it contains Fe S. What you have to do here? You have to make the total balance. First of all, you make the sulphur balance. Sulphur charged - you have to see that from all sources- you have to consider sulphur charge and in this problem that is equal to 31.44 kg; total sulphur is being charged.

Now, you know amount of lead in the matte is 9.046 kg. From there you calculate Pb S; then see how much amount of sulphur is combined with lead, and then you know the copper. How much rest of it? The amount of copper, you calculate in terms of Cu 2 S. Then the amount of Pb S will be equal to 10.44 kg, Cu 2 S will be 30 kg and Fe S will be 66.1 kg.

I hope you can calculate. So, we can calculate amount of Pb S. From amount of Pb S, you will be calculating how much sulphur with Pb S. Cu 2 S, you can calculate and balance sulphur with that will be iron and that is where you can calculate the amount of Fe S.

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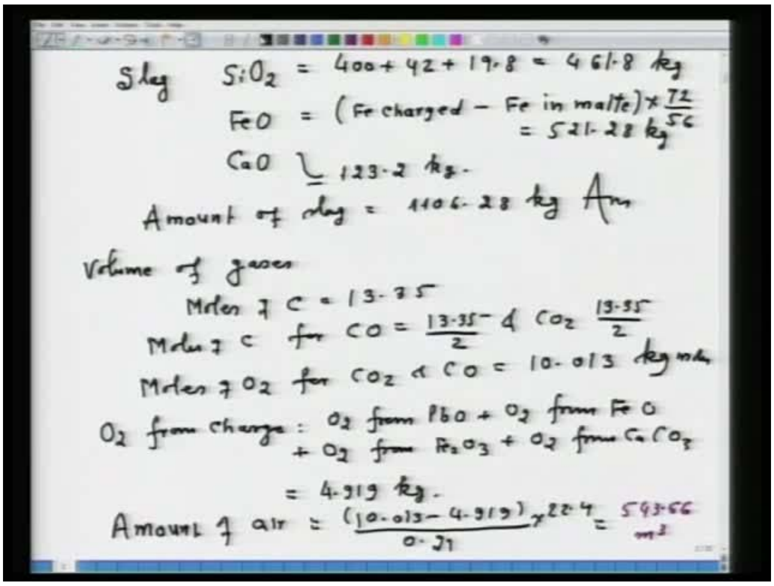

Next you have to calculate say for example, amount of slag. The slag will contain Si O 2, that will also contain Fe O and it will also contain calcium oxide. If you consider all sources - 400 plus 42 plus 19.8, that is equal to 461.8 kg -that is the Si O 2. Then F e O will be equal to iron charge minus iron in matte that will be the iron in slag and Fe O would be 72 upon 56. That amount is equal to 521.28 kg. Now, about calcium oxide, it is straight way is equal to 123.2 kg. Amount of slag would be 1106.28 kg.

Now, all that is required is you have to proceed as per what is given in the problem exactly which amount is going where. You have to be careful while converting, say, if you are considering the amount of Fe O and if you are making iron balance, then do not forget to convert to Fe O.

So, these are certain things that one should keep in mind while solving the problems. Many a times over the years I have seen that the student might commit a mistake in converting, say iron to Fe O or Si to Si O 2, whatever. It depends upon the elemental balance you do or you can directly do the Fe O in the slag and for that you have to develop an appropriate skill for that.

Here what we are doing simply - we are balancing the input and output and in between input and output where the material is going where - you should read the problem very carefully. For example, in the Fe O calculation, whatever iron you have charged, part of the iron is going into the matte, only rest iron is going to slag. So, that point is to be clear because it is a material balance, input, output and in between input and output, where it is going? What? You have to consider that and then there should be no problem.

Next you have to calculate volume of gases. Again here, there is a skill involved and method involved. I mean method will vary from whichever way I do and how you do. I will follow this way. Moles of carbon is equal to 13.35, then depending on the ratio, moles of carbon for CO will be equal to 13.35 upon 2 and that of CO 2 will also be 13.35 upon 2, because it is 1 is to 1 ratio.

Then, I can find out the moles of oxygen for CO 2 and moles of oxygen for CO. Moles of O 2 for CO 2 and CO will be 10.013 kg moles. Now I have to do oxygen from charge because that much amount of oxygen will not be derived from the blast. So, oxygen from charge – that means I have to see CO 2 from PbO, I have to consider O 2 from Fe O, I have to consider plus O 2 from Fe 2 O 3 and do not forget to consider O 2 from CaCO 3.

So, if I make all this calculation then I will be getting oxygen in the charge that is 4.919 kg moles. So, oxygen derived from the blast will be 10.013 minus 4.19. So, the amount of air amount will be equal to 10.013 minus 4.919 divided by 0.21 into 22.4, so, the amount of blast that will be required will be 543.66 meter cube at 1 atmosphere and 273 Kelvin.

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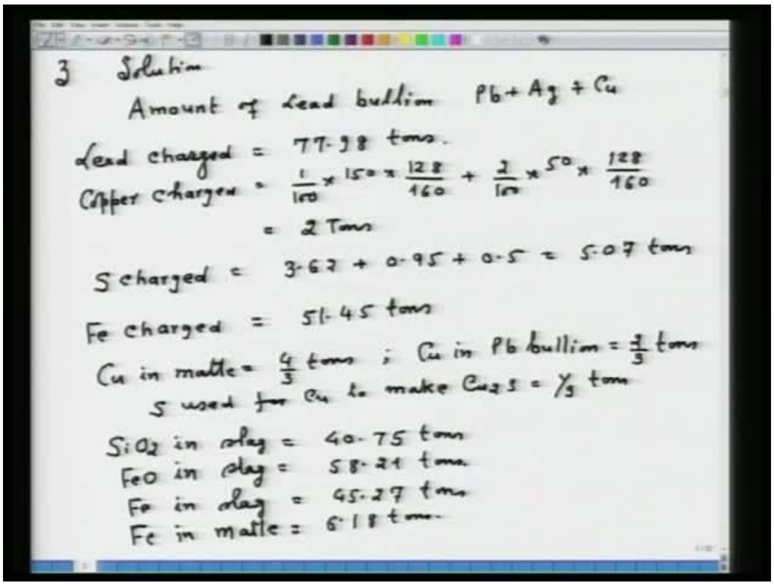

This is about the say some steps for solving problem number 2. Now, let us go to the problem number 3. In problem number three again, you have to do the charge balance of the furnace. I am proceeding to calculate the charge balance. Solution for problem number 3 - first I will calculate amount of lead bullion.

Lead bullion consists of lead plus silver and plus copper. So, this point has to be noted that all silver is entering into the lead. Now, we have to calculate the total amount of lead charged from several sources. That will come around 77.98 tons. Now, copper charged - again you have to look at the sources of copper from where it is entering into furnace. The only source is cinder which contains 2 percent copper sulphide and cinder is 50 tons and another source is sinter also. You have to see from all sources; you have to take into account the copper which is entering into the system.

That way, the copper charge will be equal to say, 1 upon 100 into 150 into 128 upon 160 plus 2 upon 100 into 50 into 128 upon 160. I mean you have to convert also. You have to excess given accordingly copper

So, that will be coming out to be equal to 2 tons - that means total copper you are charging is 2 tons. Now, you have to see sulphur charged and again you have to make some calculations. So, sulphur charge will be 3.62 plus 0.95 plus 0.5. I have omitted some steps I think they are very easy and you can come to this figure. You have to consider from all source from where sulphur is entering - that is equal to 5.07 tons - that much amount of sulphur charge.

Now, you have to calculate iron charged from all the sources from where iron is charged. I see in the problem, the source of iron is sinter that is Fe 2 O 3 which is 19 percent and cinder which also contains 90 percent Fe 2 O 3. So, you have to consider both the sources. I have just calculated and I will leave the calculation for you. That will come out to be 51.45 tons.

Now, you have to calculate the charge balance; so matte and everything we have to calculate. Copper in matte will be equal to 4 by 3 tons as per the condition of the problem and copper in lead bullion is equal to 2 by 3 tons, that 2 tons will be divided accordingly. So, sulphur used for copper to make Cu 2 S - because in the matte, the sulphur will not be free; it is combined with the Cu 2 S. So, sulphur used for copper is equal to 1 by 3 tons.

Now, say Si O 2 in slag is equal to 40.75 tons; Fe O in slag will be 58.21 tons. So, Fe in slag is equal to 45.27 tons. Now, why I am doing this thing because first of all I must know how much amount of iron is entering into the matte then I can calculate. So, iron in slag I know; now iron in matte, I can calculate. Iron in matte will be equal to 6.18 tons.

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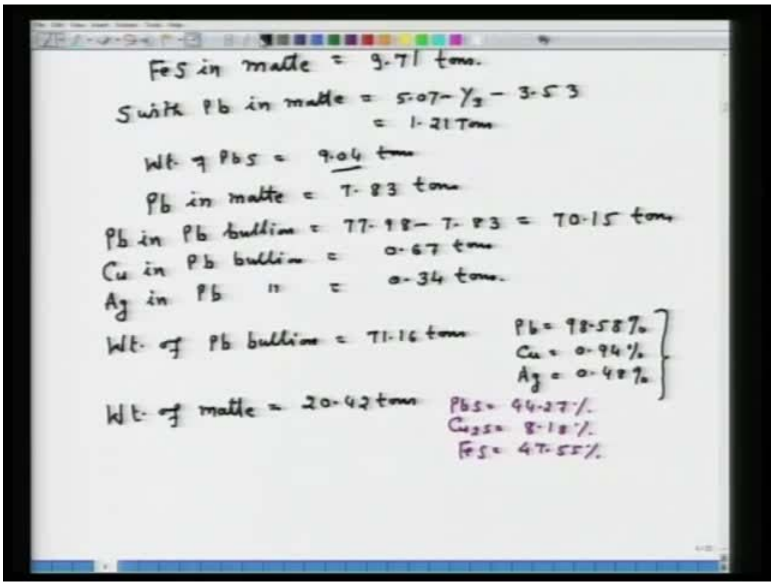

Now, I can calculate Fe S in matte. So, Fe S in matte will be 9.71 tons. I can calculate sulphur with lead in matte; that will be equal to 5.07 minus 1 by 3 as I have earlier calculated minus 3.53. So, that will be equal to 1.21 tons. Now, I can calculate weight of Pb S; that will be equal to 9.04 tons because you have to multiply by 239 divided by 32 because the sulphur with lead in matte that is 1.21. Accordingly, you will get 9.04 tons.

Now, I can calculate lead in matte. Lead in matte will be 7.83 tons; it is simply 207 by 239. So, lead in matte I know. Now, I can calculate lead in lead bullion; that will be equal to 77.98 minus 7.83- that will be equal to 70.15 tons. In order to calculate lead in lead bullion, you have to make all these exercise because some amount of lead in lost in the slag or iron is entering into matte and slag and so on and to come up with the lead sulphide and so on. So, straightaway you would not to able to calculate what is the lead in lead bullion. That is why this exercise has to be done.

Now, copper in lead bullion is 0.67 tons and silver in lead bullion will be 0.34 tons. Now, I can calculate weight of bullion or amount of bullion. Weight of lead bullion -I have to sum total, and that will be equal to 71.16 tons. Then we can just calculate the percent. Therefore, lead will be 98.58 percent, copper 0.94 percent, and silver 0.48 percent.

This is just percentage wise lead bullion. Now, we can calculate say weight of matte. Weight of matte is equal to 20.42 tons. You have to sum total and if you say percentage wise, let me give some other color, so Pb S is equal to 44 point 27 percent, Cu 2 S -8.18 percent and Fe S -47.55 percent.

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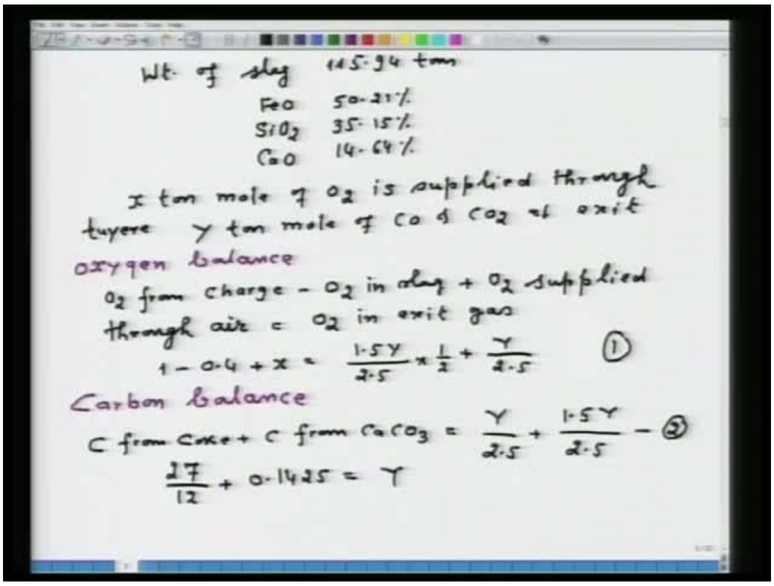

That is what the weight of matte. Next is weight of slag, slag weight is 115.94 tons and percentage wise, it has Fe O, it has Si O 2, it has calcium oxide. So, Fe O is 50.21 percent, Si O 2 is 35.15 percent and calcium oxide is 14.64 percent. Now, in this problem you should also understand what are the inputs and what are the outputs. The output is one lead bullion, matte and slag.

Since the charge does not contain arsenic, there will not be any spice. You remember in earlier lecture, I have said that the output of the less blast furnace consist of slag, matte, spice and lead. Since the charge does not contain any arsenic, there will not any spice in the output of blast furnace. The rest you had seen that whatever I said in the introduction of reduction smelting for lead, you are seeing that the outputs are slag, matte and lead bullion and also outputs you will also we have to find out. The problem says that percentage of carbon burnt at the tuyere when 90 percent carbon of the coke is burnt to CO and 10 percent to CO 2.

Now, I am giving you the solution; but then you have to think how to approach this particular problem. My suggestion would be, in order to solve this particular part, that is part c of problem 3, I will like you that not to see the solution, think over the problem and then arrive at your own solution and then compare with what I have done.

Because I have also done with a long time and long exercise and long thinking, I would like you to see how such problems should be tackled.

What I am doing now, since nothing is known; I will be doing only oxygen balance and carbon balance- that is the key. So, let us take it now - say x ton mole of oxygen is supplied through tuyeres. Now, remember why I have taken this approach, because from the blast furnace, lead is smelting. It is clear that whatever air you supply, it is used for oxidation of carbon only in this particular system.

That is the key to approach this particular problem, because whatever air you supply, it is used for oxidation of carbon. I am considering now, say -y ton mole of CO and CO_2 at the exit. I do not know any other information except this, because it says 90 percent carbon to CO and 10 percent to CO_2; rest information I do not have. So, I cannot make any nitrogen balance in order to calculate the volume of the blast. Nothing I can do. This is what the information I have.

Now, I have to do oxygen balance. I will write oxygen balance; see the oxygen balance now - O_2 from charge, because you know a part of the O_2 is also coming from the charge from Fe_2O_3 from oxidation, Fe O and so on; whatever the Pb O is there in the charge. So, oxygen is also coming. So, accordingly the oxygen which is blowing through the tuyere will be required less than what oxygen is contained in the charge. The system has its own oxygen. That point is to be clear.

Oxygen from the charge minus oxygen in slag, because it is following by oxidation, plus oxygen supplied through air will be equal to oxygen in exit gas. This balance we should be able to make in order to solve this particular problem. You have to consider the oxygen which is present in the system which is introduced in the form of the charge, also the oxygen in the slag, Fe O and all these things although has to be considered.

So, if I do that, then I form the balance; which is 1 minus 0.4 plus x -please do the calculation I have given enough hint to you - that will be equal to 1.5 y upon 2.5 into 1 by 2 plus y upon 2.. That is my equation 1. Next, let me do the carbon balance. Do not forget to take oxygen from $CaCO_3$.

Carbon from coke plus carbon from $CaCO_3$ will be equal to carbon in the exit gases; because carbon is not being accumulated. At the steady state material balance, input should be equal to output. So, that will be y upon 2.5 plus 1.5 y upon 2.5 and this is my equation number 2. If I make this equation in kg mole, that will be 27 by 12 plus 0.1425 equal to y.

Now, please think it over before you see the solution. I mean do not see the solution. First try to understand the problem and try to solve and see how to approach such problem. I mean this is a very tricky problem.

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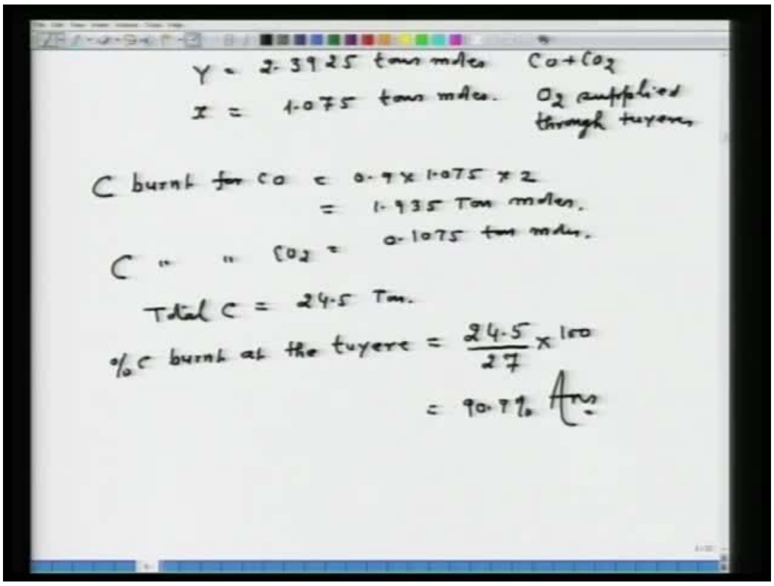

Now, I can calculate from here y by equation 1 and 2, y will be equal to 2.3925 ton moles. I hope y, we have considered as CO plus CO 2 and x is equal to 1.075 ton moles. If you recall x was oxygen supplied through tuyere or oxygen from air, whichever way you want to understand. So, now I have to find out carbon burnt for CO. Carbon burnt for CO will be equal to 0.9 into 1.075 into 2. So, carbon burnt for CO will be 1.935 ton moles and carbon burnt for CO 2 will be 0.1075 ton moles.

So, total carbon in tons will be equal to 24.5 tons. So, percent carbon burnt at the tuyere will be equal to 24.5 upon 27 into 100; so, that will be equal to 90.7 percent and that is the answer for this. Now, that is what the answer for the part c of the problem number 3. Here, it says that the charge balanced; so, ultimately you will be putting in the answer, the charge balance. All the weights inputs are given. So, in the output, you will be writing the weights of matte, weights of slag, weights of lead bullion, then carbon burnt at the tuyere and all these things will comprise of the charge balance of the process. That is what the problem number 3.

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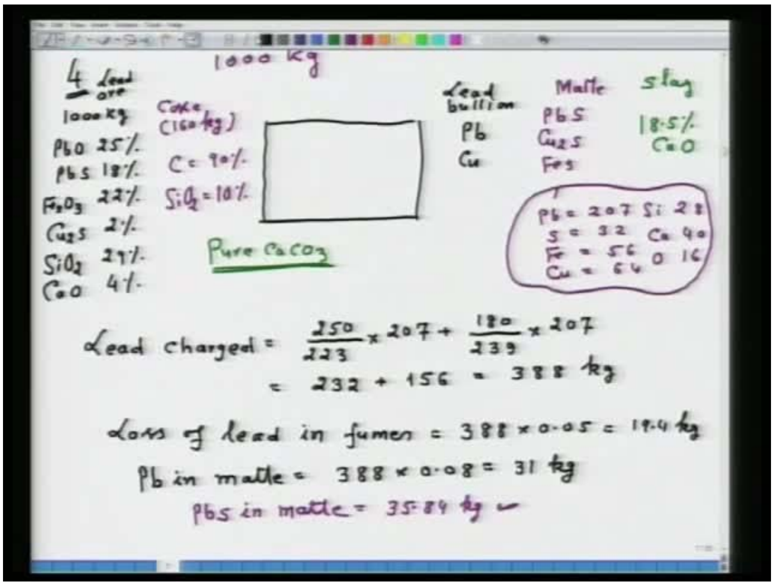

Let us see the 4th problem. 4th problem is where you have to find out amount of lead bullion, matte and calcium carbonate. Let us make a box of material balance. This is what a fuel box balance. Let us take the basis of calculation, say, 1000 kg. 1000 kg is the lead ore that we are using. 1000 kg lead ore- the composition I am writing, Pb O is given 25 percent, Pb S - 18 percent, Fe 2 O 3 - 22 percent, Cu 2 S - 2 percent, Si O 2 - 29 percent and calcium oxide is 4 percent; that is what the ore.

This is the lead ore. Coke is 160 kg and carbon is equal to 90 percent and SiO 2 is equal to 10 percent. The problem further says that pure calcium carbonate is charge; pure calcium carbonate is the flux, I mean the agent to flux. It further says you produce lead bullion and lead bullion should contain lead and copper. That is what the output I am giving. Then next output you have is the matte and matte will contain Pb S, Cu 2 S and Fe S.

Then, slag and it is said slag is having 18.5 percent calcium oxide. That is what the problem is said. Now, you have to find out the amount of lead bullion, matte and calcium carbonate in this particular problem.

Now, they are all smelt in the blast furnace and these are the outputs that are given. Now, to calculate lead bullion, we first of all, calculate lead charged. Amount of lead charged will be equal to 250 upon 223 into 207 plus 108 upon 239 into 207.

Mind you, here I have taken the atomic weights of lead 207, then sulphur I will be taking 32, iron I will be taking 56, copper, if at all needed, I will take 64, silicon if needed, I will take 28, calcium if needed, I will take 40 and that is all and oxygen of course, its atomic weight is 16. These are the atomic weights that I will be using to solve this particular problem.

So, amount of lead charge will be equal to 232 plus 156 and that makes 388 kg; that is the amount of lead you will charged. So, loss of lead in fumes and gases or whatever will be equal to 388 into 0.05; that is equal to 19.4 kg. Lead in matte, as it is said, it is equal to 388 into 0.08, that is equal to 31 kg and therefore, Pb S in matte can easily recalculate 35.84 kg.

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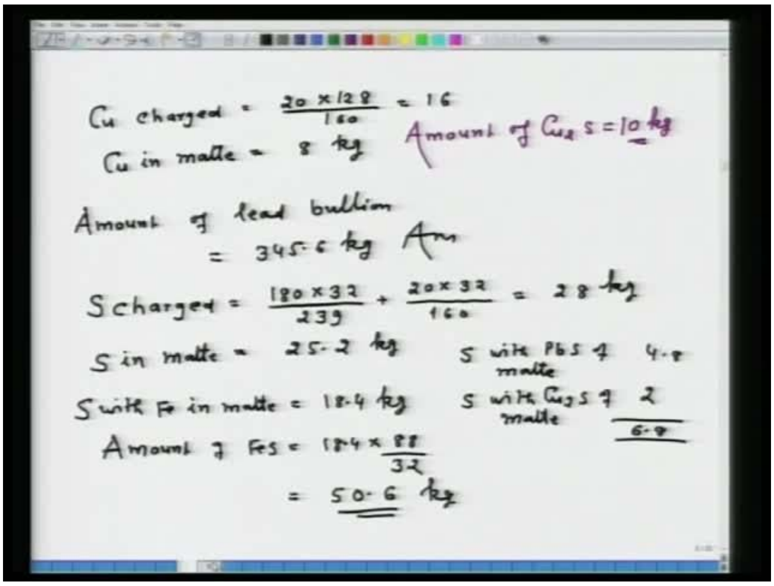

That is one compound or one part of matte, which is Pb S. Now, let us calculate Cu 2 S. So, for Cu 2 S, the copper charged is equal to 20 into 128 upon 160 that come around 16. So, copper in matte, as problem says is equal to 8 kg. Therefore, amount of Cu 2 S is equal to 10 kg. This is another component of the matte and rest copper is in bullion.

So, amount of lead bullion now we can calculate. Amount of lead bullion will be consisting of lead plus copper; so, this will be equal to 345.6 kg. That is the amount of lead bullion. You can just sum total, lead and the copper, which is entering into the bullion.

Let us calculate now, matte and calcium carbonate. We have calculated only lead bullion. Now, in order to calculate matte, we have to do some exercise. First of all, we have to calculate how much amount of sulphur is charged. Sulphur charged will be equal to 180 into 32 upon 239 plus 20 into 32 upon 160 and that makes 28 kg. That much of amount of sulphur is being charged.

Sulphur in matte is equal to 25.2 kg. Now, we have to find out sulphur with Pb S of matte and sulphur with Cu 2 S of matte. That means, first you have to find out sulphur with Pb S of matte and then you have to find out sulphur with Cu 2 S of matte. How much lead is entering into the matte; how much copper - that calculation we have done earlier, and total sulphur which is with Pb S and Cu 2 S is equal to 6.8; here it is 4.8 and that is equal to 2, of course in kg. They are all in kg.

Sulphur with iron in matte, of course, you have to subtract- that will be 18.4 kg. That much amount of sulphur with iron in matte. From here, amount of Fe S will be equal to 18.4 into 88 divided by 32, so, amount of Fe S will be 50.6 kg.

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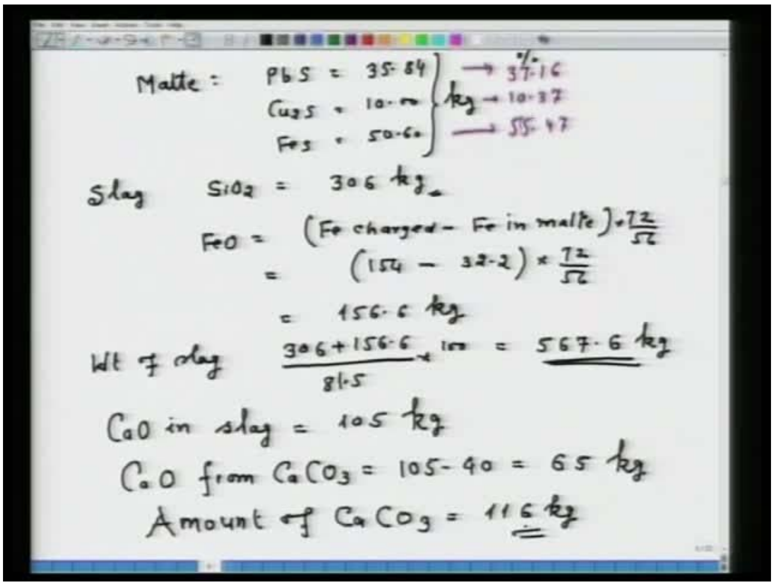

We are in a position to write down the matte. So, matte amount would be Pb S, then it has Cu 2 S, then it has Fe S. Pb S, as we have calculated, 35.84, Cu 2 S, 10.00, Fe S is 50.60. Mind you, they are all in kg. In percent wise, the percent is 37.16, 10.37 and 55.47 that is what the matte comprises of.

Now, we have to calculate the amount of slag in order to calculate amount of calcium carbonate; because we cannot calculate calcium carbonate unless you know the calcium oxide. For that purpose, first you have to calculate the amount of slag and then calcium oxide, then calcium carbonate.

So, the slag will have Si O 2 from all sources - that will be 306 kg. This is the amount of Si O 2. Then you have to calculate Fe O. Fe O would be iron charged minus iron in matte. Do not forget to convert it into Fe O - that will be 72 by 56. So, iron charge is 154 kg minus 32.2 into 72 by 56. So, the amount of Fe O will be equal to 156.6 kg.

Once you know the amount of Fe O, now I can calculate the weight of slag. Weight of slag will be 306 plus 156.6, because it says, 18.5 percent is the CO in slag. So, 100 minus 18.5 percent will be sum total of Si O 2 and Fe O. So, if I divide by 81.5 into 100, then the weight slag will be equal to 567.6 kg. Once again, in order to calculate the amount of calcium carbonate which is being asked in the problem, you must be wondering why I have calculated Si O 2 and Fe O 3, because the problem says that the slag contains 18.5 percent calcium oxide.

So, unless you calculate the amount of slag, you cannot calculate the amount of calcium carbonate. If you have another way of calculation I do not know. Think. Weight of slag I got now. Now, I can calculate calcium oxide in slag. Calcium oxide in slag will be 105 kg. Again, you have to do here calcium oxide balance; because, if you read the problem, the problem says the roasted ore has some four percent calcium oxide.

So, calcium carbonate, Ca O from CaCO 3 will be 105 minus 40 - that will be 65 kg. As such, amount of CaCO 3 will be equal to 116 kg. This is how the problems are to be tackled. Now, here in this particular session, what I have done, I have illustrated the different ways of problems and different methods to approach the problem. However, it is intended that you develop your own method of solution of the problem without seeing the solution and of course, without seeing the answers.