Materials and Energy Balance in Metallurgical Processes
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Module No. # 01
Lecture No. # 34
Exercise in Converting

This is a lecture in continuation to the lecture on converting one. There I gave the concept and I solved some problems over there and here, the remaining problem in the (( )) that I will be illustrating the basics or the operation of converting through problems. So, here some more different types of problem as correspond to the converting operation.

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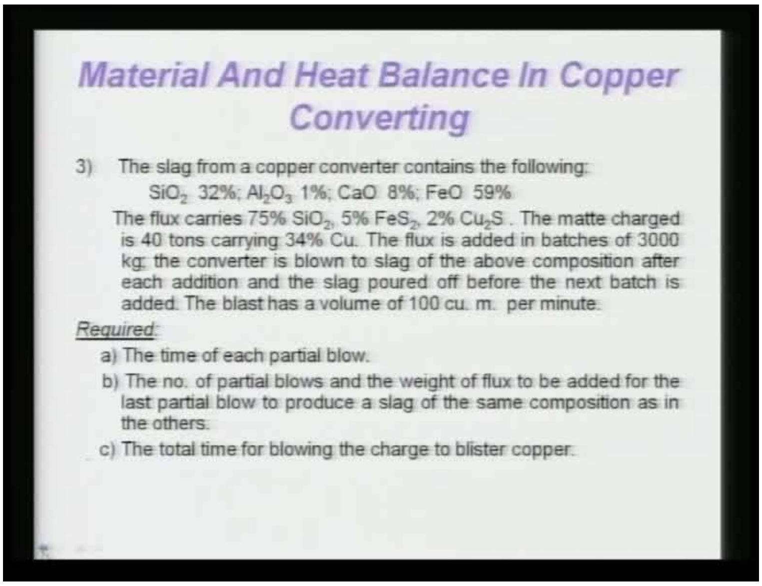

Here is the problem number 3. The problem 3 says, the slag from a copper converter contains the following: the composition of the slag is given, the flux which is charged - its composition is also given, the matte charge is 40 tons and carrying 34 percent copper or you can say this is the copper grade of the matte is 34 percent. Now, here as I said in my lecture that it is not necessary that you charge all the fluxes at the beginning. You may charge flux batch wise; that depends on the availability of the infrastructure to charge the flux into the converter. So, this particular problem addresses the issue that the flux is charged in batches. The flux is added in batches of 3000 kg, may be because of some logistic reason they are charging the flux in batches and the first batch consists of 3000 kg the converter is blown to slag of the above composition after each addition.

Once you make the addition, the next addition again you make the slag of the same composition as given earlier and the slag poured out before the next batch is added. So, every time what you are doing you are adding 3000 kg of flux making the slag, removing the slag, again adding 3000 kg of flux again making the slag and again removing the slag; so this is going on.

The blast has a volume of 100 cubic meter per minute; you are required to calculate time of each partial blow because, now there will be different partial blows. How much time for each partial blow? A number of partial blows because, we know the converting the first stage is slag formation. Only after slag formation stage, that is after removal of FeS you blow the converter content for production of blister copper.

First of all, you have to know how many number of partial blows will be required in order to accomplish the complete removal of FeS and that is what the problem b says. The number of partial blows and the weight of flux to be added for the last partial blow to produce a slag of the same composition as in the other because it is possible the last partial blow may not require all amount of flux; may be less than that so you have to calculate that. The total time for blowing the charge to blister copper and the total time of course, consist of slag forming time as well as blister copper formation stage. So, this is problem 3. what I thought thte Let me read all the problems; I will take the solutions one by one.

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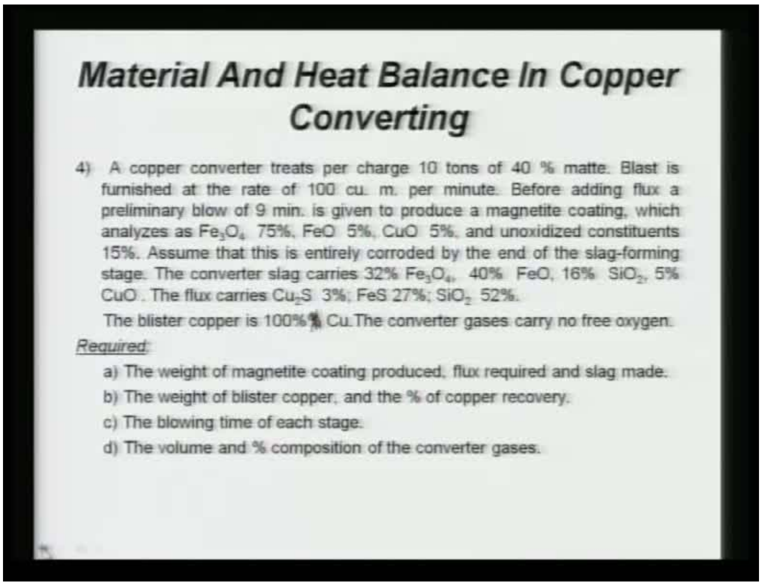

Here is the problem number 4: a copper converter treats per charge and 10 tons of 40 percent matte; that is, a copper grade is 40 percent blast rate is given; before adding flux a preliminary blow of 9 minutes be given to produce a magnetite coating. This problem is little different for the converter operation. Here, first the problem says a magnetite coating is important which analyzes the composition of the magnetite coating is given; assume that this is entirely corroded by the end of the slag forming stage.

The converter slag carries 32 percent Fe 3 O 4, 40 percent FeO, 16 percent, SiO 2 5 percent CuO. That means, what it says, at the end of coating formation stage, now you enter into the slag forming stage. So, assuming that the composition of the coating which is Fe 3 O 4 FeO and all is given which is all converted into a slag which composition is Fe 3 O 4 40 percent, FeO 16 percent ,SiO 2 5 percent CuO.

The flux caries Cu 2 S FeS and SiO 2; their percentage are given; the blister copper is 100 percent copper; the converter gases carry no free oxygen. Now, you have to calculate weight of magnetite coating produced, flux and slag weight of blister copper, the blowing time and the volume and percentage composition of the converted gases.

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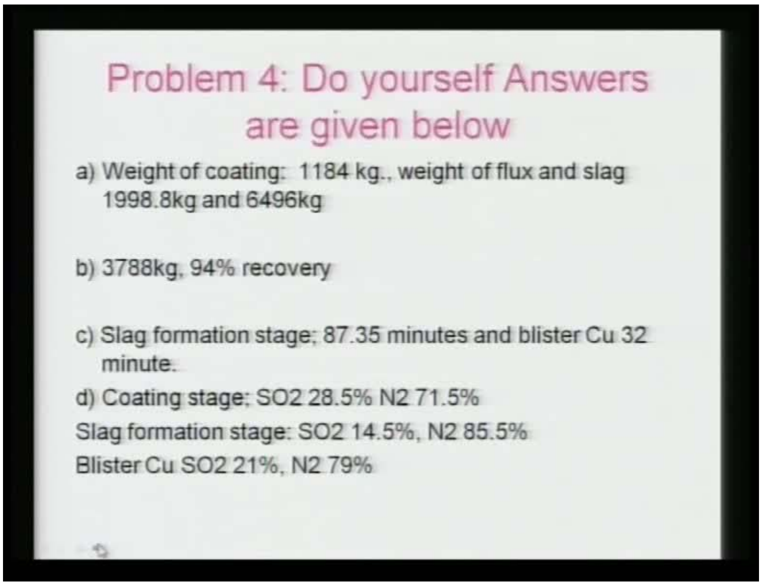

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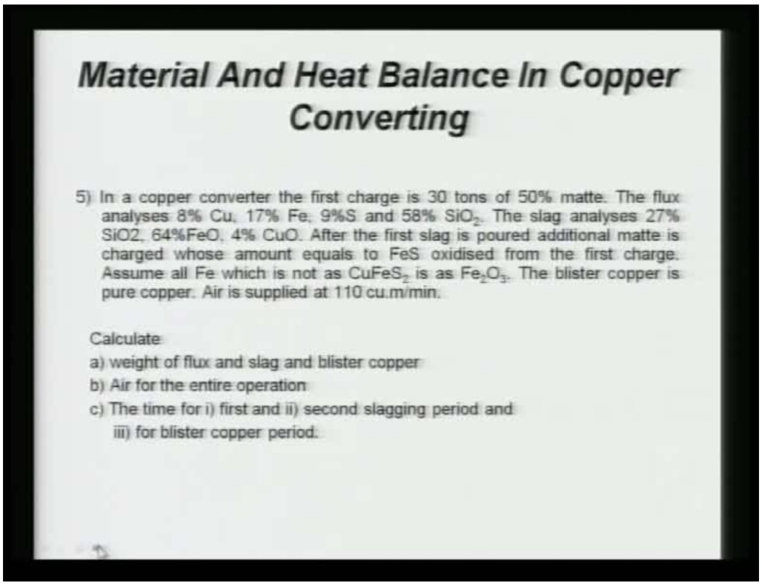

Here I have given the answers for this particular problem but, my request, please see the answer only when you have solved the problem. Here is the problem number fifth: in a copper converter the first charge is 30 tons of 50 percent matte, the flux analysis is given, slag analysis is given. Now, after the first slag is poured additional matte is charged whose amount equals to FeS oxidize on the first charge.

Assume all Fe which is not a CuFeS 2 is as Fe 2 O 3, the blister copper is pure copper; air is supplied at this particular rate. You have to calculate weight of flux slag and blister copper, air for the entire operation and the time for first and second slagging period and for blister copper formation.

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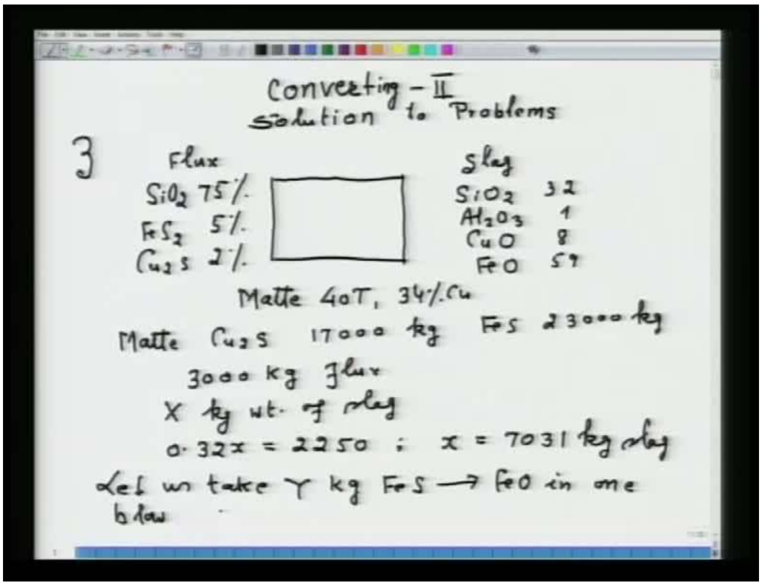

So, let me solve the problem number 3: so problem number 3, as usual I make a block diagram; say here is given flux that is SiO 2 75 percent, FeS 2 5 percent and Cu 2 S is 2 percent (Refer Slide Time: 06:00); we said the slag of composition SiO 2 Al 2 O 3 CuO and FeO SiO 2 is 32, Al 2 O 3 is 1, is 8 and FeO is 59. Now, we have to calculate the time for partial blow. It is also said matte is 40 tons and its grade is 34 percent copper.

Now as such, say the matte, you have to find out the amount of Cu 2 S. So, we can calculate say Cu 2 S that is equal to 17000 kg and FeS that is 23000 kg. You can calculate 34 percent copper and form that Cu 2 S and so on. Now the first batch it consists of 3000 kg flux; then we can calculate the amount of SiO 2, amount of FeS 2 and amount of Cu 2 S; that we can calculate. Now let us say X kg is weight of slag, then 0.32 x that is equal to 2250, that is SiO 2 in flux. It will go to SiO 2 in slag; so from here we get x that is equal to 7031 kg is the amount of slag.

Now, let us take Y kg FeS of matte. It oxidizes to FeO in 1 blow. Say we added 3000 kg of flux; now we would like to know how much amount of FeS is being oxidized because, you have to know how many number of partial blows you require in 1 blow that is by charging 3000 kg flux.

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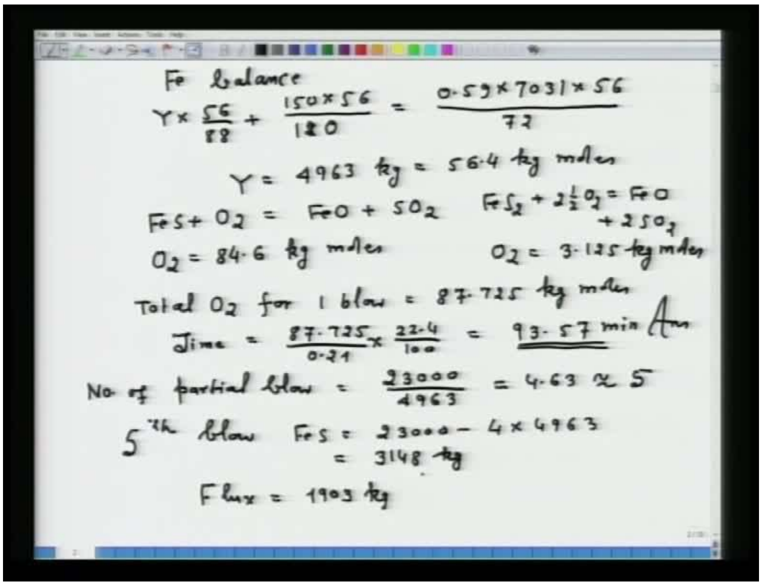

Now we will do iron balance. So, iron balance that is equal to Y into 56 upon 88 plus 150 into 56 upon 120; that is equal to 0.59 into 7031 into 56 divided by 72; where Y is the kg of FeS of matte. So, Y that is equal to 4963 kg that is equal to 56.4 kg moles.

Now, the reaction which is there for oxidization reaction you have FeS plus O 2; that is equal to FeO plus SO 2 and we have FeS 2 also FeS 2 plus 2 and half O 2 that is equal to FeO plus 2 SO 2, because FeS 2 is coming from the flux; so we have to calculate both. So, here the O 2 required for this will be 84.6 kg moles. That is, for FeS 2 FeO and here for FeS 2 O 2 require that will be 3.125 kg moles because matte contains FeS and flux contains FeS 2. And that is why you have to do separate calculation. So, total oxygen for 1 blow that is equal to 87.725 kg moles or in terms.

So the time we can calculate that will be equal to 87.725 upon 0.21. That is the amount of air into 22.4 upon 100 because you blow 100 meter cube per minute. So, the time is 93.57 minute; that is the answer for time for first blow now the number of partial blow because you know time for 1 blow is 93.57 and in 1 blow you are able to remove 4963 kg of FeS. So number of partial blow that will be equal to 23000 upon 4963 that will be 4.63; approximately you require 5 blow.

Now, in the fifth blow you will not be having 4963 kg so in the fifth blow the FeS which is left that will be equal to 23000 minus 4 into 4963. So, you require to remove 3148 kg of FeS now you can calculate the flux same iron balance. The flux required for the fifth blow that will be 1903 kg; now again in order to calculate flux you have to do the iron balance.

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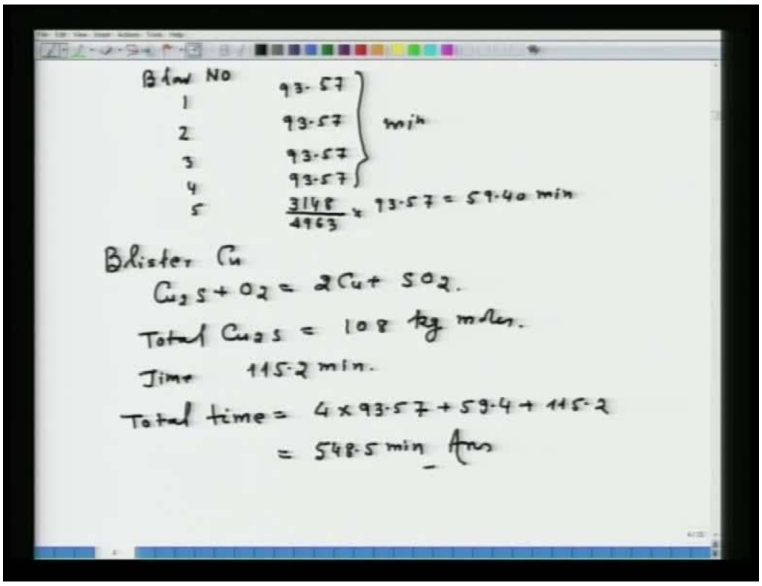

Now, we can calculate the number of blows. so we require the blow number you have 1 2 3 4 and 5 all the blows will require 93.57 - first blow; second blow also 93.57; third blow also 93.57; fourth blow also 93.57; but the last blow will require 3148 upon 4963 into 93.57; so that will be equal to 59.40 minutes.

Mind you, they are all the minutes. Now, the fifth blow will comprise of 59.40 minutes as compared to all the flows which consists 93.57, because you have to remove less amount of FeS so that is to say total, if you sum total you get the total amount. Now, the blister copper the reaction is Cu 2 S plus O 2; that is equal to 2 Cu plus SO 2. So, we can calculate now the total Cu 2 S that will be equal to 108 kg moles and the time, because 108 kg mole still requires 108 kg moles of oxygen. So, one can calculate the time that will come 115.2 minutes. Total time would be 4 into 93.57 plus 59.4 plus 115.2. The total time required that will be 548.5 minutes, so that is the answer for this question.

Let us take now the problem number 4; it says about the magnetite coating and so on.

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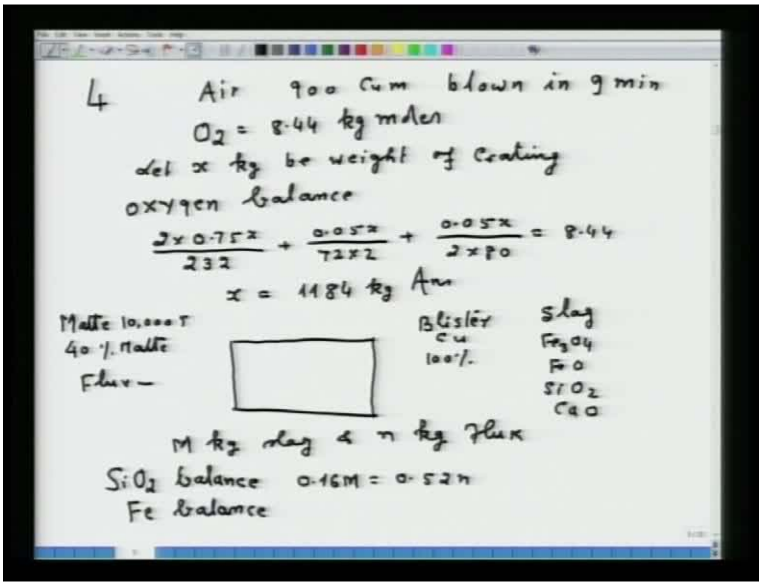

First of all, we have to calculate the weight of magnetite coating flux and slag so it is said that air is 900 cubic meter it is blown in 9 minutes. The oxygen will be 8.44 kg moles that will be available for the formation of the coating. Now, let x kg be weight of coating; then we do oxygen balance and from oxygen balance we can write down 2 into 0.75 x upon 232 plus 0.05 x upon 72 into 2 plus 0.05 x upon 2 into 80; that is equal to 8.44. Now, the clue to this problem is that the coating is formed because of the availability of oxygen. So, you have to hit the oxygen balance to get the weight of magnetite coating and if you do, then the x that is equal to 1184 kg is the weight of magnetite coating.

Now, the problem says further that suppose now, once this coating is formed, the slag formation stage begins and at the slag formation stage say we have charged now matte 10000 tons 40 percent matte. Then composition of flux is given to us; it is said that blister copper is produced which is 100 percent copper and slag. Its composition is given and it contains Fe 3 O 4, say FeO SiO 2 CaO, all the compositions are given. So, we have to find out weight of slag and weight of flux.

So let us take say M kg slag and n kg flux; so let us first of all SiO 2 balance. So, SiO 2 balance if you do it comes 0.16 M. That is equal to 0.52 n then we have to do iron balance.

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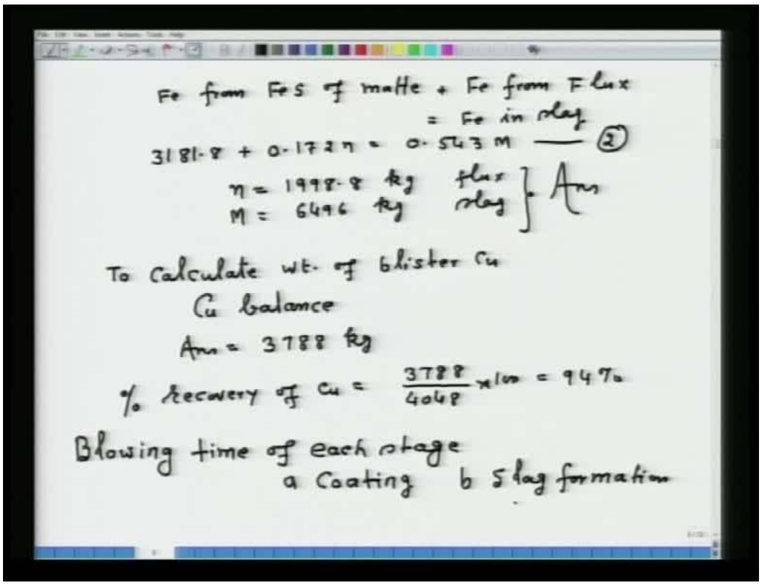

Now, here I am seeing oxygen is, I wrote 8.44 kg; in fact it is 8.44 kg moles. Now, let us do iron balance. In the iron balance, say iron from FeS of matte plus iron from flux that is equal to iron in slag. So, you have to do that balance. If you do this balance what we will be getting is a second equation that will be 3181.8 plus 0.172 n - that is equal to 0.543 M. Let us take this is our equation 2 and the earlier this was our equation number 1. So, by solving equation 1 and 2, we can get n that is equal to 1998.8 kg; this is the weight of flux and M which is the weight of slag that is equal to 6496 kg; that is the weight of slag so this is the answer (Refer Slide Time: 20:48) .

Now, next you have to calculate weight of blister copper and percentage copper recovery. For weight of blister copper - to calculate weight of blister copper what you will do? We will be doing copper balance. Copper from all sources which is entering and it is leaving, that you have to consider and if you do that then the answer - the copper balance that will come 3788; I think you can do this copper balance, because I have done in several other problems. The percentage copper recovery, say percentage recovery of copper that is equal to 3788 upon total copper was in the system 4048 into 100; so that is equal to 94 percent is the copper recovery.

Now, next we have to calculate the blowing time of each stage. Each stage means as in other problems we have slag formation stage and blister copper formation stage. Here, prior to blister copper formation stage, we have 2 stages. One is the coating stage and another is the slag formation stage. So, we have to find out what is the blowing time for each stage; that is an important thing because, here the first stage consist of coating now each stage means the stage a consists of coating; how much time it takes second stage consists of slag formation stage.

In the slag formation stage you have to consider oxidation FeS 2 FeO as well as oxidation of Cu 2 S to CuO, because you see slag also contains copper oxide. So, in the slag formation stage you have to calculate the time required for complete oxidation of FeS to FeO as well as, whatever amount of CuO that is present that also constitutes the slag formation stage because Cu 2 S is also being oxidized.

So, we can do those balances and ultimately you have to calculate how much oxygen is required and from the oxygen you can calculate. I hope you can do all this calculation because these type of calculations have been done earlier.

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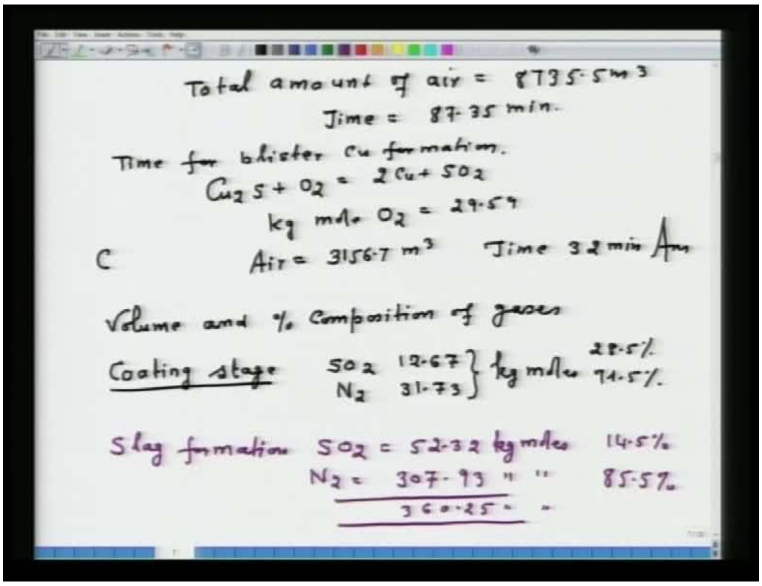

So I will just write down here the total amount of air which is required for coating as well as for slag formation stage that comes out to be equal to 8735.5 meter cube and the time would be 87.35 minutes because, we are given the rate of blowing then we are required to calculate time for blister copper formation. Now, here you know the reaction Cu 2 S plus O 2 that is equal to 2 Cu plus S O 2. So, you have to find out how much kg moles of Cu 2 S has being oxidized in this stage. If you do those calculations, whatever moles of Cu 2 S same moles of oxygen would be required. The answer comes kg mole of

O 2 required that is equal to 29.59 and from here, if you calculate air that is equal to 3156.7 meter cube at 1 atmosphere in 273 kelvin and the time which comes that is equal to 32 minutes; so that is the answer for the part c.

Now, the part d says you have to find out volume and percent composition of gases; so here you have to find out the volume and percentage composition of in each stage. Say the first stage you have coating stage. You have to write down the relevant chemical reaction that we have written already in the coating stage. You have SO 2 and nitrogen because you are blowing oxygen. FeS is converted to Fe 3 O 4; so you have SO 2 and N 2 and the SO 2 will be 12.67 kg moles and N 2 is 31.73; they are all in kg moles.

So the percentage that is equal to here 28.5 percent and here it is 71.5 percent (Refer Slide Time: 27:00); so this is in the coating stage. Now, the gas composition in slag formation stage SO 2, that will be equal to 52.34 kg moles and nitrogen would be 307.93 kg moles. So, the amount if you sum total both it becomes 5 12 6 and 365.25 kg moles is the amount of converter gas that is produced. If you want to calculate, you multiply by 22.4 you get the meter cube.

The percentage SO 2 is 14.5 percent and nitrogen is 85.5 percent ;that is what the amount and the percentage composition of the gases in the slag formation stage.

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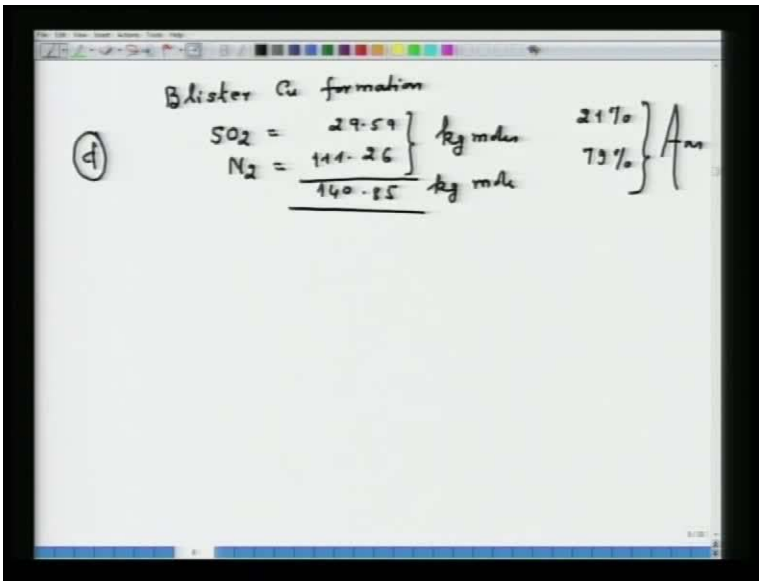

Now the third stage consists of blister copper formation stage. Here again, SO 2 it is simple Cu 2 S plus you have already the equation. You have already the reaction Cu 2 S plus O 2 so 29.59 is the kg moles of O 2 and therefore 29.59 moles will be of SO 2 also because, 1 mole Cu 2 S is giving you 1 mole SO 2 or 1 mole oxygen is producing 1 mole of SO 2. So, SO 2 that will be equal to 29.59 and nitrogen would be 111.26 that is in kg moles. If you want to calculate, the amount will be 140.85 kg moles and volume will be 140.85 into 22.4 that will be meter cube and the percentage would be here 21 percent and nitrogen is 79 percent. So, that is what the answer for part d; this is what I thought of problem number 4.

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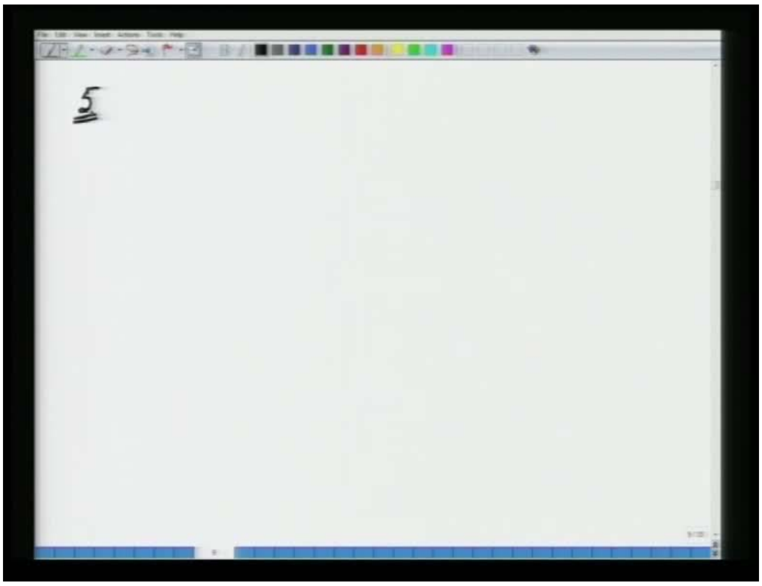

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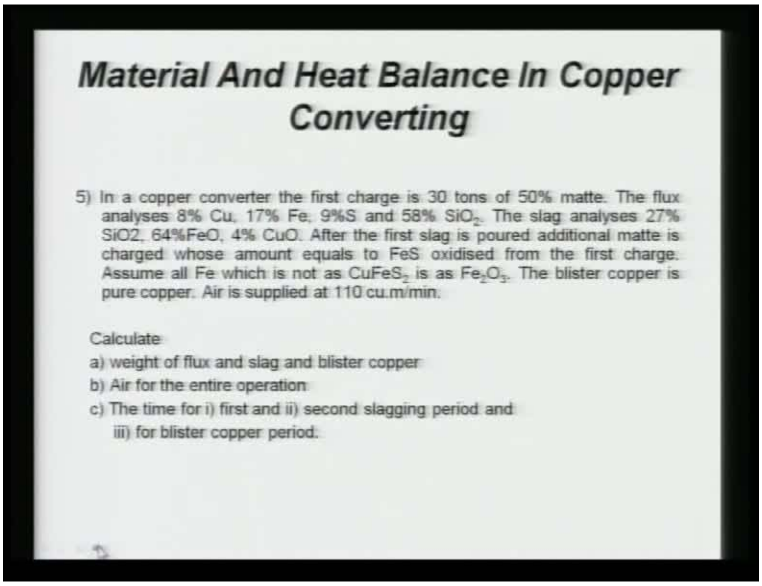

Now let us go straightaway to problem number 5. now problem number 5 It is say, the charge is 30 tons of 50 percent matte. Let me represent over here: so this is the block diagram here, I am charging 30 tons matte the copper grade is 50 percent.

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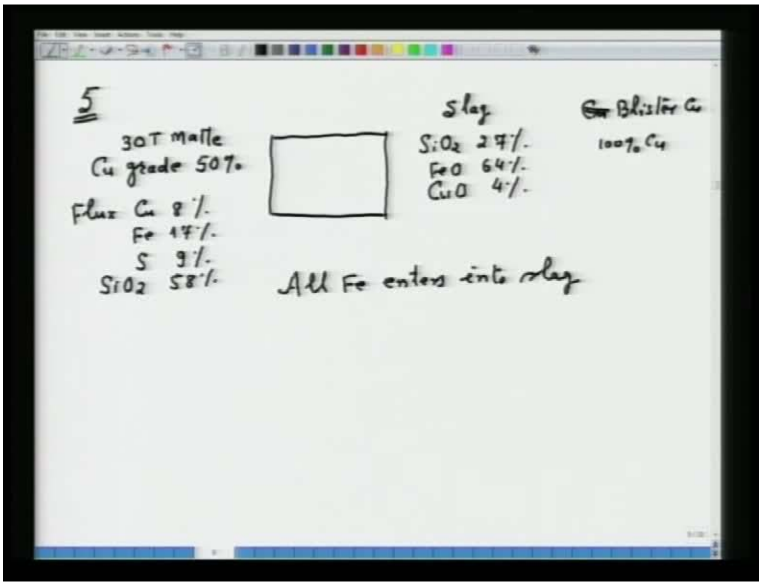

Now the flux; it is copper 8 it is all in percent iron 17 percent sulphur 9 percent and SiO 2 that is equal to 58 percent. The slag which is produced you have SiO 2 27 percent, FeO 64 percent and CuO loss of copper to the slag it is 4 percent and copper which is the blister copper I mean, say blister copper that has 100 percent copper.

Now, again for weight of flux and slag and blister copper formation and also its says that all iron enters into slag. So, first of all, we have to do now in order to find out weight of flux weight of slag we have to do SiO 2 balance and iron balance as I have done in earlier problems; so I will be little quick over here.

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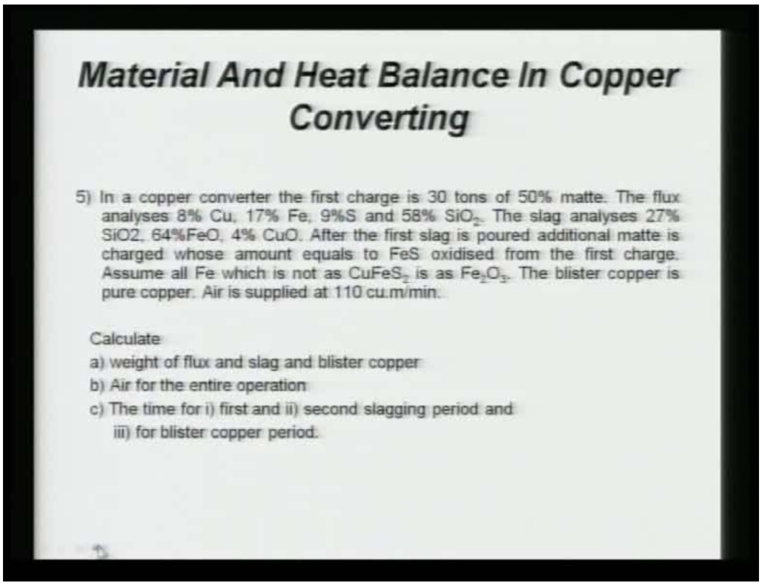

Now this problem is slightly different. What has been said in this problem is that, after the first slag is poured, additional matte is charged whose amount equals to FeS oxidized from the first charge; so that is a slightly different problem.

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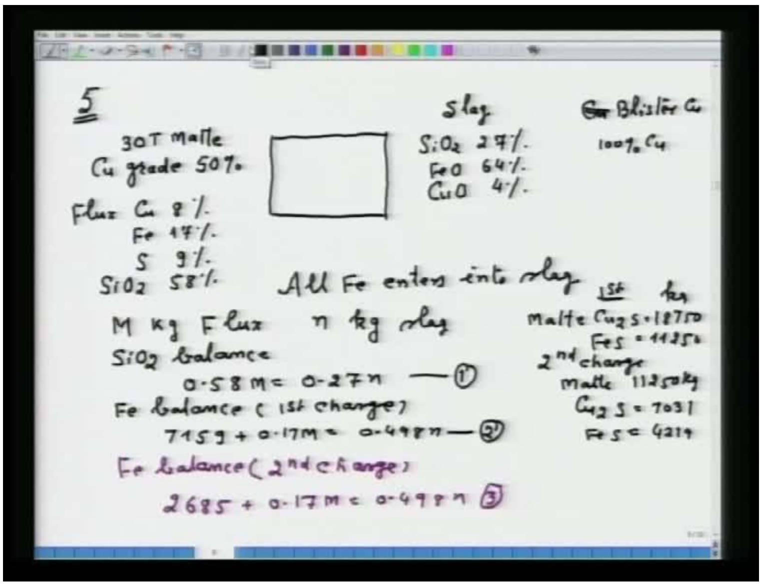

Here first, you have to calculate weight of flux and slag and blister copper. So, as usual say, M kg flux and n kg slag; now say matte, Cu 2 S that is equal to 18750 kg from the first charge and FeS of the first charge that is equal to 11250 kg that is the first charge.

Now, the second charge in the second charge matte 11250 kg matte is charged; so the second charge matte is 11250 kg whose grade is 50 percent. So, we have now Cu 2 S that is equal to 7031 kg and FeS that is equal to 4291 kg; that is the difference here. When you consider the total amount of FeS oxidize, the total amount of slag, then you have to consider the FeS which is charge from both the stages; so again, I will be doing SiO 2 balance. So, SiO 2 balance that is 0.58 M that is equal to 0.27 n and I do iron balance - this is from first charge which contains 11250 kg FeS.

If you do the balance I hope you can do it. I am straightaway writing the equations 7159 plus 0.17 M that is equal to 0.498 n and this is my equation 1; this is my equation 2 (Refer Slide Time: 35: 20).

Let me do iron balance for second charge. If I do iron balance for second charge, then the equation is 2685 plus 0.17 M that is equal to 0.498 n and this is my equation number 3.

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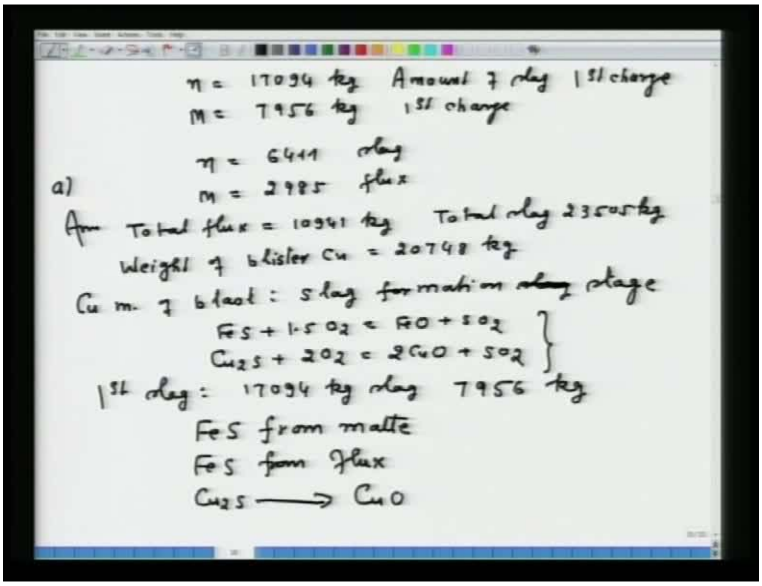

Now I can solve equation 1 and 2 and equation 1 and 3 in order to get the amount of slag and amount of flux in each stage. If I do that then the n that is equal to 17094 kg, this is the amount of slag in the first charge, then M amount of flux that is equal to 7956 kg this is for the first charge.

Similarly, by equation 1 and 3, I can get the n and M n will be equal to 6411 and m will be 2985. This is slag and this is the flux which is resulting after charging additional matte. (Refer Slide Time:).

The total flux will be the addition of both, that is, 10941 kg and total slag that will be 23505 kg; so that is what the answer for that particular part. This is in fact the part a; now the b part we have to find. Even the a part we have to find out weight of blister copper. Weight of blister copper can be easily formed by doing copper balance and this is equal to 20740 kg. Now, the problem further wants to know air for the entire operation.

That means, slagging period and blister copper formation period. So, we require cubic meter of blast; say in the slag formation stage, we require for oxidation of FeS plus 1.5 O 2. So the chemical reaction is this another reaction is the Cu 2 S plus 2 O 2; that is equal to 2 CuO plus SO 2. So, these are the 2 reactions which are occurring in the slag formation stage. I think I wrote a mistake here; we can put it a slag formation stage. So, you know that for first slagging period the slag was 17094 kg; this is the first slag and the flux we needed 7956 kg; this is what we have calculated.

Now, why I have written this thing? Because, you have to know FeS from matte, so what is required to know first you have to know. FeS from matte and then you have to know FeS from flux and then you have to know how much amount of copper is being lost as a result of Cu 2 S plus 2 O 2 plus 2 CO reaction. This you can find out also by knowing amount of CuO in the slag.

Then you have to find out how much amount of Cu 2 S is being oxidize to CuO in this stage so for that you will be needing the amount of slag as well as amount of flux in the first slagging stage

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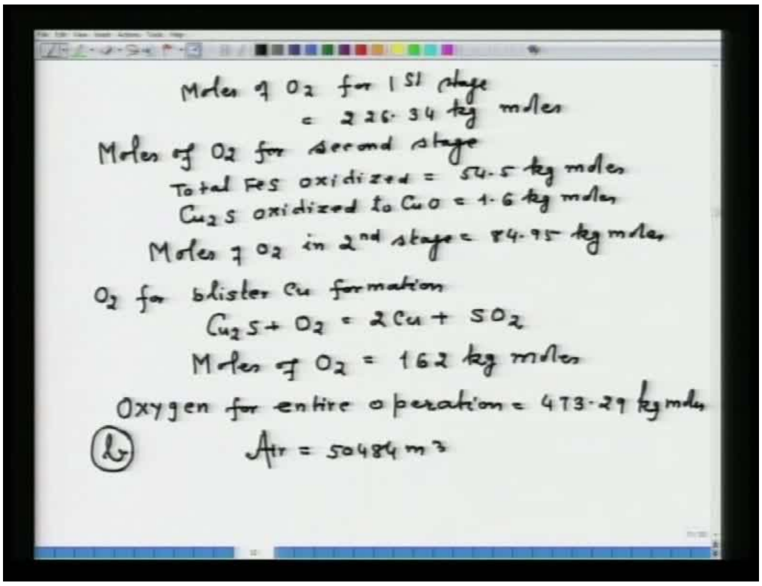

So having known all these things, one can calculate the moles of oxygen for first stage. I think, you can calculate there is no, it is not at all difficult. You have to calculate all the amount of FeS coming from all sources and plus the Cu 2 S which is being oxidized to CuO. The best way to calculate amount of CuO oxidized is from the percentage CuO in the slag. So you know how much oxygen is required for that purpose, so moles of oxygen for first stage that will be equal to 226.34 kg moles.

Similarly, you have to find out moles of oxygen for second stage. Same thing here; the total FeS oxidized in the second stage, total FeS oxidized from all sources that will be equal to 54.5 kg moles, alright. Then Cu 2 S oxidized to CuO; that is 1.6 kg moles. Now, having known this thing, it is easy to find out moles of oxygen in second stage that is equal to 84.95 kg moles; so, this is what the oxygen required for second stage.

Now, you have to calculate the air for entire operation that is what the problem says. The air for entire operation consist of both the slag period as well as blister copper stage, so oxygen for blister copper formation stage the reaction is Cu 2 S plus O 2 2 Cu plus SO 2.

We have to calculate the amount of Cu 2 as which is oxidized. You have already calculated the amount of copper which is formed. So, whatever amount of copper which is formed in the blister copper reformation stage, the same amount of in kg moles because 1 mole of Cu 2 S is giving you 2 moles of copper; you have to take into notice that also. From the total amount of copper that you have calculated if you make it in kg moles and write the appropriate reactions that is 1 mole of Cu 2 S is 2 moles of CO and then you can calculate amount of Cu 2 S that is required. This is one way; another way is how much amount of Cu 2 S is available for oxidation? You know the Cu 2 S of the matte in both these stages plus copper which is lost in the slag convert to Cu 2 S. Both ways you can do it; one way is from copper and another way is from Cu 2 S; both way you can do it. If you do this, it will come say moles of oxygen moles of O 2 for this stage that will be 162 kg moles.

So now oxygen for entire operation will be sum total of all the 3 oxygen for entire operation that will be equal to 473.29 kg moles so of course air will be 50484 meter cube; so that is the answer for part b.

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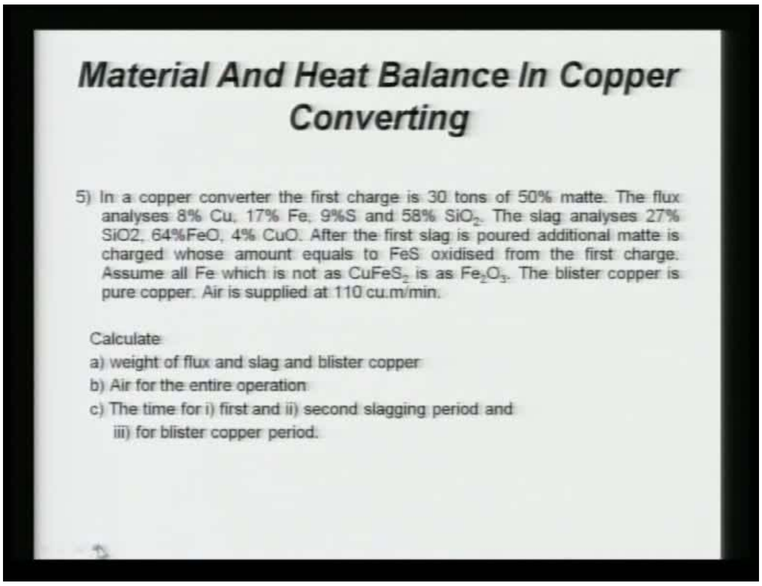

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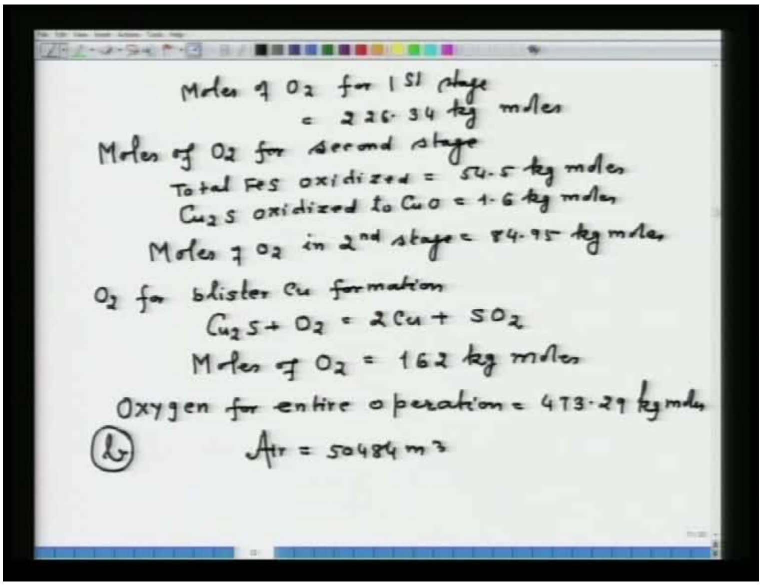

Now, the part c it wants the time for first and second slagging period and time for blister copper formation stage. We can find out; we know the amount of air and from the amount of air we can find out the time for the respective stages.

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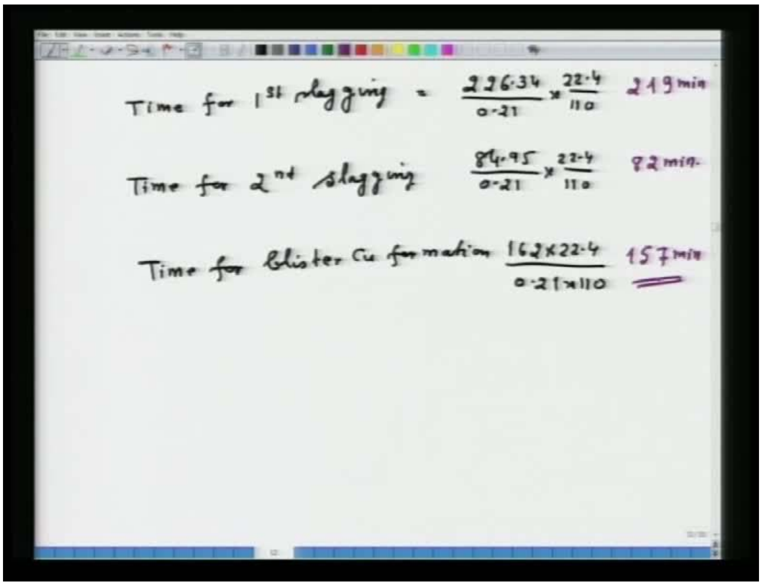

The time for first slagging time, for second slagging and time for blister copper formation stage; so time for first slagging you know because the air is blown in the rate of 110 cubic meter per minute.

So, time for first slagging you know that 226.34 upon 0.21 into 22.4 upon 110; here it will be 84.95 upon 0.21 into 22.4 upon 110; here it will be 162 into 22.4 upon 0.21 into 110. So, the answer would be here 219 minutes - the time for first slagging time. For second slagging, it is 82 minutes and time for blister copper is 157 minutes.

So, you look these are the respective times which are involved in this converting operation. Now, with these 3 problems which I have illustrated today, I have tried to give you the converting operation quantitatively. All different aspects of converting operation I have tried to cover by considering the different type of problems we have considered the different partial blows; we have considered the charging of matte in different stages and so on. I hope this will make you clear the converting operation.