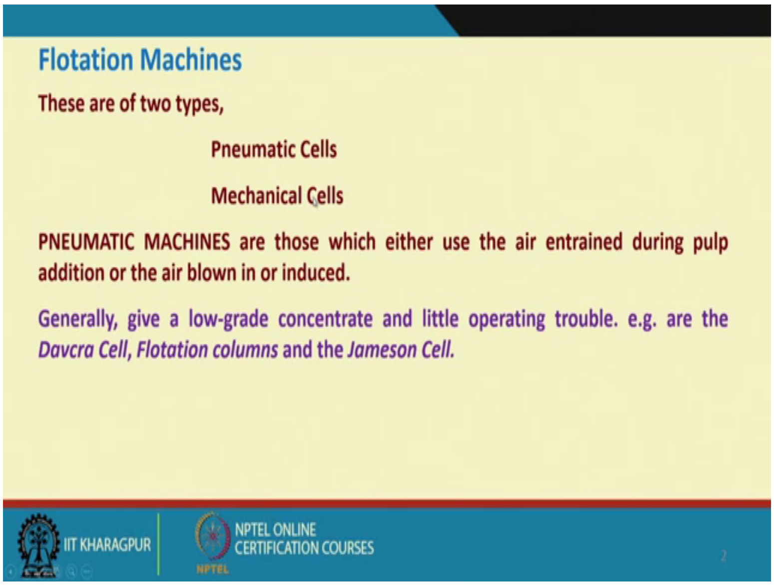
Introduction to Mineral Processing
Prof. Arun Kumar Majumder
Department of Mining Engineering
Indian Institute of Technology, Kharagpur

Lecture - 59
Flotation Machines

[noise]

Hello welcome back [noise]. So, the last few lectures I have discussed about the floatation chemicals in brief. Now, I was [noise] talk about the Flotation Machines in brief, [vocalized-noise] that other different types of machines available and what the very purposes of these machines I just like to discuss that [vocalized-noise]. So, flotation machines again there are 2 types; one is called Pneumatic cells another is called Mechanical cells.

(Refer Slide Time: 00:57)

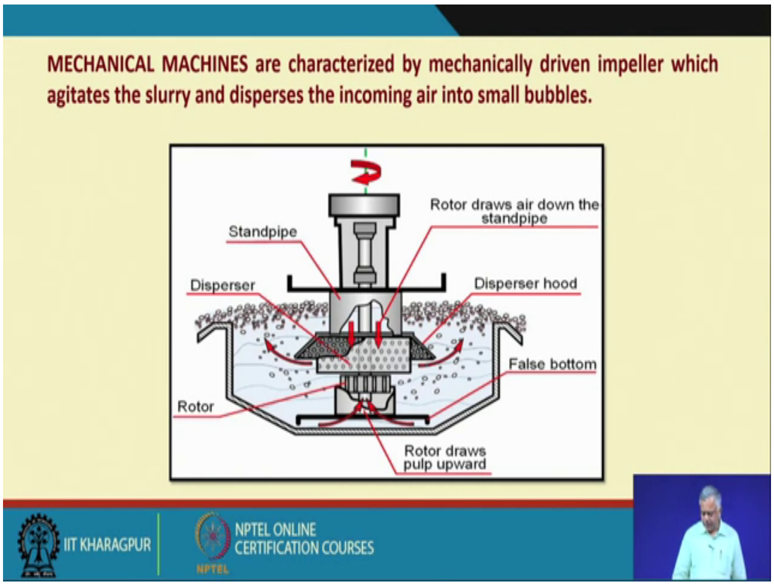


So, essentially they cells actually how do generate the bubbles and how do enable the particles and your chemicals to be mixed properly and the how the froth phase is being created? And then how the froth is being transferred to a separate launder, where you are collecting the you are separated materials?

So, pneumatic machines are those, which either use the air entrained during pulp addition or the air blown in or induced; that means, ah the pneumatic machines either use the air entrant during the pulp addition, because you will be having some entrained air or artificially you are blowing the air in or maybe the air can be induced.

It generally gives a low grade concentrate and little operating trouble. Examples are the Davcra cell, Flotation columns and the Jameson cell. These are the varieties of designs, but they are basically the pneumatic cells [noise].

(Refer Slide Time: 02:20)

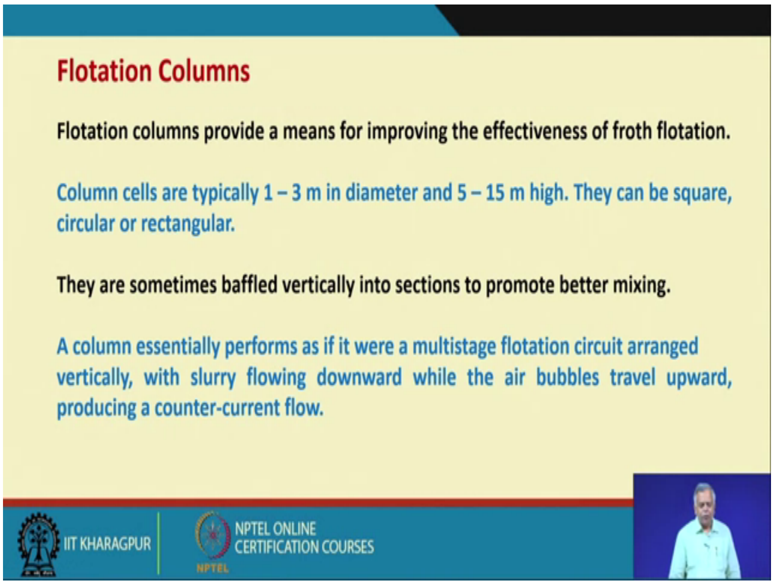


Mechanical Machines are characterized by mechanically driven impeller, which agitates the slurry and disperses the incoming air into small bubbles; that means, in this mechanical machines you have got an impeller and that basically rotates and because of the rotation, the slurry gets agitated; that means, you create a turbulent condition. So, that your fluid phase your solid and your chemicals they try to get basically having a environment where they get an opportunity to be mixed properly with the collectors.

And, it also should disperse the incoming air into small bubbles; that means, it helps in bubble generation. An example is shown here that is where you have got an impeller here [noise] that is a rotor and it rotates and that is called a disperser. So, that basically disperses the bubbles and the how the bubbles are being generated? Now, the impeller may be your hollow and through that you can inject air into that and that air basically you have got a disperser. And, that because of that your bubbles are generated when it tries to go up it will have you are controlling the bubble sizes based on the your say the arrangement you have made here.

And, when you try to basically rotate it this your rotor draws pulp upward; that means, it rotates like this and it creates a basically and turbulent atmosphere inside this and the slurry would like to go up, because you are trying to rotate it like; if I take a bucket of water. And if I put my hand into that deep into that and then if I rotate that water, you will find that the entire thing it tries to go up. So, and along with that you are having a a basically disperser that is called a disperser and then you are generating the bubbles and it disperses the bubbles also in inside that.

(Refer Slide Time: 05:00)



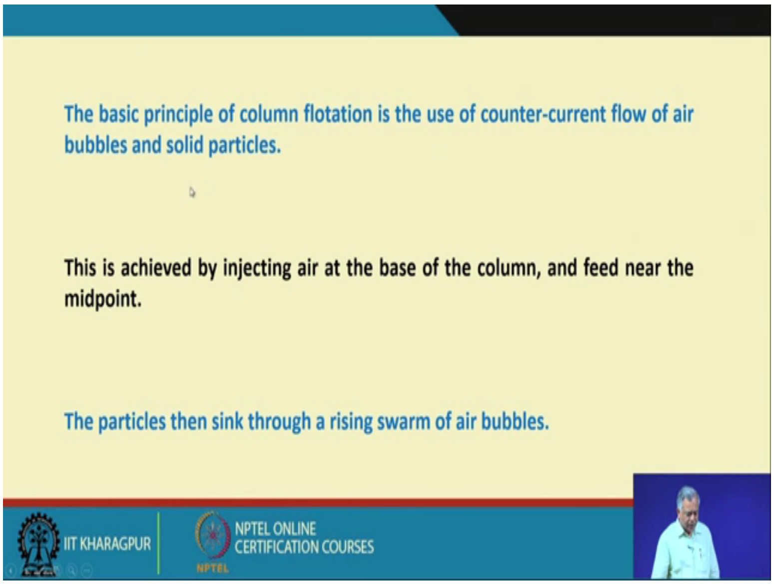
There are floatation columns [vocalized-noise]. Now, that is another type of cell it provides the means for improving the effectiveness of froth flotation process. It is also a froth flotation process, but the cell design is different with an aim to improve the effectiveness of the froth flotation process. These columns are typically 1 to 3 meter in diameter, at 5 to 15 meter high it is like a very huge column. The column could be square circular or rectangular, there sometimes baffled vertically into sections to promote better mixing.

So, mixing is very important phenomena here mixing of what now mixing of between the particles and the your floatation chemicals? A column essentially performs as if it were a multistage floatation circuit arranged vertically. Means you have got stages of flotation arranged vertically it is like that, with slurry flowing downward slight rise to flow downward while the air bubbles travel upward, producing a counter-current flow;

that means, slurry is trying to go down and the air is trying to go up. So, that you can have a proper mixing between them there is a typical design.

The basic principle of column floatation is the use of counter current flow of air bubbles and solid particles.

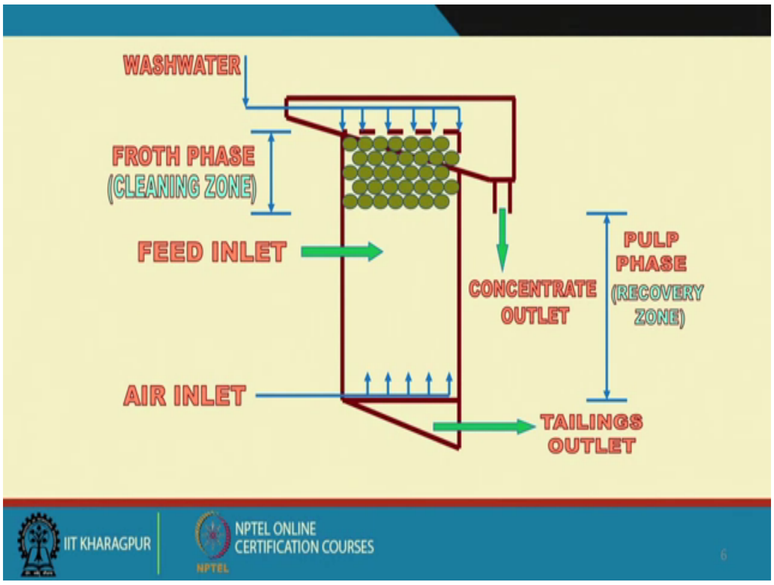
(Refer Slide Time: 06:44)



So, that my particle bubble attachment is much more effective the counter current flow we have also discussed while discussing about you are settling columns. The similar principle, but there are no bubbles here we have got bubbles particle will try to go down, because of his settling velocity and the bubbles will try to go up because of his buoyancy and if the bubbles [vocalized-noise]. So, the your ah interaction between the particle and bubble is much more higher and the hydrophobic particles they will get attached to the bubble surfaces. And, if they are settling velocity is lesser than the upward velocity of my bubble, they will be transported to the top. This is achieved by injecting air at the base of the column and feed near the midpoint.

The particles then sink through a rising swarm of air bubbles. It is a very complex hydrodynamic situation and basic aim is that your proper mixing between your bubble and particle attachment or [vocalized-noise] or the you are giving every particle or creating a situation, where every particle has a chance to decide, that whether I will adhere to the surfaces of the bubbles or not, that that is dictated by the nature of those particle surfaces that is whether they are hydrophobic or hydrophilic.

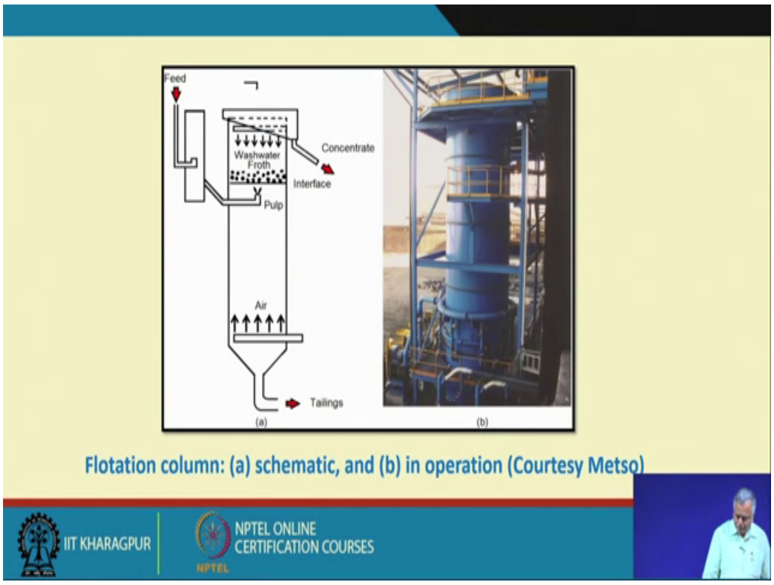
(Refer Slide Time: 08:34)



There is an schematic of a column flotation cell say that here the air inlet is there there is a spurger and through that air is basically purged into that and you generate air bubbles. There is a feed in the form of slurry and they try to the particles will try to come down and the bubbles are trying to go up, and there you create a froth phase with the your hydrophobic minerals, and then through that what you are doing an additional feature here is that that is called the froth phase, you add additional water from the top that is called the wash water. It helps in dislodging the entrained particles in between the this bubbles; that means, one of the particles are entrained, which are not which may not be hydrophobic, but they are basically entrained in ah a in between the your bubble the void spaces in between the bubbles.

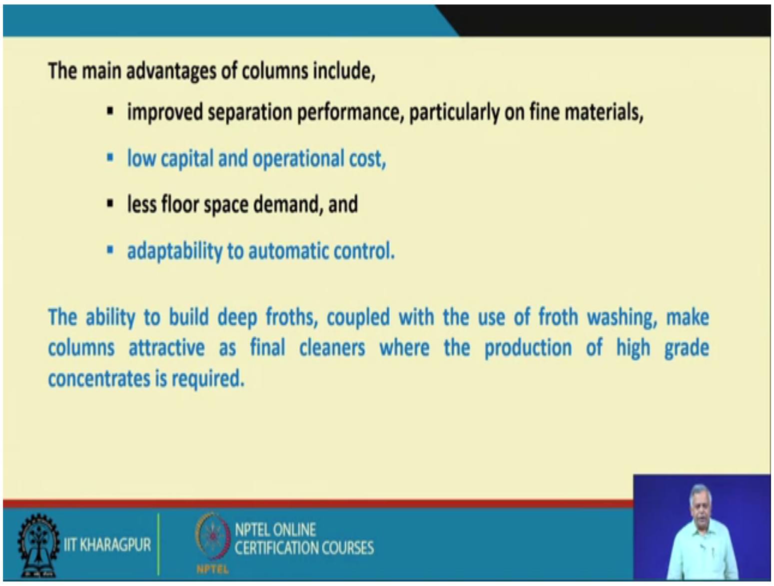
And so, that they can get dislodged and then the your with the mechanism of a like a wire flow flow through wires, ah they overflow wire the froth phase is being [vocalized-noise] you are collected into the concentrate outlet we call it. And, this is the pulp phase that is between that pulp means is the solid liquid mixture and that is the particles, which are basically hydrophilic, they will sink they will not get adhered to the surfaces of the bubbles and that is the tailings that is the how [vocalized-noise] we have a collection mechanism is called a tailings.

(Refer Slide Time: 10:26)



So, [vocalized-noise] this is basically a ah another a or as a schematic and in ah ah real one, that is a column flotation cell; the courtesy Metso site we have ah ah I have taken it from them I greatly acknowledge that. And it is how the feed is base basically ah in the pulp hop they fade here there is the wash water coming from there, and that is how the air is going up and this is an interface between your pulp and your froth phase, and that is how the concentrate is being collected? This is ah your typical column flotation cell ah made by the Metso.

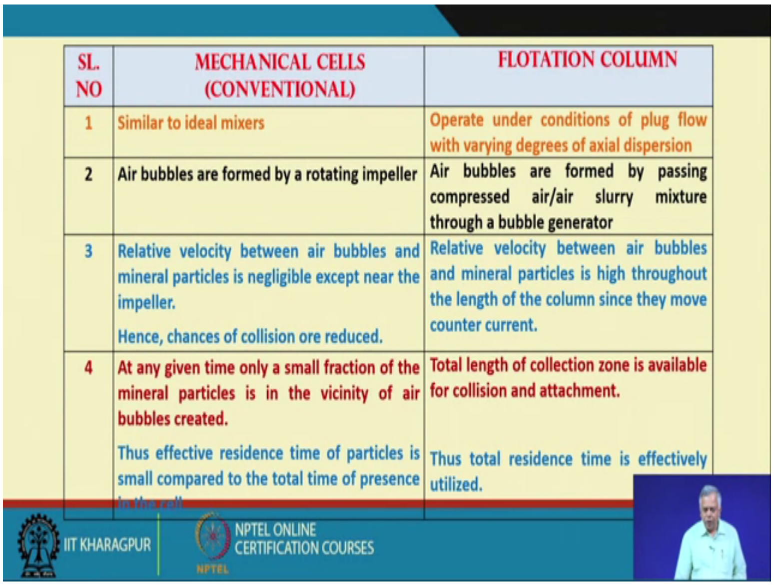
(Refer Slide Time: 11:11)



The, main advantages of columns they include the improved separation performance particularly on fine materials, because the residence time of the particle is much more higher the gap between your froth phase and your pulp phase is much higher, than in comparison to your normal floatation cells. And, they are very good for particularly very fine materials because fine materials you have a large surface area. So, it is very difficult to maintain selectivity of this. So, when it is because of the counter current flow principle and because they are dispersed enough, because of the degree of your turbulence you have created, as a multiphase [vocalized-noise] your situation ah.

So, it has been observed that you get a better separation performance or ah while dealing with very fine materials. It requires a low capital and operational cost, because in one cell you are doing many stages, it requires less floor space because you are using the height. And adaptability to automatic control you can control each stage in a much better way than the conventional cells. The ability to build deep froths coupled with the use of froth washing make columns attractive as final cleaners, where the production of high grade concentrates is required.

(Refer Slide Time: 13:00)



SL. NO	MECHANICAL CELLS (CONVENTIONAL)	FLOTATION COLUMN
1	Similar to ideal mixers	Operate under conditions of plug flow with varying degrees of axial dispersion
2	Air bubbles are formed by a rotating impeller	Air bubbles are formed by passing compressed air/air slurry mixture through a bubble generator
3	Relative velocity between air bubbles and mineral particles is negligible except near the impeller. Hence, chances of collision ore reduced.	Relative velocity between air bubbles and mineral particles is high throughout the length of the column since they move counter current.
4	At any given time only a small fraction of the mineral particles is in the vicinity of air bubbles created. Thus effective residence time of particles is small compared to the total time of presence	Total length of collection zone is available for collision and attachment. Thus total residence time is effectively utilized.

Now, if I make a comparison between the mechanical cells that is the conventional cells and the floatation column, these are the only the ah broad classification that is your comparative your parameters. The mechanical cells work like an ideal mixers, but flotation column they operate under conditions of plug flow, with varying degrees of axial dispersion [noise. Mechanical cells the air bubbles are formed by a rotating impeller in a floatation column air bubbles are formed by passing compressed air or air slurry mixture through a bubble generator.

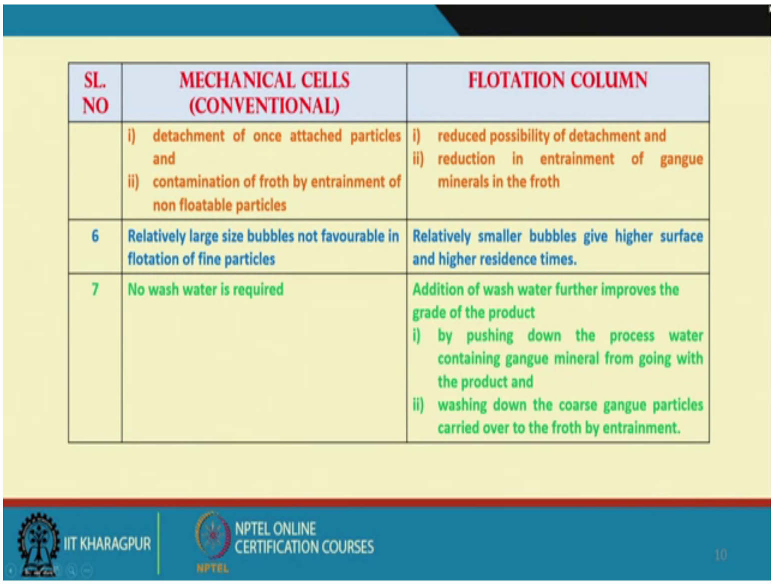
So, you are using a bubble generator here. So, you can control the bubble sizes in much more effective manner than the mechanical cells or the bubble size distributions to be precise. In mechanical cells the relative velocity between air bubbles and mineral particles is negligible, except near the impeller. Because, near the impeller what is happening there because the particle mass is much more higher, than the bubbles the particle may have much more higher velocity than the bubbles, but in other zones it is almost identical.

Hence, chances of collision are reduced [vocalized-noise]. Here the floatation column the relative velocity between air bubbles and mineral particles is high, throughout the length of the column since they move counter current particle is trying to go down bubble is trying to go up.

So, the relative velocity differences are very high. Mechanical sense at any given time only a small fraction of the mineral particles is in the vicinity of air bubbles created; that means, they are dispersed based on their masses. So, the particles are much more towards the wall and the bubbles are away from that, but eventually when they so; that means, the effective residence time of particles is small compared to the total time of presence in the cell. In the floatation column total length of collection zone is available for collision and attachment the entire zone you are basically using it for your collision and attachment.

So; that means, you have giving more time for the bubble particle attachment. Does the total residence time is effectively utilized.

(Refer Slide Time: 15:49)

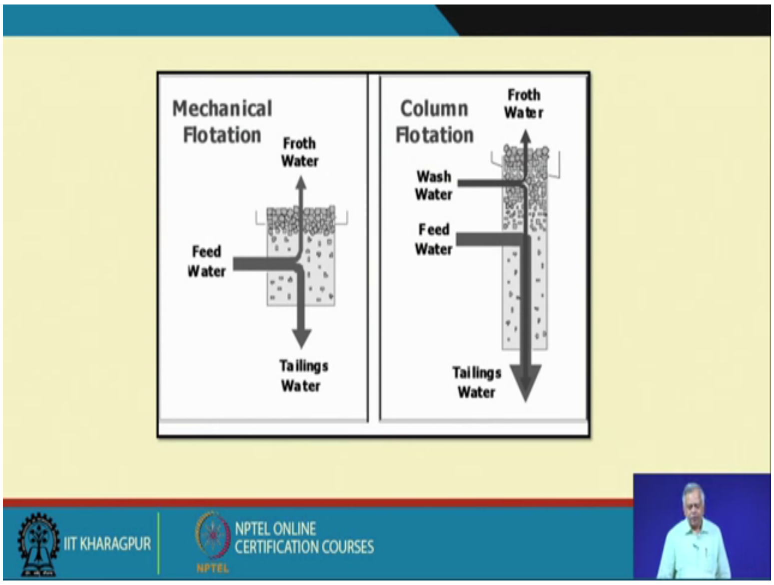


In mechanical cells the detachment of once attached particles and contamination of froth by entrainment of non-floatable particles occur, because [vocalized-noise] the way you are generating the bubbles by using a your rotor a because of high shear forces. The detachment of your attached particles also can occur. In flotation column there is a reduced [vocalized-noise] possibility of detachment, because it is based on the counter current flow principle, there is no additional force you are using. So, that the once there attach they will be detached again.

A reduction in entrainment of gangue minerals in the froth, because you are using wash water, in mechanical sense relatively large size bubbles not favorable in flotation of fine particles these are the selectively as your selectivity may be lost. In flotation column relatively small bubbles give higher surface and higher residence times. Actually in flotation column you can also control the bubble size distributions much ah ah so, much adequately than in mechanical cells.

In mechanical cells no wash water is required a floatation column addition of wash water further improves the grade of the product, by pushing down the process water containing gangue mineral from going with the product. And washing down the coarse gang particles carried over to the froth by entrainment [noise].

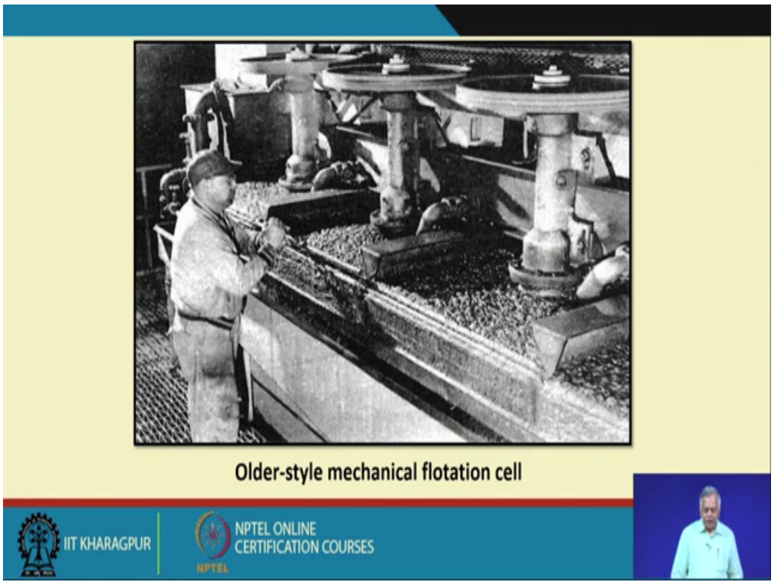
(Refer Slide Time: 17:40)



This is what, I was trying to tell you the points what I have mentioned there can be easily understood by these 2 comparative schematics; like in a mechanical flotation cell you have got your feed water, and that is your [vocalized-noise] and then you have got these your pulp formation, and here you have got forth water and you have got tailings water.

So, there is no wash water there. So, you are not able to further clean this froth. So, that you can ah you can help the entrain particles to be dislodged from that froth phase. Or as in the column cell you see that there is a wash water here so, there are 2 ah locations where you are adding water to the system. And this wash water basically helps in dislodging your entrained particles too and you are forcing them to report to the sink, that is how you are getting a better quality of product.

(Refer Slide Time: 18:51)



If I look at the evolution of this cell design these 2 images. This is the older style mechanical flotation cells and you see that these are all ah older styles and then the next one I will show you the what are the modern cells.

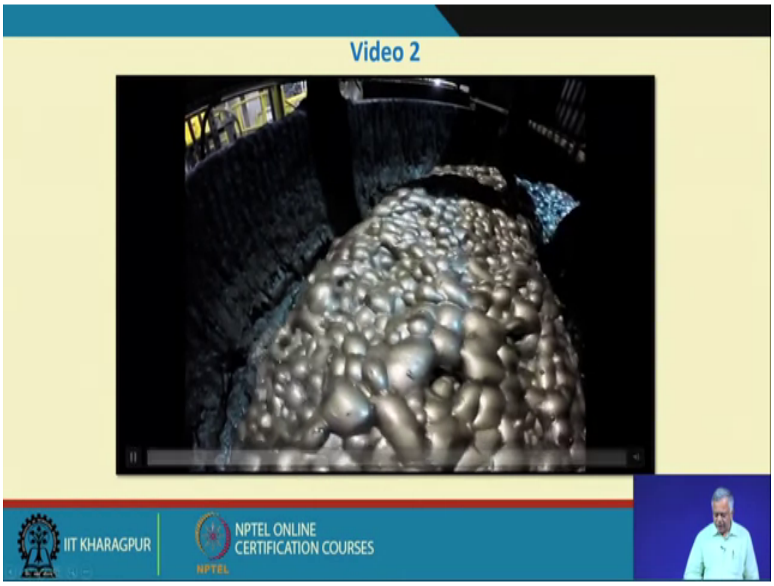
(Refer Slide Time: 19:30)

Through a video and it is also downloaded from a ah open source you see here, that is flotation cells in the Humboldt mill.

(Refer Slide Time: 19:35)

These are like your flotation cell and you see that, how they are [vocalized-noise] are used to separate the copper and Nickel minerals.

(Refer Slide Time: 19:41)



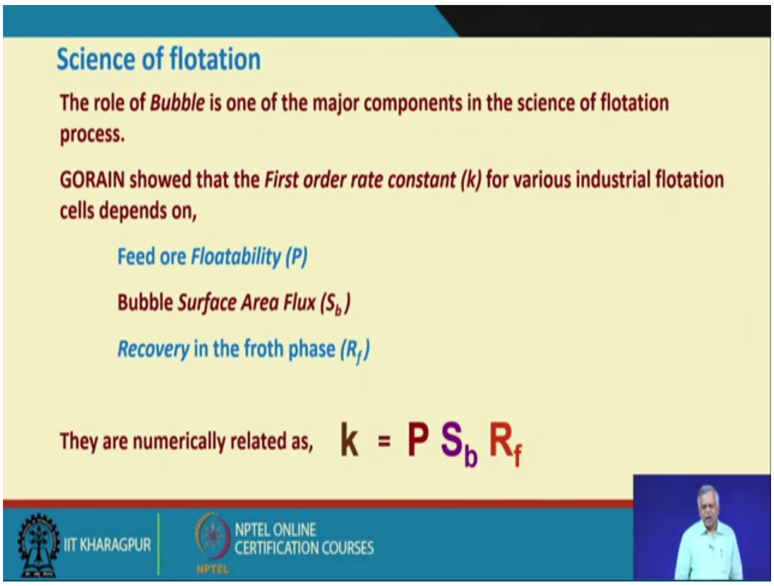
And you see that they are much more automatic.

(Refer Slide Time: 19:50)

And you are collecting the [vocalized-noise] ah froths, the same processes are replicated in a first in a laboratory process, which I had shown you also in the beginning of this flotation lecture. And this small scale tests help you to decide about the right selection of the right kind of your chemicals and their dosages, and then you try to implement it into a model cell and the model cells are much more instrumented.

So, that you can ah continuously add your chemical reagents and monitor many other parameters [noise].

(Refer Slide Time: 20:28)



This called the science of flotation in our is a very popular um ah topic, that is was a popular title given in the modern textbooks, but whatever we had discussed that is also part of the science of flotation, but this is this should be called the hydrodynamics of flotation process according to me, but I have used the similar term. So, that you do not get confused, when you look at the textbooks? A relatively newer ah research outcome the Gorain that is your name is Doctor Varun Gorain, I did this work in JK Marci Australia during his PhD.

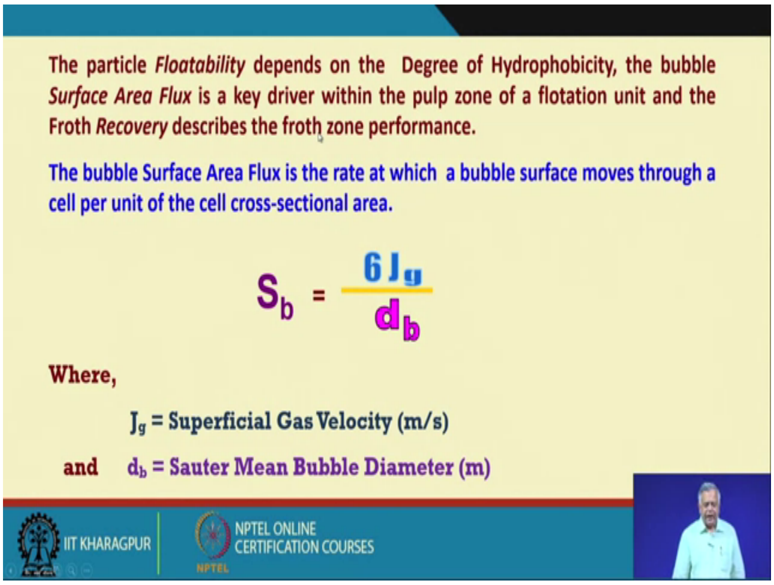
The role of bubble is one of the major components in the science of flotation process. That is you may have made your materials your mineral surfaces hydrophobic, but it is the collection of these hydrophobic minerals or the separation between your hydrophobic and hydrophilic materials. They are dictated by that how effectively you have controlled the bubble size distributions? There rising velocities, they are stabilities, all sorts of things.

So, bubble plays a critical role in deciding ultimately that whether your flotation kinetics is in ah is in favorable condition. So, Gorain showed that the first order rate constant k for various industrial floatation cell depends on let me tell you first the floatation kinetics is normally modeled by a a first order [vocalized-noise] ah reaction kinetics, anyway do not worry about this this introductory course.

So, and he has shown that the various industrial floatation cell the the rate constant that is based on which your kinetics of the process a basically depends. It depends on feed or floatability that is called the P. That is what type of material you are trying to float? And what is the floatability characteristics of that there are various tests, various method to do that. And you have to test it in the laboratory with a small amount of materials and that is called the floatability. Then another term we had use that is called the bubble surface area flux S b and recovery in the froth phase that is R f, that is your material could be hydrophobic, but whether they are actually recovered into the froth phase or not.

So, there is a correlation he has developed and realized that k is equal to P S b R f.

(Refer Slide Time: 23:50)

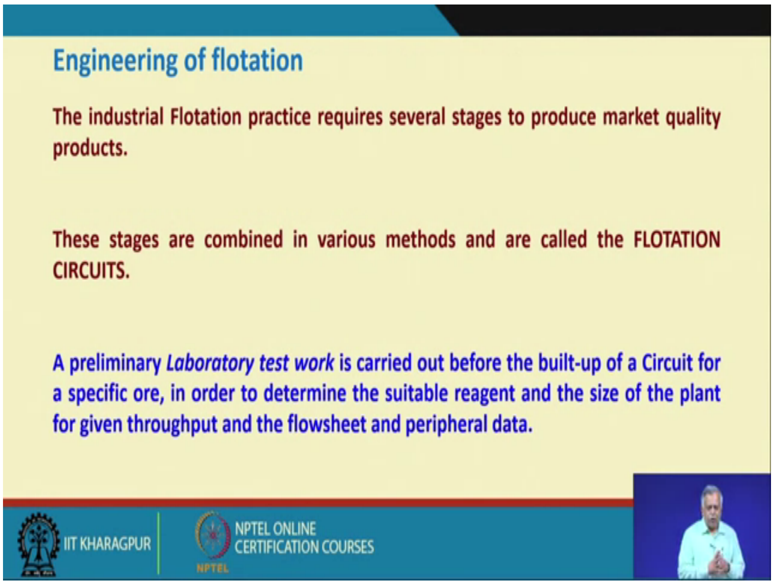


The particle floatability again depends on the degree of hydrophobicity, which is evident what if we understand the basics of flotation we agree to this. The bubble surface area flux is a key driver within the pulp zone of a floatation unit; that means, how much of what is the surface area of your bubble, is it lesser than your the surface area of your floatable materials or more than that all this.

And the froth recovery describes the froth zone performance; that means, the various issues what I discussed we had already discussed during the discussion of frothers. So, the bubble surface area flux how do I calculate it? The bubble surface area flux is the rate at which a bubble surface moves through a cell per unit of the cell cross sectional area.

Now, has again a proposed a correlation there is S b is equal to 6 J g by d b, where J g is the superficial gas velocity meter per second and d b is the shorter mean bubble diameter, that is what are the mean sizes a sort of mean sizes is again another way of representing this particle size, if you consider a bubble a particle.

(Refer Slide Time: 25:40)



Now, if I look at the engineering of floatation, now that is the science, now how do I engineer it? The engine industrial floatation practice requires several stages to produce market quality products; that means, in an industrial floatation practice, when we are handling large tonnages of material only in one stage you can have your targeted degree of separation.

So, you have to do it in stages, it is analogous to what we do it in combination process; like I were to break the entire material to below 40 micron the ro amour, I do not charge the entire material to a grinding mill I first cross it and that crossing is also at different stages and they know you finally, try to do it in a grinding mill. It is also same thing that you first remove some of the materials and then you further improve the quality of your product in stages. These stages are combined in various methods that is again if we compare it with your combination circuit, that it can be of different orientations like your I can have a closed circuit crossing circuit, I can have open circuit crossing circuit, I can have your closed circuit grinding circuit, I can have open circuit grinding circuit, and I can have even your primary grinding, and secondary grinding circuit like your crossing, I can a primary cross secondary tertiary crossing like that, in a floatation also we try to do that.

So, these stages are combined in various methods and are called the floatation circuits. How do I decide about this? To do that first a laboratory test work is carried out, before the built up of a circuit for a specific ore, in order to determine the suitable reagent. What is I say that even for an iron ore you can have many collectors, but which collector I should use.

So, for that first what you have to do that is what is the degree of liberation, what is the liberation behavior of your iron ore? Then you may test the different reagents and different concentrations and you should see that where the response is the best of course, you have to keep in mind the economics also of the process.

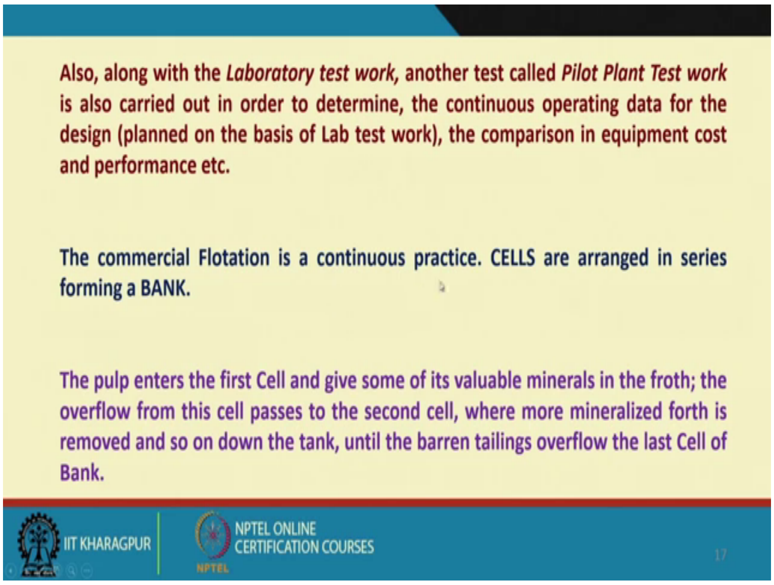
So, first you have to determine the suitable reagent and the size of the plant [vocalized-noise] what should be the tonnages? For given throughput and the flow sheet and peripheral data. So, normally what is advocated, what is suggested? That you first go for your laboratory test, and then you go for a pilot plant test, and then you go for a actual you are so, built up of a circuit.

Now, again the all 3 that triangle if you remember. So, it is not only the chemicals you have to look at also the your ah cell design and you have to that is the machine variable, and also the process variables, like your feed rate concentration, all sorts of things. Along with the laboratory test work, another test called pilot plant test work is also carried out in order to determine the continuous operating data for the design that is planned on the basis of lab test work.

And is in a laboratory test work it is much more controlled condition. Suppose, I have to handle only 500 grams of samples, I do not need any material handling equipment, I do not have to worry about the wear and tear of our machines, but and then you are only looking at the whether my chemical is appropriate or not, but the kinetics of the process and the what is the optimum dose of my reagent? How do I ensure that the mixing of the reagents and the particles are proper? And a little bit larger scale in a continuous operation, for that I have to have a pilot plant test work, the comparison in equipment cost and performance etcetera.

And you use different types of cells maybe different types of your peripheral equipment like your conditioning tank, all these what type of pumps I will require everything you just optimize it in a pilot based on pilot plant test data along with the performance of your flotation process.

(Refer Slide Time: 31:00)



The commercial flotation is a continuous practice. The commercial flotations are always continuous one; cells are arranged in series forming a bank I will show you, that what do I mean by the bank of floatation cells. The pulp enters the first cell and give some of it is valuable mineral minerals in the froth the overflow from the cell passes to the second cell where more mineralized froth is removed and so on down the tank until the barren tailings overflow the last cell of bank; that means, you try to remove your unwanted material in stages, but along with the material what do you try to remove along with that you are also possibly removing some of your wanted materials, because the appropriate selectivity appropriate separation in one stage may not be possible. Because you have to have a compromise between your economics of the process so, the residence time you cannot increase because your capacity will go down.

So, we do it in stages like your your combination we do it progressive breakage. So, that I do not want to generate much more, finer particles than what is required. So, here I do not want to lose my much of the valuable minerals along with the tailings. So, ensure that I have to do it in stages will continue this in next lecture till then.

Thank you very much.