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. # 12

Exercises in Mineral Processing

Today, I will be solving some problems on material balance in mineral processing. I have given the necessary concepts that are required to solve these problems. However, for the detailed reading you see the references, which I had given in the lectures and you can update yourself. With that let me take the problems on material balance in mineral processing.

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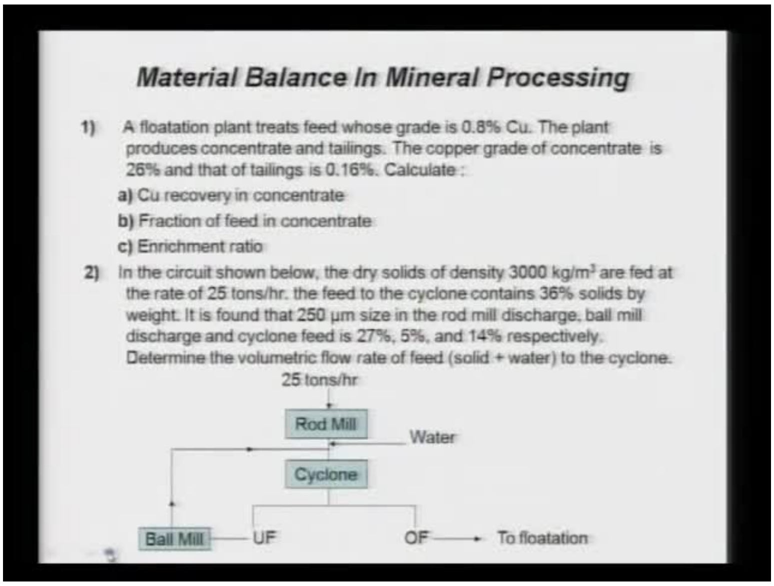

Now, as such, the first problem is a floatation plant treats feed, whose grade is 0.8 percent copper. The plant produces concentrate and tailings, the copper grade of concentrate is 26 percent and that of the tailing is 0.16 percent. Now, calculate copper recovery in concentrate, fraction of feed in the concentrate and c - enrichment ratio.

Problem number two: there is a ball mill circuit which implies rod mill and for ball mill typical milling operation is shown, the problem is as follows. In the circuit shown below, the dry solids of density 3000 kilogram per meter cube are fed at the rate of 25 tons per hour. The feed to the cyclone contains 36 percent solids by weight; it is found that 250 micron meter size in the rod mill discharge, ball mill discharge and cyclone feed is 27 percent, 5 percent and 14 percent respectively. That is what has been done. All the particles which are of 250 micron meter have been analyzed in the feed, as well as in the discharge; ball mill discharge, rod mill discharge and cyclone feed percentage are given. Determine the volumetric flow rate of feed; feed means solid plus water; that is, you have to find out the flow rate of water as well as that of solid.

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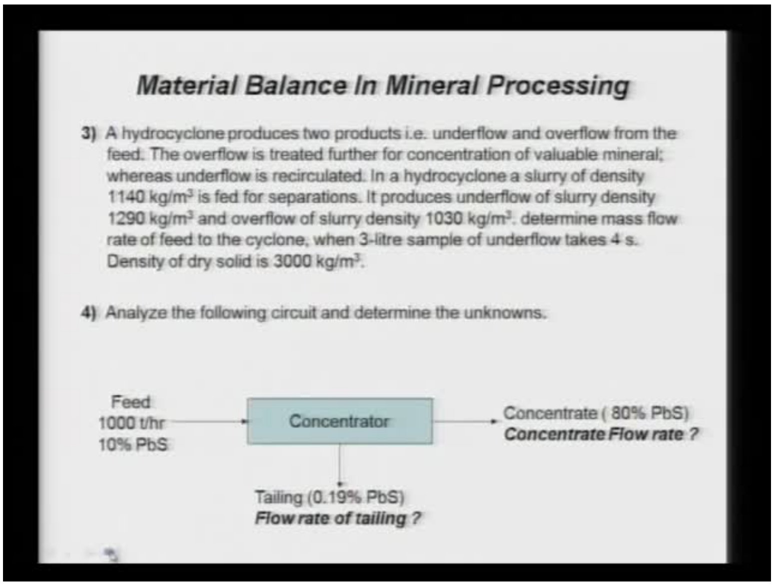

Problem number three: a hydrocyclone produces two products. Now as I have said, the hydrocyclone, it separates feed into overflow and underflow. So again, here two product formulas have to be used. A hydrocyclone produces two products that are underflow and overflow. From the feed the overflow is treated further for concentration of valuable mineral whereas, underflow is re circulated.

In a hydrocyclone, slurry of density 1140 kilogram per meter cube is fed for separation. It produces underflow of slurry density 1290 kilogram per meter cube and overflow of slurry density is this one. Determine mass flow rate of feed to the cyclone when 3 liter sample of underflow takes 4 seconds. Density of dry solid is given to you.

Fourth problem: analyze the following circuit and determine the unknowns. Now here, the circuit is given, in the circuit what is done? Feed 1000 tons per hour, 10 percent lead sulphide is here, mineral grade is given, concentrate and tailing are given, you have to find out concentrate flow rate and flow rate of tailing.

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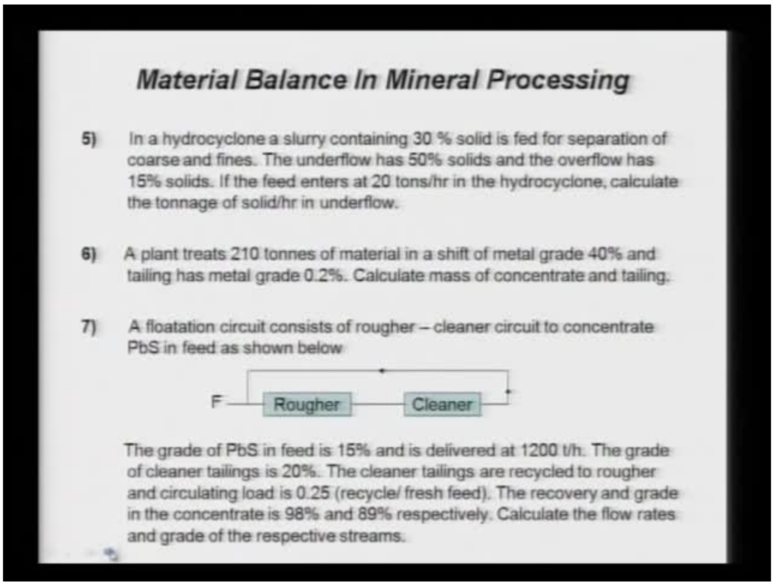

Problem fifth: in a hydrocyclone, a slurry containing 30 percent solid is fed for separation of coarse into fines. You can call coarse as underflow and fines as overflow. Overflow will be taken for further concentration operation; that is, to recover the particle containing minerals. The underflow has 50 percent solids and the overflow has 15 percent solids. If the feed enters 20 tons per hour in the hydrocyclone, calculate the tonnage of solid per hour in underflow.

Problem six: a plant treats 210 tons of material in a shift of metal grade 40 percent and tailing has metal grade 0.2 percent, calculate mass of concentrate and tailing. Seven: a floatation circuit consists of rougher - cleaner circuit to concentrate lead sulphide in feed as shown below. Either rougher or cleaner, the grade of lead sulphide in feed is 15 percent and is delivered at 1200 tons per hour.

The grade of cleaner tailings is 20 percent, the cleaner tailings are recycled to rougher and its circulating load is 0.25. The recovery and grade in the concentrate is 98 percent and 89 percent respectively, calculate the flow rate and grade of the respective streams.

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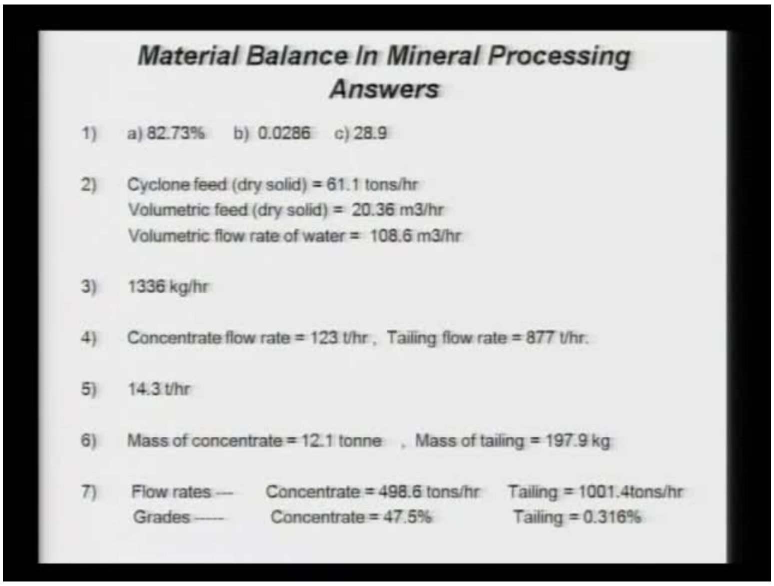

The last slide gives the answer for the various questions. Now, I will take question one by one, so let me take now the question number one.

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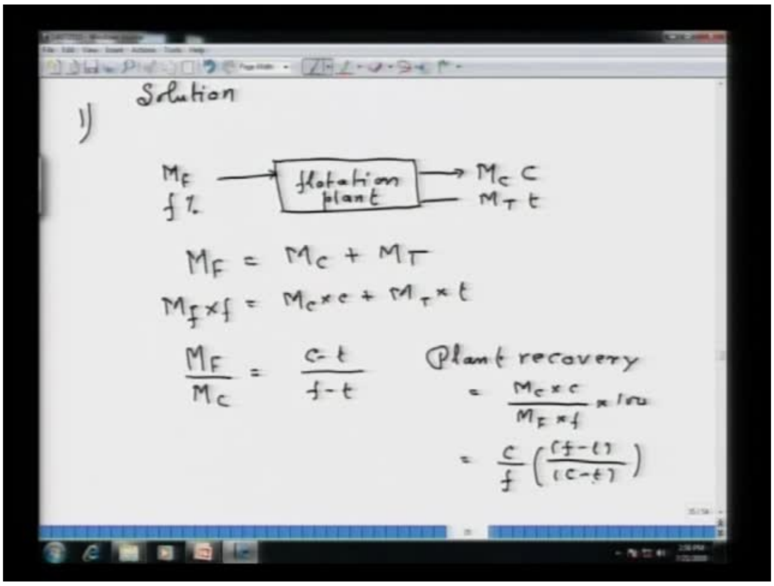

Now, solutions, but again I will appeal to all of you that please see the solution after you have attempted it by yourself. Now, this problem is as follows. We have a floatation plant; this is a floatation plant. In the floatation plant, you have mass of feed, where f percent or fraction is a grade of the feed. You have mass of the concentrate and C as the grade, and mass of the tailing and t as the grade, take percent of fraction. Mass balance MF is MC plus MT and M capital F into f that is equal to M C into c plus M T into t.

That is what we have done in the conceptual presentation, then straight away we can find out from here that MF upon MC that is equal to c minus t upon f minus t. Therefore, the plant recovery is equal to M C into c upon M F into f; that is equal to 100 or we can also find out the recovery as I have derived this particular formula f minus t upon c minus t.

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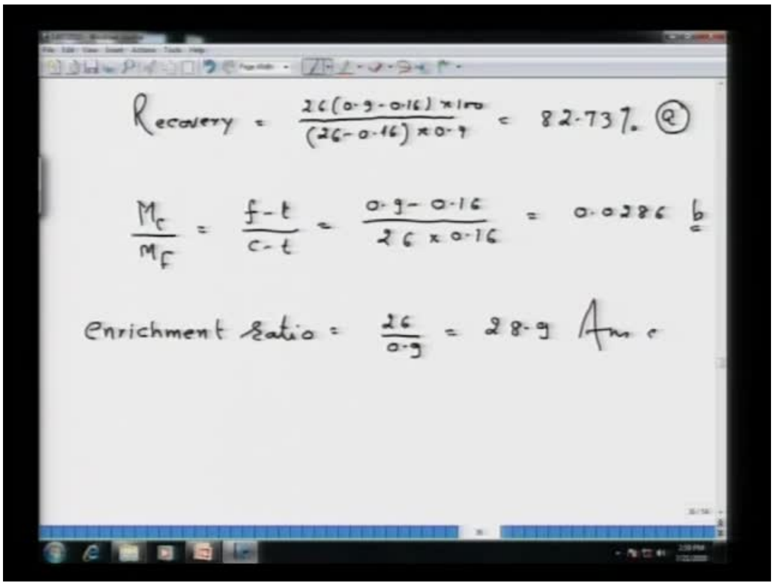

Now, we will substitute the values say recovery; recovery that is equal to say 26 into 0.9 minus 0.16 divide by 26 minus 0.16 into 0.9 that is into 100. So, the recovery is 82.737 percent that is the answer for this. Now, you have to calculate fraction of feed in the concentrate; so, this is the a part. The b part fraction of feed in the concentrate, you have to find out, this ratio is equal to f minus t upon c minus t. If you substitute the values 0.9 minus 0.16 upon 26 into 0.06 and that gives you 0.0268; that is the answer for part b.

Now, you see that the concentrate is hardly of 2 percent, in the 2 percent of the feed. So, a large amount of tailing is produced. The message that I want to give from here is that one of the important consideration in metal extraction is upgrading the ore in the mineral beneficiation, as a result of upgrading you produce a large amount of waste; that point is to be understood.

Now, enrichment ratio; this simply becomes what is the grade of the concentrate and grade of the feed, so that will be equal to 26 upon 0.9, so the enrichment ratio is 28.9; that is answer for c1(Refer Slide Time: 09:55).

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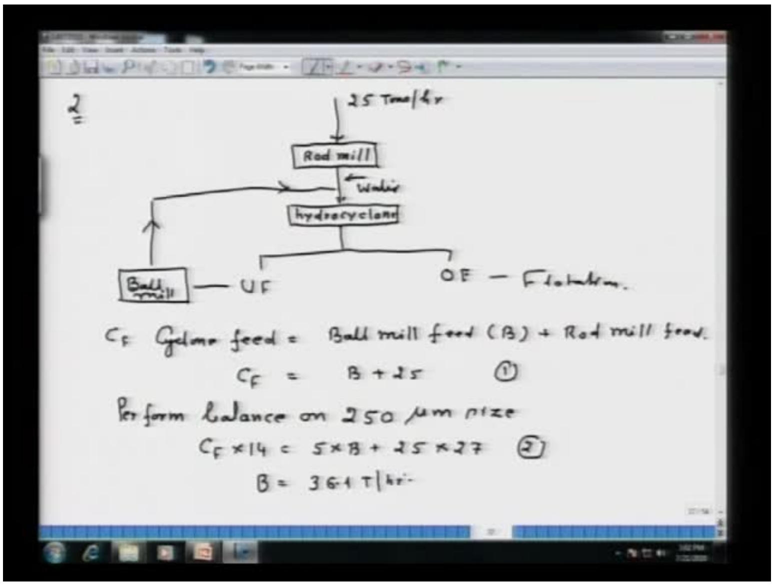

Now, let us see the problem number two: problem number two is as such, say we have a circuit, here is a feed, you have 25 tons per hour, you have here rod mill and from here it goes to hydrocyclone that is was given to you. Hydrocyclone; it separates underflow overflow. Underflow; it enters into ball mill and that further goes to the hydrocyclone for separation and here water can be added. So, the problem says 25tons per hour and this goes to floatation whatever concentration operation.

Straightaway, we have to do the mass balance that is the cyclone feed. Cyclone feed that is equal to ball mill feed, let us take it equal to B and plus rod mill feed. Cyclone feed, let us take it is equal to C F, so we have given the values, so C F cyclone feed that will be equal to ball mill feed plus we are given 25 tons per hour; this is our equation number one.

Now, perform balance on 250 micron meter size particles. As they are given to us, simply again we will do that C F into 14 that is equal to 5 into B plus 25 into 27, so that is our equation number two. Now, from this equation one and two, if you simplify, I will just leave on it to you. So, B will be equal to 36.1 tons per hour.

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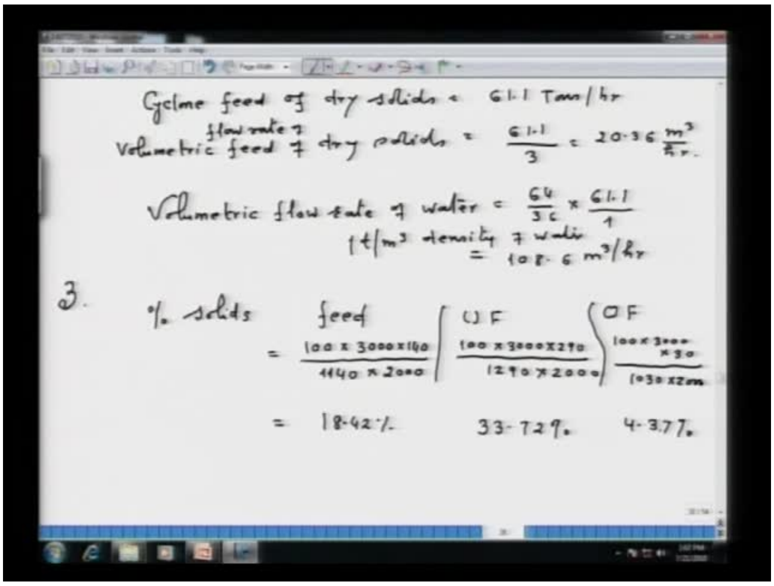

We can find out the cyclone feed of dry solid; cyclone feed of dry solids becomes 61.1 tons per hour; that is what the answer. This is a dry solid, now you have to find out the volumetric flow rates of feed. Feed consists of solids as well as water. So, first of all, we will find out the volumetric, we find out volumetric feed of dry solid that is volumetric flow rate. Volumetric flow rate of feed of dry solids is equal to 61.1 upon 3 tons per meter cube; it is given as the density, so it becomes 20.36 meter cube per hour.

Now, how will you find out the volumetric flow rate of water, any clue? I am just writing and you think before I finish my writing. So, volumetric flow rate of water will be 64 upon 36 which is the dilution ratio multiply by 61.1 and divide by 1, because 1 ton per meter cube is the density of water. So, we get the volumetric feed. This is the density of water. So, volumetric flow rate will be 108.6 meter cube per hour.

You see, what all these problems require is a clear cut idea of mass balance. You have to see from where the mass is entering and from where the mass is being out. You have to wait in the mass entry from all sources; for example, in this particular problem, the cyclone feed was having rod mill and ball mill. So, these things are to be kept in mind while solving this particular problem.

Now, let us take the problem number three. The problem number three says you have to find out the mass flow rate of c to the cyclone. Now, here a clue is given, 3 liter sample of underflow takes 4 second of time, why this is given because from this value you can find out volumetric flow rate; volumetric flow rate of underflow you can find out.

Before we do that you recall that I have given the derivation for this type of problem. So, what will I do first, we will find out the percent solid, we will find out say percent solids in the feed then in underflow and in overflow, because percent solid is not given. Now, percent solids in the feeds will be equal to 100 into 3000 into 140 divide by 1140 into 2000. Now, in that of underflow, this is 100 into 3000 into 290 upon 1290 into 2000 and in overflow, this is 100 into 3000 into 30, this is divided by 1030 into 2000, just like making a compartment.

If I calculate, I am getting here percent solid 18.42 percent. Here, it will be 33.72 percent and here, will be 4.37 percent. Now, why I calculated the percent solid? I calculated the percent solid simply because, one can find out the dilution ratio; that is why I have determined the percent solid.

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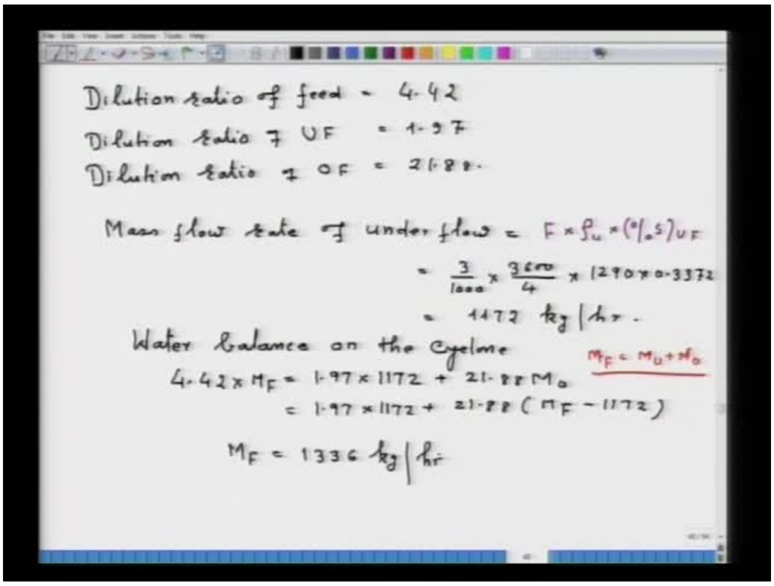

Now, I can find out dilution ratio of feed. Well, I already given the formula, so feed that is equal to 4.42, dilution ratio of underflow that is equal to 1.197 and dilution ratio of overflow is equal to 21.88. Once we determine the dilution ratio, we can find out mass flow rate of underflow. Mass flow rate of underflow will be equal to the formula F into density of underflow into percent solid in underflow.

Now, here naturally we have assumed that the density of the solid does not change in the underflow or overflow, it remains the same. If we solve it that will be equal to 3 upon 1000 - I am just substituting the value that you can also do it - into 3600 upon 4 into 1290 into 0.3372, so that gives 1172 kilogram per hour. Now, you have to find out water balance on the cyclone. If you do water balance on the cyclone - by performing water balance on the cyclone, I am just straight away writing down say 4.42 into M F that is equal to 1.97 into 1172 plus 21.88 into M O.

Now, we know that by mass balance we can replace M O, so that will be equal to 1.97 into 1172 plus 21.88 into M F minus 1172. Since, we know that the mass balance is M F that is equal to M U that is underflow plus M O. From here one can replace M O by M m, as just what I have done it over here. So, we just solve it, so we get M F that is equal to 1336 kilogram per hour; it is the answer for this particular question.

Now, the problem four, it is very simple. So, I will skip it and I will see that you can solve this particular problem. It is simply a mass balance to find out the various unknowns. Now, let me take problem number five.

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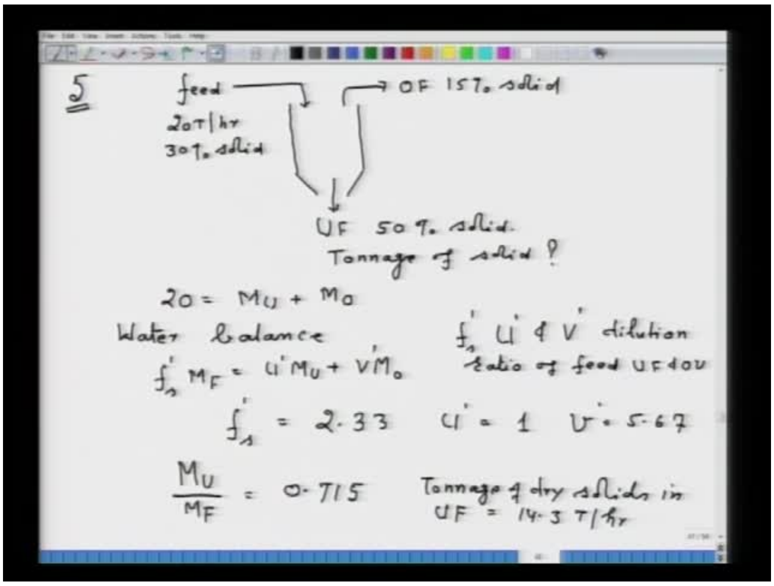

Now, problem number five. This is the say sort of hydrocyclone, we are having the feed which is 20 ton per hour having 30 percent solid. You have overflow, which is 15percent solid and we have underflow, which is 50 percent solid. We have to find out, if the feed enters at 20 tons per hour in the hydro cyclones calculate the tonnage of solid per hour in underflow. So, you have to calculate tonnage of solid. Tonnage of solid required to be calculated in the underflow.

Now, again, you have to proceed with the mass balance that is 20 that is equal to M U plus M O; M U or M O F, M U F whichever we want; that is, input is equal to output. Now, water balance; we can perform water balance and for water balance we have; recall f dash s into M F that is equal to u dash into M U plus v dash into M O, where I will write once again. Though I put in the lecture f dash s u dash and v dash they are dilution ratio; dilution ratio of feed underflow and overflow.

Now, we can calculate the dilution ratios; the dilution ratios f dash s. You can calculate by yourself, so that value is 2.33. For u dash the dilution ratio of underflow that is equal to 1 and dilution ratio of overflow that is equal to 5.67. Now, I can calculate M U upon M F from the dilution ratios and this will be equal to 0.715. You can calculate by yourself these values, because the formula everything is given to you and you know how to calculate. So, when you know this value we know M F, so tonnage of dry solids per hour in underflow. Tonnage of dry solids in underflow will be equal to 14.3 tons per hour, so that is the answer or the solution of this particular problem.

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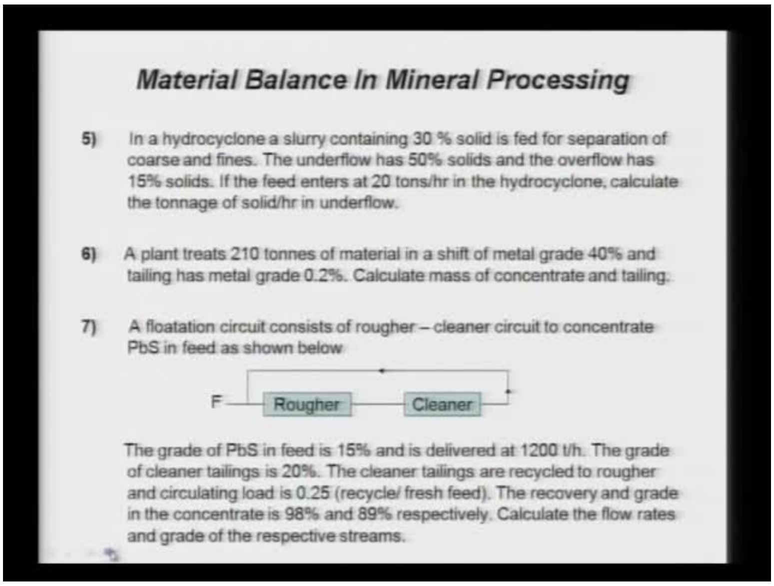

Now, let us take the problem six. Problem six again is a very simple problem; it simply says a plant treats 210 tons of material in a shift of metal grade. This one concentrate in metal grade, tailing metal grade is given, calculate mass of concentrate and tailing.

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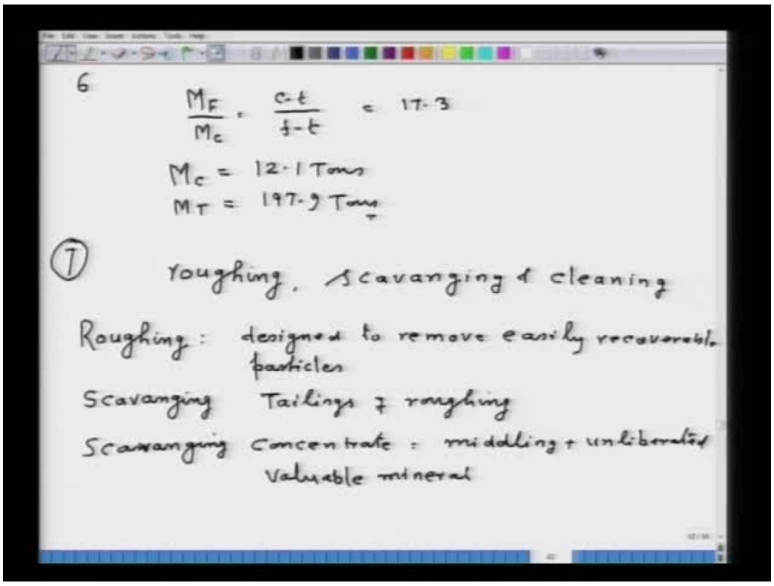

Now, that is very simple, you know that the ratio M F upon M C is equal to c minus t upon f minus t, so that become 17.3. Therefore, M C will be equal to 12.1 tons and M T that will be equal to 197.9 tons. This problem you can do, I do not think this is a very problem it is a very easy problem.

Now, let me take the problem number seven. Now, in a problem number seven a floatation circuit is given, which consist of rougher and cleaner. In fact, let me give you little bit background of this floatation. In case of floatation what happens? When the concentration that is, when the flow is very large then the concentration is carried out in two stages, rather is carried out in several stages. The stages are roughing, scavenging and cleaning. It is done in three stages if the volume to be treated is very large enough.

In the roughing stage what is done? In the roughing stage, this is designed to remove easily recoverable particles. The stage scavenging; in the scavenging stage what is done? The tailings, because roughing will concentrate in tailing, so the tailings of roughing operation are used to recover the valuable mineral. Tailings of scavenging are worthless and they are no more recycled in the circuit.

The third stage is scavenging, let us say scavenging - scavenging concentrate; scavenging concentrate that is equal to middling plus un liberated valuable mineral; that means, it has to be ground, so the entire circuit it looks something like this.

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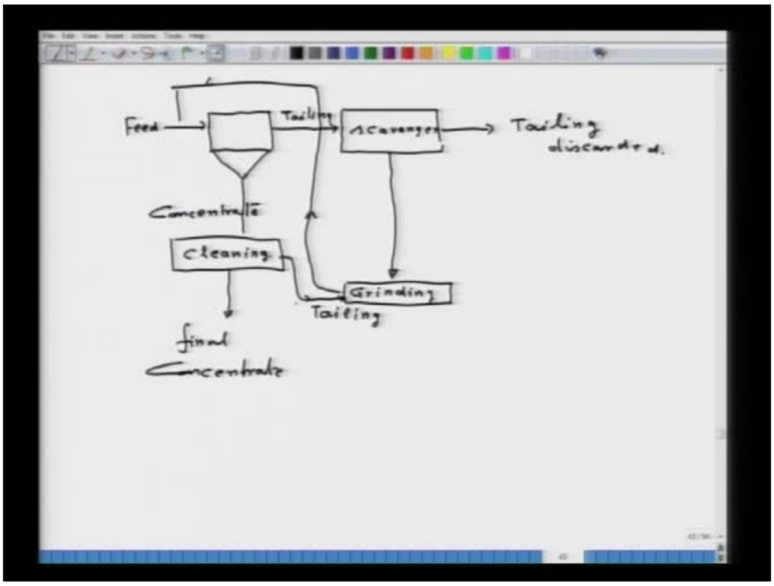

Say for example, if this is the operation, this is the feed, then it goes to scavenger and scavenger tailings are discarded. Now, the concentrate is further subjected to grinding operation as it contains some of the un liberated particle. Now, this grinding is again taken to the feed; from the concentrate, the feed it the concentrate rather enters into cleaning.

It is a concentrate, is a concentrate is a tailing. So cleaning; cleaning once we have from here, the final concentrate. The tailing of the cleaning, it may undergo to grinding operation. This is the tailing, so this is how just a feed side information what is done in the floatation. So, this particular problem is based on this particular concept.

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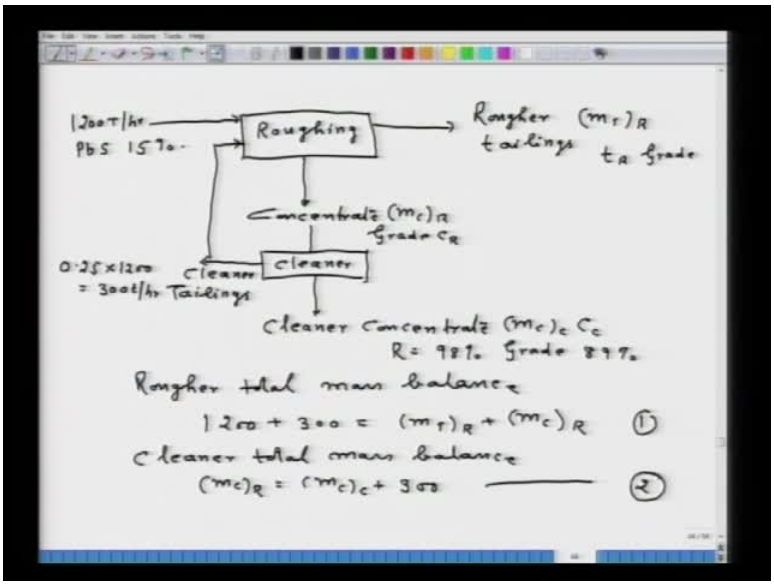

In the problem, what is given is you have a roughing operation; this is roughing operation. Here the concentrate, let us say concentrated m C R, it enters into cleaner and its grade is C into R. Then, we have from here the cleaner concentrate; that is what the problem says, have cleaner concentrate, let us say its mass m c c and its grade is C c. Now, it is given say R that is equal to 98 percent recovery and grade is 89 percent.

Then the cleaner tailings, these are the cleaner tailings. Cleaner tailings is given to us 0.25 is the load ratio into 1200 that is equal to 300 tons per hour is given to us. Now, this cleaner again undergoes so called roughing operation and so the cycle completes. In the roughing, the feed you have 1200 tons per hour and lead sulphide grade is 15 percent. Here, you have rougher tailings, these rougher tailings, let us consider this is m T R and its grade let us say is t A.

So, you have to find out the flow rates and grade of the respective streams. Again, a simple mass balance type of problems, input is equal to output. If you do rougher total mass balance then this is equal to 1200 plus 300 that is equal to m T R plus m C into R; that is the equation number 1. Now, similarly, we can do cleaner total mass balance. Cleaner total mass balance will be equal to m C into R that should be equal to m C into C plus 300; that is our equation number 2.

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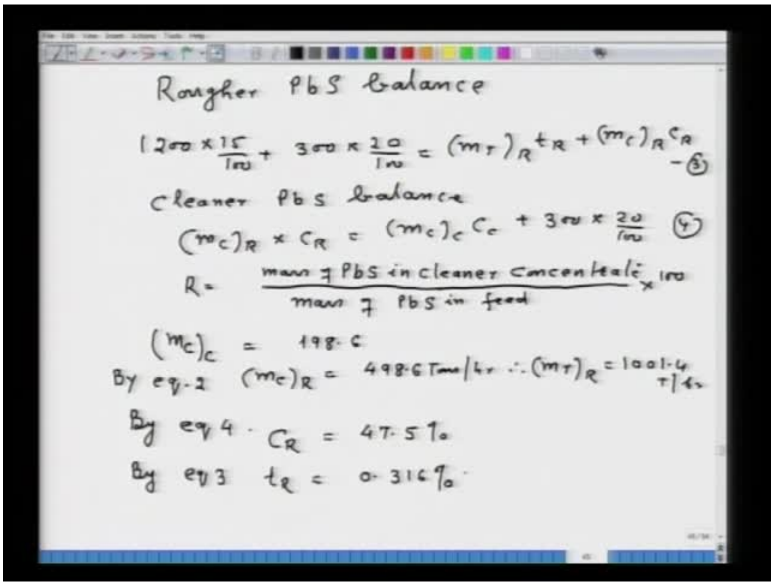

Then proceeding further, we will do rougher lead sulphide balance where the mineral grade is given. So, we can write down this one 1200 into 15 by 100 plus 300 into 20 by 100 that is equal to m T R into t R plus m C R into C R; this will be our equation number 3. Similarly, we can also do cleaner lead sulphide balance. Cleaner lead sulphide balance will be equal to m C R into grade that is equal to m C C into concentration grade plus 300 into 20 by 100. So, if we solve all these equations, recovery R that is equal to mass of P b S in cleaner concentrate divide by mass of P b S in feed into 100 that is the definition of recovery. If I substitute all the values, then from here I can find out the mass of concentrate in the cleaner that will come out to be equal to 198.6. So, by equation 2, I can find out m C R that will be equal to 498.6 tons per hour and therefore, m T R that will be equal to 1001.4 tons per hour.

Now, by equation 4, I can get the value of C R, which is the metal grade of the rougher concentrate that will be equal to 47.5 percent; a formula everything I gave you. So, by equation 3, in which t R is the only unknown quantity, if I substitute all the values, then I will get t R that will be equal to 0.316 percent.

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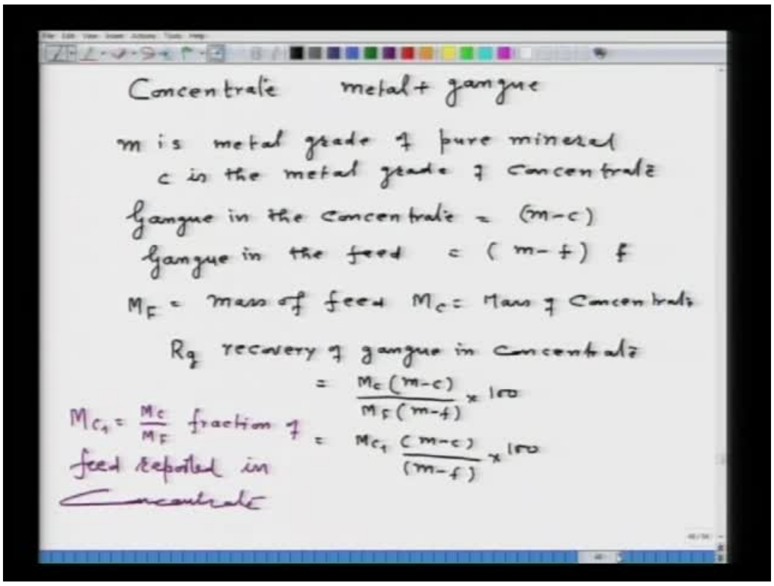

Now, one more thing I want to say about the concentrate, because it is the concentrate; that is the most important. I have said that a concentrate consist of metal plus gangue. Now, again, I tell you very clearly, though I am writing the metal concentrate, it does not contain the metal; I am writing metal, because that concentrate will be used for extraction of metal. A concentrate in fact contains valuable mineral of which we are interested in finding out the metal, because from the extraction purposes the oxygen or sulphur part of the valuable mineral is also a tailing or is also a gangue; that is why I am writing here metal plus gangue. I am writing simply metal, because the concentrate will be used to extract the metal, otherwise the concentrate does not contain mineral, so that point is to be clear.

Now, let us just quantify it. So, let us say if m is metal grade of pure mineral, c is the metal grade of concentrate. Now, I am analyzing the concentrate, gangue in the concentrate will be how much? Gangue in the concentrate that will be equal to m is the metal grade of the pure mineral and c is the metal grade of concentrate. So, m minus c has become gangue in the concentrate. Similarly, I can find out gangue in the feed that is equal to m minus f, where f is the metal grade in the feed, so this m minus f so called gangue in the feed.

Now, if I say M F that is equal to mass of feed and M c that is equal to mass of concentrate, then recovery R g that is recovery of gangue in the concentrate recovery; that will be equal to M c is the mass of concentrate multiplied by m minus c, which is gangue in the concentrate divide by mass of the feed into gangue in the feed; that point should be clear. That is what is most important from the evaluation of the concentrate, its quality of the concentrate and its separation efficiency.

So, recovery of gangue in the concentrate that is equal to into 100, so we can also put that equal to M c 1 into m minus c upon m minus f into 100, where M c 1 is equal to M c upon M F that is equal to fraction of feed reported in the concentrate.

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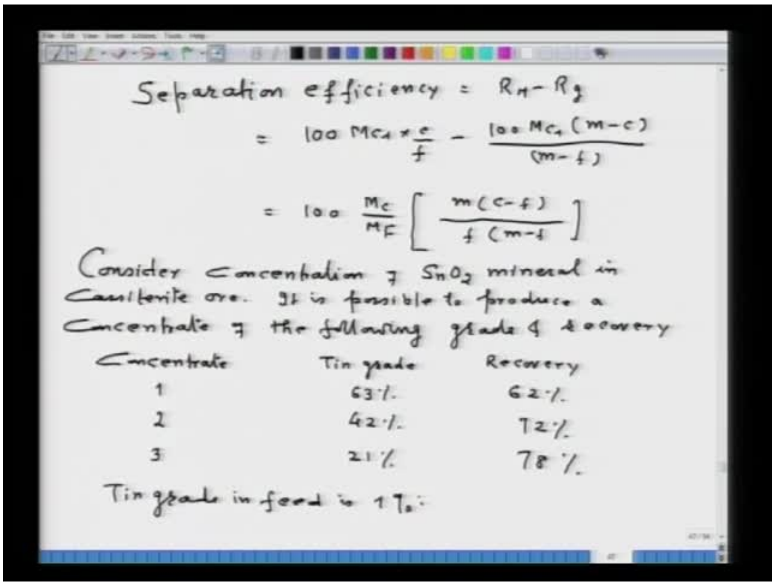

Now, similarly, I can also find out the recovery of metal, so the separation efficiency will be equal to R M minus R g. So, if I substitute the value of R M, R M will be 100 into M c 1 into c upon f minus 100 M c 1 m minus c upon m minus f. So, I further simplify it, so I will be getting 100 M c upon M F. I simply replace M c 1 by M c upon M F that is equal to m into c minus f upon f into m minus f, so that is the separation efficiency and the evaluation of (()).

Now, let me give a very simple problem to illustrate this. Now, let us consider concentration of tin oxide mineral - SnO 2 mineral in cassiterite ore. It is possible to produce a concentrate of the following grade and recovery by utilizing different methods. So what is given, let us take it, concentrate then tin grade and recovery; concentrate number 1, tin grade is 63 percent and recovery is 62 percent; concentrate number 2, 42 percent and 72 percent; concentrate number 3, 21 percent and 78 percent. Now, tin grade in feed is let us give 1 percent.

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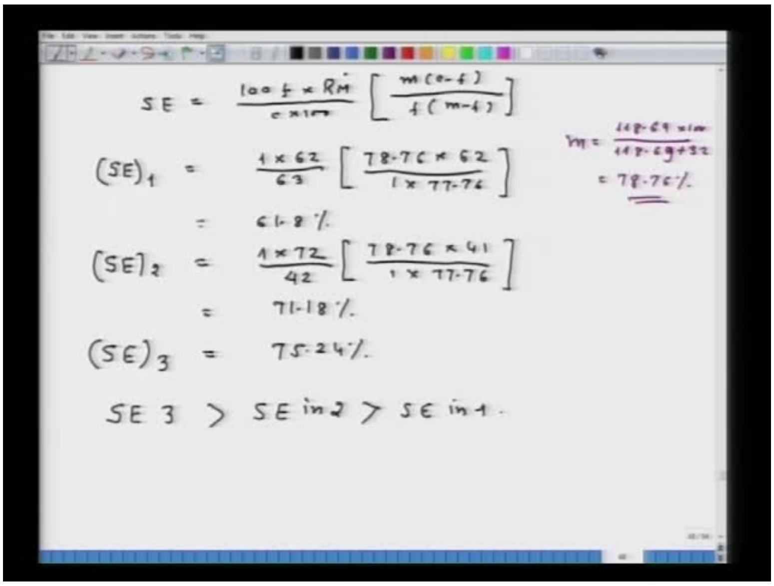

Now, we have to find out the separation efficiency and analyze the result. So, what will I do? I will find out the separation efficiency, so separation efficiency that will be equal to 100 into f into R M upon c into 100. You can convert the formula in this way also M into c minus f upon f into m minus f, because here recovery is given and the formula can be made in terms of the recovery. I have written in terms of the recovery that is R M.

Now, straight away, I can substitute the value. So what I do now, I find out the separation efficiency for concentrate 1 that will be equal to 1 into 62 upon 63 78.76 into 62 upon 1 into 77.76. Now, you are wondering from where I am getting 78.76, 78.76 is the metal grade of the pure SnO 2 mineral. I can just do m that is equal to 118.69 which is the atomic weight of tin.

One 118.69 plus 32 that becomes into 100 of course and then it becomes equal to 78.76 percent; so that is the metal grade of the pure mineral that is from where this come. So, the separation efficiency becomes or that is equal to 61.8 percent. Now, in the similar way, I can find out separation efficiency 2 that will be 1 into 72 upon 42 into 78.76 into 41 upon 1 into 77.76 that will be equal to 71.18 percent. I can find out now separation efficiency 3, you can do the substitution, answer will be 75.24 percent.

Now, you can see from here that the separation efficiency in 3 is greater than separation efficiency in 2 and is greater than separation efficiency in 1. Now, naturally one is tempted to go for the method which produces concentrate number 3, but here the most important thing also to see is what the tin grade in the concentrate? In the concentrate number 3, the tin grade is the lowest one.

The tin grade in concentrate is 21 percent only, so you can imagine the amount of gangue is very large as compared to concentrate number 1. However, the concentrate number 1 has a separation efficiency of around 61.8 percent is lower than that of 3rd one. But however, the grade of the tin is very high, so in a way you have to meet a compromise, either to go for a very high recovery and compromise with the tin grade or metal grade, or go with the low recovery and high tin grade; that will depend upon the type of ore, type of mineral and the methods to be employed and so on, so forth. In fact, the objective of mineral beneficiation is to increase the metal grade of the ore; that is the main objective of the mineral processing. That is why we do the mineral processing to increase the grade of the ore.

In this attempt, we have to lose or we have to sacrifice the recovery, because the more the recovery it is possible that we are bringing grade lower down. So, one has to compromise what should be the grade and what should be the recovery; that is what my objective of illustration of this particular problem.