Introduction to Mineral Processing

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Lecture – 45
Mass Balancing

Hello, welcome to this the 9th week of this lecture series, so far whatever we have discussed about hydro cyclone closed circuit grinding everywhere we have seen that these are wait processes we are adding water. Now when we add water and so, what we require that is we want to recycle back this water because that water in the ultimate product the final product you have to dry up, otherwise that is you need again external energy to evaporate that water and then your fresh water requirement to the plant also will go up.

So, it is required that how much of water how much of fresh water you really require and how much of recycled water is coming back that is whatever you have used is through the grinding circuit to the n processes and how much of water is coming back. Similarly, you have also seen that in a closed circuit grinding operation some underflow product of the hydro cyclone in the form of slurry that is your relatively coarser particle and the water they are coming back to your grinding circuit.

So, they are also you need to maintain a certain volumetric concentration of solids into the grinding circuit. So, how much is coming and how much of water and how much of solids are going where that we need to know. So, for that we need to apply some mass balance approaching mass balancing approach means that is your input is equal to output based on that principle.

Before we go to the subject let me explain you some of the common terminologies we use in the winder processing industry.

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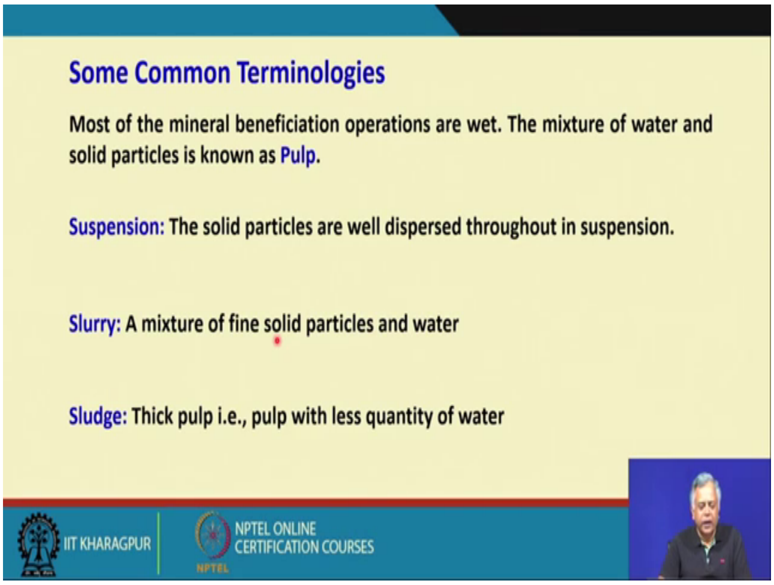

A many times I have already altered these words probably by now you are getting confused that what are those. So, I want to give explanation to that most of the mineral beneficiation operations are wet the mixture of water and solid particles is known as in general that is called the pulp so, it is a solid liquid mixture in general and that is termed as pulp.

There is another term that is called suspension, suspension is the solid particles are well dispersed throughout in suspension; that means, the pulp we are saying that it is a mixture in that mixture we are not saying that whether the particles are in suspended or not. So, in a suspension I mean the solid particles are well dispersed throughout the suspension; that means, it has got minimal effect of sedimentation or the settling.

Slurry, what is the definition of slurry? The slurry normally we call a mixture of fine solid particles and water. Now what is the difference between your pulp and slurry? When we are talking about slurry; that means, it is having fine solid particles. So; that means, the slurry density becomes very important because most of the particles will be in suspension and then there are a rheological aspect of this fluid mixture that is because the particles are very fine.

So, you have got large surface area and when you have large surface area of the particles then it may impose the some kind of your resistance to the normal flow characteristics of the fluid another term which probably I have not used so, for that is called the sludge. So, this is a thick pulp; that means pulp with less quantity of water. So, it is a relative percentage of solids is higher much higher than the percentage of water.

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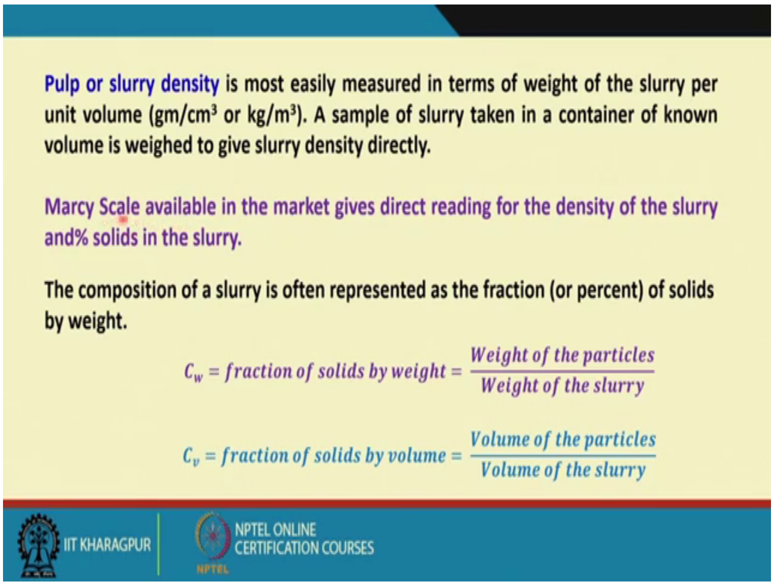

Now, we normally use a term called pulp or slurry density; that means, slurry means when it is a fine particle suspension that is a fine particles a mixture with water and pulp is in general that is your solid liquid mixture. So, we need to know the density of that density means what is the it has got commonality with the bulk density of the material that is what is the weight of 1 liter of that mixture because it will give me some idea about how much of solid is there and then I will show you gradually how we use these for my mass balancing purposes.

So, pulp or slurry density is most easily measured in terms of weight of the slurry per unit volume, the volume could be kg per meter, cube or gram per centimeter cube like what you have to do, you take a sample of slurry in a container of known volume that is a suppose 1 liter container, you have taken you have poured it with that slurry for which you want to measure the density and you weigh that. So, that one liter of slurry if it gives you a density of 15000 kg per meter cube that way around 1.5 kilogram if 1 liter gives that 1.5 kilogram then it is density is called to be 15 1.5 into 1000, that is your 1500 kg per meter cube.

So, that is how you can get the slurry density directly right, one scale that is devised by Marcy that this is readily available in the market that is you have got a container which is having your calibrations done that is that will directly give you the density of the slurry that is called a Marcy scale. So, Marcy scale available in the market gives direct reading of the density of the slurry and it also gives you the percentage solids in the slurry that is the weight percent solids in the slurry there is how much of your solid is there and how much of water is there.

Now the composition of slurry is often represented as the fraction or percent of solids by weight and it is a suppose if I have a slurry density of 1500 kg per meter cube where the fluid is water how much of solid is there by weight? So, how do calculate it, normally we calculate it by fraction of solids by weight and if we denote it by C w that is the C w. So, C w is equal to fraction of solids by weight, how we get it? Now it is the weight of the particles divided by weight of the slurry.

So, it is very easy to measure how will you do it? Now you take 1 liter of slurry that is you take it into a known volume of say your 1 liter can that slurry you have taken and now you weigh them that I know that what is the quantity of slurry I have got, now put that slurry into an oven and keep it at 105 degree centigrade for a longer duration maybe overnight or maybe you can do some kind of filtering before that and then you put it into oven and 105 degree centigrade for around 1 hour. So, your moisture will be evaporated; that means, the principle is that you have to ensure that your it is moisture free.

So, you get the dry solids now, now you weigh that, that what is the weight of my dry solids. So, that is the weight of the dry solids divide by the weight of the slurry, should I repeat it? I think I should repeat it. So, what I have to do so, that is C w is the fraction of solids by weight how do I get it I take a measured volume of slurry and then I divider it without losing any particle I have to take extreme precaution in that, that is you may take as less filter paper and you can filter it first and then you put you just put it back into the oven to ensure that there is no moisture surface moisture and then now you weigh that how much of solid particle you have got.

So, in that case what will happen that say suppose that will give you that what is the fraction of solids by weight, similarly I can convert this now in terms of volume fraction of solids that is your fraction of solids by volume and for that if I denote it by C v that is your fraction of solids by volume that is volume of the particles divided by the volume of the slurry. How do I get the volume of the particles? Now I have got the weight of the particles by drying it now if I know the density of this because mass is equal to volume into density right.

So, I have got the mass, if I know the density of that particle. So, mass divide by density will give you the volume. So, that is the volume of the particles and I already know the volume of my slutty was 1 liter. So, I can get these 2 conversions that is so be very clear when you are saying that percentage of solids it is percentage of solids by weight or percentage of solids by volume otherwise your are all calculation will be wrong.

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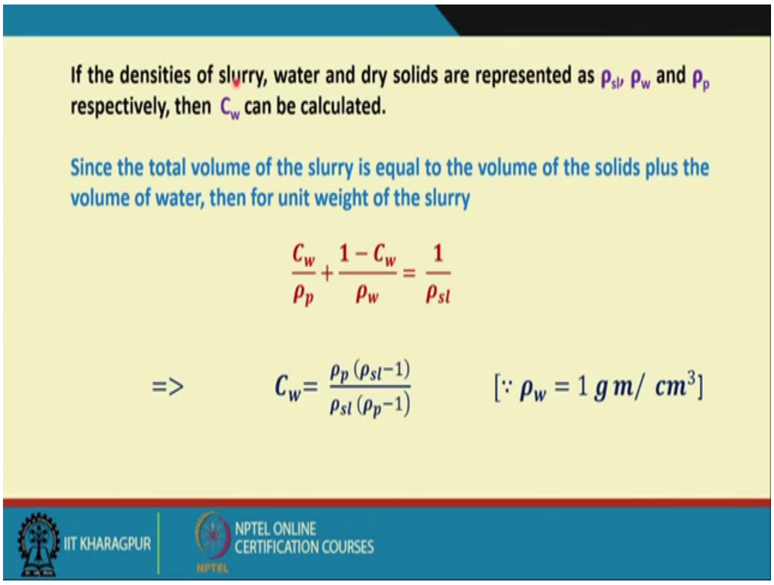

Now, if the densities of slurry that is the pulp density of your slurry water and dry solids are represented as rho sl that is your slurry density that I have already explained that how will you get it you may use a Marcy scale or you may measure it on your own then rho w for that water density may be you have to know the temperature of water and you look at your standard handbooks that what is the density of water at that temperature or normally for our calculation purposes we take water density as thousand kg per meter cube and rho p that is the particle density that is your density of the dry solids assuming that they are all uniform density solids.

So, then C w can be calculated that is if density of the slurry water and dry solids are represented as rho sl rho w and rho p then c w what is C w? C w I have defined it that is fraction of solids by weight and C v is the fraction of solids by volume right. So, since the total volume now that is how we can calculate the C w if we know that densities of that since the total volume of slurry is equal to the volume of the solids plus the volume of water because whatever the slurry volume. Slurry volume means is the volume occupied by solids a remaining portion will be the volume occupied by water.

Now for unit weight of the slurry suppose it is for then for unit weight of the slurry we can write that is C w by rho p C w is the what fraction of solids you have. So, that I am converting into volume fraction that is by rho p. So, this is for solids I am dividing it with the density of the solids. So, this is the mass and this is the density so, I am getting the volume fraction of solids.

Now once I know that if 1 kg of slurry is having 250 grams of solids so; that means, the remaining that is your 1 minus 0.25 that is 0.75 kg will be the water. So, if C w is my mass fraction of solids in one unit weight of the slurry then my water weight will be what is the fraction of water we have, that is 1 minus C w and what will be the volume of this volume fraction of this that is 1 minus C w divided by rho w. So, that will be equal to well I said one unit weight.

So, what will be the volume of the slurry so, that should be equal to that is the volume of water, that is the volume of solids and this is the volume of water. So, that should be equal to volume of my slurry. So, one you unit weight I have already mentioned. So, it is one unit weight divided by rho sl that is the slurry density. So, I am balancing this is called say conversions. So, that is the solids volume plus water volume that is the fluid volume in this case it is water is equal to the volume of the slurry 1 by rho sl.

So, if I rearrange this in terms of C w which you should do it should be able to do it I hope that is what you have to do you take rho p and rho w here. So, it will be C w rho w plus rho p into 1 minus C w is equal to 1 by rho sl and they there are 2 3 steps here very simple step. So, you can convert it and the C w is equal to rho p into rho sl minus 1 divided by rho sl into rho p minus 1. Where is that rho, w has gone now rho w I am assuming that it is equal to 1 gram per centimeter cube that is density is 1000 kg per meter cube at 4 degree centigrade.

So, that is why I say that if the density is of slurry that is if the densities of slurry densities of water I have already considered that that is 1 gram per centimeter cube and the density of dry solids density of dry solids are represented as this then the C w can be calculated that is the percentage of solids that is a fraction of solids by weight can be calculated by using this formula. That is C w is equal to rho p into rho sl minus 1 divided by rho s l into rho p minus 1 by rearranging these terms right.

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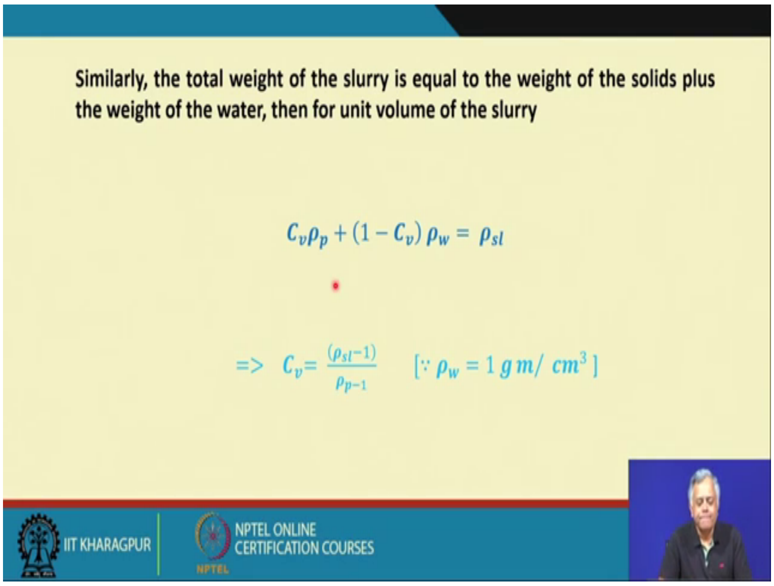

Similarly if the total weight of the slurry is equal to the weight of the similarly the total weight of the slurry is equal to the weight of the solids plus the weight of water. So, what is the total weight of slurry means is the total weight of solids plus total weight of water. Now for unit volume of the slurry it should be C v, what is C v? C v is the fraction of solids by volume multiplied by density of the particle. So, it is a volume into density. So, I am getting the mass. So, that is the your C v into rho p plus 1 minus C v because if my volume fraction of solids is represented as C v and we are talking about one unit volume.

So, what would be the volume of my water, it is 1 minus C v multiplied by a rho w that is the density of water. So, that is the C v into rho p that is how much of what is the weight your say solid particles and this is the weight of my water. So, that should be equal to my weight of the slurry so, that is your rho slurry that is, what is the slurry density. Again if I use a rho w is equal to 1 gram per centimeter cube.

So, I can write it from here cv is equal to the rho w is 1. So, it is C v is equal to rho sl minus 1 divided by rho p minus 1, we can easily do that because it is C v rho p plus 1 minus C v is equal to rho sl. So, if I take out this 1 here. So, it will become rho sl minus 1 and if I take a common of C v that will be rho p minus 1.

So, that then I can write C v is equal to rho sl minus 1 divided by rho p minus 1. So, these are the simple conversions either you can remember it or maybe we can derive it whenever the need arises why you are doing all these conversions, now because many a times in a processing plant you may not have access to all this data you may have access to collect some samples for some specific measurements not for all the possible measurements. So, how do I convert from each data from one data form to another data form that is what is basically we are trying to do.

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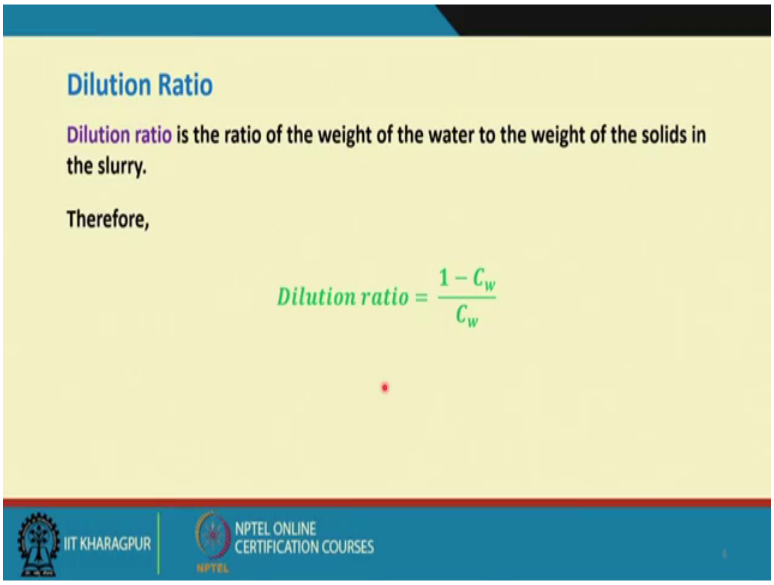

Now there is another term that is called a dilution ratio, this dilution ratio term we use extensively in the mass balancing of in the mineral processing operations. So, what is the dilution ratio? The dilution ratio is the ratio of the weight of the water ratio of the weight of the water to the weight of the solids in the slurry; that means, is the weight of water divided by weight of solids. So, dilution ratio I can write that if C w is the weight fraction of my solids. So, the weight fraction in one unit weight of your slurry then what is the weight fraction of my water is 1 minus C w. So, dilation ratio is defined as weight of the water divided by weight of the solids in the slurry.

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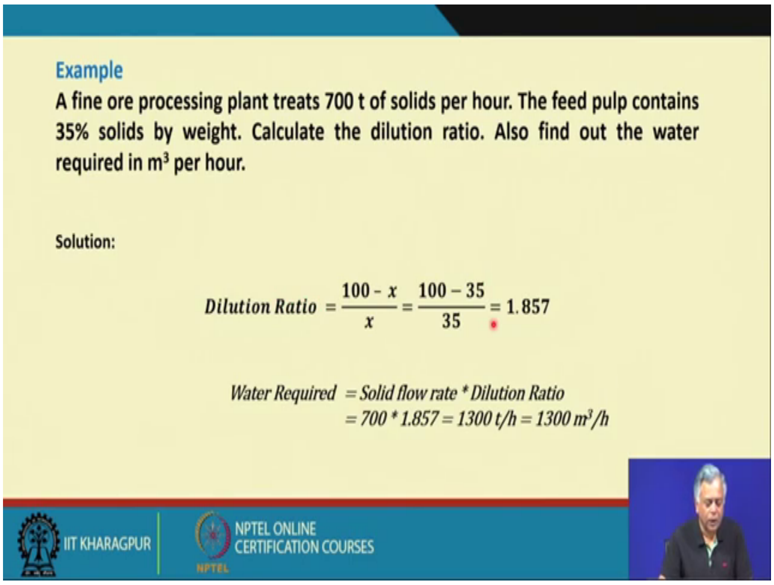

Now let us see that how we can apply this, this is an example I am giving a fine ore processing plant treats 700 ton of solids per hour. So, the plant processes 700 tons of solids per hour, the feed pulp that is your mixture of solids and your water contains 35 percent solids by weight, be careful about this whether it is by volume or by weight. So, this is 35 percent solids by weight.

Now I want to calculate the dilution ratio and also we want to find out the water required in meter cube per hour to maintain that your 35 percent solids by weight in the feet one. So, what I have to do, that is dilution ratio is equal to weight of water divided by weight of solids, let us say that weight fraction of solids is x or weight percent of now it is I am converting it to into in terms of weight percentage so, directly I am writing 100. So, suppose it is the x percents solids. So, if the x percent solids my weight in the pulp then my weight of water will be 100 minus x.

So, what is the dilution ratio is 100 minus x divided by x, but in this case the x is given that is 35 percent solids. So, the dilution ratio will be 100 minus x that is 35 divide by x that is 35 so, it is 1.857. Now how I can calculate the water required, the beauty of this dilution ratio is that that is if I know the solids flow rate then if I multiply it with the dilution ratio I also can calculate that, what is the flow rate of my water?

So, now, this is the final processing plant treat 700 terms of solids per hour. So, water required is equal to dilution ratio that is your water by solid multiplied by solid flow rate, you see that how we can use it. So, how much of water you will be required, so solid flow rate multiplied by dilution ratio so, solid flow rate is 700 tons. So, city 700 a ratio is a does not have any unit so, it is 1.857. So, it will be 1300 tons per hour or we can write your 1300 meter cube per hour. So, you see that this example tells you that is how I can calculate based on this concept of simple tab called dilution ratio.

Now I am coming to this I am very sure that this basic concepts of weight percent solids or fraction weight of the solids percentage, solids by volume or fraction of solids by volume, pulp density your percentage your dilution ratio all these terms you are familiar with by now. Now as I said that we need to know the balances because we need to control we need to process a certain amount of solid material along with water in a processing plant. So, I need to know that which where my how much of water and how much of solid is going and how much we are taking it out so, how much we have to add freshly.

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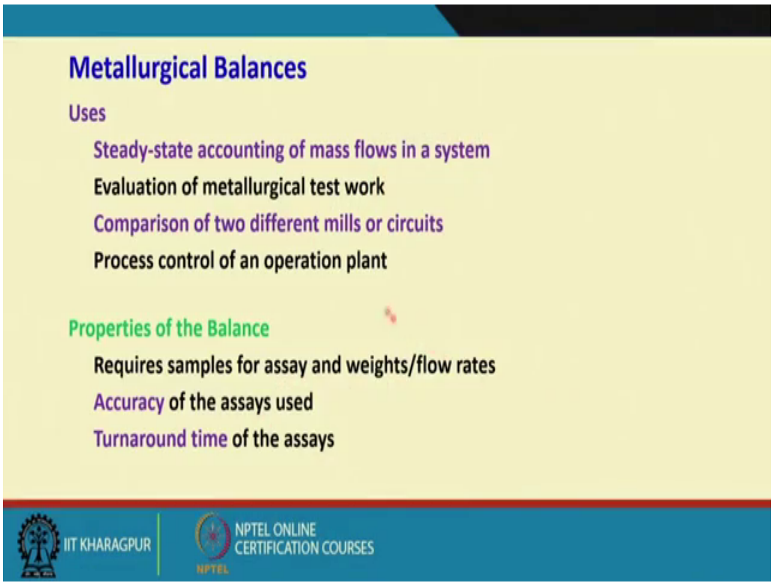

So, matter we call it metallurgical balances, what are the uses for metallurgical balances? Now steady state accounting of mass flows in a system, that is whether my steady state means is input is equal to output; that means, there is no change in my flow conditions with time or the change in flow rate with time. So, it is in a continuous mode material going in inside a box and then going out at the same rate so, that is the perfectly balanced.

So, whether that is being done; that means, whether some material is getting accumulated inside your equipment; that means, whether I am or maybe whether we are losing some material in the process whether if there is some leakage into the pipeline then I may be losing some material in between. So, that also I can find out based on this mass balances then your mass will never be balanced.

Evaluation of metallurgical tests work at is many a times I need to know that my say suppose I am processing a copper ore it has got 1 percent copper in my feet. So, I need to produce suppose I have got a it is linked to with my mineral plant is linked with a extraction plant. So, I need to produce 100 tons of copper per day now for that it is 1 percent in 1 percent in my feed. So, 100 tons of copper I need so, how much of ore I have to process it is 100 into 100 that is 10 to the power 4 tons of material I have to process say suppose per day so, I convert it with power hour basis.

Now one day I see that I am having 80 tons of copper produced. So, now, I want to find out that where is that 20 tons of copper has gone; that means, it is not 20 tons it is now 20 into 100 because we have got only 1 percent copper in your feed. What is that material gone, that I can find out if I do mass balancing in each circuit it each sector that is then I can find out that there is a huge your leakage or maybe some other problem or maybe my ore what I am processing that is not having 1 percent copper it is a much lower grade copper and that is why my ultimate productivity has gone down.

So, that is for metallurgical test work we can do it they comparison of 2 different meanings of circuits suppose I have got 2 parallel circuits, both are having a capacity of 500 tons off per hour that the design capacity. Now I want to compare that whether both of them are equally efficient how I do it. So, I have to take representative samples from each stream that is your product stream and I have to do the balancing that is how much of water is going, how much of solid is going and even we can do it for different particle sizes even based on the we can do the essay analysis of the materials and then we can get back that is then we can finally, conclude that both my circuits are working perfectly or maybe there is some problem with one circuit because another circuit is working much better than that we can find out the faults.

Now, process control of an operation plant that is if we have how we can have a process control, that is now with the availability of the sophisticated equipment measurement measuring equipment like we can have now online flow meters, even we can have some online essay analyzers like for pool processing plants we have got your automatic s analyzers. So, s is nothing, but an essay it is like your quality check of your whole.

Similarly we can have some kind of your say the mass flow meter that is by percentage of solids how much it is going. So, when we are getting this data these numbers now if we know how to use them for metallurgical balancing calculations, then can get to know the health of my plant and if we know that the problem is here in this circuit then we can rectify it accordingly as I have written that is for process control of an operation plant.

So, what should be the properties of the balance, that is it requires samples for assay and weights or flow rates now you see that what is the importance of your sampling now you have to take representative samples and you have to do assay analysis, you have to correctly measure the flow rates or maybe the mass flow meters there should work perfectly then you can do the balancing in a right manner.

Accuracy of the assay is used we have already discussed about the importance of accuracy and precision in my lecture on sampling. They turn around time of the assays how quickly we are getting this data because by the time I do mass balancing with this, but if this your say data acquisition time is taking too long, they might turn around time for the your mass balancing calculations and then for taking remedial measures for betterment of my circuit performance would take a long time by that time we may be losing some good amount of material as well as the money.

We will continue this lecture I will show you more examples that is how we can use this your mass balancing or metallurgical balances for all this that is your process control and of operation plan and how we can compare the different means of circuit performance with some simple numerical examples in my next lecture till then.

Thank you very much.