Mechanical Unit Operations
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Lecture 37 - Floatation – 2

Welcome to the MOOCs course Mechanical Unit Operations, the tittle of this lecture is floatation part 2. In the previous lecture on floatation what we have seen? We have seen basic principles of floatation, that is what is the principle that is causing the floatability of certain material and then being separated along with the froth. Those things we have seen and then we have also seen what are the floating agents, what are the froth agents, what are the modifying agents, et cetera those kind of basics about the floatation that we have seen in the previous lecture.

This lecture is the continuation of the previous lecture, in this lecture we will be discussing the floatation cells which are basically like floatation equipment and then floatation circuits we will be discussing and then also we will be discussing a problem on floatation, how to solve problems related to the floatation. Those things we are going to discuss in this particular lecture.

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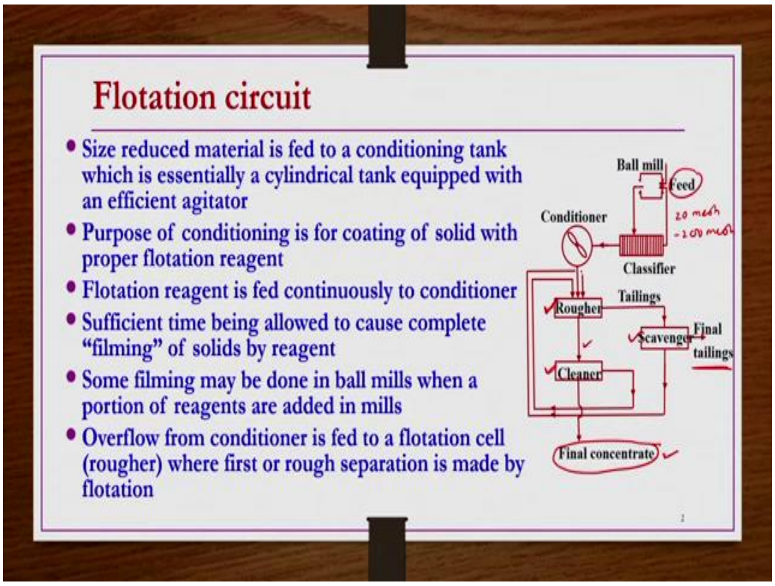

Floatation circuit, actually floatation circuit is like you know we have a number of floatation cells and then arranged such that the concentrate, whatever the main concentrate of the solid that is there, that is required that is active element that we wanted to take off from the mixture, so that has to be in collected as a kind of pure concentrate and then whatever the gangue et cetera, mud et cetera, all those things are there they should be discarded as a tailing.

So that whatever the wastage that mud et cetera which sinks at the bottom that is called as kind of the tails or tailings. So, what we have to make sure? We have to make sure that no solids, important active solids should not be going into the tailings, that is what the purpose is that. So that is the reason, what happens in general, it is not possible to get such kind of pure fractions like only concentrate as one phase and then only tailings are the other phase like that, that separation is in general not possible by using one single floatation cells.

Because what happens in sometimes, the tailings gangue whatever are there so they also contain some amount of the active solids which we try to concentrate. So that is the reason different flotation cells are arranged in such a way that no active solids or no concentrate is going waste in tailings, that is the purpose. Though some amount of tailings may come into the concentrate because if some amount of tailing is coming into the concentrate, we can make use of another floatation cells and then further discard those tailings, but we do not want any solids active ingredients to be present in the tailings. For that reason only we need to use more than couple of floatation cells in a kind of circuits, so that is what known as the floatation circuit.

So, what we see? Here we see a kind of basic floatation circuit, how a floatation circuit works in order to get the pure concentrate. It not necessary that all the circuit should have like this only, they can be depending on the applications. So, let us say for example we have a floatation circuit like this, whatever the feed material that is that you get from the natural resources that you crush into the smaller size let us say ball mill you are using. So after the ball mill, whatever the material that you get that you have to see by passing through a classifier as per the required size.

The size of the material should not be more than 20 mesh, it should be between 20 mesh to 200 mesh size only, so that whatever the material after the ball mill that you get as a kind of product of the size reduction process that you should pass through the classifier and then whatever the material or the solids that is having more than the 20 mesh size they should be feed back to the ball mill and then further reduction should be done.

So once the, whatever the underflow from the classifier is there that you know that is like you know of having size less than 20 mesh, those particles will be taken in a kind of conditioner tank. Conditioner is nothing but a kind of tank in which we take a kind of a reagent, surface-modified reagents, so they will be modifying the surface of the solid particles so that they can easily float in subsequent floatation process.

So, whatever the material that has been conditioned that will be taken in a kind of floatation cell which is known as a kind of rougher. The first floatation cell in which we are taking the material from the conditioner is known as the rougher because here a kind of rough separation takes place, that is neither the concentrate from the rougher is pure nor the tailings that is coming from the rougher are pure. So the tailings from the rougher will also have a considerable amount of solid concentrate as well as the concentrate from the rougher will also have a kind of sufficient amount of tailings, so they have to further pass through other floatation cells.

So the tailings of the rougher they will be taken to another floatation cell known as the scavenger, so where you know whatever the solids are there they are important concentrate solids which are, which we are trying to make a kind of concentrate, so they will be recovered and then they will be sent back to rougher again along with the feed. So here, whatever the final tailings without any solid concentrates are there that will be discarded as a kind of final tailings.

So, from the scavengers whatever the concentrate that we get that will be taken back to the rougher. So from rougher whatever the concentrate are there, so concentrate in the sense that is the solids that we are trying to purify, important ingredient that we wanted to separate from the gangue et cetera those material we call as a kind of concentrate. So, concentrate from the rougher whatever is there, so that may be having sufficient I mean large amount of tailings possible, that is because it is a rougher it is first floatation cells where pure separation may not take place.

So, whatever the concentrate from the rougher is there that will be taken to the another floatation cell known as the cleaner. In the cleaner once again the floatation will take place, whatever the pure solids without gangue et cetera, that will be collected as a kind of a final concentrate from the cleaner and then the gangue or the tailings whatever are there so they may be having some amount of active solids or active concentrate. So that is the reason the tailings from the cleaner are also feed back to the rougher, are also feed back to the rougher so that the process, the circuit continues.

So, here the final concentrate that we get from the cleaner and then final tailings we get from the scavengers, whatever the remaining are there from the cleaner and then scavenger they will be feed back to the rougher. Like this circuit continues, this is known as the floatation circuit. Sometimes we may need more than one scavenger and more than one cleaner, so under such applications you can have more scavengers and then more cleaners in series so that you can try to have a kind of final concentrate without any gangue and then final tailings without any concentrate solid in that one.

Because the solids which we are trying to recover you know may be having high value, so we cannot afford to lose them by final tailings. So, size reduced material is fed to a conditioning tank which is essentially a cylindrical tank equipped with an efficient agitator. Purpose of conditioning is for a coating of solid with proper floatation reagent, sometimes this floatation reagents are also added in a ball mill so that partial modification or slimming of the material can take place during the size reduction process itself.

So floatation reagent is fed continuously to conditioner. Sufficient time being allowed to cause complete filming of solids by reagents. Some filming may be done in ball mill while a portion of reagents are added in the mills itself. Overflow from the conditioner is fed to a floatation cell known as the rougher where first or rough separation is made by floatation.

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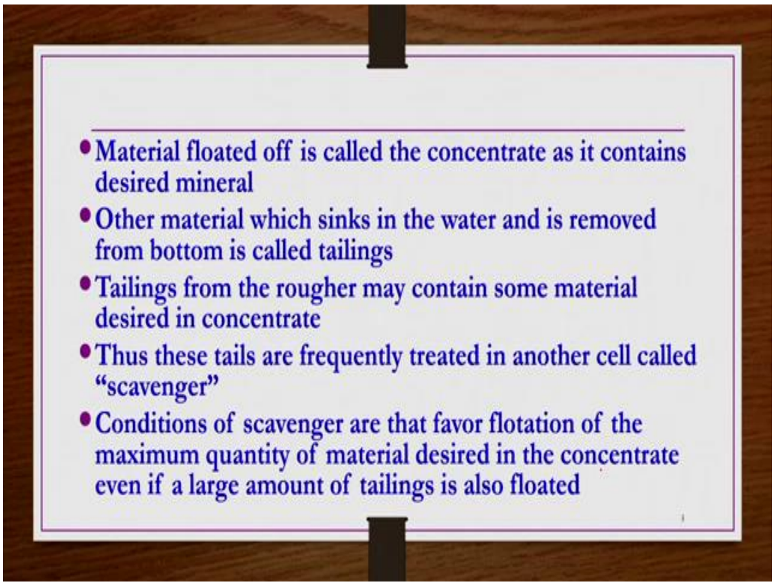

Material floated off is called the concentrate as it contains desired minerals. Other material which sinks in the water and is removed from the bottom is called tailings. Tailings from the rougher may contain some material desired in concentrate. Thus these tails are frequently treated in another floatation cell called as the scavenger. Conditions of scavenger are that favor floatation of the maximum quantity of material desired in the concentrate even if a large amount of tailings is also floated. Because from scavenger whatever the concentrate that we are getting, that again we are feeding back to the rougher.

So from the scavenger whatever the concentrate we get even though if it is containing large amount of tailings, that is no problem at all, but the tailings going out from the scavenger they should not contain any minerals. If one scavenger is not sufficient then we can use more than one scavenger in series so that to make sure that in the final tailings there are no minerals present.

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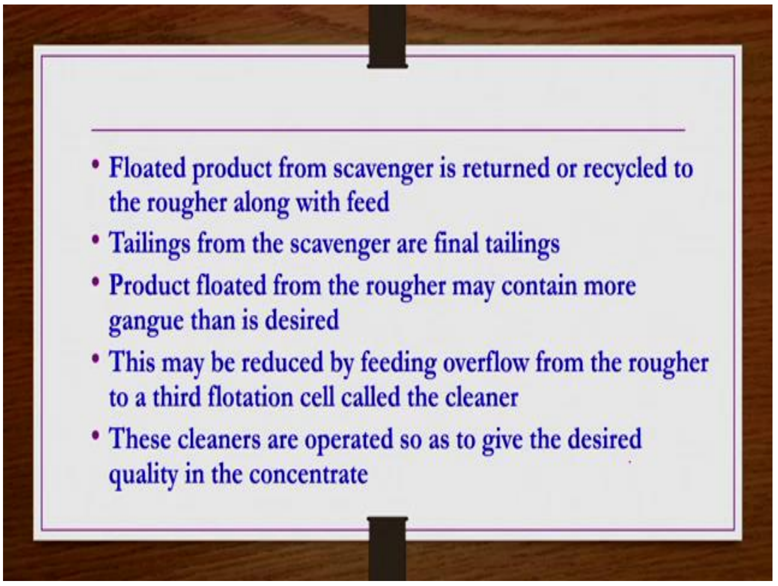

Floated product from scavenger is returned or recycled to the rougher along with the feed. Tailings from the scavenger are final tailings. Product floated from the rougher may contain more gangue than the desired. This may be reduced whatever the gangue that present in the concentrate of rougher that may be reduced by feeding overflow from the rougher to a third floatation cell called as a cleaner. These cleaners are operated so as to give the desired quality in the concentrate.

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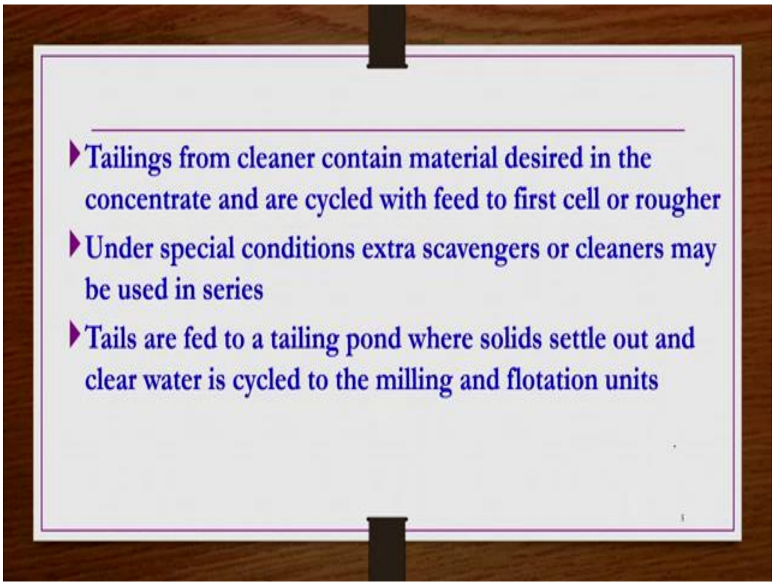

Tailings from cleaner contain material desired in the concentrate and are cycled with the feed to first cell or rougher. Under special conditions extra scavengers or cleaners may be used in series if required. Tails are fed to a tailing pond where solids settle out and clear water is cycled to the milling and floatation units again. So that is about the floatation circuits. So now in the floatation circuit we have seen there are several flotation cells which are nothing but a kind of floatation equipment. So how these floatation cells are designed based on that one different types of floatation cells are available, so those things we are going to see now.

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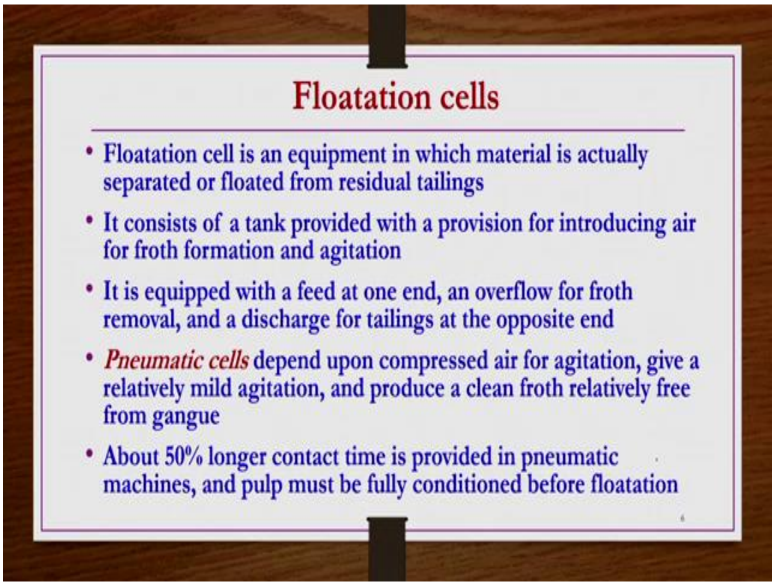

Floatation cell is an equipment in which material is actually separated or floated from residual tailings. It consists of a tank provided with a provision for introducing air for froth formation and agitation. It is equipped with a feed at one end and overflow for froth removal and a discharge for tailings at the opposite end. So these are the path that in general we have in a floatation cell.

So pneumatic cells and mechanical cells are the two different types of broad classification of floatation cells we can have, so under the pneumatic cells these cells depend upon compressed air for agitation, give a relatively mild agitation and produce a clean froth relatively free from gangue. About 50% longer contact time is provided in pneumatic machines and pulp must be fully conditioned before floatation.

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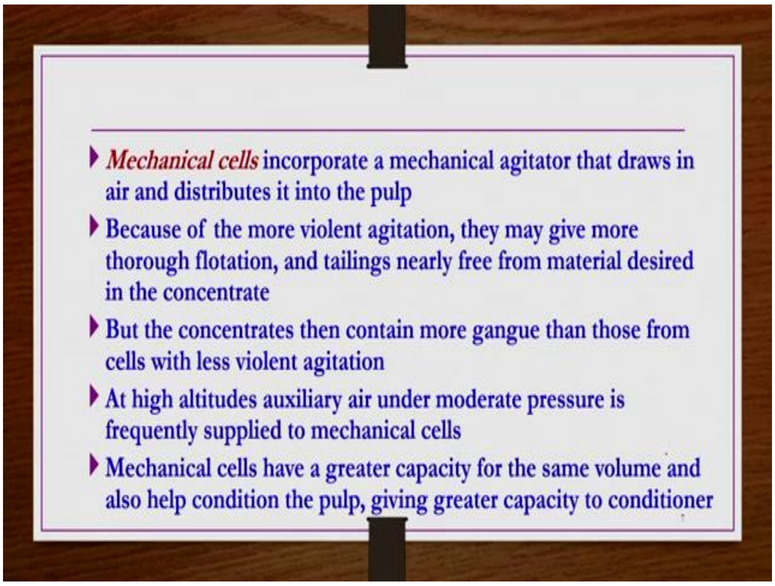

Whereas mechanical cells incorporate a mechanical agitator that draws in air and distributes it into the pulp. Because of the more violent agitation in mechanical cells they make more thorough floatation and tailings nearly free from material desired in the concentrate. But the concentrates then contain more gangue than those from cells with less violent agitation. At high altitudes auxiliary air under moderate pressure is frequently supplied to mechanical cells. Mechanical cells have a greater capacity for the same volume and also help condition the pulp giving greater capacity to conditioner.

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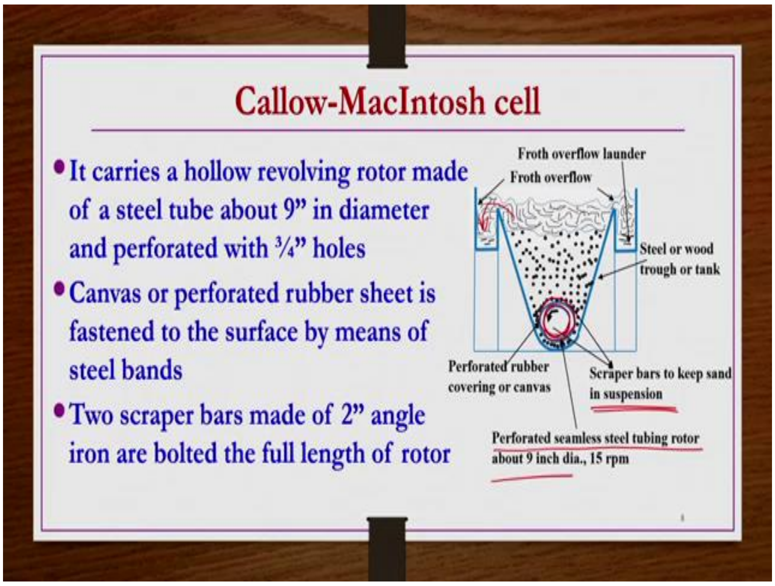

Now we are going to see three different types of floatation cells in general used in mineral industries. Callow-MacIntosh cell, it consist of a hollow revolving rotor made of steel tube about 9 inch diameter and perforated with 3/4 inch holes, there is a kind of a perforated seamless steel tubing rotor is there which is having the 9 inch diameter so that is this rotor. So it is having a kind of a perforation, perforation of 3/4 inch holes and then it is covered with a kind of perforated rubber covering or a kind of canvas kind of thing.

And there are a kind of scraper bars to keep sand in the suspension, when this rotor rotates the material will also be mixed and then bubbles will also be generated. So those bubbles will be carrying the particles float to the surface and then from the surface we will have a kind of overflow launder. The froth overflow will go into the overflow launders, from there we can collect the concentrate. So this is the basic principle of this Callow-MacIntosh cell. Canvas or perforated rubber sheet is fastened to the surface by means of steel bands. Two scraper bars are also provided of 2 inch angle iron bolted the full length of the rotor, so that the whatever the sand is there that should be in the suspension.

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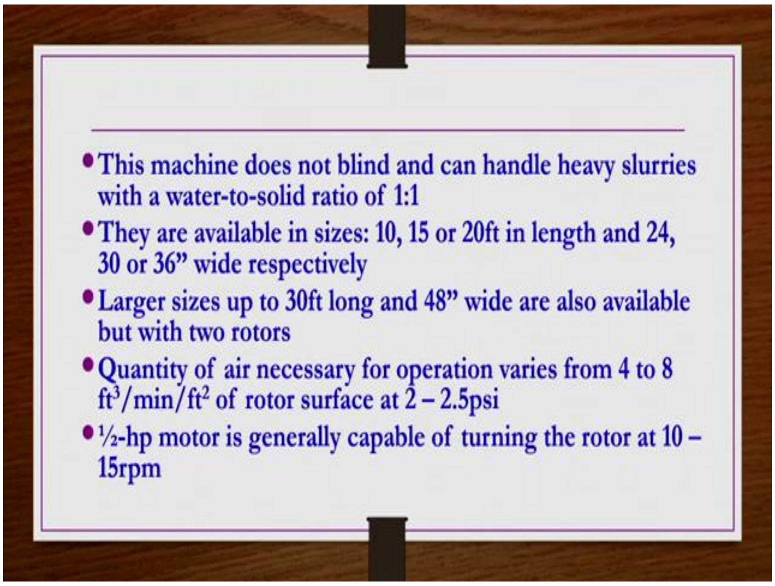

This machine does not blind and can handle heavy slurries with a water to solid ratio of 1 is to 1, 50-50% of water solid ratio it can handle. They are available in different sizes 10, 15 and 20 feet in length and 24, 30 or 36 inch wide respectively, in those sizes are in general available. But however, further larger sizes are also available up to 30 feet long and then 48 inch wide with two rotors.

If the larger size floatations or cells are used by this design then usually they are provided with two rotors so that efficient bubble generation can take place. Quantity of air necessary for operation varies from 4 to 8 feet cube per minute per feet square of rotor surface at 2 to 2.5 psi. Half HP motor is generally capable of turning the rotor at 10 to 15 rpm and these rotors in general rotate at small rpm, 10 to 15 rpm that is sufficient.

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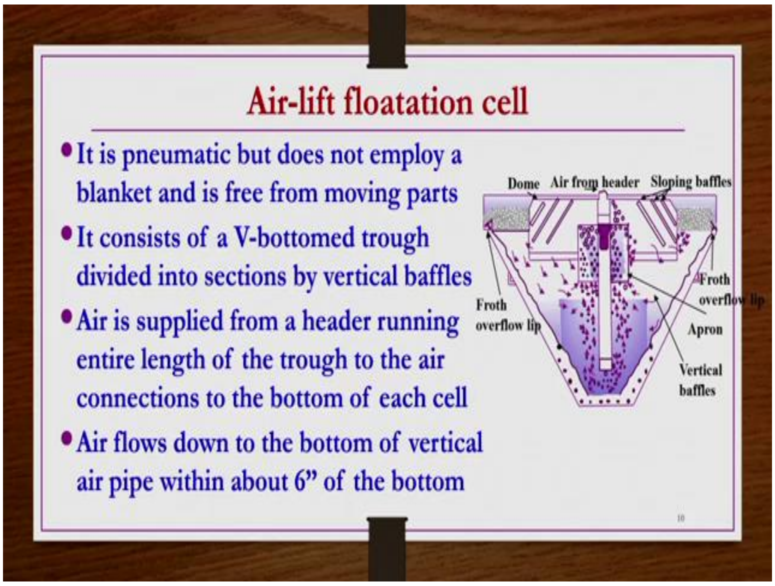

Air-lift floatation cell, it is a pneumatic cell, but does not employ a blanket and is free from moving parts. So, what happens here, air comes in from the top and then goes through the bottom to the bottom of the cell and then the bubbles are being generated here, when this air is flowing and then those bubbles are being moving up to this floatation surface. So it consists of a V-bottomed trough divided into sections by vertical baffles. Air is supplied from a header running entire length of the trough to the air connections to the bottom of each cell. Air flows down to the bottom of vertical air pipe within about 6 inch of the bottom.

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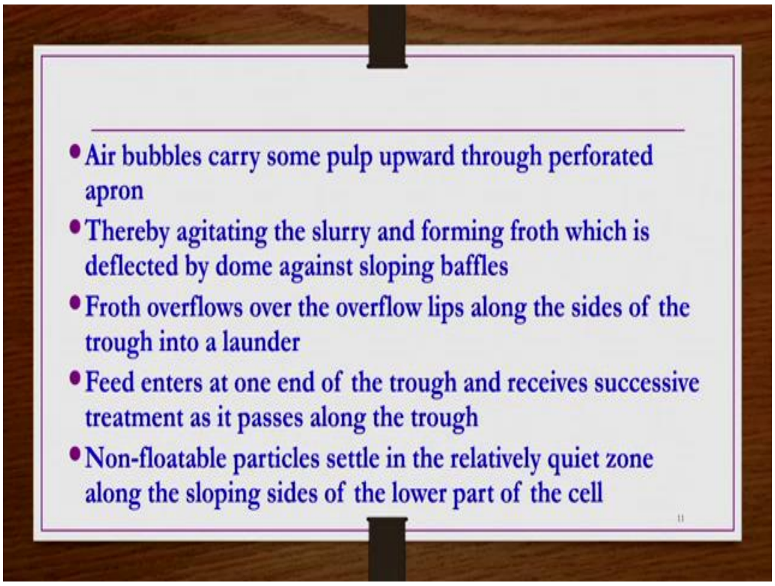

Air bubbles carry some pulp upward through perforated apron thereby agitating the slurry and forming froth which is deflected by dome against sloping baffles. Froth overflows over the overflow lips along the sides of the trough into a launder. Feed enters at one end of the trough and receives the successive treatment as it passes along the trough. Non-floatable particles settle in the relatively quite zone along the sloping slides of the lower part of the cell.

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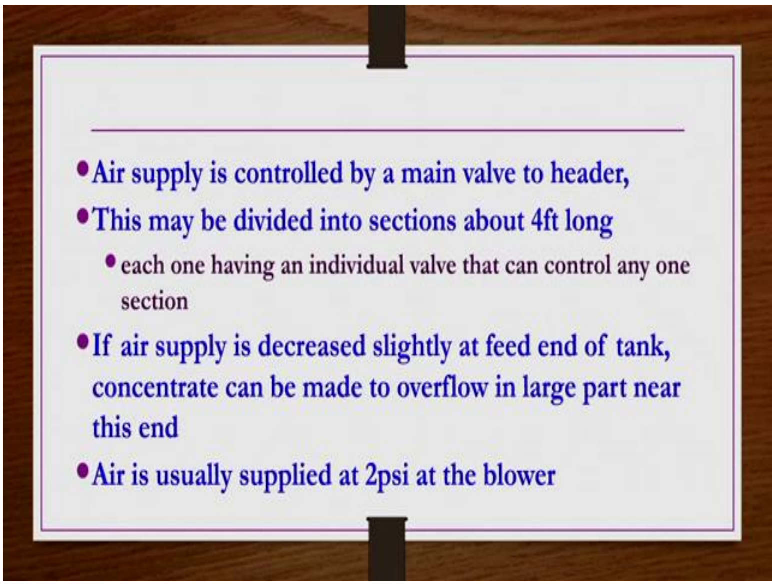

Air supply is controlled by a main valve to header because the process it depends on the how the air is supplied. So this may be divided into sections about 4 feet long and each one having an individual valve that can control any one section. If air supply is decreased slightly at feed end of tank, concentrate can be made to overflow in large part near this end. Air is usually supplied at 2psi at the blower.

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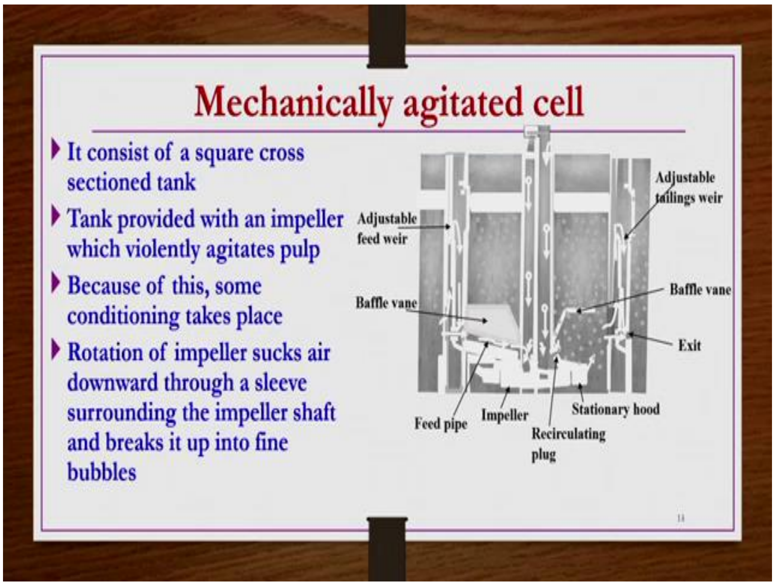

Mechanically agitated cell, we have impellers in this one that rotates at very high speed, so because of that one agitation will take place as well as well bubbles will form and those bubbles will carry the solid particle to the interface and then from there through the adjustable weirs that overflow may be taken as a kind of a product and then the solids are collected, this is the basic principle here.

So it consists of a square cross-section tank, tank provided with an impeller which violently agitates the pulp. Because of this some conditioning also takes place and rotation of impeller sucks the air downward through a sleeve surrounding the impeller shaft and breaks it up into fine bubbles and those bubbles eventually carrying the solid particles to the surface of the, to the surface and then from there the material is, concentrate is collected.

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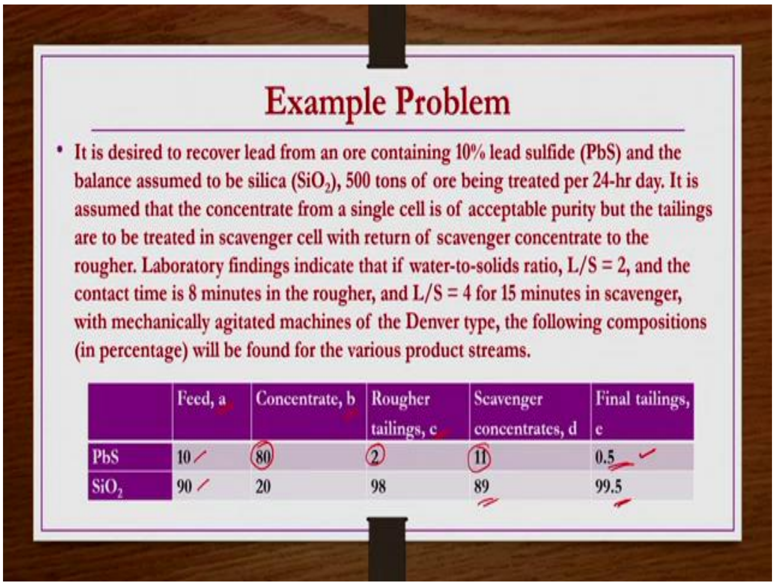

Now, we take an example problem on floatation. It is desired to recover lead from an ore containing 10% lead sulfide and balance assumed to be silica. So in the feed what we have, 10% PbS is there and then 90% silica is there, 500 tons of ore being treated per 24 hour per day, so that much amount is being treated. It is assumed that the concentrate from a single cell is of acceptable purity, but the tailings are to be treated in a scavenger cell with return of scavenger concentrate to the rougher. That is here in this problem we have what, only two flotation cells.

Because you know in the rougher whatever the concentrate that we get, that is of sufficient purity as per the problem statement, but the tailings may also contain some concentrate. So in order to avoid those wastage of minerals from the tailings so another scavenger is used, but there is no cleaner. As one example we have seen floatation circuit, there is no cleaner in this problem, we have a rougher and then we have a scavenger. That is it, only two floatation cells we are having.

Laboratory findings indicate that if water to solids ratio L/S is equals to 2 and then contact time is 8 minutes in the rougher and L/S is equals to 4 for 15 minutes in scavenger with mechanically agitated machines of the Denver type, the following compositions in percentage will be found for the various products streams. So, whatever the feed stream is there that is designated as it has been mentioned that it is having 10% PbS and remaining silica.

Concentrate from the rougher whatever is there that is given as stream B, it is having 80% PbS and then it is sufficient purity, so further cleaner is not required. So tailings from the rougher whatever is there that stream is given as c, so it is having 2% of PbS and 98% of silica, so this has to be further purified so that we are collecting, we are trying to separate PbS. So 2% PbS, we do not want to lose.

So further what we do? The rougher tailings are taken to the scavenger where the concentrates are getting improved to the 11% and those things are feed back to the rougher again and then silica 89 percent is there, so this final tailings the whatever are coming from the scavenger concentrate it is having only 0.5% PbS. So we can discard this one as a kind of tailings and then stop the process, so remaining is 99.5% silica.

So, now we are separating like 99.5% silica as one tailings and then remaining 80% PbS as a kind of pure concentrate from the rougher, so this is the separation taking place.

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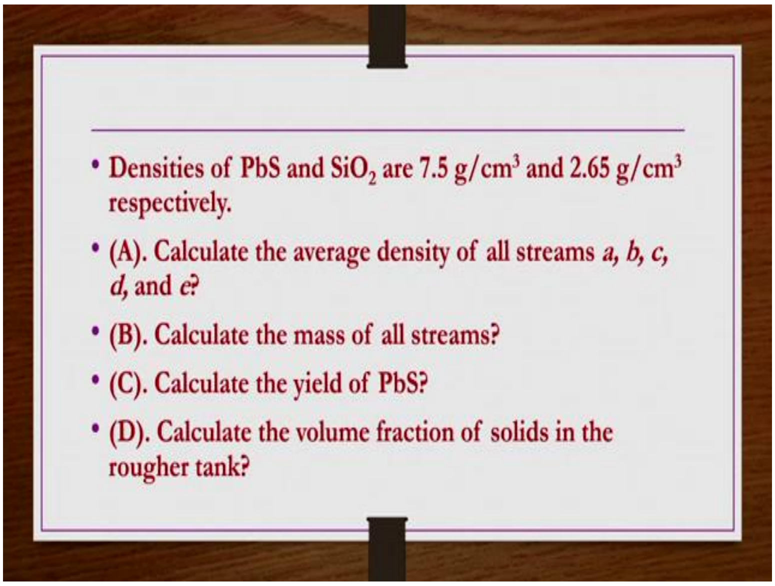

So the densities of PbS and silica are given. Part of the, four parts of the questions are there, first part of the question is calculate the average density of all streams a, b, c, d and e, calculate the masses of all streams, calculate the yield of PbS and then calculate the volume fraction of solids in the rougher tank. So these four parts are there, we take one by one.

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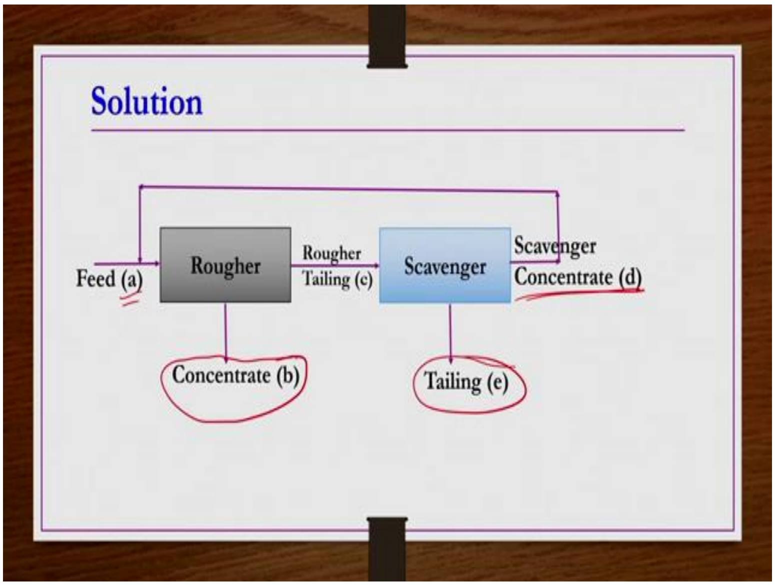

Before that one as per the problem statement we have to draw the floatation circuit. So when you draw the floatation circuit, the feed stream a is coming into the rougher from where we get the concentrate PbS 80% and then it is sufficient enough, so we are not going to the cleaner that is given in the problem. But the tailings, rougher tailings are having some PbS that we wanted to recover, so those tailings are taken to the scavenger where whatever the concentrate that we recovered they are feed back to the rougher, feed back to the rougher along with the feed. That is what the statement and then tailings from the scavenger whatever are there they are taken as a kind of final tailings.

So, now from this circuit we try to get the average densities, masses of each stream and then PbS yield and then also the volume fraction of solids in rougher, these four questions we are going to solve now.

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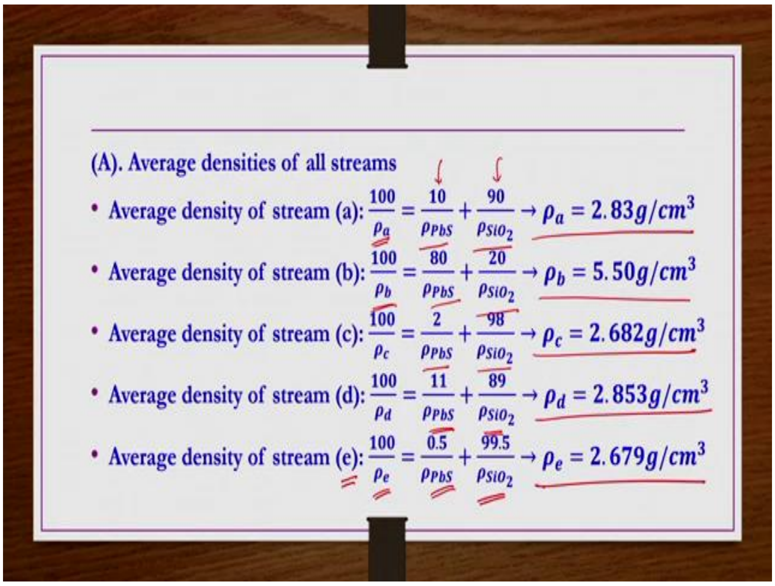

So average densities of all streams, let us say average density of stream a if you wanted to do, the average density of stream a if you designate as rho a so then in the stream a what we have feed? We are having 10% of PbS and then 90% of silica, so $\frac{100}{\rho_a} = \frac{10}{\rho_{PbS}} + \frac{10}{\rho_{SiO_2}}$ that is what we have to do. ρ_{PbS} is given, ρ_{SiO_2} is given, so from here rho of stream a you will get 2.83 g/cm^3.

$$average\ density\ of\ stream(a) = \frac{100}{\rho_a} = \frac{10}{\rho_{PbS}} + \frac{10}{\rho_{SiO_2}} \rightarrow \rho_a = 2.83\, {}^{g}/_{cm^3}$$

Similarly, in the table it is given that the stream b is having 80% PbS, stream b is nothing but the concentrate, concentrate is having 80% PbS and 20 percent silica. So $\frac{80}{\rho_{PbS}} + \frac{20}{\rho_{SiO_2}}$ should be $\frac{100}{\rho_b}$, ρ_b is nothing but the average density of the stream b. So, now here ρ_{PbS}, ρ_{SiO_2} if you substitute and simplify ρ_b or the average density of stream b you will get 5.50 g/cm^3.

$$average\ density\ of\ stream(b) = \frac{100}{\rho_b} = \frac{80}{\rho_{PbS}} + \frac{20}{\rho_{SiO_2}} \rightarrow \rho_b = 5.50\, {}^{g}/_{cm^3}$$

Likewise average density of stream c, the stream c is nothing but the tailings from the rougher that is having 2% PbS and 98% silica, so accordingly here also we can get ρ_c that is the average density of stream c, we can get it as 2.682 g/cm^3.

$$average\ density\ of\ stream(c) = \frac{100}{\rho_c} = \frac{2}{\rho_{PbS}} + \frac{98}{\rho_{SiO_2}} \rightarrow \rho_c = 2.682\ {}^{g}/_{cm^3}$$

And stream d is nothing but the concentrate from the scavenger that is having 11% PbS which is feedback to rougher and then 89% of the silica. So then $\frac{11}{\rho_{PbS}} + \frac{89}{\rho_{SiO_2}}$ should be equals to $\frac{100}{\rho_d}$ and then from here ρ_d you can get it is 2.853 g/cm^3.

$$average\ density\ of\ stream(d) = \frac{100}{\rho_d} = \frac{11}{\rho_{PbS}} + \frac{89}{\rho_{SiO_2}} \rightarrow \rho_d = 2.853\ {}^{g}/_{cm^3}$$

And then finally average density of stream e, stream e is nothing but the tailings from the scavenger, tailings from the scavenger is having only 0.5% of the PbS and then 99.5% of silica, so $\frac{0.5}{\rho_{PbS}} + \frac{99.5}{\rho_{SiO_2}}$ should be $\frac{100}{\rho_e}$, ρ_e is the average density of the stream e. So substituting ρ_{PbS}, ρ_{SiO_2} here, we get ρ_e as 2.679 g/cm^3. So this is the average densities of all streams.

$$average\ density\ of\ stream(e) = \frac{100}{\rho_e} = \frac{0.5}{\rho_{PbS}} + \frac{99.5}{\rho_{SiO_2}} \rightarrow \rho_e = 2.679\ {}^{g}/_{cm^3}$$

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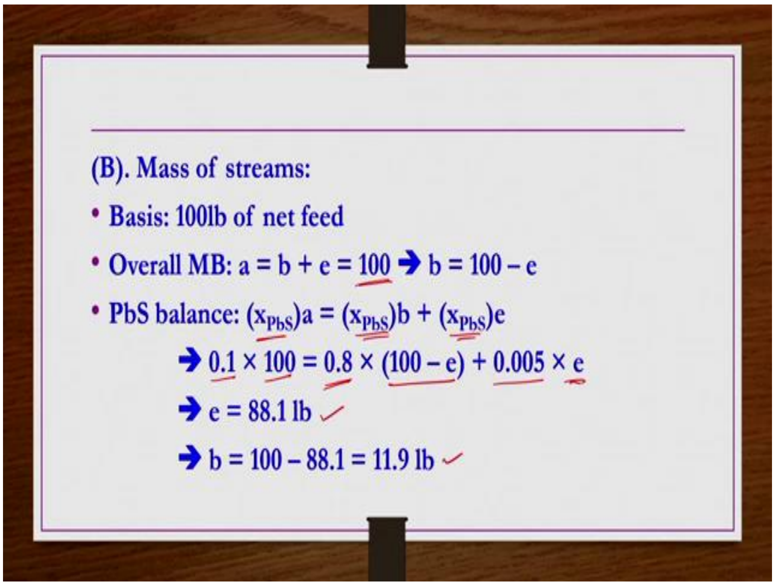

Now we have to find out the masses of all stream, each stream how much mass is containing. So, let us say basis as a kind of 100lb of net feed, 100lb of net feed we can take. So overall material balance what we are having, a = b + e, a is the feed and then b is the concentrate from the rougher and then e is tailing from the scavengers, these are the final outcomes.

So the feed a = b + e should be the material balance, so a feed that we have taken as a kind of 100lb of net feed, so b + e = 100 then b = 100 - e. Then PbS balance if you do, overall PbS balance this is for the overall circuit, overall PbS balance if you do (x_{PbS}) in a so that is $(x_{PbS})a = (x_{PbS})b + (x_{PbS})e$, x is nothing but the fraction of this PbS that present in this a, b and e streams, so those are given.

So (x_{PbS}) in the feed 10% it is there, so 0.1 and then a is 100. (x_{PbS}) in the concentrate it is 80% is there so 0.8 and then b = 100 - e and then plus in the final tailings from the scavengers only 0.5% of PbS is there so $0.005 \times e$, so from here e we will get it as 88.1 lb, so b should be 100 - e, so then b is coming out to be 11.9 lb. So average mass of b stream and then e stream we have already got and then a stream we have to take a basis that is 100 lb we have taken. So remaining c and d streams we have to obtain their average masses.

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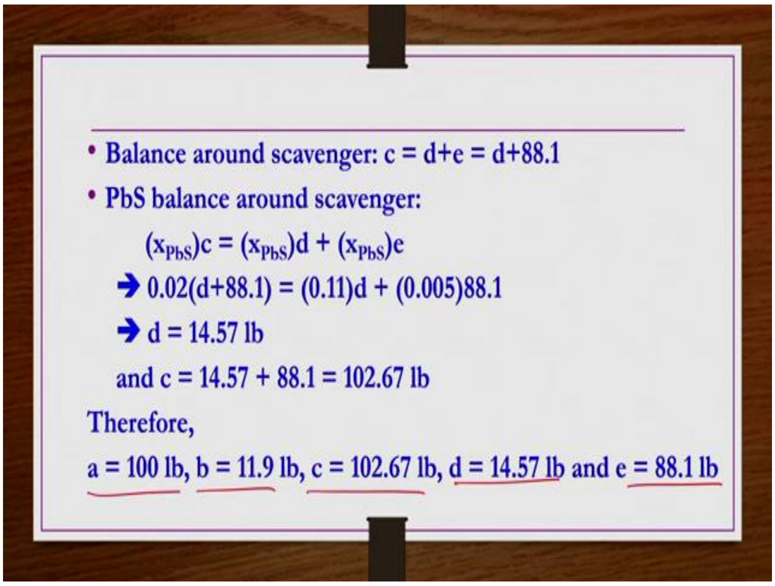

So balance around scavenger we do, so what is the input of the scavenger? That is the tailings from the rougher whatever is coming that is input for the scavenger, so that is c and then what is the output from the scavenger? Is nothing but the concentrate from the scavenger d that is going back to the rougher and then final tailings e, so c = d + e should be the overall, should be the balance around scavenger. So then we have c = d + e is nothing but 88.1.

Similarly, around the scavenger if you do the PbS balance then we have $(x_{PbS})c = (x_{PbS})d + (x_{PbS})e$; so this (x_{PbS}) in c, d, e streams is given as a kind of table anyway. So x in concentrate of the rougher is a input for the scavenger that is having only 2% of the this PbS, so $0.02 \times c$ that we can write d + e is nothing but 88.1 and then (x_{PbS}) and d stream, d stream is nothing but the PbS that is in concentrate coming out of the scavenger, so that is 11% of PbS is there in the concentrate that is coming out from the Scavenger, so $0.11 \times d$.

And then in the final tailings that is c is nothing but the final tailings from the scavenger that is having only 0.5% of PbS, so $0.005 \times e$ is nothing but 88.1 that we already got it in the by the overall balance. So now here you can solve for d, that you can get 14.57 lb, so what you get? c = d + e is nothing but 102.67 lb. So therefore, finally the masses of each of these streams we got like this a is 100 lb, b = 11.9 lb, c = 102.67 lb, d = 14.7 lb and e = 88.1 lb, this is the B part of the question.

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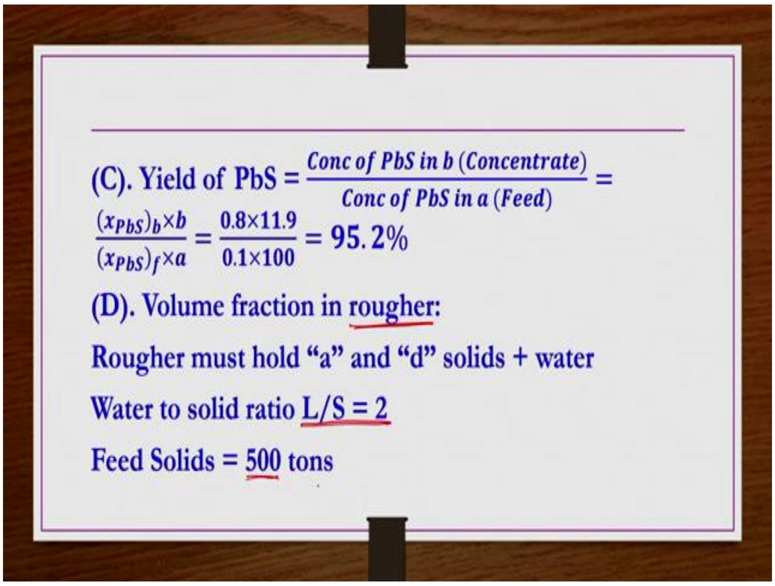

C part of the question is yield of PbS, yield of PbS is nothing but concentration of PbS in b because concentrate is the yield, final concentrate that whatever is there that is the b stream, ok concentrate of PbS in b divided by concentration of PbS in a that is feed. So in the concentrate we have 80% of PbS multiplied by the mass of the b stream is nothing but 11.9 we just now obtained and then divided by concentration of PbS in the feed is nothing but 10% that is 0.1 and then mass of stream a that is feed is nothing but 100 lb that basis we have taken.

So when you do $\frac{0.8 \times 11.9}{0.1 \times 100}$ that you get 95.2%, that you get 95.2% yield of PbS. Now, the last part of the question is volume fraction in the rougher, in the rougher what we are having? It must be holding a stream and then d stream solids, whatever the rougher must hold "a" and "d" solids + water. So we have to find out how much solids in a and d and then how much is the water and then substitute here, so then we will get the fractions. Water to solid ratio in the rougher is given as L/S = 2.

In the scavenger L/S = 4 it is given but in the rougher because we have to find out volume fraction in the rougher, so in the rougher water to solid ratio L/S is given as 2 by weight percent. So feed solids also given as 500 tons per 24 hours or per day kind of thing that is given, so feed solids how many tons are there? 500 tons.

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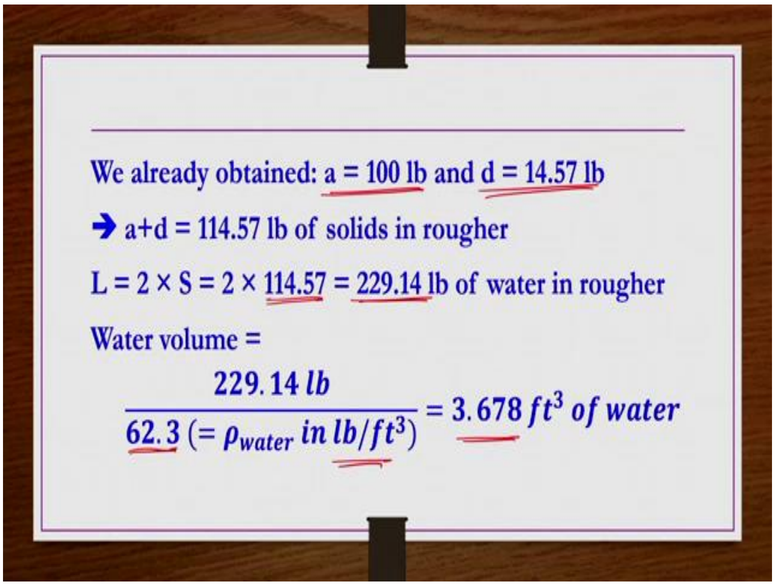

So from here we can start doing this, obtaining this weight of solids in this a and d streams because a stream we already know there is a kind of 100 lb material and then d stream we already know that 14.57 lb of material that is there, average masses that we already calculated. So a plus d should be nothing but 114.57 lb of solids in the rougher, so 114.57 lb of solids in the rougher are available.

So, how much liquid will be available then? Liquid should be nothing but 2 into the solids, the solids. So 2, L/S is equals to 2 is given, so L is equals to 2 x S, now S that is there in the a and d streams is nothing but 114.57 so that is coming out as 2 x 114.57 = 229.14 lb of water in rougher. So in the rougher we have to 229.14 lb of water and then 114.57 lb of solids.

So water volume if you wanted to know, this whatever the mass is there that you divide by the density of the water, so that is 62.3 in lb/ft^3, the density of water in lb/ft^3 is nothing 62.3, so and then mass of the water is 229.14 lb, so $\frac{229.14lb}{62.3}$ that you will get 3.678 ft^3 of water, 3.678 ft^3 of water that is present in rougher. The same in masses is 229.14 lb of water, in volume it is 3.678 ft^3 of water present in the rougher.

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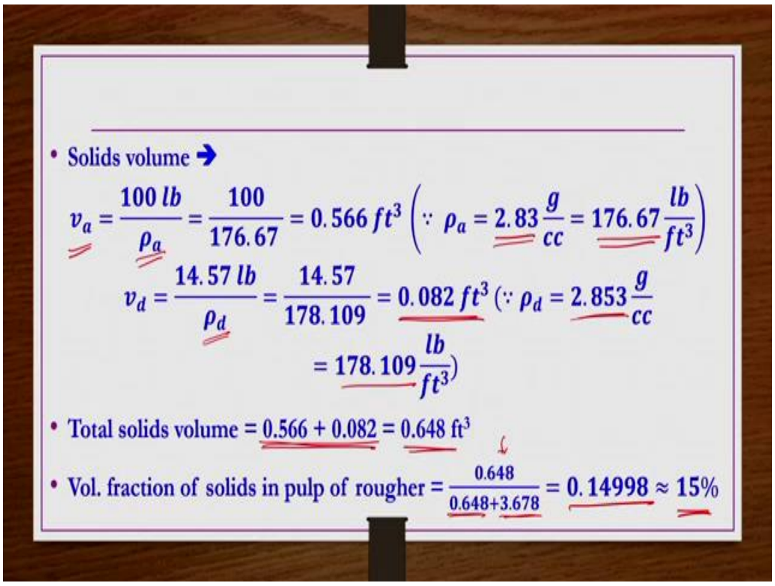

Then solids volume, we know that v a that is nothing but the solids volume v_a is nothing but the mass of a stream divided by the density of a stream, average density of a stream, so mass of a stream is nothing but 100 lb that we have seen and then average density of a stream we have found it as 2.83 gram per cc. That if you convert in lb per feet cube you will get 176.67 so $\frac{100}{176.67}$ is nothing 0.566 ft^3.

Likewise solids volume in d stream is nothing but $v_d = \frac{d}{\rho_d}$, d is nothing but 14.57 lb that we got, ρ_d that is average density of stream d we got it as 2.853 gram per cc, when you convert it into the $\frac{lb}{ft^3}$ you will get 178.109 so that v_d is equals to now $\frac{14.57}{178.109}$, so that comes out to be $0.082ft^3$. The total solids volume that present in the rougher is nothing but the total solids of a and d streams, so that is 0.56 + 0.082 that is coming out to be $0.648ft^3$.

And then what must be the volume fraction then? 0.648 divided by 0.648 plus water volume 3.678, so that comes out to be approximately 0.14998 that is 15%.

So in the rougher approximately 15% solids are there and then remaining 85% is the water by volume. This is about the floatation.

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So the references for these lectures on floatation: we have a Unit Operations of Chemical Engineering, McCabe, Smith and Harriot. And then Unit Operations of Particulate Solids: Theory and Practice by Ortega-Rivas. And then Coulson and Richardson's Chemical Engineering series second volume by Richardson and Harker. And then Transport Processes and Unit Operations by C. J. Geankoplis.

And then Unit Operations by Brown et al. And then Principles of Unit Operations by Foust et al, so this is very important reference for this floatation. Some details you can also find in the Richardson and Harker. So, other references also are given some kind of information, but majorly the floatation topic is discussed from this reference book, Foust et al that is Principles of Unit Operations.

With this we complete the topics on the floatation, finally all the topics related to the Mechanical Unit Operations which are related or required at the user level have been completed. So, the entire course we have 37 lectures; all the 37 lectures very much essential for UG Chemical Engineering Students. I thank you all for your kind attention, thank you.