Introduction to Mineral Processing
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Lecture – 54
Flotation (Contd.)

So, welcome back, we are discussing about the froth Flotation process. Now, I have briefly explained you how it works, let me get into little bit deeper. True flotation dominates the recovery of the valuable minerals.

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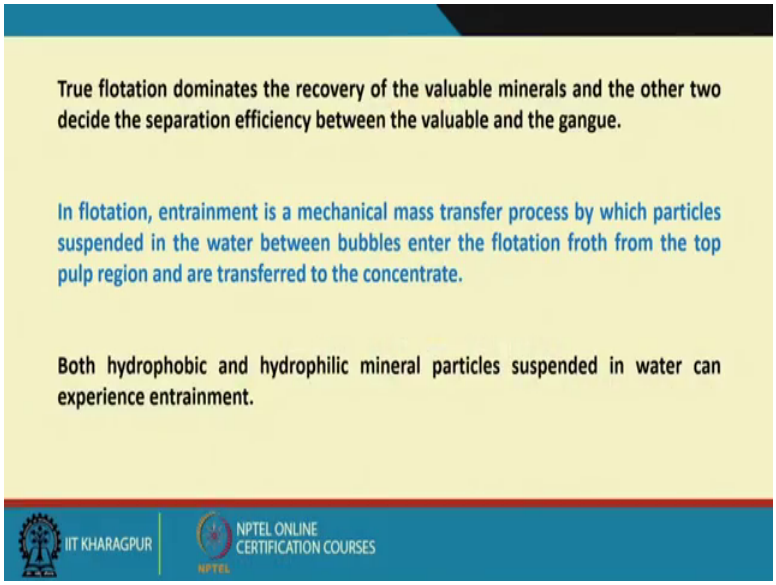

Now, what is true flotation? The true flotation means that, the mechanism what I had shown earlier like in this way.

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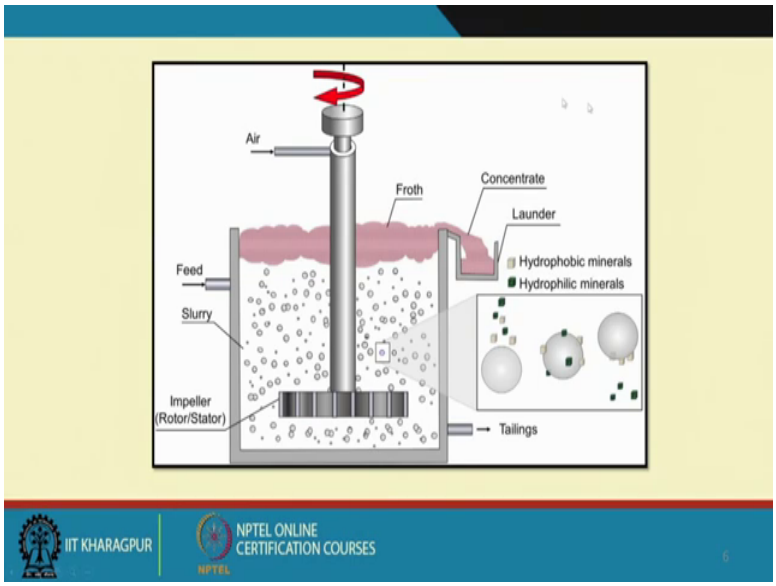

That is your selectivity that is selectively your particles are collected, which are hydrophobic in nature in the air bubble. So, that is the true flotation, but there are some other ways, some other means also your particles may be reported to the froth phase.

So, the true rotation dominates the recovery of the valuable minerals and the other two that is your aggregation and interment, decide the separation efficiency between the valuable and the gangue. What the meaning of that? That is if we have that how much of material we have recovered, through the true flotation process, because that is what is my objective what is my primary aim, that I want to recover by valuable minerals in most of the cases by making it is surface hydrophobic.

So, as a perfectness or at what level you have basically used this true flotation phenomena so that will decide that your the recovery of the valuable minerals. Because in the other two it is mostly the probabilistic base phenomena. So, the other two decide the separation efficiency between the valuable and the gangue, because the other two may not that selective. Why I am saying so? Let me explain it that in flotation entrainment is a mechanical mass transfer process, is a mechanical process is a mass transfer process.

By, which particles suspended in the water between bubbles entered the flotation froth from the top pulp religion and are transferred to the concentrate. That means, when the

water is going to the going to report to the froth phase, it is those particles, which are basically carried along with the water to the froth phase. So, it is not that selective.

So, if you can minimize that so; that means, it will give you a much it is guaranteed cleaner product. But if you cannot reduce it, that means, the entrainment is basically decide that what is that your entrainment, weather only the your wanted minerals are entrained or your unwanted materials are also entrained. So, that is why the separation efficiency is nothing, but that is how much of wanted material you have in the feed material and how much of that you have recovered or you have collected into your concentrate.

So, now when the entrainment process is not selective so, and if it is the dominating mechanism for floatation, then it is very difficult, that is your of the to maintain the efficiency between efficiency of separation, between the valuable and the gangue minerals. Both hydrophobic and hydrophilic mineral particles suspended it wonder in water can experience entrainment. Because, it is only the suspended particles because of the aeration you have, because of the impeller you are trying to start. So, you have got the aerated water and then the particles are suspended irrespective of their your whether they are hydrophobic or hydrophilic.

So, because of these entrainment phenomena, that is not selective. So, this decides if the entrainment is the dominant phenomena, then the separation efficiency will be drastically reduced because it is not selective.

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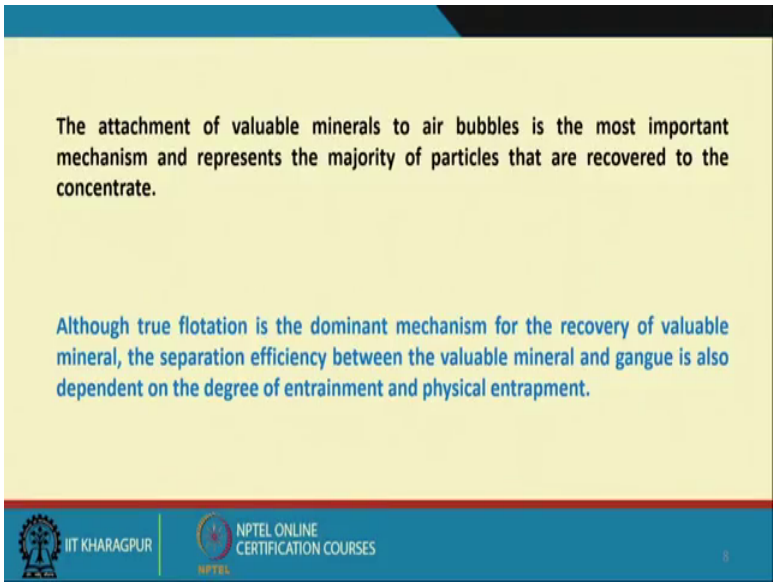

The attachment of valuable minerals to air bubbles is the most important mechanism; that means, if my materials if my minerals I have made them hydrophobic the surfaces, but I suppose they are not attached to the air bubble surfaces. So, what will happen? So, they will still rem reain remain into my flotation chamber. They are not reported into the froth phage. And so, the attachment of valuable minerals to air bubbles is the most important mechanism and it presents the majority of particles that are recovered to the concentrate. That is majority of my particles, which are reporting to the concentrate if it is a flotation cell. So, this in this attachment of the hydrophobic particles to the surfaces of the air bubbles and that is the mechanism, which is basically responsible for majority of the particles recovery in the concentrate range.

So, how do make sure that all my hydrophobic materials they are gaddy get adhered to the surfaces of the air bubbles, that is also another challenge to the mineral processing people or the floatation scientists and engineers. All the true flotation is the dominant mechanism for the recovery of valuable mineral and that is the essential goal. The separation efficiency between the valuable mineral and gangue is also dependent on the degree of entrainment and physical entrapment. As, I said that in any flotation cell we cannot have only one single phenomena, that is the true flotation.

Because, the water will have to go up certain portion of water will be going up. Now, when they start going up whatever material is coming up into their path and if they are

very lighter mineral, they will be also that is they are settling velocity less than the rising velocity of water then they will be transported to the froth phase. And the physical entrapment that is on top of the surfaces like, when you are feeding it feeding the material into the by flotation chamber the very fine particles irrespective of their degree of hydrophobicity, they may be lying in the top layer or the just below the top layer of my water into that vessel.

So, when the froth phase is established because of the rising bubbles. So, these particles are getting entrapped there. So, that is the physical entrapment. So, how far they are playing the role that is how much is that is the entrainment and interment. Because, you do not have much selectivity in that process that will decide that what is the separation efficiency?

Because you may have carried out the true flotation perfectly, but if you cannot minimize the effect of entrainment and physical entrapment, then your separation efficiency between the valuable mineral and gangue mineral will be hampered.

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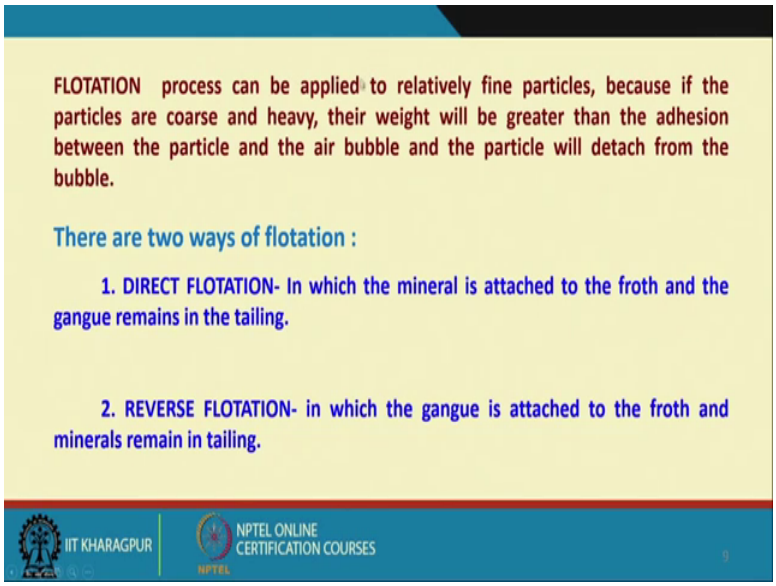

So, flotation process can be applied to relatively fine particles, why now, because if the particles are coarse and heavy, their weight will be greater than the adhesion between the particle and air bubble. How the particles what is the mechanism? Through which the particles get adhere to the surfaces of the air bubble, that I will discuss at later stage, but just imagine that you have got a bigger particle a coarse and heavy particle. And you

have got an air bubble so, your the force downward force, that is your the mass of that particle if it is very high, in relation to your bubble size or the bubble stability the air bubble and the particle will detach from the bubble.

That is what I have said that their weight will be greater than the adhesion between the particle and the air bubble, where there is a force you require it is called addetion adhesive force in between the particle and the air bubble, but if the particle mass is more than that will be weaker and the particle will get detached from the bubble. I will explain it through some diagram and through some equations that what do I mean here?

So, there are two ways of floatation; one is direct floatation, another one is called reverse floatation it is nothing, but the mechanism remains same, but whether you want your wanted material to report in the froth phase which, that is whether you want to make your wanted material as hydrophobic or sometimes you want to make your unwanted material to be hydrophobic.

So, when you want your wanted material to be hydrophobic I report to the froth phase that then we call it direct floatation most of the cases it is direct floatation, but there are some instances suppose my unwanted material and as I do not want these materials, and they are relative volume percent volume fraction volume percentage in the entire your particle volume is much lesser.

So, what I try to say that suppose I have got only 1 percent or 2 percent of the entire volume fraction of my particles and that is my unwanted material. And, you have got thirty percent of the volume fraction occupied by your wanted minerals. Why should I try to make the 30 percent volume fraction of my wanted material to be hydrophobic I try to collect it through the overflow in the froth phase, but if we can then try to add let much lesser quantity of chemicals and try to make my 1 percent or 2 percent volume fraction of your unwanted material to be separated out from the mixture of my wanted and unwanted material, by lifting them up by forcing them to report to the froth phase. So, that is called the reverse flotation.

So; that means, in simpler terms direct flotation is in which the mineral is attached to the froth and the gangue remains in the tailing here, the mineral means your desired mineral. And gangue is which you do not want. In your flotation in which the gangue is attached to the froth and minerals remain in telling. About the, your direct flotation and reverse

flotation, now we will get into much more detail on this subject. So, we will discuss about the various other phenomena which occurs that is, but before that I want to show you that in much more greater detail, that what are the different applications of this your froth flotation processes, in various other your applications in mineral processing.

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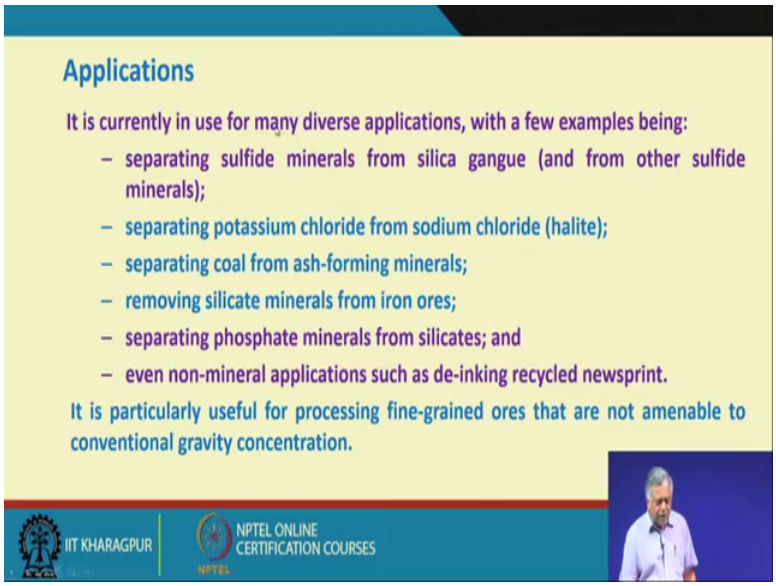

That it is currently in use for many diverse applications with a few examples being although I have already mentioned there briefly, but again I am repeating those there is separating sulfide minerals from silica gangue and from other sulfide minerals, that is even many a times you use this to separate say suppose you have got laid gene copper roles. That is in that assemblage you have got laid ore that is P B S your copper ore is a C U F E S 2 and then the zinc ore that is your Jaden S. So, this all 3 are sulfide minerals. So, and all 3 are wanted, but the challenge is that how do I separate P B S from C U F E S 2 and your Jaden S or maybe Jaden is from C U F E S 2 and P B S and like that.

So, they are also we use floatation even for separating the 3 different wanted minerals from one another. Then separating potassium chloride from sodium chloride, separating coal from ash forming minerals, removing silicate minerals from iron ores many a times we do it, separating phosphate minerals from silicates maybe carbonates, even non-mineral applications such as de-inking I have already mentioned.

It is particularly useful proposing fine grained ores that are not amenable to conventional gravity concentration technique; this is what I have already explained to you.

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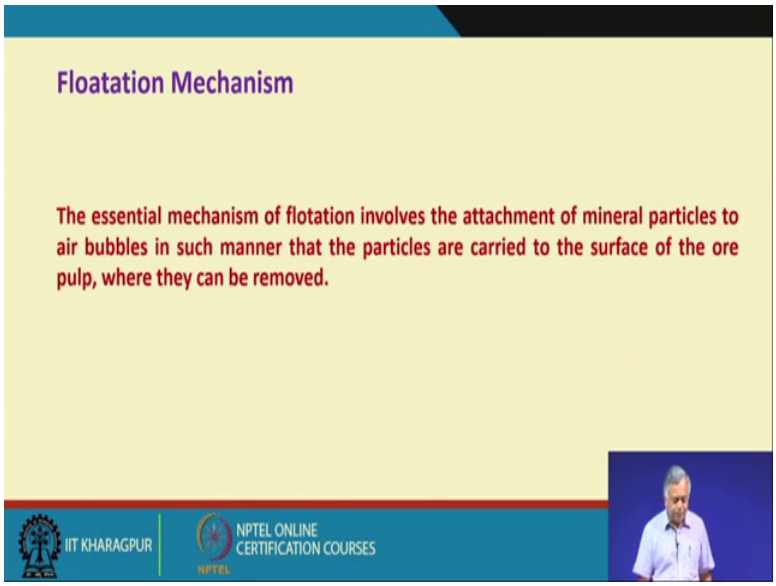

So, if you look at the essential mechanism of floatation involves the attachment of mineral particles to air bubbles, in such a manner that the particles are carried to the surface of the ore pulp, where they can be removed that is in the froth phase.

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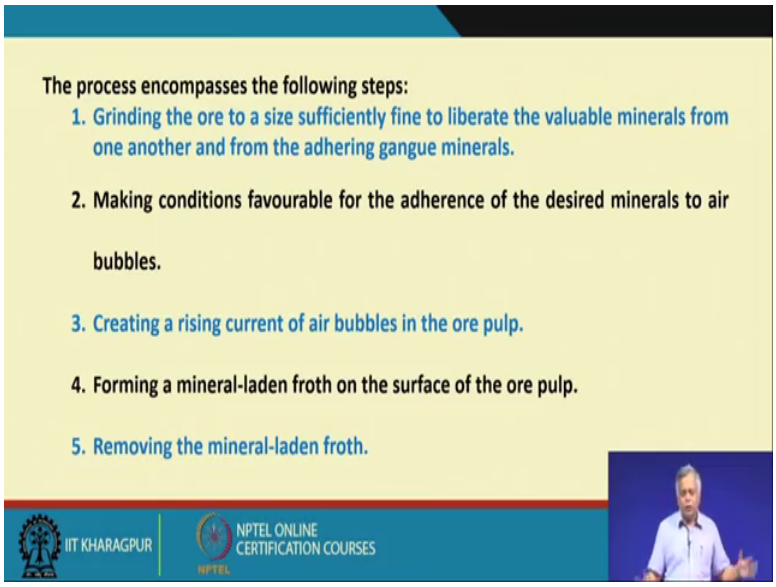

The process if you look at the entire process of the froth flotation, what it demands or what it should have? That is the process encompasses the following steps first you have to liberate your wanted and unwanted minerals. Most of the cases as I said that it has to be very fine sizes, because is the liberation size demands, but your flotation also

demands that it should be in fine sizes, because as I have explained that if you have coarse and heavy minerals the bubbles may burst or maybe they will be dislodged from the bubble surfaces. So, the product rotation process will not be that efficient.

So, you have to grind the ore to a size sufficiently fine the grinding the ode to a size sufficiently fine to liberate the valuable minerals from one another and from the adhering gangue minerals, that is the first condition, that you should have proper liberation. Making conditions favorable then for the adherence of the desired minerals to air bubbles.

So, how do you create a favorable condition inside your flotation chamber? So, that the particles your which are which you want to get idea to the bubble surfaces, that should get idea you know properly. Then you are creating a rising current of air bubbles in the ore pulp; that means, you should have a or rising current that is the you should push your bubbles, by some means that. So, that they rise to the up to the froth phase up to the top layer of the pulp.

Then forming a mineral laden froth on the surface of the ore pulp; that means, you should have a your froth, which is a stable and then this should have more concentrated your ore minerals, that is what you want. Then removing the mineral laden froth that is if you leave the froth phase there then automatically because of the atmospheric pressure the bubble will start will start bursting and because of that again those mineral particles which were lifted up they will try to get subtle because of their own mass.

So, what is the time difference between the one that is called the froth stability and within that time you have to remove the your froth from that your chamber quickly, but and if you do not do that it is not only the meanders particle, which are already carried to the froth phase, they will return to the your flotation chamber, but also if you have a froth phase and if it is not collected at a in such a manner. That it is synchronous with the fresh minerals, which are being carried again by the bubbles they will not have adequate space to get your to get in touch with my scraper. That is through which you are basically collecting them so; that means, there will be buildup of your froth depth.

So, you are collecting from a particular depth and if that starts building up so; that means, that is no it will not reach a steady state and your recovery will start getting sadistically reduced. So, how you are removing the mineral laden froth?

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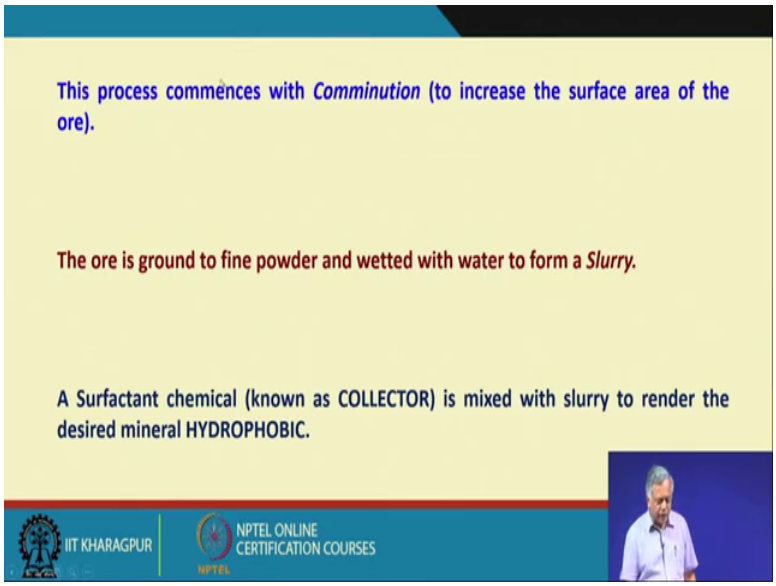

So, this process so, therefore, commences with combination, that is to increase the surface area of the ore. So, that is when the particle surfaces are finer you are increasing the surface area of the or, the over each ground to very fine your into fine powder, that is decided based on your liberation side and waited with water to form a slurry, that is it gets you try to mix them up with your water to form a slurry.

Now, you add a surfactant chemical that is which will selectively sit on your surfaces of your wanted material and in most of the cases it is your ore. And this is known as collector and there is also mixed with the slurry to render the desired mineral hydrophobic; that means, you just prepare the your feed material like you have got a mixture of your wanted and unwanted material finally, ground material you pour water, you try to mix them up. So, that the particle surfaces are properly weighted and then you add some chemical that is the collector and you try to also makes them up. So, that your entire particle surfaces of your wanted mineral, they are getting coated with this kind of your say surfactant, that will promote the hydrophobicity of those particle surfaces.

This slurry is then placed in the water bath containing Frother.

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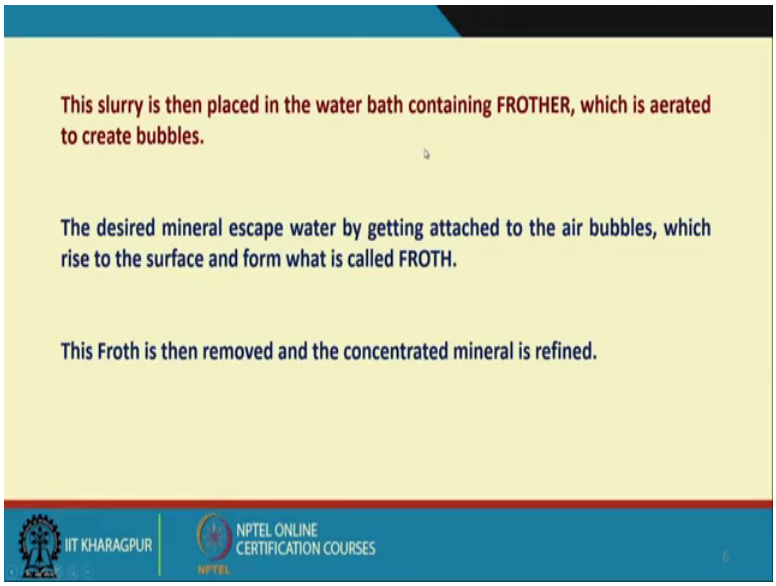

So, there is also another chemical we use that is called frother we discuss it later at depth, that is that gives the stability to some extent the stability of the froth phase; that means, the froth phase does not your get collapsed immediately after reaching the your top layer of the say floatation cell. Which is aerated to create bubbles, that is how we have we are generating the bubbles that I have already explained you, the desired mineral escaped water by getting attached to the air bubbles, which rise to the surface and form what is called froth this thing I have already discussed. This froth is then removed and the concentrated mineral is refined.

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Now, there is a small video I have downloaded from the open source and it is by one of the it is uploaded by one of the Indian equipment manufacturing companies in the mineral processing field it is my in smart systems head of history in Hyderabad. And these shows that this is a floatation cell and this basically shows that how do you carry out a laboratory floatation experiment and where you are how you are adding, but these are all manually done in actual plant scale floatation cell. These are all being done automatic automatically, they are all done automatically in recent times, but this will give you the ideas and this will give you some visualization that how it is being done?

So, you see that this is the froth flotation cell that is they are using that is and this is the impeller ok.

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So, first thing what they will do then this is my mineral that is what I want to separate them out.

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So, first for laboratory experiment you have taken a pre weighed material you are pouring it into that your floatation cell, now you are adding water.

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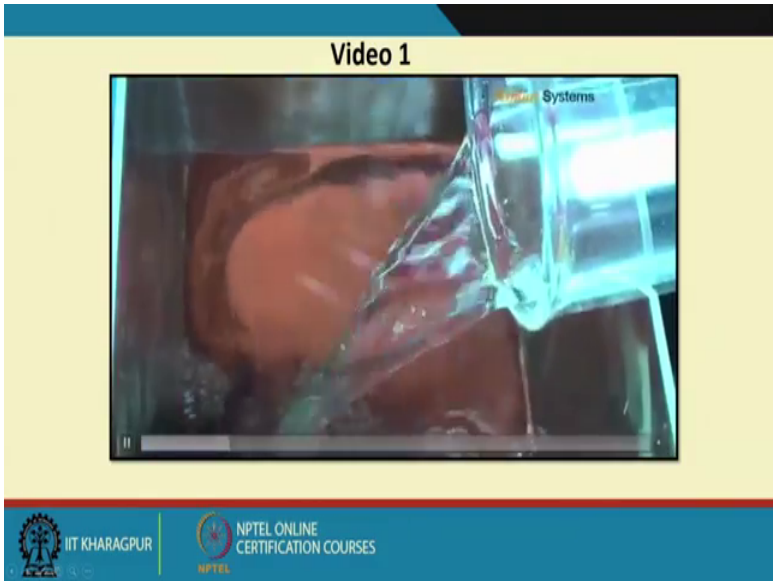

And after this you would try to stir it by that your star impeller.

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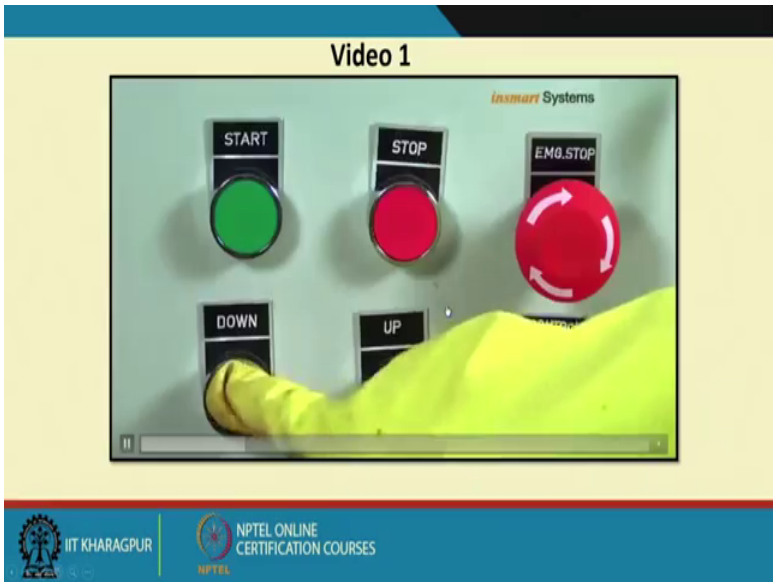

Do you see that these are the impellers and it is their typical design, but in actual scale it may be designed separately by different manufacturers?

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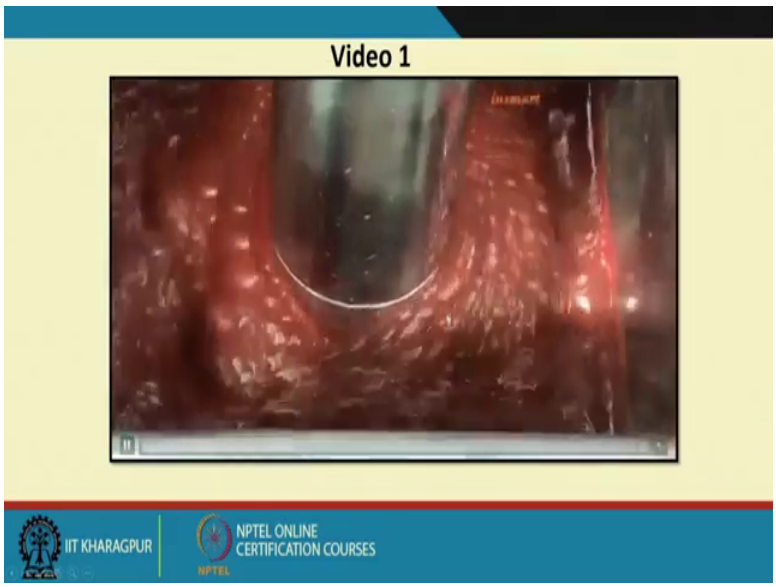

And now you are trying to makes them aerating them you have not passed much of air bubble now, because you have not added any chemical, now you are adding chemicals and you are checking with the litmus paper that what is the P H of that?

Now, you are adding some other chemicals that is you add different types of chemicals for different reasons, what is for making hydrophobic and then P H adjustment, then you

may be adding some kind of your say froth stabilities. So, many chemicals are there that I will discuss in due course of time, but for the time being you just see that that it is being added. Now, you will be stirring it again. So, that these chemicals are also getting properly mixed with this slurry. Now, you are preparing slurry and you are giving sufficient time, now you have started passing air through that and you see this is the froth.

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Now, they are being lifted and this is the you see the viscosity of this froth and all this you have main maintain, and this is automatically getting reported because you have made such an arrangement that the froth will be collected.

So, these are all the design features and now what you do you try to recover it this is a lab skills experiment in actual operation it is being done all automatic. So, you are now collecting all the materials now what will you do you lift them impeller up. So, that they are free from this material. So, that you do not lose this and you are just taking it out and to see that how much of material remained into that flotation cell and how much you are collecting?

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So, these are the 2 differences in the colors you see that these are much darker than these phase. So, you have collected both the materials in separated stage. And now what you have to do you have to dry them up and you have to evaporate the moisture and you get the dry powders, which are basically you are wanted and this case it may not be wanted material or it depends whether it is a reverse floatation or your direct floatation.

So, this is a laboratory demonstration by one of the equipment manufacturers who manufacture this floatation cell mostly for laboratory purposes and there is a video I thought, that it will help you to understand that how it works to visualize how it works? So, I gratefully acknowledge the in smart systems for uploading this video into the open domain.

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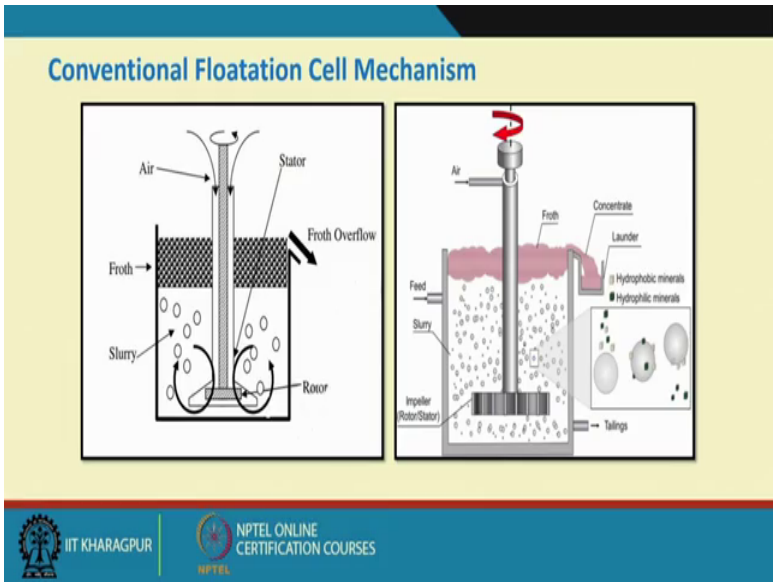

Now, you see that these are the conventional floatation cell. So, why I am saying conventional floatation cell, because how you generate the bubbles? How you makes the your water and the fine particles and the chemicals and then how you are collecting your froth? How you are collecting your that tales, that is your rejects? This all differentiates, that is there are different manufacturers design and then what are the capacities of each individual cells so, that is also another aspect of this flotation cell.

So, here see that this is the froth phase if we have so, this is the froth overflow in this case you call it your stator and this is the rotor and these are the air how it is coming we have already discussed this picture. So, there is no point in explaining it again.

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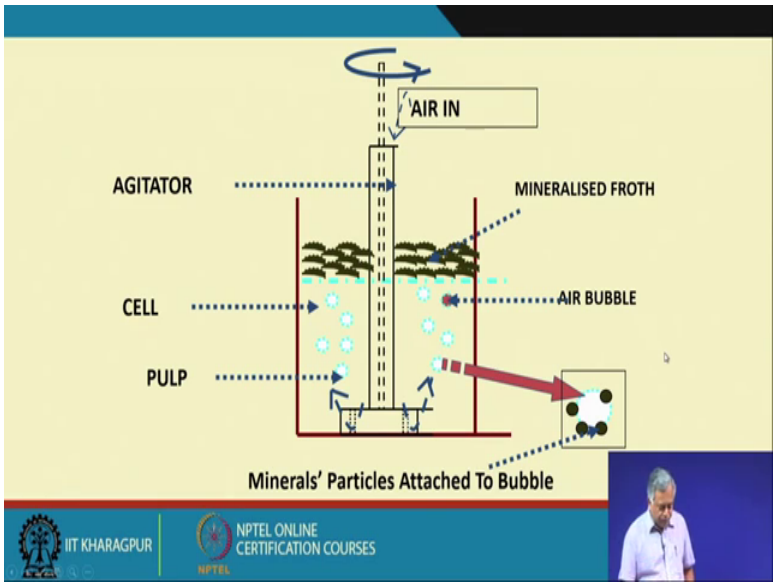

This is another demonstration how the particles get adhered to the bubble surface? So, you have got the agitator this is the same, this is the pulp, and now you have got this your air bubble and this is the, your demonstration the minerals particles get attached to the bubbles, and this is the mineralized froth and you have passed the air through this. This is again I have taken it from the open domain; I forgot to acknowledge this your source because I do not remember it right now.

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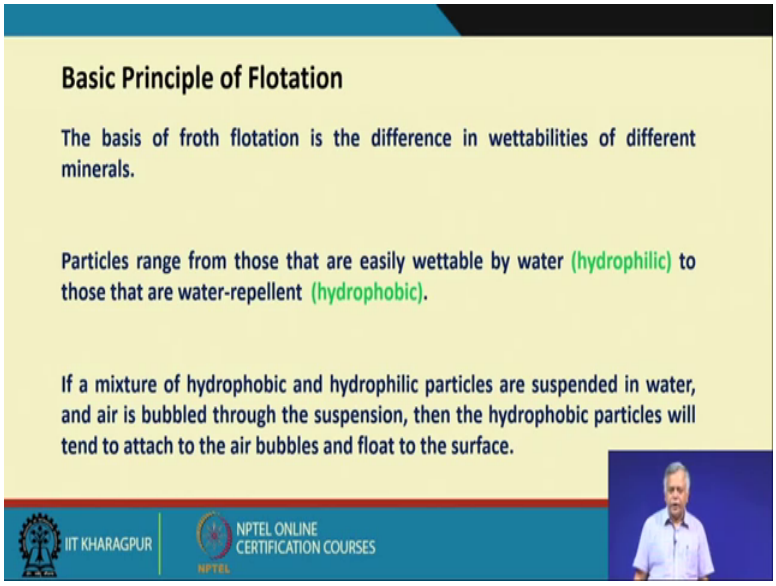

So, the basis of froth flotation is the difference in weight abilities of different minerals, particles range from those that are easily avoidable by water, that is called a hydrophilic to those that are water repellent that is hydrophobic some particles are naturally hydrophobic. For example, coal particles their surfaces these particles are naturally your hydrophobic, but still when you try to float the coal particles many times you add some chemicals, to make the to increase the intensity of the hydrophobicity or that degree of hydrophobicity of the surfaces. So, that your separation process becomes faster and much more selective.

If a mixture of hydrophobic and hydrophilic particles are suspended in water and air is bubbled through the suspension, then the hydrophobic particles will tend to attach to the air bubbles and float to the surface that is what we have shown you and I have explained you.

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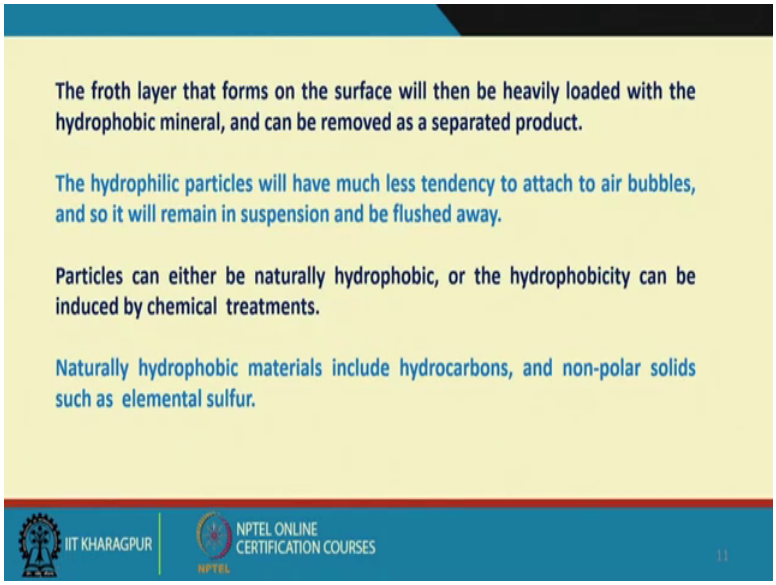

The froth layer that forms on the surface will then be heavily loaded with the hydrophobic mineral and can be removed as a separated product, the hydrophilic particles will have such less tendency to attach to air bubbles. And so, it will remain in suspension and be flushed away, that is what you do it in laboratory scale your experiment. Particles can either be naturally hydrophobic or the hydrophobicity can be induced by chemical treatments, that is what I have shown you that you are adding some chemicals to make the to increase the degree of how hydrophobicity?

Even the particles may be naturally hydrophobic. So, you want to control that your rate of your transport phenomena and all this.

Naturally hydrophobic materials include hydrocarbons one example I have given you the coal and nonpolar solids such as elemental sulfur. So, these are all naturally hydrophobic minerals and like your hydrocarbons and all this, but most of the cases the degree of hydrophobicity of the naturally occurring minerals is not that pronounced that we can have your froth flotation without adding any chemicals. So, we need to add some chemicals to accelerate this particle separation mechanism based on these froth flotation mechanism. So, we will continue this lecture and till then.

Thank you very much.