Bulk Material Transport and Handling System
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Lecture - 34
Froth Flotation Techniques, Magnetic Separation

Welcome, we are in the discussion of mineral processing plant equipment particularly for handling the bulk material in a mineral processing plant. We require different type of processing operations out of which this concentrating is one of the major operation that in which we need to separate the gangue material so that in the mineral we are having higher concentrations of the valuables. So, for that; there are various methods and various techniques.

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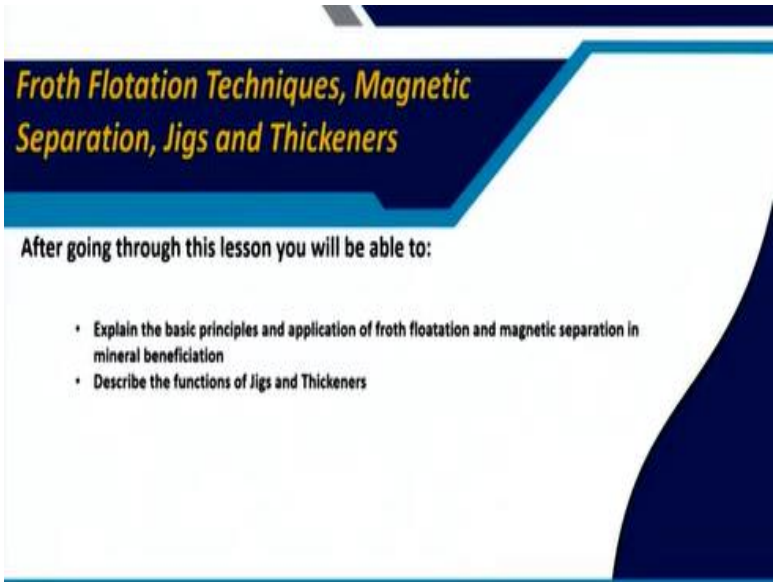

So, we have introduced earlier in our discussions certain nomenclature you have heard about called froth flotation, magnetic separation, jigging, this thickening all these applications are there. So, after this class you will be able to explain the principles and the applications of these processes.

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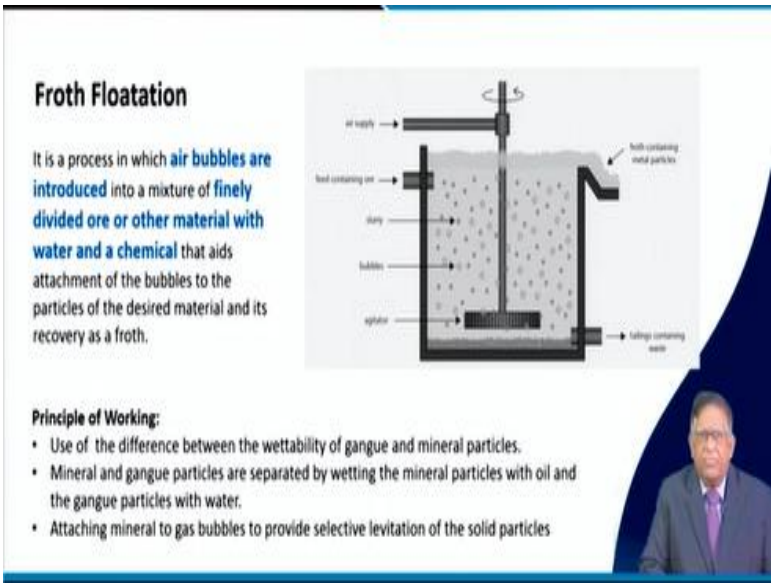

The froth floatation is one of the oldest techniques and it is being used in the processing plants of various types of ore particularly wherever we are having the sulphide ores or even in some of the other minerals also. But there are whether to separate out in the froths. The mineral ore we are separating out the gangue material. So, this process basically it involves that is you introduce air bubbles.

As you can see here there are air bubbles and then the mixture when you put it this mixture over here that when the air going at a high velocity and with a stirrer, we are stirring it out. In that the bubble formation is there and these bubbles there. We give this all this grind material after the ball mill or autogenous mill or the ground minerals that with ore that rock form or rock forming materials all these things together, they are introduced over there.

And then you add some other reagents and oils. So, what happens there? There is a difference in the wettability. That is how these finely divided particles how they get wetted there is a difference. Some particles they are exactly wetted by oil. Some particles are wetted, wetted means moistens. Say for example if your certain particles the sulphides particularly if there is oil it has got more affinity to that it and they get exactly wet by oil.

But some things they do not get wet by oil but they get wet by water. So, these differences of property that is used in separating them out. So, depending on how they get attracted to that oil

and then they get picked up by these bubbles. And then as you know that because of the band shape bubbles have got that inside volume is more. So, that they get come up to the top. So, they in that environment of agitations and air these bubbles they make this foam or the froth.

And that froth you take it out as you can see here, we are having the agitator and then we are getting this air. And there they make this bubbles formation. This feed containing ore in a form of slurry that is when they are coming over here, they make the measured things with that bubble. Now these; your ore particles if surface particles with the oil and all they will get attracted to the bubbles, and they will be collected over here. And then those gangue materials they will be taken out through this as an underflow.

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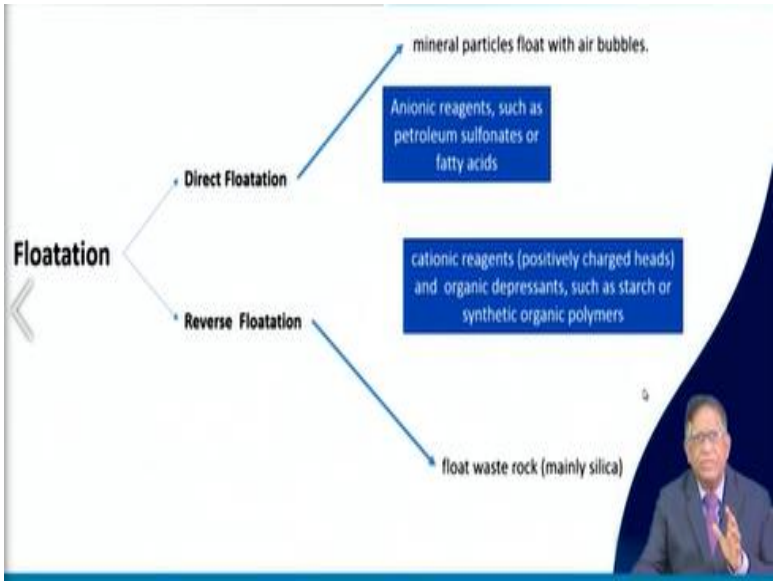

So, this is how but we have this floatation system as 2 type. That is direct flotation or reverse floatation. In the direct flotation your mineral particles they float with the bubbles. So, this is what is happening? Mainly the anionic reagents such as your petroleum sulfonates or fatty acids when they are put it over there, they will attract those things and it will be going. And then normally what happens?

If you are using cationic reagents then these organic depressants such as starch or synthetic organic polymers, they are used with this. And then the waste rock they will be going along with this float and that is called your reverse floatation.

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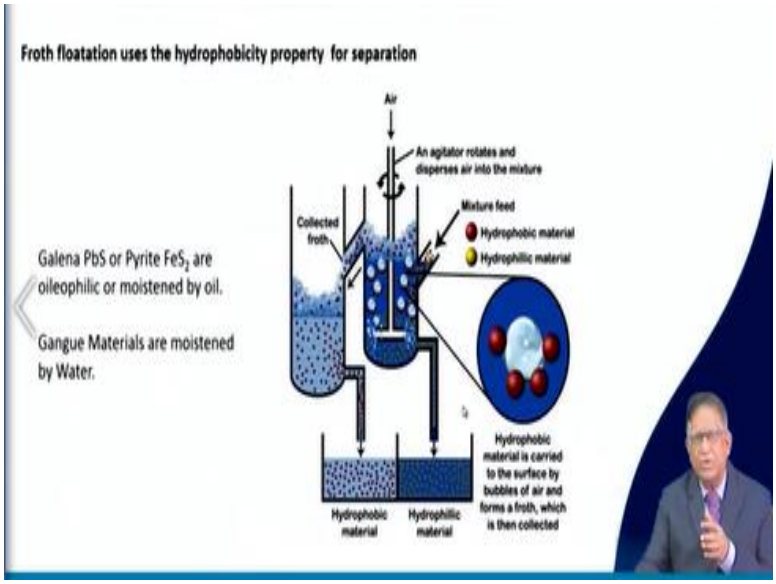

So, in the whole process of froth flotations there are different types of the systems are exactly you can design depending on the plant size depending on where it will have to be accommodated. What is their location with the other processing lines? Then the design will be done in the plant design. But basically, as a component wise how it will be there? You can think of with this diagram that is if we are doing this or mainly for the hydrophobicity or this oileophilicity.

Depending on that, this your lead sulphide or iron sulphide that pyrite or galena they get moistened by oil and that gangue material moistened by water this thing is considered. And that how they put the things in one chamber when the whole mixture of the feed they are coming over there. Both hydrophobic and hydrophilic materials are entering into this and then when the bubble is being formed.

At that time this adjusts on how into the bubble this hydrophobic material they will get attracted. That is your oily substances. They will get attracted over here. And then they will be coming as a froth at the top and they will be taken out. So, like that you have to have. Now this system in the plant how will you make the chamber? Where from it will be coming? What will be the size of those chambers? These are things done in the bulk mineral processing plant design.

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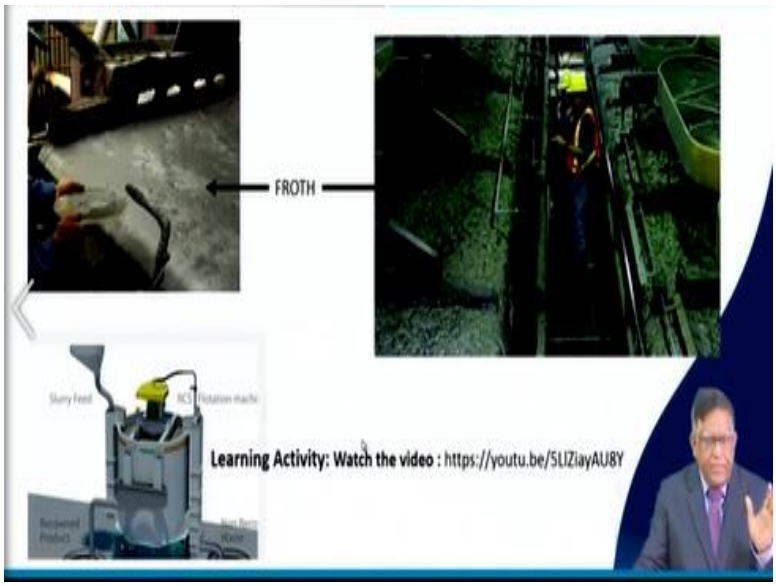

Now you can see that in real life if you see how the froth is coming? That is from there this is flowing over this they collect the froth. Test it whether the things required reagents and all are given properly or not. There could be number of chambers the froth is getting formed. Now the efficiency of the system performance how it is performing? Whether any valuable minerals all are coming into this froth or not. That will be depending on number of operating parameters.

In a plant design the handling people they will be doing mostly the chemical engineers the metallurgists they will be finding out taking the sample test it over there. Then they will be giving that mechanical engineers they will be making the control over the systems over there. The electrical engineers they will be maintaining the control of how the agitators will be rotating? What will be that motor control will be there?

Whether you are doing it a frequency control, voltage control? Or how you are doing that thing which are remotely from one centralized point? Whether both the systems that how the froth is forming? And how the operating parameters are changing? Whether they can be integrated and from the one control panel everything will be operating? Those are the things that even the existing plants they need to continuously keep on studying over there.

If the system deteriorates how, it can be improved? So, that is where this area is important. Then I have given you this link in YouTube. You can see a video to get a better picture of how these things in real life occurs.

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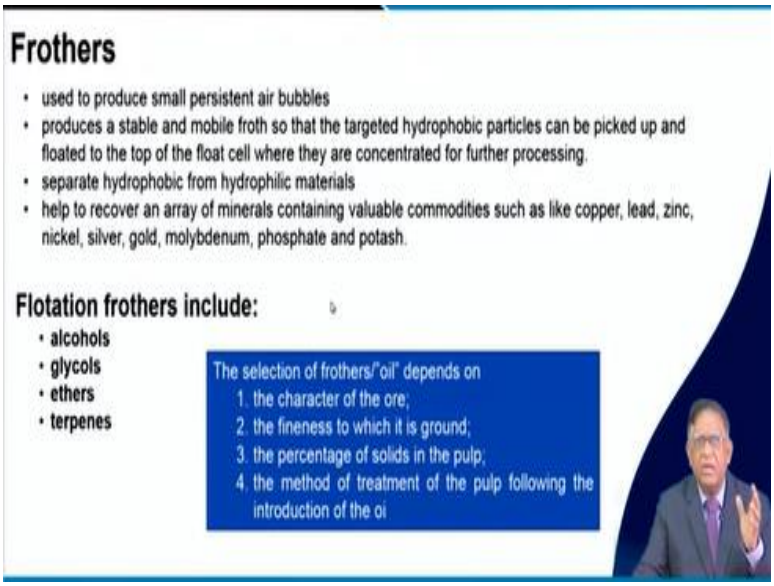

Now what is there in this froth flotation system? Basically, there will be this frothers. Frothers is how the froth will get formed? That means the bubbles will have to get formed and the bubble will have to come up to the surface. And while the bubble come; bubble should not collapse or that should not burst and then there is again the mineral particle should not go to the liquid. There will be certain bubbles always collapsing and then they will be re-picking up and things like that.

So, these frothers they are exactly used to produce small persistent air bubbles. So, that the bubbles do not collapse. And it produces a stable and mobile froth so that the targeted hydrophobic particles can be picked up and they are floated to the top of the things. That is whatever we have said that is the basic principle of taking the mineral out of this. Separating the gangue mineral and that froth will have to be formed and they will have to keep on flowing.

While flowing over there, there will be bubble to bubble interactions will be there. And then all the time new bubbles are coming over there at that time. To maintain that mobility and maintain this without collapsing you will have to add some materials which is always called that is the

frothers. So, that is the frothers help to recover the area of minerals because sometimes what happens the same mineral, they may have different elements.

Each of these elements if it is to be separated that is also can be controlled. That mineral processing engineering does that one. But you know that this basic type of frothers that are used alcohol, glycol, ethers, terpenes like that your organic oils are used. And sometimes you will find that pine oil and all are also used there. The selections of this oil that will depend on that what type of ore you are using.

You need to get only one type of elements will have to be separated or different type of elements are there. And then what is the grinding level? That is what is the size range size distribution? That is whether you are having say 150 micron above or you are having a 50 to 70 micron. And above particles are coming over there or we are having in some very fine even a 0.01 millimetre size. Whatever is coming depending on that you will have to see and select these frothers?

Then what is the percentage of solids are coming in that pulp? That is your slurry when it is coming what is the concentration of it? Because the slurry density it is a matter of all differences are taking place because of the density differences over there. In the pulp what type of it that will exactly have a big say over here. Then how will you treat the pulp or that slurry? And then after introducing the oil how it will behave? Those things separately in a laboratory it is studied.

So, that is why in any this type of handling of material a laboratory study of the properties and the characteristics and their behaviour it is very important.

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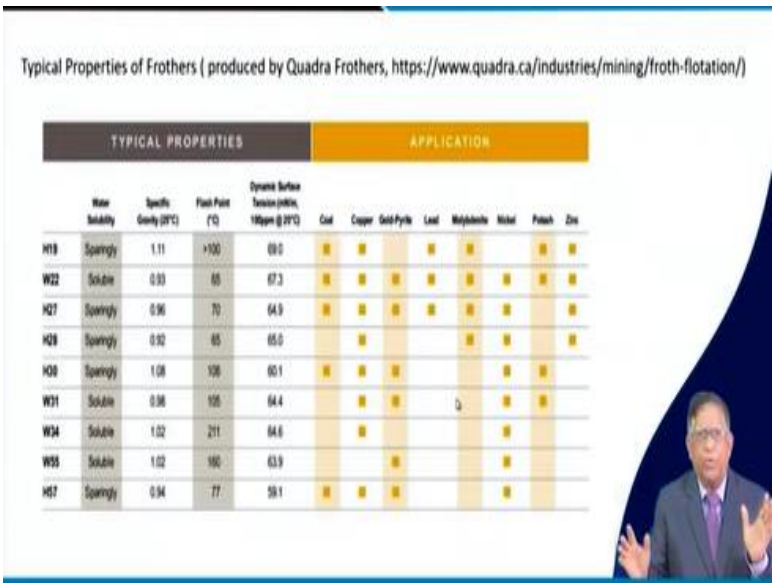

Now there are different type of these frothers have been used. There are many companies they produce and they give it over there. But now some of this where they get used? Particularly in coal, copper, your gold, lead even in molybdenum that is nickel, potash and zinc. This type of elements they will be getting attracted to different type of frothers and the different type of environment which depends on the specific gravity at that particular temperature.

And their flash point also affect that and dynamic surface tensions you know that this is your milli newton per meter they have given the values over here. You know these whole phenomena here are of your surface tensions because the bubble formation that itself is a phenomena of your surface tension. So, these are to be measured in a laboratory and check it over there. As this company is there, they give different companies are there.

Quadra company, they have got different type of frothers in which their water solubility is a property. They see some of them are very water soluble. Some are sparingly soluble and then you can see here the water soluble frothers are used in coal, copper or gold pyrites. That is separation they are using. But the sparingly soluble they can be used in this. So, that is a very basic general selection criteria. But while you are going for a particular case this is for a particular case only.

So, most important thing is how the froth floatation will be done. It will have to be determined by laboratory study.

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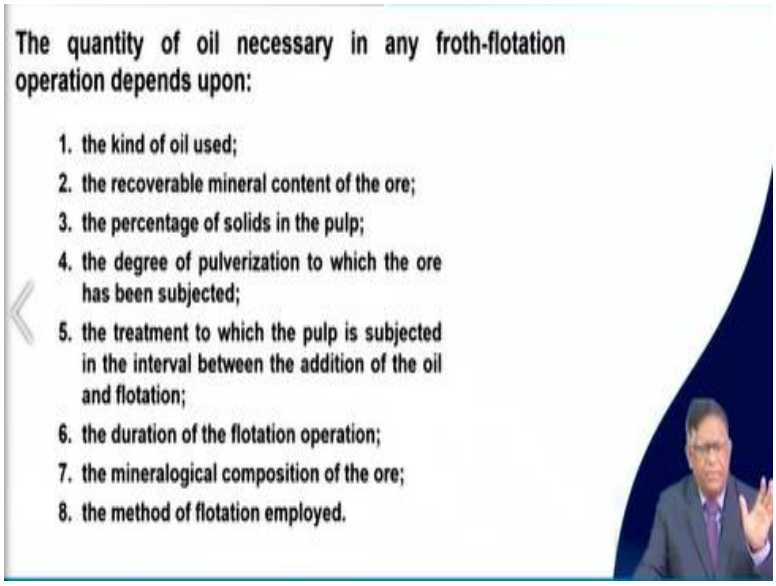

Now the quantity of the oil necessary in any froth flotation operation depends upon number of factors. That is what kind of oil is used? The recoverable mineral contents of the ore then the percentage of the solids in the pulp, the degree of pulverization. I told already the how much the quality of grinding. The treatment to which the; pulp is subjected to in the interval between the addition of the oil and flotation.

During that time whatever the dynamics is going over there that is also very important. The duration of the floatation operation that means how long the material is there. And that is once you have introduced the slurry over there and then oil and all things have introduced in that media how long these bubbles will be staying from it will be going and getting raised. And then toward there this retentions time of the floats at that time this there will be interactions.

New bubbles will be coming. That duration is also very important and mineralogical compositions of the ore then the method of flotation employed. That is whether you are taking in an inclined way or you are just only in a horizontal you are taking it out. All those things are taken care of. That means while you are going to design these things in the real-life situations these factors will have to be taken into consideration.

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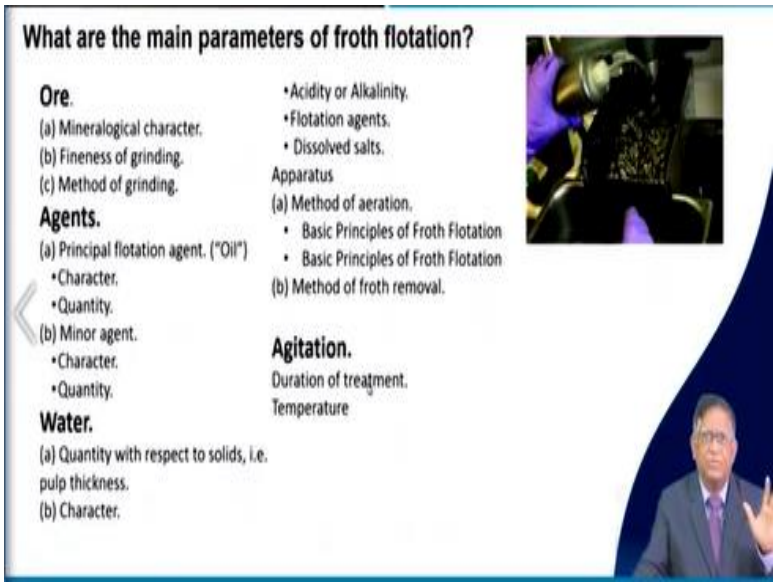

Now the overall that when you are doing this operation of forming the froth and adding oil and things like that you are controlling you need to consider different parameters which are related to the ore. Their mineralogical character, their fineness of grinding, and their method of grinding depending on which method you have made it whether it is autogenous mill only, whether it is a ball mill, whether it is a rod mill they will be giving different characteristics of the material.

Then what type of essence reagents you have used? Then what type of your collectors you have added? Then the water which you are using that water quality whether it is hard water or soft water, whether it has got a higher alkalinity. What is a pH value they also affect this? And also, the apparatus that what for the agitation purposes how you are using? How you have given the stirrer for mixing it? Whether there is all the type rotation or you are giving a pulsating also? All these things will be affecting.

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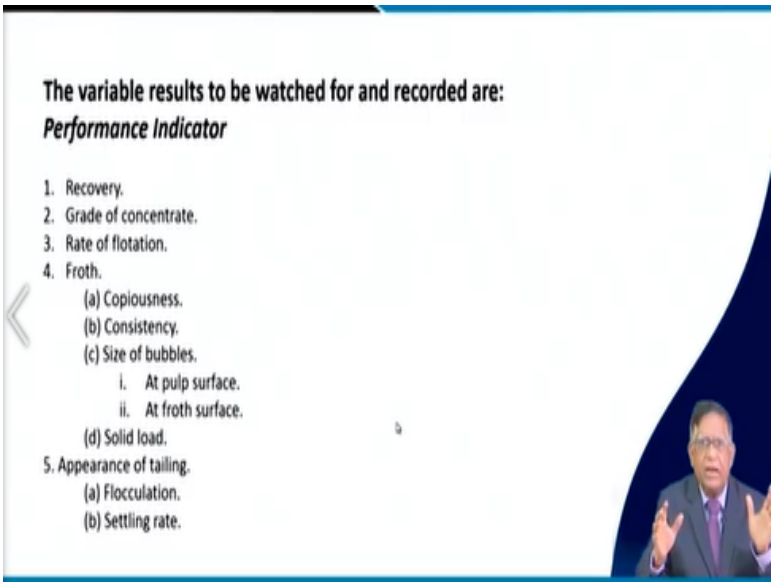

And the whole treatment method will have to be taken care of. Now how will you observe that your things are going ok or not? For that you will have to measure that when you keep observed at how much is the recovery? That means how the percentage differences are coming in your waste and things that recovery is a very important thing. Then the grade of concentrate that is when you are collecting the material over there that after the froth when you are getting that concentrates their grade is determined.

Then the rate of flotation that is at what rate how much quantity is coming per hour? Then this what are there exactly copious this? Their consistency, then the size of the bubbles these are the things and then size of the bubbles when they are at the top or at the froth surface they are coming. And then what is the solid load in the bubbles? That how much exactly it is bringing in the mineral particles? How much it is bringing?

And then this is how there are exactly appearances of the tailings whether the tailings whatever going as a reject there also lot of froth is going or not. So, these are the things observed and that will be telling about the performance whether you are doing it well or not.

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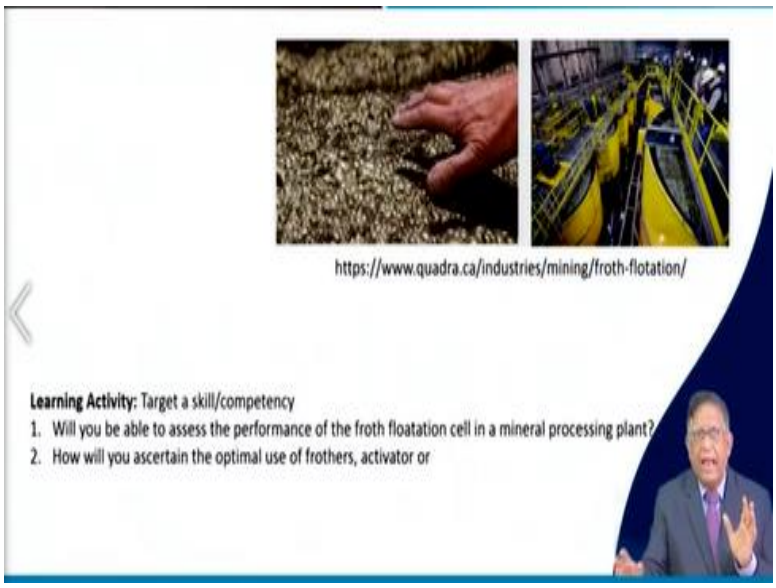

And that is where exactly in a froth floatation as I was telling you that they can be arranged in a number of them. And then there will be in a plant at one particular platform. Then there should be the proper system that they can keep a check and all. And many times, the look of the froth that will be telling whether the experienced persons can know if the froth is coming like that is ok the plant is ok or that when they will find that there are more.

That uniform that is this ruggedness which is coming over here. That is getting different. And this is an area where you can see that if now with the new data acquisition of the images. From the image itself you can do it and you can find out. In the system this such a controlling parameter whether that amount of oil or whether the agitator speed or the concentration of the slurry coming in the flotation cell if there to be varied.

They can be seen from that air even optically you can keep on monitoring. And remotely you can give an indication and you can sense. So, those type of modernization and retrofitting services will be coming in near future we will see it. So, as a learning activity you target a skill and competency what you want to do. Whether you want to exactly that handling in the introduction side you want to do some improvement. In the monitoring side you can do some improvement.

In the control side do you want to develop? Say exactly how digitally this whole system will have to be managed and controlled. What type of data and informations will have to be brought

in? Those things you can first make yourself that what type of skill and competency you want to have. And then ask yourself that whether will you be able to assess the performance of the froth floatation cell in a mineral processing plant.

Then you can start studying and searching and developing your own competency. How will you ascertain the optimal use of frothers, activators or the whole system? So, if you can find out this type of question you ask yourself. Then it will go.

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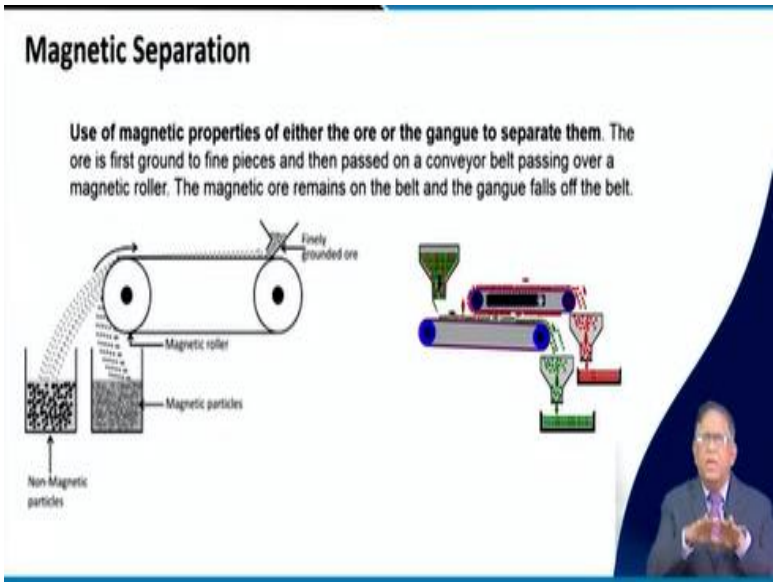

So, then we are switching over to another system which is our magnetic separation. This also I told you earlier that the magnetic separator it is done. We can do it in the wet form or in the dry form when the materials are moving. At that time if your feed material has got the magnetic property magnetic susceptibility magnetic that is say it can be attracted by magnet. Under that conditions you can use this system.

System as such the principle is very simple that in the mixture there are certain minerals which can get attracted to the magnet. So, when they are passing through a conveyor belt this end pulley can be a magnetic pulley. You can make it a magnetic pulley we can do it again. You know in the magnetism you have studied. There are permanent magnet there are they say or temporary magnet.

Nowadays with the ceramic magnets that can be manufactured with a magnetic property. And then when it is there the magnetic particles being attracted over here. They will be going over here in this way. And the non-magnetic particle will throw at a projectile. And these two get separated. So, if it is your magnetite or any magnetic property is there then their concentration is increased your purpose is solved. So, this can be done as schematically.

You can see over here the feed material is coming like this when it is going. Now a cross conveyor is running over here. This conveyor belt has got that magnetic item here. So, when this is a non-magnetic one. The whole thing that magnet inside up to here a main strong magnet is kept. So, that this material gets attracted over here and then they carried on this plate and then they will be discharged over here. So, this type of systems can be there.

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Now basically what you are doing here? You are taking the advantage of the natural magnetic properties. That is naturally certain materials are available with the magnetic property. You take that and then you engineer it for separating it out. Now what you separate you separate out those things which are exactly valuable for you it has got economic value. And then which do not have the economic value that is the gangue material you can take it.

So, particularly in the iron ores like magnetite or that ilmenite these are iron ores. They can be separated from this rock forming materials of the host rock which is considered as a contaminant

and the gangue material from there you can separate it. Now this magnetic separation it is not only in the mineral processing or where you are handling bulk material as ore but in other sector also in the bulk material handling this comes in.

In a biomass where you are having producing these wood pellets or that crushing the woods and then their wood processing units. So, to making these powder boards and things like that there also lot of conveyor belt and that crushed wood pulp and wood powders are removed. There if any iron particles or any mainly these magnetic particles are coming they may go into the next processing they may create problem. So, they are called your tramp metal.

Tramp metal means whenever in your system some foreign magnetic particles metallic particles come in so you are having a magnetic system to separate it out. In bulk handling there are lot of in particularly in ship loading and unloading then many time there may be nut, bolts where many things may get mixed up. And then if they are going with some of the other consumer materials like its handling grains, minerals etcetera.

Sometimes what may happen you may get, an importing wheat in the budge that wheat when it is getting unloaded and a conveyor belt you are taking over there. Now in that if there is some foreign materials like a nut, bolt or any iron component wire etcetera comes in then it becomes very difficult. So, that can be separated from there. Then pulp and paper in the paper industry also these things if that metal particles go over there.

It will be destroying the quality of it in the wood processing and mining we can use this magnetic separator also in the well main in the mines that when the conveyor belt is carrying the material and then putting into the crushing plant. Before putting in the crushing plant all the tramp material must be removed or again, we are using in the mineral processing plant when it is ground. At that time if the magnetic particles as I was telling it is a concentrating purpose is also used.

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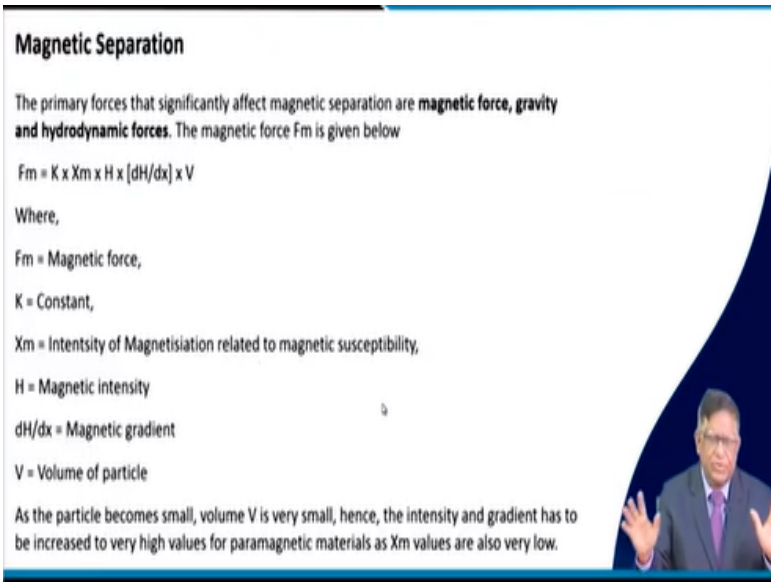

Now what is the basic principle of that magnetic separation? That is the magnetic force that is how the gravity force and the hydrodynamic force all these forces they need to be analysed for seeing that how much exactly the magnetic force will be required to separate that out. Basically, this is one of the very common equations you will find where this magnetic force this is exactly related to it K here is a constant and then this is your intensity of magnetizations.

That is related to the magnetic susceptibility and we have got the magnetic intensity H here. And then the gradient that is your magnetic gradient and then this is your volume of particles. Now if we are very finely dividing the particles then what will happen? The volume will increase. And at that time, we will be requiring then more magnetic force. Then that magnetic force will have to come from again creation of that magnetic flux. So, this is very important there.

That means how will be the magnetic force? How much will be there to take if your tramp material that whether the tramp metal which is going over there they will be attracted or not. If the gravity force of the tramp material is more than this magnetic force then the material will not get attracted. So, wherever you see over there then by seeing that what type of metals are being attracted and kept over there.

And then after what time if there are a lot of material have already come. Then when you will have to remove that and then put it fresh again, these are the things decided on the basis of calculation of the magnetic force.

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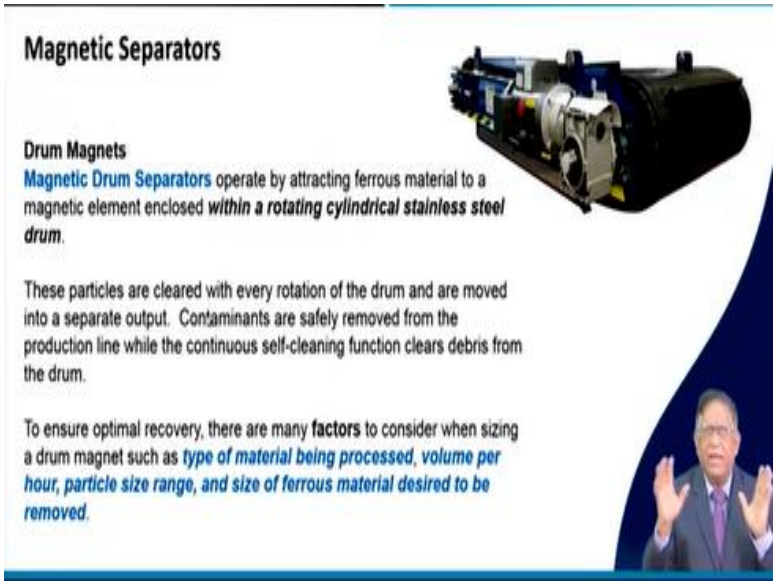

And then there are different companies they manufacture this type of devices. Now as a magnetic separator there we say is a drum magnet exactly this drum or that your end pulley that will be considered that will be made a magnetic thing. So, that is then we are telling it as a magnetic drum separator. They are attracting the ferrous material to a magnet element enclosed within a rotating cylindrical stainless steel drum. So, there inside they keep it.

And that will be coming as a magnet and they will attract the magnetic particles. These particles are cleared with every rotation of the drum and are moved to a separate output. There exactly the main material when it is coming where it is discharged the magnetic one is separated. And they give it to another discharge panel. Then so how to get that your optimal recovery? The best recovery you can get that it will be depending on number of factors.

Those basically the type of material being processed. That is in that what type of magnetic particles are there? Then how much volume per hour it is carrying? And then what is the particle size? As I said if your particle size is less volume may be more. And then the size of ferrous

material desired to be removed. Then if we know these things then you can decide that what should be the power of the driving motor? What should be the size of the drum?

And then what will be the weight of the whole things? Whether you will be suspending it over there or you will be having a separate structure? Those things will be decided. Basically, you will have to know the basic principles. And then those components how they are to be designed for your particular system? That is important.

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Now, there are different types of drum magnets. There are different companies you can see the websites of the manufacturer to find out over here. That drum magnet may be your enclosed type of drum magnet. There are structural drum separators and then there are standalone drum separator and wet drum separators. Out of these your enclosed drum separator that is your enclosed magnetic drum.

There for the vertical gravity fit should applications in dry free flowing material they use it. And then structural drum separators they are exactly used as a tramp metal removal. If your conveyor belt is going over there then you can keep a drum that is your magnetic plates with structures. You can keep it over there as a suspended and it will be working. That is structurally drum separators.

Then standalone magnetic drum separators can be very high intensity rare earth and ceramic magnetic cores. These rare earth magnets which are manufactured as a permanent magnet you can see that this is your another very important thing. That type of magnet they do not lose their magnetic property. And then they can give a long life and so once you install there all the time they will be working.

But when you use that type of permanent magnet then the whole system how will you separate it out either by scrapping or by things will have to be done. If you use an electromagnetic magnet that is your temporary electromagnet then what happens it is a matter of just if you put it outside the conveyor belt to switch off that this electromagnetism drum material get dropped. So, their differences are there.

But those type of units can be as a structural unit or it can be as a standalone unit. But the most interesting for the mineral engineer in the mining industry you will have these wet drum separators. There is a different method also. That is your high intensity magnetic separator WHIMS with wet separators are used in iron ore beneficiations in our country also it is used. Then advantages of these drum magnets when they use it.

They can be used as a self-cleaning, available in different sizes, accommodate very high volume and easy to operate and that is electromagnetic things over there.

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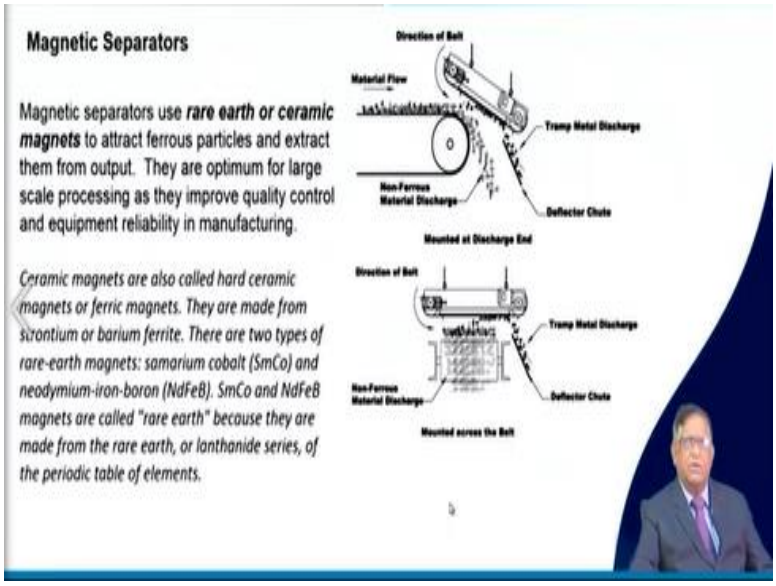

So, now coming you have already you know about it. Earlier also we introduced, these magnetic separators what exactly they are? In the drawing you can see this that is you are having the main separator over here. And then you can see then an inclined way you kept it and then the whole material when it is coming over here before the charge they get attracted to this magnet. And then they have got a deflection chute. Through this chute this material is taken.

And you can collect the conveyor or a hopper or bin wherever you want to take this material can be taken it out. So, this may be your ore coming over here. These are the tramp metal may be these are not required for you that those may be iron plate, some small nut, bolts, wires these may get attracted over. You take it out now you are getting better cleaner things to feed into the crushing plant.

Now this sometimes instead of incline it can be a horizontal that means across the conveyor belt you are putting it over there. So, this material is taken around. It is just only your convenience space location and the design which is again a science and art that in which way you consider that how will be the interior? How it will look like? How aesthetic the place will be there? That designer will have to look into those things in the bulk material handling.

Now the rarer ceramic magnets as I was telling it that is they are very optimum for large scale processing they are used. And that you may know that ceramic magnets are also called that is

your ferric magnet or hard ceramic magnet. They are made from strontium or barium ferrite. And there are two types of rare earth magnets one is samarium cobalt and another is neodymium-iron-boron cobalt.

That samarium cobalt and this neodymium-iron-boron these are rare earth mineral. And because of that they are manufactured sometimes we say it is a synthetic magnet also. But they are very useful you can keep their property you can control by while manufacturing you can design it. And then you can keep it they will not get damaged easily and they can give a long life.

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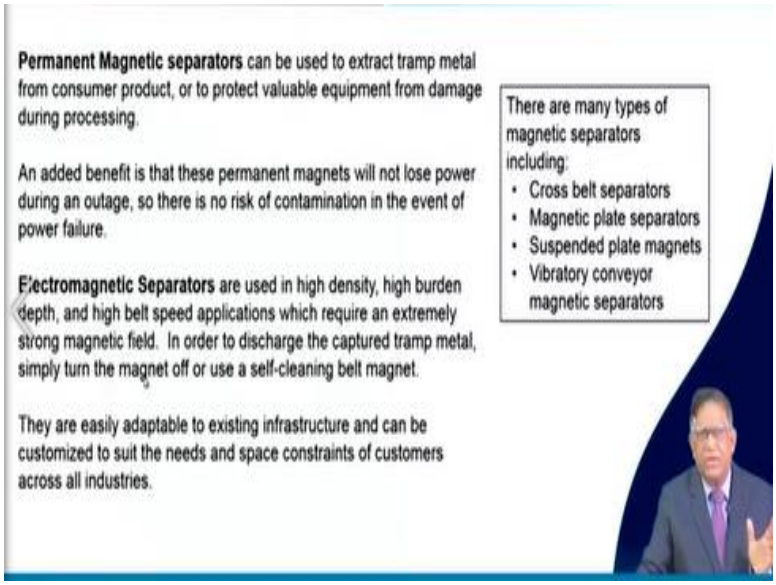

That is what is the permanent magnet. Now in a permanent magnet separator can be used to extract this tramp metal from consumer product or to protect valuable equipment from damaged during processing. Now there are different benefits because that if you are using a permanent magnet, you do not use the electricity for operation. So, that means there could be energy saving. And then this electromagnetic one there because of the convenience as I already said the convenience and their utilizations it is also good.

And then the whole thing is under your control. If it is damaged also, you can remove certain part, change it and then again reinstall you can do it. So, these are the pros and cons are of all you should study a little bit to find out what are they? Then there are many types of magnetic

separators. These many types means how they have designed for a particular situation to do. Basic principle is same basic things are there. Now it is how you are engineering it.

They are used as a cross belt. They are using as a magnetic plate. There is a suspended plate. They can be having a vibratory conveyor magnetic separator. You can keep a vibrating also you can do it depending on the situation. Sometimes in that container you are keeping then making the material to flow through that giving a vibration so that the particles which are going there if there is something inside that is not coming within the magnetic range that can be also attracted. That arrangement can be done depending on the situation.

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Here there are lot of such type of photographs and figures you can see in the net that is where a conveyor belt is going. On that there could be some magnetic particles coming over there. Across the belt we are suspending one electromagnet. Then what is there? In that electromagnetic disk plate which is rotating over here. Any scrap material is going on this they get attracted and this belt they will be driven.

And then the magnetic particle will be discharged by the side. And that is here how a magnetic head pulley is given as I was telling in a conveyor belt for separating the particles away.

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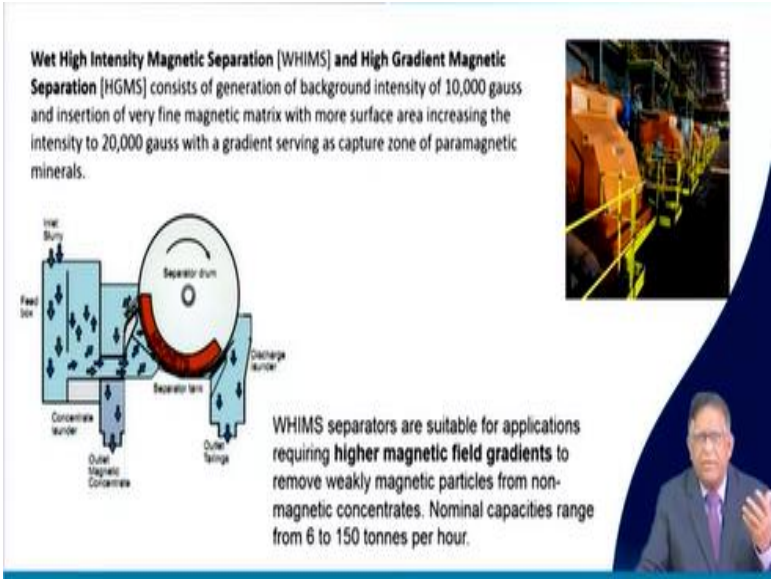

Now this wet high intensity magnetic separation that WHIMS or that the high gradient magnetic separation called HGMS. These two are the techniques which are as an advanced technique they have been used in many sulphide ore beneficiation. Now you can see here that is the intensity of about 10,000 gauss of that is your magnetic intensity you will have to create. That is one gauss is 10 to the power minus 4 tesla.

That much intensity if you had to get over there then you will have to get a system design and then place in a way very carefully. And that is why you can have number of different separators in the line putting over there and they do it. Now there is also as the wet means what? Exactly in a slurry form the feed is coming over here. And then they are just getting attracted to those magnetic particles will be getting attracted to the drum and they will be discharged over here.

And the other one which is nonmagnetic will be coming as again in the slurry form it will go out. So, that is where you will be having the launder where your concentrate will be going. And then this your discharges that two slurry discharges separating in out where the concentrates are there where this non-concentrates. So, the whim separators are suitable for applications requiring higher magnetic field gradients. And also, it can remove weak magnetic particles.

Even if you use this, that the other systems which we discussed earlier they may not be able to take out. If the particle have got a very weak magnetic properties but by WHIMS even very

weaker something normally we may not get attracted to the magnet easily. Because they are having a very fabulous that is your magnetic attractions, they can also be done by it. That is what exactly the use of this.

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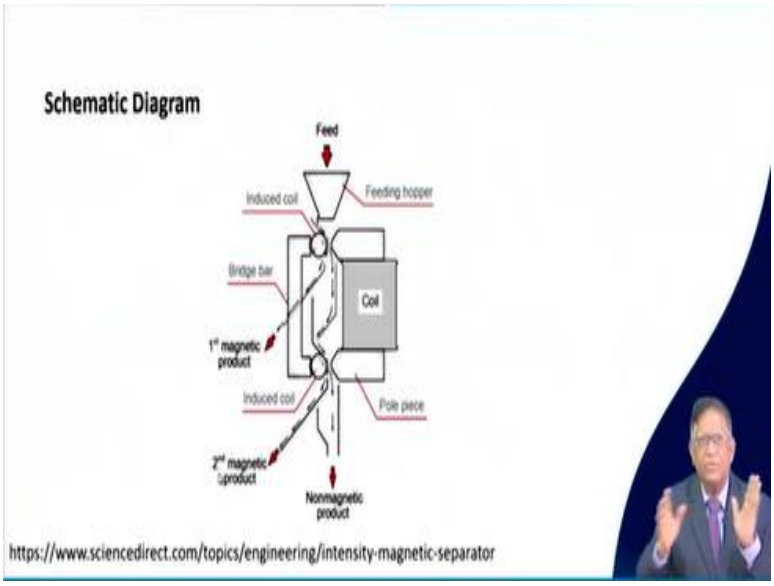

So, how that schematically if you see that in a WHIMS or in any of these magnetic separations your feed is coming over here and there is your induced coil your generating a magnetic flux over here. When it is going the magnetic particles which have got strong magnetic property, they will be getting attracted to this and through this chute they will be coming out. They have got the first magnetic product. Now then the material will be going through another.

That is where you can use a 20,000 gauss like that type of magnetic intensity can be generated over here. And under that high magnetic intensity this will when it will flow, they will get again attracted by these magnets and then they will be discharged over there. And then whatever the nonmagnetic particles they will be going on flowing over there and that is so. In this wet system that by the magnetic they get separated out, so, these are the things you need to know about it.