Introduction to Mineral Processing
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Lecture – 49
Gravity Concentration (Contd.)

Hello, welcome. So, we are discussing in the last class the gravity concentration and in general and we had started discussing about the sluices.

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So, this was the earlier designs of the sluices, this is relatively your improved design what it is being tried that is suppose gold; gold when you have a free gold and so, they are in ppm level that is ppm level means it may be around 2 ppm or 3 ppm and if they are fine free gold so; that means, a 1 ton of material that is in 1000 kg of material, you are having on an average of 2 to 3 grams of gold.

So, in that case what we can do that is if we have a channel like this and if you have some kind of your gaps that is in between that is you call it the capturing riffles. So, what will happen? The gold particles will be captured and they are very high settling velocity particles because their density is 19000 kg per meter cube. And most of the your unwanted materials they are mostly silicates and all this they are around 2650 kg per meter cube.

And if I have a high velocity of your flowing water; so, these gold particles get captured here and you are just taking out the gold and it can be a batch process also. And you may have a concentrated form of these gold particles here and after you remove it from them you can take out your free gold particles. So, this is one of the techniques, but nowadays you hardly get free fine free golds though.

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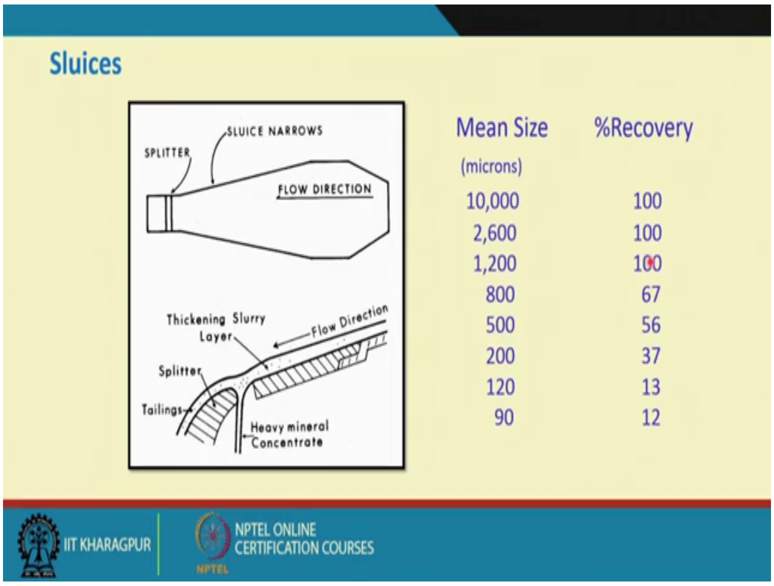

Now so, this is another way of representing that that is what I was trying to say that this is the flow direction and for a flowing film concentrator, you have got a film thickness.

So, if I have as your splitter at is imagine it is splitter. So, I will have the overflow that is the tailings that is your lighter particles and these are your heavy mineral concentrate; the most of the cases relatively heavier fraction is my wanted material. So, you can have a separation of the concentrate and tailing; this is another design that is your flow is going towards this and you have a pinch that is you are trying to increase the flow depth at the towards the end, towards the discharge; why now here you have got a very thin film thickness.

And now here you want to have a your much of a pull of that water of that fluid. So, what will happen? The you can have much more your segregation or maybe your split and positioning will be easier because here you may have a film thickness of around 2 millimeter, but within that 2 millimeter it is very difficult to have a splitter at a position of say 0.5 millimeter, but if that 2 millimeter if I increase to a your say your depth of 20 millimeter; I can easily have a splitter.

So, there is also another modification to this design; now this one is telling that by applying this principle, these are all textbook things that what is the mean size and what is the recovery percentage? You see that as the particle become finer and finer; this way of separating particles becomes the recovery wave gets your deteriorated faster. If your mean size is 10000 microns; the recovery could be 100 percent; that means, it is possible if you design it properly if you monitor the flow conditions accurately; up to 1200 microns the recovery is 100 percent.

Now, if it size becomes 800 micron; it becomes 67 like that when it become 90 micron meter it will be like your 12 percent recovery. So, that it is not applicable for very fine separation and very fine size ranges, but there are say if we can control it properly that feed flow rate and your film thickness and then other the splitter positioning appropriately, then probably we can achieve this for relatively coarser size ranges of particles.

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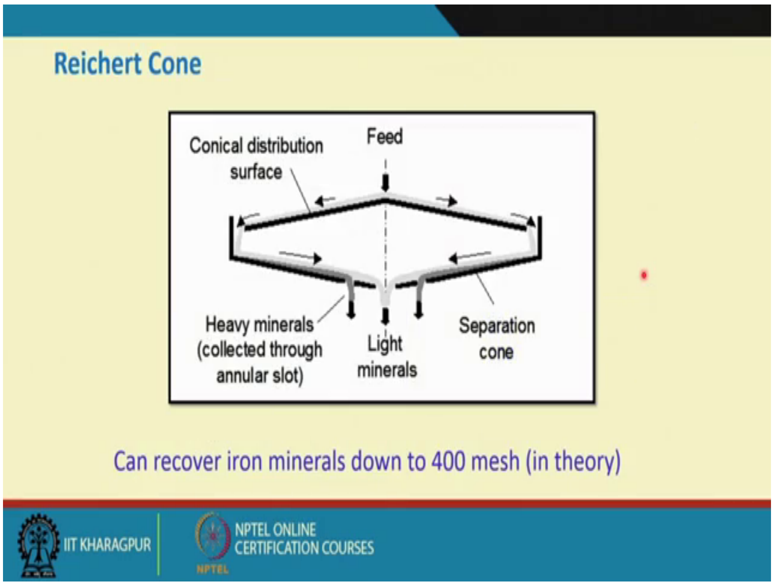

There is another version of this that is relatively modern design; improved design I would say of these flowing film concentrator; this word this is known as Reichert cone. So, here what we try to do we try to increase the capacity because you have seen that there the unit capacity may be less and what you try to do? You try to do it in stages like you have a feed here and you have got these surfaces and you want to spread that feed into these two surfaces and because of the gradient here the feed in the form of slurry they will start traveling. And when they start traveling, you will have a film your form and within that film there will be a separation with that similar principle.

So, what will happen at the bottom you will have more of these concentrations of relatively heavier material and on the top you have the lighter materials? So, when your lightest stream when it is collected here we are collecting light minerals and the bottom most one is the heavy minerals. So, that is basically it can work up to 400 mesh in theory you have to convert it into micrometers.

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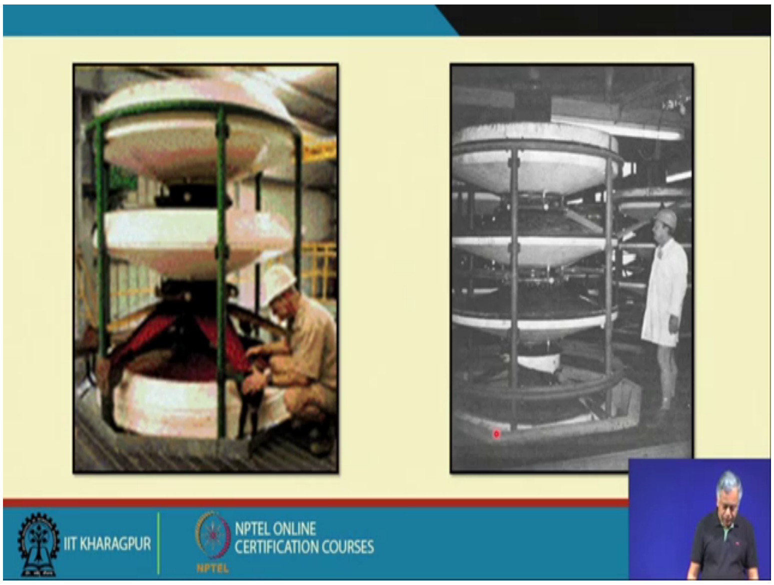

These are some of the; your designs of your many film concentrators it is our sense of your modified Reichert cones or maybe the Reichert cones itself also.

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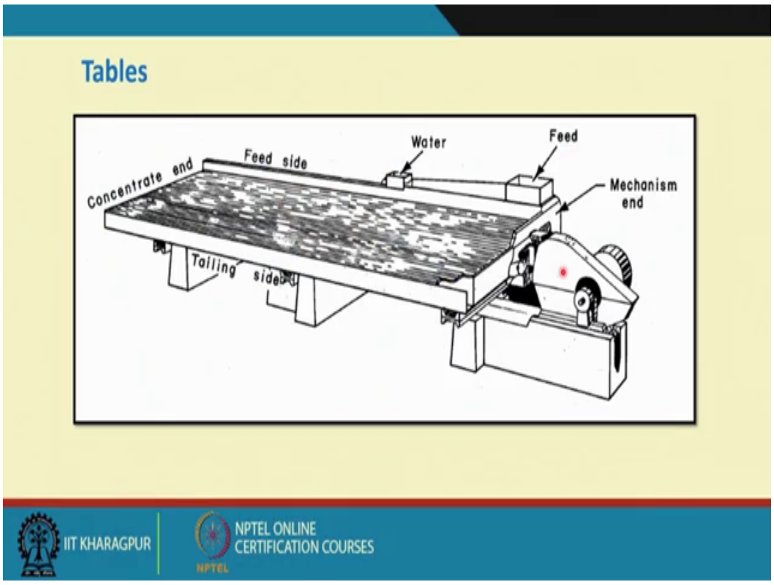

Another your this is another piece of equipment which is fundamentally working based on that flowing film principle, but on top of that we are adding some other forces, some other mechanism to your improve the separation performances. These are known as tables; this is tables now what you do that is here you have got a feed and this is a slightly inclined.

So, this is inclined like this and the deck we call it deck that deck is also inclined. So, the feed in the form of slurry that is your heavy and light particle mixture with water, you are feeding it here. And then you have got the riffles here these are the artificially made riffles, these riffles could be made of wood or it may be by some other materials also earlier deck is used to be made by wood.

So, now, the when the feed is entered here and because of that and then you your shake the machine shake the entire table a bit like this. And because of that what happens? The material your slurry starts flowing in this direction. So, what will happen and you keep on you add some water also. So, that you maintain some kind of your consistency in the flow rate and the thickness of the flow.

So, what will happen? Your heavier particles will be captured in between the riffles and your lighter particles will just slide because just imagine that if I have a table; it is just like your this screen like this; it is tilted and suppose this is slightly angled like this inclined then what will happen your material is fed from here.

So, the fluid will try to flow like this; now when the fluid is flowing like that you have a film. Now within that film that your heavier material are getting captured because they are at the bottom most layer and you are not allowing them to travel faster. So, what will happen? This material are basically captured here and the top layer that is your lighter relatively finer lighter materials; they are carried by the water because and then they are that is called the tailing side.

So, that is you are having your lighter material here. So, now, once the heavier material are captured here you are adding more water here gently. So, that how much of water you will be adding because if it is too high; then again this captured material may be in suspension. So, you lose this material and this material you are allowing them to travel through this and you are collecting it through that that is called the concentrate end.

So, here the trick is mainly what should be the your height of each riffle and what should be the distance between each refill because when the fluid is moving traveling through this because of the hindrance offered by the refills, the flow may become turbulent. So, it may try to lift the particles which are already captured in between your refills they may be again say reporting through the tailings that is your finer material. So, these are the basically the operating and design variables and what should be the length of this what should be the gradient and what should be the angle of tilt all these are basically the variables.

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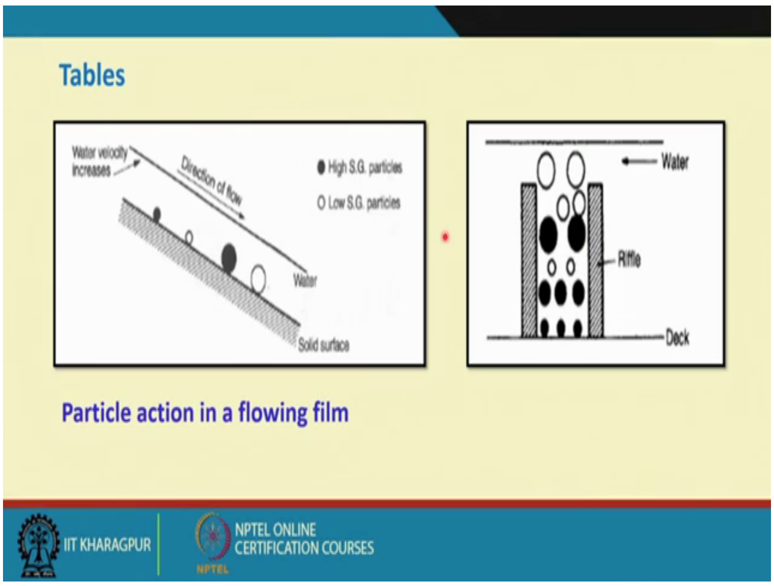

So, this is the tables in a particle action in a flowing film that is your I have already discussed about it that how it will work, but this is only explanation almost for some a few particles it is not that simple. When you are dealing with millions of particles it becomes little bit complicated, but that much of information is enough to understand whatever I have explained that how it works.

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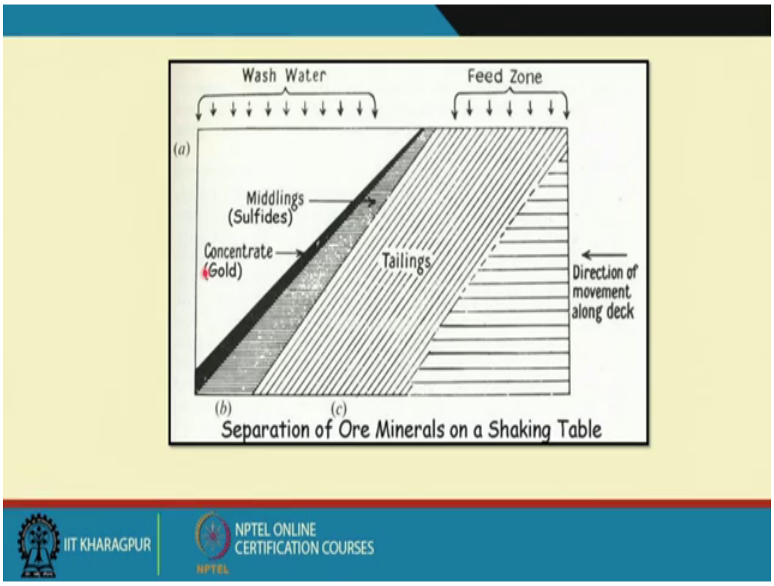

This is basically in detail of the how that table works and what is the wash water and feed zone direction of movement that is I said your deck also moves like this.

So, what is the direction of movement? Why you want the movement of the deck now because I want the fluid to travel like this in this direction. So, so that my lighter particles they are basically reporting through this end they do not get diverted to my concentrated end concentrated.

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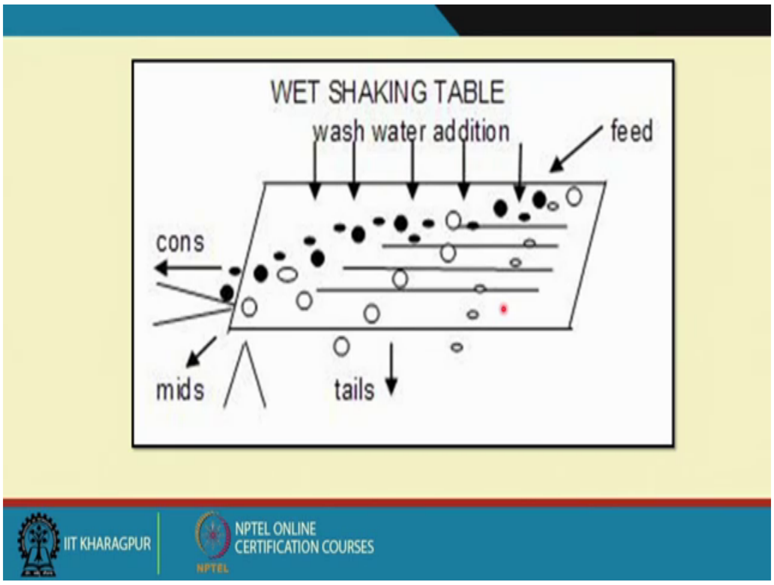

Now, there are also the weights checking tables, there are different varieties of tables now and they were they used to be very popular in gold industry, in tea processing industry; why the differences in the densities between the heavies and the lights were very high.

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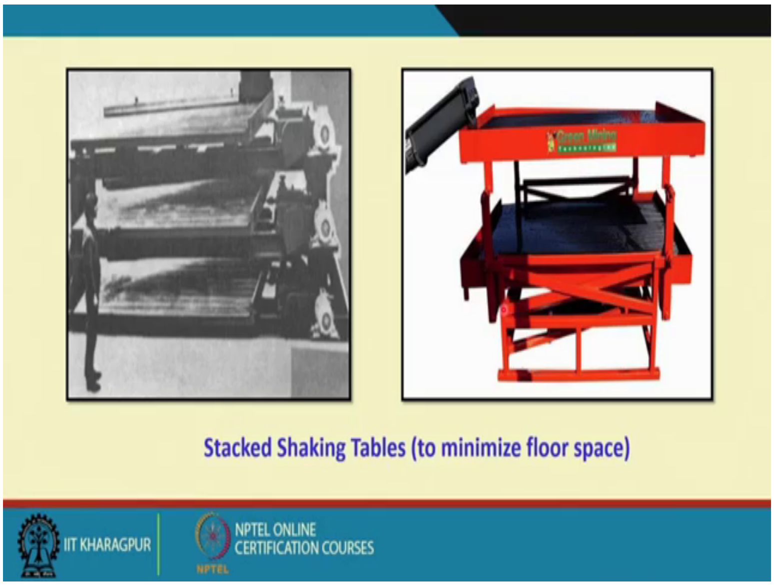

So, these are again the stacked shaking table like you can have multiple tables; like you can have this, your lighter materials what is coming here. If you are not very sure that they are free from any gold particles or any of your heavier particles. So, you put it into another table and you try to do it and when you are very sure that you are not losing much of your valuable mineral. Then you are saying that that is my reject and this is another your relatively modern version of these your second tables. And sometimes they are being stacked like this to minimize the floor space occupied for a given capacity.

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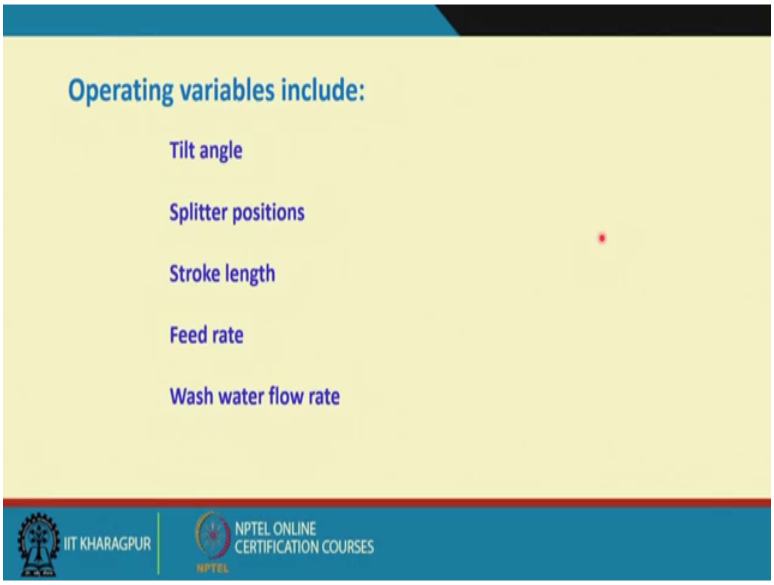

So, what are the operating variables for this tabling where the tilt angle it is the splitted positions that is where from you will split it the stroke length it is feet rate and wash water flow rate, but this is not that popular these days in mineral processing industries; we have got many more modern equipment than this. So, what we have learned about the flowing film concentrators. Now what I say that there are some modern equipment based on that flowing film principle it is one of them is spiral concentrator which is becoming very popular these days in across many mineral processing industries.

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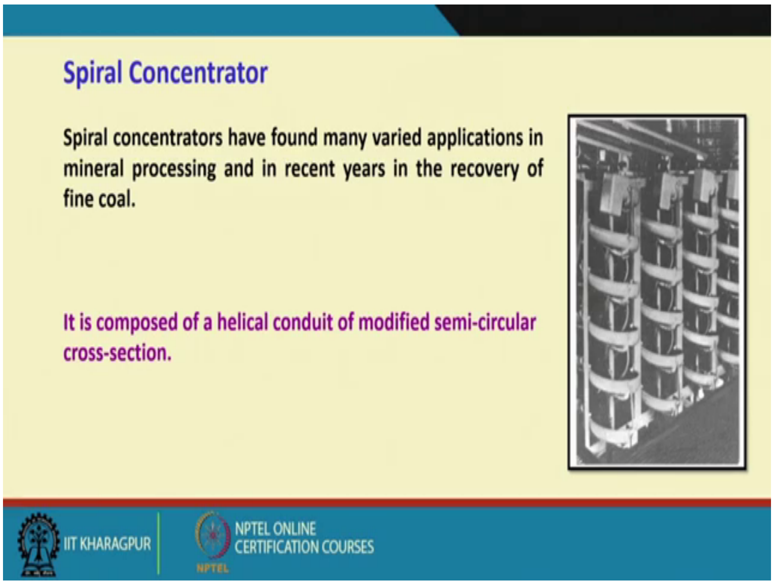

Because of many advantages associated with it is called a spiral concentrator, as a spiral concentrator have found many varied applications in mineral processing. And in recent years in the recovery of fine coal even it is composed of a helical conduit of modified semi circular cross sections like this. So, what we are trying to do we are trying to use the height so, that I can use the gravitational force field as well as the it is having a helical conduit I just try to show you in the next slide.

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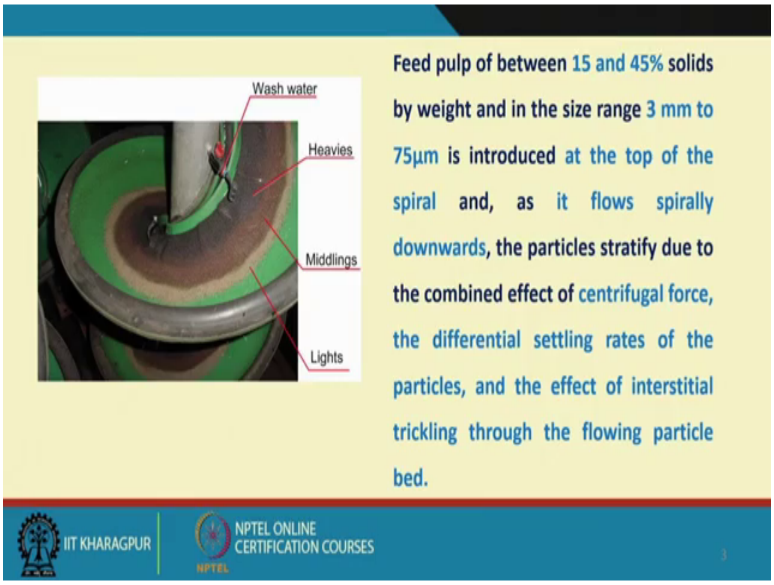

That, what is happening that you are we are feeding the material that is in the form of slurry and up from the top and then you have got a helical conduit like this.

So, the fluid is traversing like this; so, that fluid is now a slurry mixture of your water plus your heavies and light particles they are traversing like this. And there you have got a gradient also here what is being shown here that you have got a gradient in this direction and because of that now it is more clearer.

So, what will happen? When the slurry is coming from top and it is going like this it is a spiraling. So, the particles are also experiencing to some extent some scientific force because now it is in rotating motion it is like this. So, what will happen? The heavier particles will be relatively heavier particles. So, you are having a thin film of fluid and the particles are also experiencing a bit of centrifugal force.

So, because of these two that is because of gravitational phenomena force field and which is replaced by some kind of your centrifugal force field, and because of the relative motion of the fluid at each layer of the fluid across the your say y axis. So, the heavies will be settled towards this region and the lighter particles will be much more concentrated towards the upper flow; because they are being transported through the top layer of the film. And in between if you have in between some particles which are having in between density, they will be concentrated here.

So, it is a your say phenomena what do you observe if we take a bitch place terminal like where you have got different density particles that is the very fast picture I have shown you of one of the your say when I gave this example of how nature is doing the gravity concentration. So, that is the material if I put it into a spiral; so, the lighter particles that is your sand particle will be concentrated in this region your the heavies particle that is the ilmenite, that is this particle will be concentrated here in between density particles will be concentrated here.

So, that is how you have a separation and then you are having different turns like this. So, it keep on doing this and you have a splitter at the end of this that is and that splitter is basically helping you to separate the heavies lights and your middlings. Normally what are the conditions for this flow conditions now feed pulp of between 15 and 45 percent solids by weight it is not by volume.

So, feed pulp of between 15 and 45 percent solids by weight and in the size range 3 millimeter to 75 micrometer; it depends on what density range you are playing with he is introduced at the top of the spiral. And as it flows spirally downwards the particle stratified due to the combined effect of centrifugal force; the differential setting rates of the particles and the effect of interstitial trickling through the flowing particle bed what is this interstitial trickling.

Now, when I have a coarser particle bed form; so, there will be some void spaces in between these coarser particles. So, these void spaces will be occupied by relatively finer and heavier particles and that is the meaning of this your interstitial technique.

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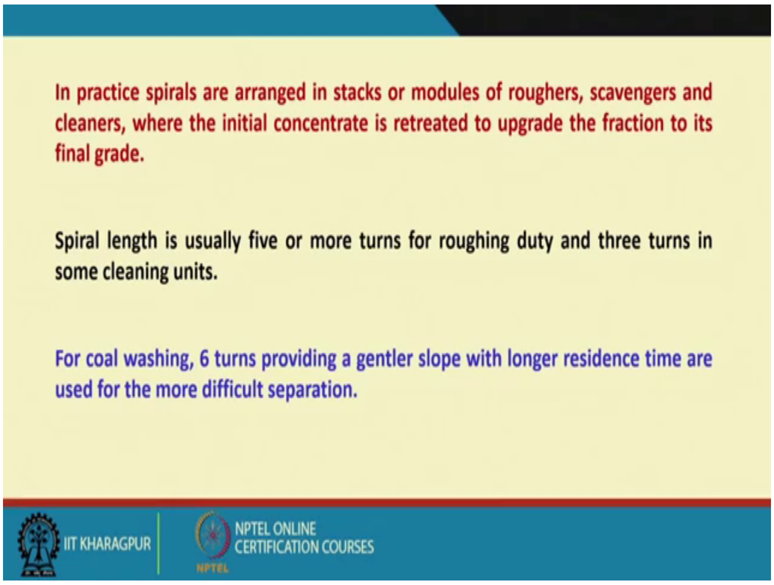

In practice the spiders are arranged in stacks or modules of roughers, scavengers and cleaners; what is the roughers why do keep it in stacks now. The spirals are normally designed like we have a maybe your say why stacks now I need; much more residence time of the particles to decide that whether I will be in the concentrate zone or the tailing zone. And many times what happens that you may lose some of your heavier particles in the tailing stream. Or maybe sometimes your heavier particle stream they are not that concentrated of my desired quality.

So, what we do? We have got stacks of spirals suppose you have got five turns spiral here. So, we generally depict the your say use the terminology of the how many turns you have. So, suppose you have got five turns spiral; so, that is not enough to give you the right kind of product. So, what we do? Depending on where I will have more of misplace materials; I divert that into here another set of spirals. And we keep on doing it may be your say your stack of three spirals like that and then we try to do it.

So, it is decided based on that how much of that valuable material is there and how much of purity we want my spiral separated to give me a concentrate. Many times these are stacked because we want to do the separation in stages like what do you do in other cases like your screening that is we do it in stages; we have got a your primary crusher then secondary crusher then tertiary crusher; here we name them as roughers; that means, the whatever the easily separable mineral that we try to separate it in the first core. Next one we try to further clean it and then in the cleaner section we try to clean it further and further.

So, where the initial concentrate is retreated to upgrade the fraction to its final grade; that is first I try to recover most of the heavier mineral into my concentrate stream, but when I try to do it when I try to increase the recovery; that means, the grade will be deteriorated; that means, some coarse light particle may also be reported through the my in my concentrate stream. Then next stage I try to remove some of them and the final stage I try to remove most of them.

So, that I get a finer cleaner concentrate; spiral length is usually five or more turns for roughing duty and three turns in some cleaning units. Because more the turns more the residence time; so, lesser the capacity, but you need volume of this spiral we are having. So, we give more residence time in residence you are roughing duty and for some cleaning stages we give more lesser this time, but it is not a fixed rule it depends on what is your material and what is that you want your spiral to do?.

For coal washing, normally 6 turns providing a gentle slope with longer residence time are used for the more difficult separation. For coal, the density difference between your coal and shell particle is much less that is why you need more residence time. But, so it is dictated by the concentration criteria and the differences in the particle sizes; that means, what is their settling velocity differences.

If the settling velocity differences is much higher; we need lesser turn that in we need less at residence time if the settling velocity difference is less then we need more residence time to separate it based on this principle.

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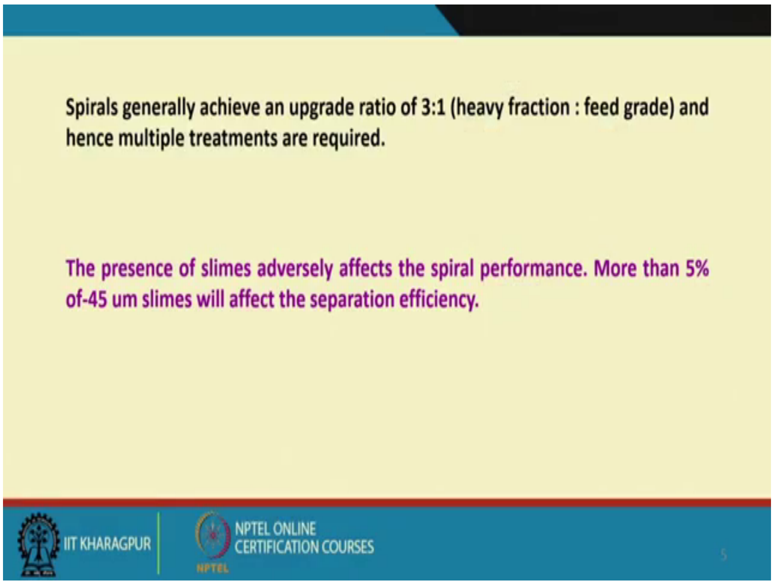

Spirals generally achieve an upgrade ratio of 3 is to 1 that is heavy fraction is a feed grade that is your ratio of up gradation is 3 is to 1 and hence multiple treatments are required; that means, in one go in a set of spiral that is you can have a upgrading ratio of 3 like it is analogous to again; that is what is your reduction ratio that is the instead of in place of crusher.

So, I want my material to be upgraded 25 times then in each stage I will have an upgraded ratio of 3. So, I may need 8 your 8 sets of spirals whether that is economically viable logistically possible that is a different thing a theoretically we need more than 8. The presence of slimes adversely affects the spiral performance slimes in general in a new water based processes; it will have adverse effect that is slimes means ultrafine particles. Because as I had repeatedly said that slimes will increase the viscosity of your fluid in general. And your recyclable water recycling of water also becomes very difficult because it is very difficult to get rid of these very fine particles.

So, more than 5 percent of minus 45 microns slimes will affect the separation efficiency; that means, if I have more than 5 percent of below 45 micrometer particles; in generally it has been observed that the separation efficiency gets affected in a spiral.

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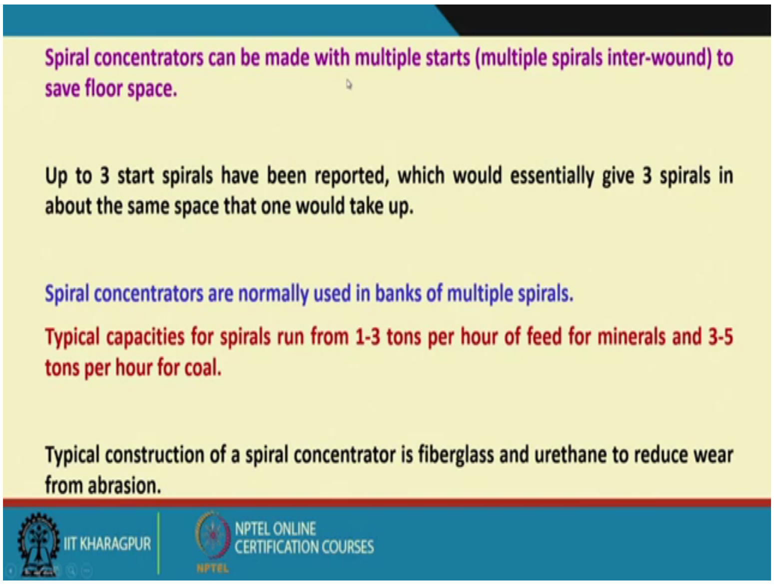

Now, what is the material of construction of spirals? Now spiral concentrators can be made with multiple starts that multiple spirals inter wound to save floor space sorry we will come back to the material of construction later on. So, that is like that that is you can have multiple stars like as I had shown you in the previous picture; that is you can have a stack of your spirals.

Up to 3 start spirals have been deported which would essentially give 3 spirals in about the same space that one would take up that is I can have 3 sets of spirals and each spirals could be of your 5 tons; that means, it all together you will having 15 turns.

So, your structure and stability is a very important factor for that you have to take care of that. Normally we it is common to see that your three star spirals are in operation in the plant. Spiral concentrators are normally used in banks of multi well spirals I will show you some pictures of that we can have multiple your banks also and banks of spirals like it is again analogous to your small diameter cyclones; how they are basically assembled together to meet the required or desired capacity.

Typical capacities for spirals run from 1 to 3 tons per hour of feed for minerals and 3 to 5 turns per hour for coal. So, you see that it is very each spiral is having relatively much lesser quantity with a lesser capacity. So, if I need a 100 tons of material to be processed per unit time per hour.

So, we need at least 33or 35 your a parallel your it is spirals lying in a in some manner. So, that is called the basically the bank of spirals; we need multiple spirals to meet the your capacity requirement. Typical construction of a spiral concentrate that is the material is fiberglass and urethane to reduce wear from abrasion.

Because the bottom layer will be severely your own out if your material is not your wear a resistant material. Because the relatively coarser and heavier particle will be always traveling through your floor; so, if that material has to be abrasion resistant. So, normally it has been seen that fiberglass and urethane are the best material to be used for spiral manufacturing.

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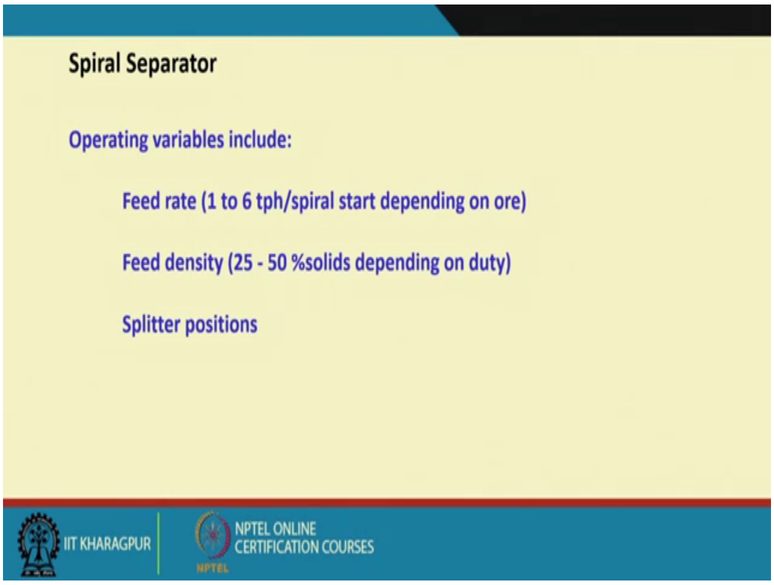

What are the operating variables for spirals at the feed rate; it is normally we have seen that it is one to 6 tons per hour per spiral start depending on the ore characteristics feed density that is your part density 25 to 50 percent solids depending on the purpose for what you are using the spiral that whether the spirals you are using for only for roughing duty or up to the final cleaning stages. Then splitter positions where you are positioning the splitters that is; how do I know that how much of that your floor space is occupied by the concentrate and by the middling and by the your lighter minerals that is your tailings.

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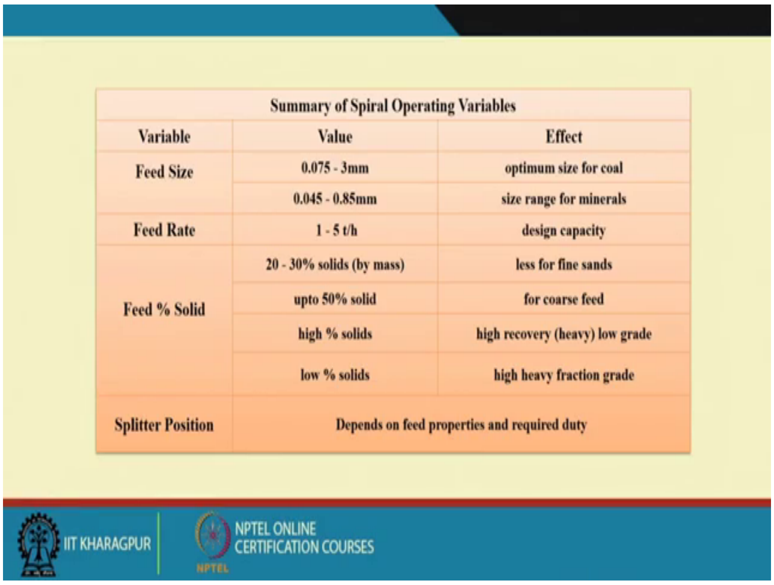

Summary of Spiral Operating Variables		
Variable	Value	Effect
Feed Size	0.075 - 3mm	optimum size for coal
	0.045 - 0.85mm	size range for minerals
Feed Rate	1 - 5 t/h	design capacity
Feed % Solid	20 - 30% solids (by mass)	less for fine sands
	upto 50% solid	for coarse feed
	high % solids	high recovery (heavy) low grade
	low % solids	high heavy fraction grade
Splitter Position	Depends on feed properties and required duty	

So, these are some of the summary of your spiral operating variables and their effect like feed size it normally varies accepts from 3 millimeter to 75 micrometer and optimum size for coal this is for optimum size for coal.

And it can go up to 0.85 millimeter that 850 micrometer to 45 micrometer for minerals feed rate could be 1 to 5 tons per hour depending on the design capacity; it can it works best that 20 to 30 percent solids by mass; less for fine sands if you have the very fine sand which are having lesser density also; it could be less 8 percent solids up to 50 percent solid for coarse feed high percent solids for high recovery and low grade that is if you have a high percent solids.

So, recovery you will be high, but grade will be low; it is all common phenomena low percent solids high heavy fraction grade and the quality will be good, but your capacity will be less. Splitter position depends on feet properties and required duty and that need that requires the understanding of house spiral works and also it depends on what is the material characteristics and your experience also.

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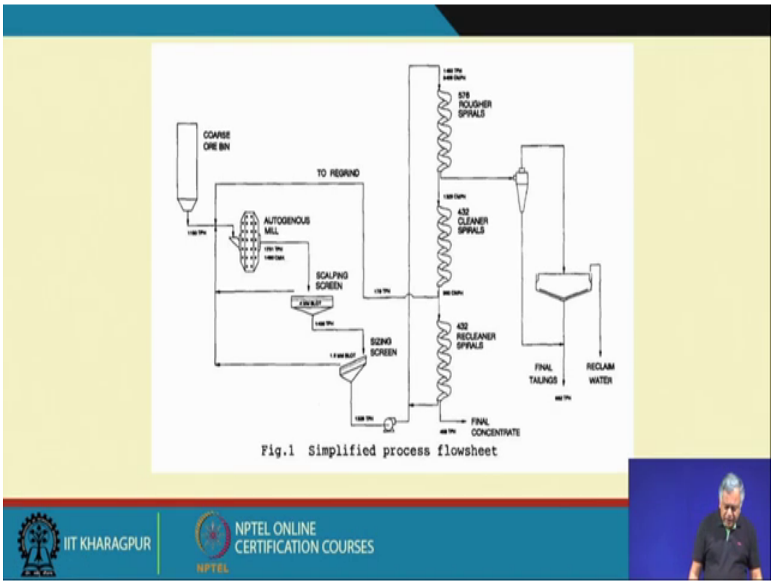

There is a simplified process flow sheet; that is this is the we are calling it stack of spirals that is you have got your spirals and you see that your some product you are taking it out and you are classifying and then dewatering it and sending it back; sending it to the either the reject stream. And then you are trying to clean it further and further until you get the final concentrate. This is nothing, but the screens and your grinding circuits because you have to prepare your feed to a particular size for the liberation.

So, this is the combination circuit, this is the processing circuit and this is the your final your checking that is your classification and your thickening circuit and your this water you are basically trying to recycle it back.

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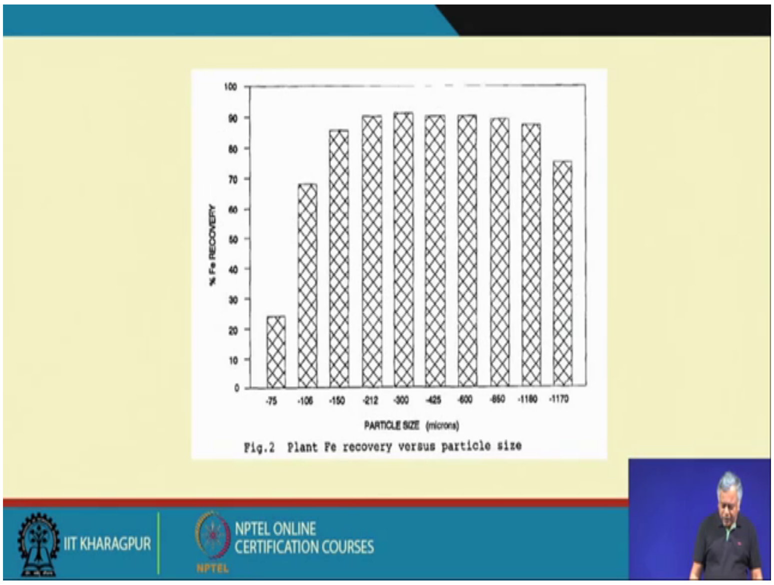

So, this is in short about the spirals and you see that this shows that your plant iron recovery versus particle size, these are the some data I have got it from literature that as the particle size decreases; the percentage iron recovery becomes less. And with the coarser sizes the recovery increases, but when the sizes become much coarser; again it deteriorated because it cannot move. So, you do not have a flowing film separation when the particles become very coarse. So, you have a optimum size range for the spirals to separate your material.

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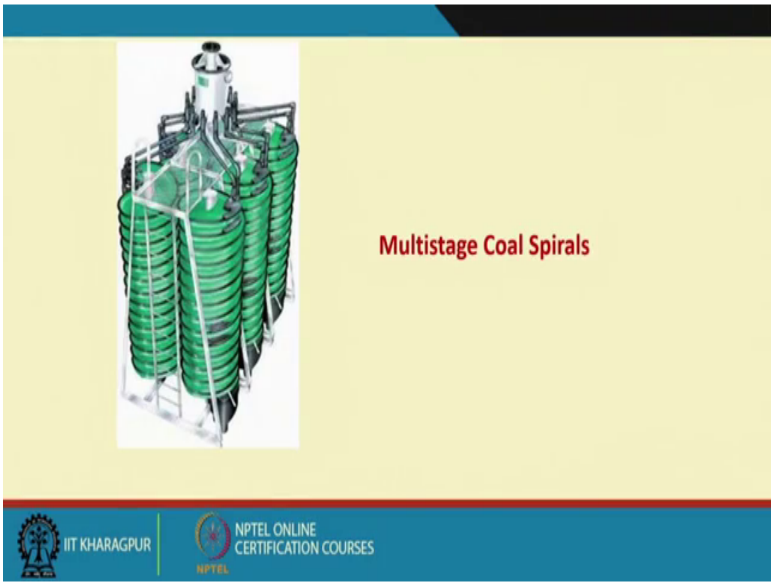

This is the how they are stacked like I need to match the capacity it is just analog as to how you have stacked the cyclones; that is you have your different yours your a stages that is you can have multiple spirals your stacked like this. So, you have got multiples your spirals into this way and then to match the capacity you are stacking them like this.

Now you have got a central feeder centrally your say feeding system and then that slurry that is again the challenge to the mechanical engineers; that is how do I maintain the solid percentage solid concentration in my slurry as well as the flow rate of the slurry in each spiral and at a consistent rate and is similar to your hydro cyclone what we did; so, this is all about spirals.

So, next lecture we will start with another type of gravity concentration and that will be the week tenth lecture till then.

Thank you very much.