Introduction to Mineral Processing
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Lecture – 41
Hydrocyclone (Contd.)

By the last class we have discussed about one of the application areas for hydrocyclone in solid liquid separation. Now there are 2 extreme cases even in that there in solid liquid separation and those 2 extreme cases we give different we use different terminologies one we call it clarification, another one we call it dewatering.

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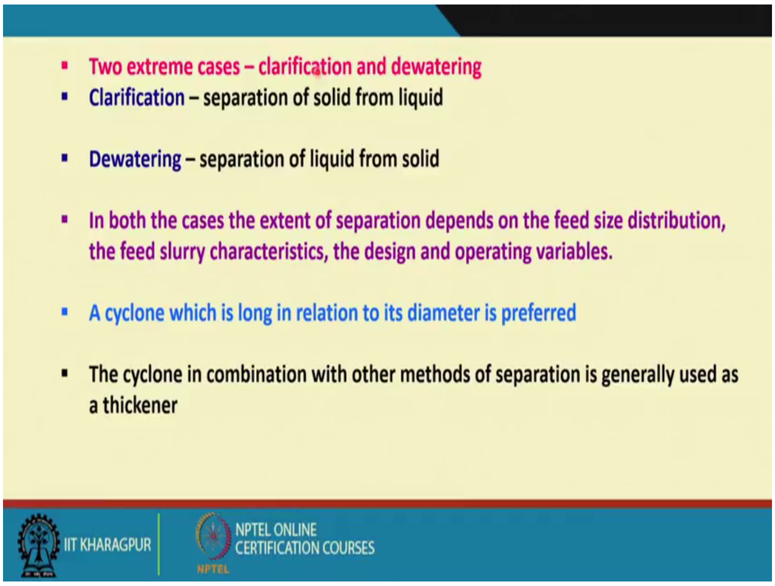

The clarification means separation of solid from liquid; that means, my target is to separate the solid from my liquid medium mostly the liquid is water so then we call it the clarification. In another case they recall it dewatering where the separation is aimed at more on the liquid than the solid that is I want to recycle back that water I want to get rid of that water from my your pulp.

So, that is where we use it why we use these 2 terminologies because when we know that this is a clarifier or these a clarification this cyclone is used for clarification we know that what is the job it has to do, when you know it is dewatering we know what is the job it has to do that is why we give the 2 different terminologies.

In both the cases the extent of separation depends on the feed size distribution that what is the size distribution of your particles you have, the feed slurry characteristics; that means, whether you have got a very dilute suspension or you have got a thickened one; that means, what is the relative percentage of solid into your slurry if you have a dilute you do not have your logical problem, but if you have relatively higher percentage of solids you have to take into consideration the geological characteristics of that slurry.

What are the design and operating variables of cyclone? So, the design although it is cylinder conical, but as I said that, what should be the angle of this conical part? What should be the cylindrical diameter? What should be the length of the cylindrical portion? What should be the inlet diameter? What type of inlet diameter? What should be the your under flow or if it that is the speaker diameter? What should be the overflow or if it that is your vortex finite diameter? What should be the material of construction all this coming to picture. We will discuss briefly about all this design and operating variables a later time.

So, for these cases a cyclone which is long in relation to it is diameter is preferred; that means, when the conical part is much longer than the cylindrical part that is what is being used, what does it mean? So; that means, when the included angle that is the cone angle is smaller. So, when the cone angle is smaller what will happen now, you will be generating much more centrifugal force in that area.

So, your m v square by r because your r is smaller. So, you can generate more of institute you can intensify the centrifugal force in situ and when the centrifugal force is more. So, you can even have the solid particle separation to be possible at relatively finer sizes and because of that also what will happen, the more pressure drop will be created. So, at the velocity of my air core we you can increase it. So, that more of my water can be transported through the overflow.

So, that I can have a your separation between your solid and liquid in a much faster rate and much more accurate, the cyclone in combination with other methods of separation is generally used as a thickener; that means, when we are using it as a thickener that is for solid liquid separation whether it is clarification or whether it is dewatering, then we try to separate most of the solids or more majority of the water from that, but as I said that the cyclone separation is never perfect it is far from perfect.

So, we try to combine with other mechanism also like maybe the cyclone product that is your say suppose we are using it for a your dewatering purposes. So, that solid liquid that is your thicken your slurry what you are getting it into the underflow many times we try to send it to a filtration unit that is for your further dewatering purposes or maybe we can send it to a thickener that is where we add polymers and then we try to propagate them and we try to have much more separation between the solid and liquid.

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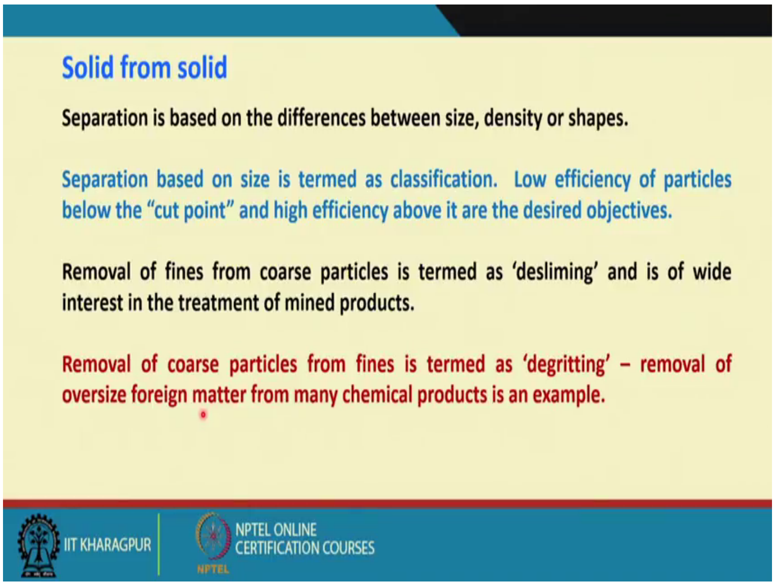

Now, solid from solid that is a very important application for hydro cyclones as I had explained you that is why I said that the hydro cyclone is a is probably the heart of any mineral processing plant and that is for solid separation that is your separation based on sizes, that is where it is used as a linkage between your combinational circuit and your processing circuit, that is where it is being used as a classifier that is your solid separation based on their differences in the sizes.

So, they solid from solid separation could be based on the differences between size that is when it is based on size we call them as a classifier, when we try to separate based on the density differences we call them as a your density separator like your dense medium cyclone and many times you can use it also for separation based on shape, but it is not that preferred equipment or it is not that frequently used in minerals processing industry for separation based on shapes whereas, in other industries like food processing industry they are using cyclones for separation based on shapes.

Separation based on size is termed as classification that is your centrifugal classification low efficiency of particles below the cut point and high efficiency above it are the desired objectives that is what I want in simpler terms, that is we want that your hydrocyclone should gave me a size based separation, what a screen would have given me or what an ideal size separation device would have given me that is I want to have a separation at forty micrometer irrespective of the particle densities. So, I should get that type of separation into a hydro cyclone but that is what is the desired one, but we hardly get it.

The removal of fines from coarse particle is termed as desliming we have discussed it many times we have seen also that even the knee or mechanical classifiers or maybe the spiral classifiers like your spiral classifiers we can use it as a desliming unit and many times when the desliming has to be done at a relatively finer sizes we use it the cyclone and when we use it for desliming purposes we call it desliming cyclone and is of wide interest in the treatment of mind products because mostly the mind products we have got clays.

So, we want to first get rid of these clays at the very beginning. So, that it does not interfere into my other separation processes because these clays are very fine particles they will increase the viscosity of my fluid and then I will have problems in the material flow characteristics into a fluid medium. Removal of coarse particles from piles is termed as degrading like many times we use it the cyclone that we have got certain amount of coarse particles coming from mine upstream processes or maybe many mind like your query products many times I want to have a size product say suppose from 100 micrometer to your 50 micrometer and you have got a few particles which are even coarser than you have 500 micrometers.

So, there also we can use the cyclone and when it is used for that we call it degrading purposes. So, removal of oversize foreign matter from many chemical products in an x is an example. So, in many cases that we want to remove this your relatively coarser particles and where the volume metric concentration of this relatively courser particles is much lesser and we do not want them and when we use cyclone for that we get we call them degritting. So, sometimes you want to remove the very fine ultrafine particles then we call it desliming cyclone when you use them or relatively coarser particle removal we call them degritting cyclone.

So, the design of the cyclone, the dimensions of the cyclone and the operating conditions of cyclone will differ based on the purposes for what for which it is being used.

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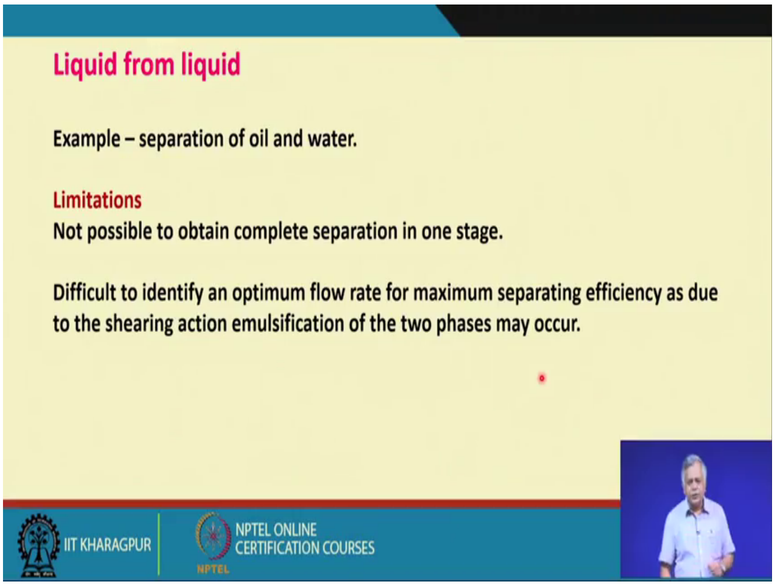

The liquid from liquid separation example I have already given it that is separation of oil and water that is if you want to separate oil and water you can use it, but limitations is that not possible to obtain complete separation in one stage and difficult to identify an optimum flow rate for maximum separation efficiency as due to the shearing action emulsification of the 2 phases may occur.

So, that is the your trouble, what should be the optimum your say you are shearing action you can impose on this mixture anyway that is not the part of our subject. So, mineral processing people normally it does not have to deal with this liquid separation.

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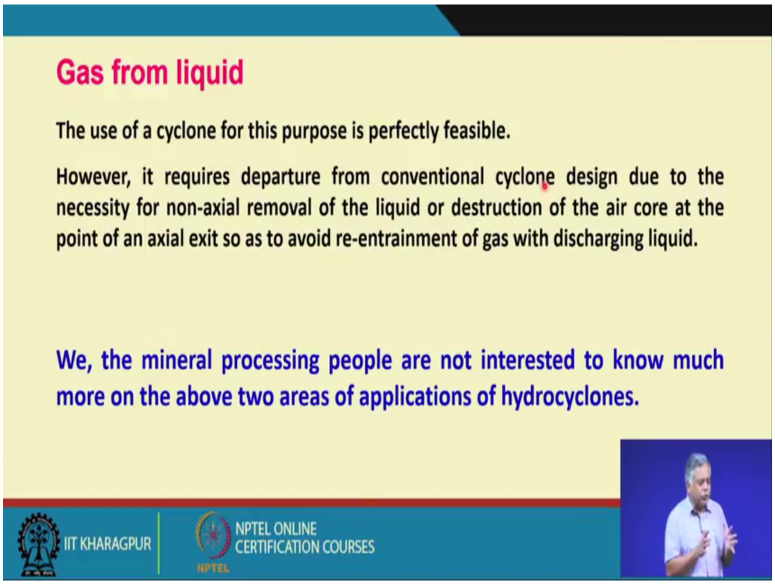

Then gas from liquid there is also another application the use of a cyclone for this purpose is perfectly feasible; however, it requires departure from conventional cyclone design due to the necessity for non - axial removal of the liquid or destruction of the air core at the point of an axial exit.

So, as to avoid re entrainment of gas with discharging liquid, do not worry about this I just wanted to tell you that even the hydro cyclones can be used for gas from liquid, but we normally mineral processing engineers are not interested to know much more on this subject that is your liquid liquid separation and gas from liquid, but I wanted to give you this information that if you are interested in this cyclone separator you may look at the literature in many other industries like mostly the chemical industries they are being used chemical and petroleum industries they are being used extensively for liquid liquid separation and gas liquid separations.

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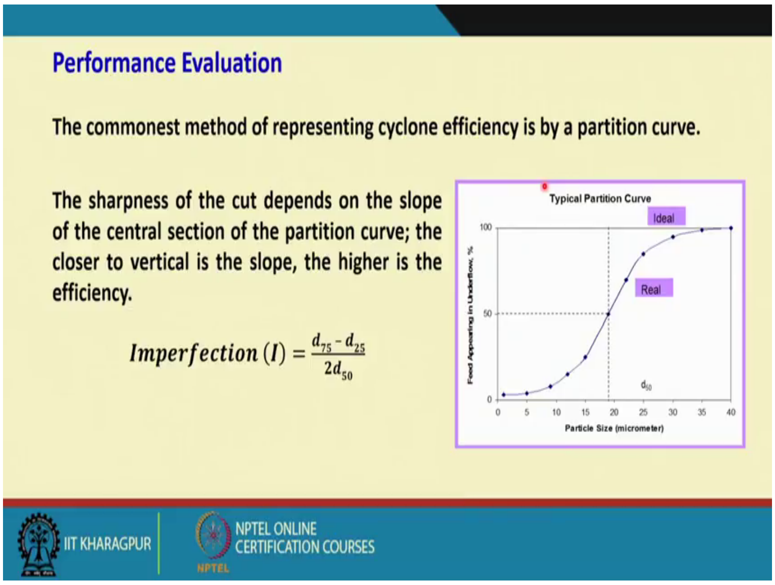

Now, how do we evaluate the performance of a hydrocyclone hope you all remember that when we had discussed about the performance evaluation of industrial screens that is a gentleman called traum, what he proposed that do not look at that do not evaluate the performance based on what you have got, you look at that different sizes of the particles how much difficulty the individual particle classes they have faced in getting separated from the mixture and based on that concept I have already discussed and I have already shown you through a numerical example that is how you have to calculate the difficulty in terms of partition coefficient.

If we do not remember I would request you to go through my previous notes or to previous lectures on industrial screens performance evaluation you will get to know that and there we have plotted the your the partition coefficient versus your particle size. So, here also we do the same thing because it is purpose when we are using it for size separation device. So, we have to look at the each particle class how much of difficulty they have faced. So, in that case what we do that is your feed appearing in underflow percentage; that means, what percentage of a particular size class they wear in this feed and out of that how much we have got it in under flow.

So; that means, suppose in under flow for a certain fraction from 100 to 90 micron particle I have recovered 90 percent of the available material of that fit size of that size particle available in the feed. So, that is the 90 percent and that 90 we plot against the size that is your 100 to 90 we take a mean size of that and we plot it 95 micrometer. So, like that when we plot it based on underflow you can plot it also based on overflow that is nothing wrong in that, but conventionally the mineral processing people they plot based on the under flow because the under flow is easier to collect in most of the cases in the plant and the overflow they are basically directly sent to a downstream processes and the overflow.

So, probably because of that reason that you collect under flow and the under flow you have got lesser water. So, your time of filtration is less your time requirement for dewatering is less in a laboratory and you can do the size analysis very easily and relatively coarser particle the size analysis is much more accurate than the much more finer particles. So, here what you do the, this your recovery terms or the partition coefficient in terms of how much of a particular size was available in the feed and how much of that you have recovered into the underflow as a function of your size.

Then you get a curve like this what you had observed in case of industrial screening also. So, that is called a real curve that is called a partition curve. So, the commonest method of representing cyclone efficiency is by a partition curve. So, that is what a partition curve and again if you remember that what we did that what is the d 50 size here. So, d 50 size is close to 19 micrometer here based on this size. So, what it is saying that if we have an imaginary size separation at 19 micrometer the entire your particle sizes would have been equally distributed into the oversized and undersized fraction at that size.

So, now, that is the d 50 size 19 micrometer now if I have an ideal separation at 19 micrometer this curve shape would have been converted into a shape like this that is I would have recovered all the particles in my underflow at 100 percent your recovery I would have recover 100 percent of all the particles coarser than 19 micrometer into the cyclone underflow and all the particles finer than 19 micrometer I would have recovered them 100 percent into the overflow because when the underflow is showing 0 person; that means, they have reported to the overflow.

So, there is a deviation from this. So, again based on that concept that is your d 75 that is what is the d 75 size here and what is the d 25 we have already explained that this portion becomes the it will give you mostly the straight line and because of that your concept of slope. So, this has come that is the imperfection is the same formula we had used for screen efficiency calculation. So, that is d 75 minus d 25 divided by 2 d 50. So, that is called the imperfection.

So, what do we do, we try to calculate it and for a perfect separation this imperfection value. So, the d 75 would have been 100 d 25 would have been 100 and I should have got it you are saying imperfection would have been 0 for an ideal separation. If you look at close to this curve there is another interesting feature that in most of the cases it does not pass through the your origin that is at your 0 percent.

It is somewhere it is going towards the your some percentage is remaining here and the mineral processing researchers they were trying to understand that why this curve is not passing through the at a point of your origin that is a 0 0 point because at you should have an infinite size particle class which should not have reported which would have 0 percentage recovery into the underflow, but we could not do it because probably that we could not measure up to that size that could be one reason.

But that has prompted many mineral processing researchers to propose something that is, how do I force this curve to pass through the origin and for that.

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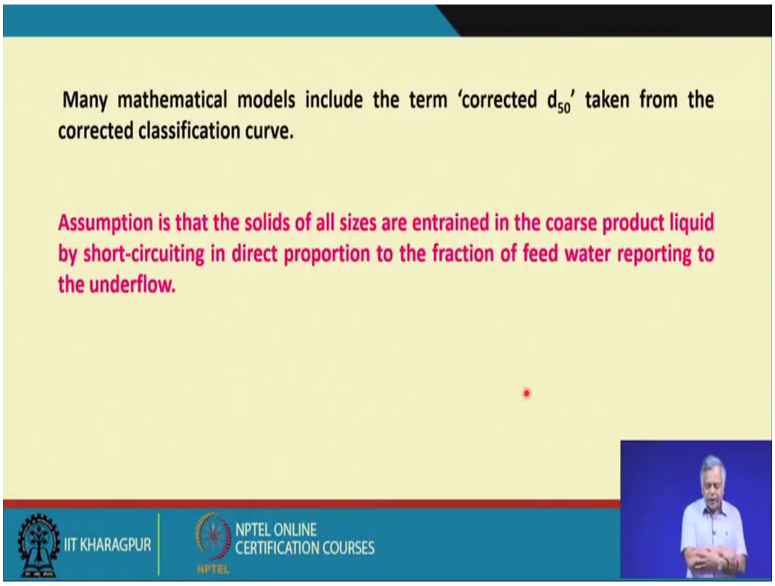

Many mathematical models have been developed and instead of using a d 50 they have proposed to use a corrected d 50 terms it taken from the corrected classification curve I will discuss it what is that, but for that there is an assumption, what is that assumption?.

So, assumption is that the solids of all sizes are entrained in the coarse product liquid that is, whatever the liquid is coming that is your water is being reported through the underflow in that particles of all sizes I had a certain amount they are entrained into that and the mechanism they have said that that is by short circuiting.

That is once they are entering some part of the feed as it is they are by passing the by classification chamber that is there by some means they are reporting through the underflow along with the water what is going what is passing through the underflow; that means, they are not being classified and the amount of this material is directly proportional to the feed water reporting to the underflow.

So; that means, if I have 25 percent of my feed water reporting to the underflow then the assumption is that 25 percent of my feed material will report to the under report through the underflow which is not classified at all; that means, which has not been subjected to for size separation. So, what is the meaning of this?

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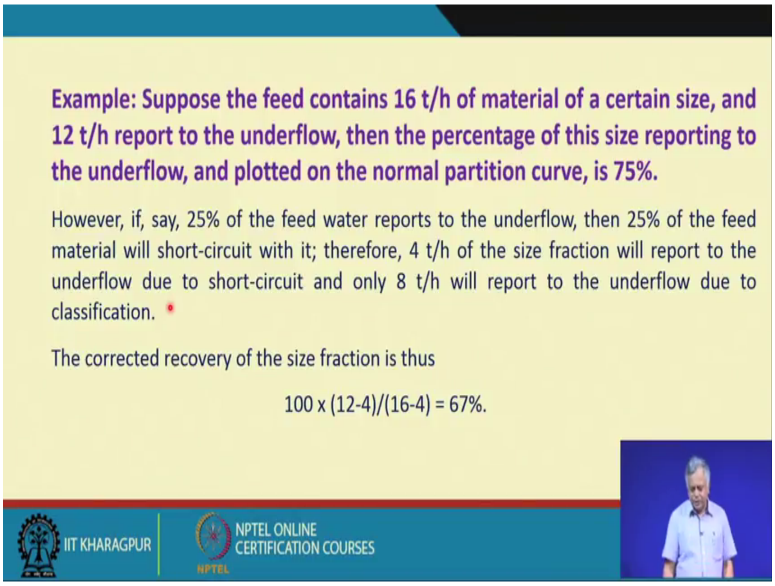

Now, suppose the feed contains 16 tons per hour of material of a certain size as a size distribution of a size distribution and you have a mean size and 12 tons per hour report to the underflow; that means, you have a feed rate at 16 times per hour and out of that 12 times per hour of that size report to the underflow I am talking about a particular size fraction, then the percentage of these size reporting to the underflow based on this conventional analysis that you have got you are feeding it at a sizes suppose x into that feed size distribution at a rate of 16 tons per hour out of that 12 tons per hour you are recovering that size into the underflow stream.

So, what is this percentage under flow or percentage feed material reporting to the underflow that is your 12 by 16 into 100 that will give you 75 percent that is how the original curve is plotted. Now what is this group of researchers they are proposed based on that, that is if say 25 percent of the feed water reports to the underflow then 25 percent of the feed material will sort circuit with it; that means, they will not be subjected to classification they will just 25 percent of the feed material. So, when the 25 percent of the feed material is coming; that means that 25 percent of that particular size material will also come to the underflow due to short circuiting.

So, 25 percent of 16 term means it is 4 tons per hour of the size fraction will report to the underflow due to short circuit. So, only 8 tons per hour that is 12 minus 4 will report to the underflow due to classification so; that means, whatever 12 tons per hour of that particular size fraction you are getting through the underflow out of that 4 terms per hour you are getting it because of short circuiting because 25 percent of feed water has reported through the underflow.

So, what is this corrected recovery now? So, the corrected discovery is 12 minus 4 divided by 16 minus 4 that is this is 8 and this will become 12, this is 2 by 3. So, it is around 66.6 percent or if we round up this, they become 67 percent. So, now, based on this concept if I calculate the corrected recovery of each particle sizes and then I replot it as a function of size then we get a corrected classification curve and which should pass through the origin and that is the corrected classification curve.

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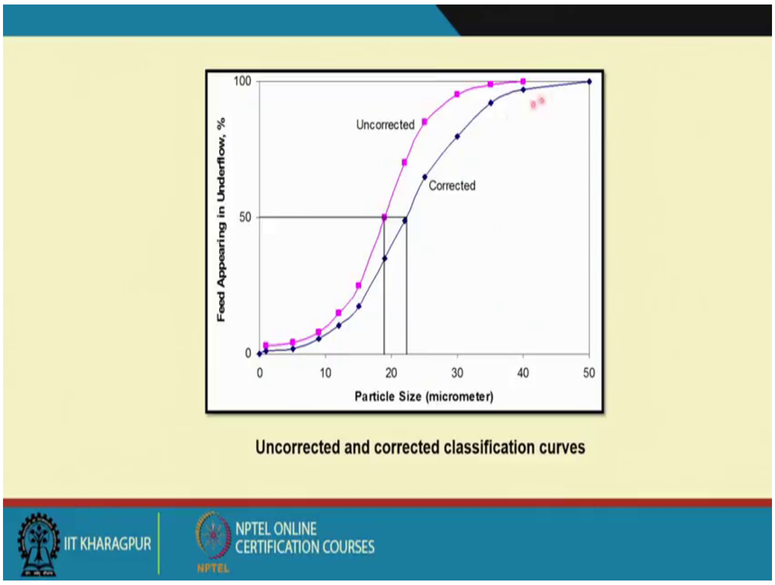

So, this is my uncollected one that is what we have calculated based on simple mass balance and is how much I had in my feed and how much of that particular size class has deported to the underflow based on that we have calculated now when we have a corrected one. So, now, we have to take the corrected d 50. So, previous example the d 50 was 19 micrometer now the corrected d 50 denoted as d 50 c will become like your 22 micrometer or 23 micrometer. So, this is the difference between your corrected classification curve and unconnected classification curve now, what is the advantage of doing this.

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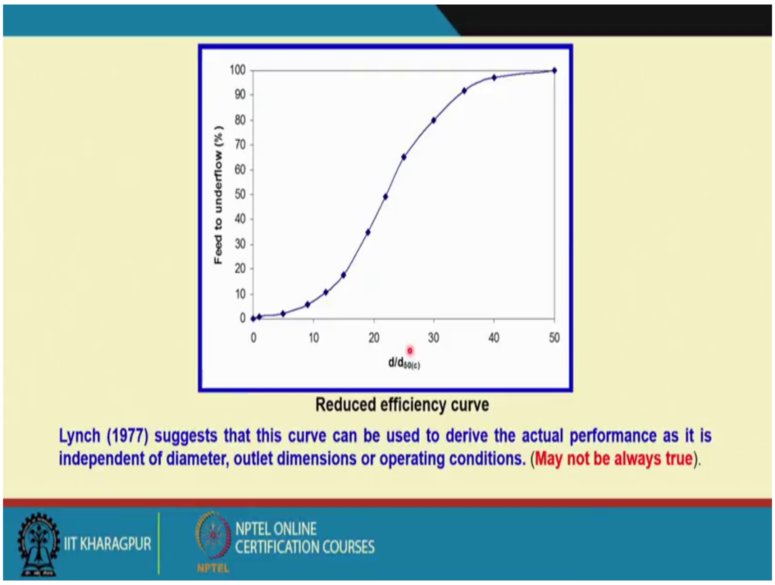

According to the scientists who proposed it no this professor Lynch of university of Queensland he named it as reduced efficiency curve he plotted another curve that is called a reduced efficiency curve where he had plotted the d by d 50 c, d by d 50 c means that what is that size given to know suppose I have got a size distribution. So, you have got a d 50 c of 22 micrometer.

Now, the size what you are trying to plot in the x axis say suppose that is 10 micrometer. So, that is 10 by 20 2. So, that is d by d 50 c you are plotting it in the x axis and the feed to underflow that is how much of that you have recovered into the underflow of that particular size based on the corrected your efficiency curve concept. So, what is happening, when you plot it like this, Professor Lynch suggests that this curve can be used to derive the actual performance of a cyclone as it is independent of diameter outlet dimensions or operating conditions, what he has suggested that, this reduce efficiency curve is independent of the operating and design parameters.

However this is my personal opinion that it may not be always true because my reasoning is that your d 50 c that is your corrected d 50 depends on the operating and design variables and everything so, but that is a debatable thing and this is what is already documented in many literature. So, I just raised this question and I said that may not be always true I leave it to you to have a debate on this topic and you can try at your operation and see that whether it is always true I may be wrong also.

So, now based on these reduce efficiency curve many models have been developed and those models are basically frequently used in the industrial scale cyclone operation for their selections for their your design and process parameter optimization anyway will carry on this topic and the next lecture till then thank you very much .

Thank you.