Bulk Material Transport and Handling Systems
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Lecture – 13
Basic Design Calculations

Welcome back to our discussions today, we will be talking about the basic design of hydraulic transportation system which is also called your slurry transportation system.

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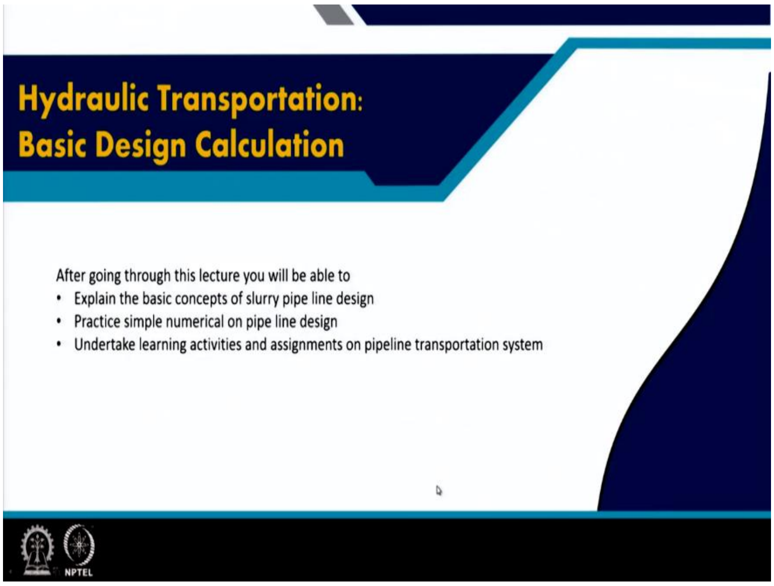

So that after going through this lecture, you will be able to explain the basic concepts of slurry pipeline design and you should be able to practice some simple numerical on this pipe design calculations. And also you should be able to take up some learning activities and assignments on the pipeline transportation system and there is a wide range of literature available and also there are quite a variety of experimental studies carried out on this slurry transport and pipeline flows.

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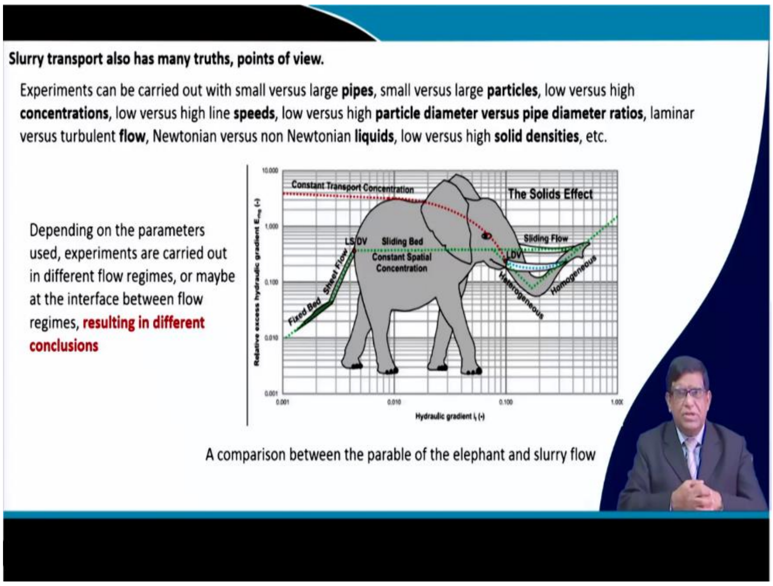

So, you will be finding out that there are many routes regarding this slurry pipeline because there could be wide variations, there would be very large pipe and very small pipe. That pipeline transportations can be used in a plant or it can be for a very long distance conveyor and also there could be wide variation of the concentrations that means, even with a very less particle suspended in a fluid or it can be a very highly concentrated fluid.

And also they can, they can travel with a different speed with different pump capacities. And also there is a how they are related with the particle diameter and the pipe diameter, their ratio it can have a wide varieties of things, there could be graded material and ungraded material going over there, there could be a big solid along with some fine particles of it and then they are traveling.

Then there could be the flow in the pipe could be laminar could be trouble and then this liquid can be that they can be having like a Newtonian fluid or it can be a plastic fluid being lumped with different type of system could be available. And depending on these parameters then the different people have given different way of doing the calculations. So, once you start studying about in different articles and different papers.

You may get confused that which is to be corrected which is to get it which is to be rejected or whether, if sometimes while reading one you may feel the others have gone totally wrong, but thing is not I think you know that story of the elephant and the blind man. Exactly, when those 6 blind persons were looking into the elephant everyone was right. But at the same time they were wrong.

Similarly, in case of hydraulic transport, slurry transport, different people have studied different aspects and they have come to different conclusions. Pitch conclusions may be right at their end, but thing is that and when you go for designing a thing with taking one result may be the other thing can be, this is exactly a problem of multivariable functions dependent design.

So that is why I say that you need to be a little bit careful about which particular formula to be adopted or which unless and until for your particular site installations, if you do not carry out your own experiment because that when you are doing a mineral transport or in a particular specific every site they may be having a totally different type of arrangements. So, mainly when we talk of some long distance industrial study pipeline.

We often talk of that how in the US for the that is your oil sand that is tar sands are being transported from the mining industry. We talked yesterday in the last class about the black Mr. Cole pipeline. Similarly, we have this iron ore could remix pipeline or the gene pipeline or the newly coming pipeline everything depending on the site conditions when they do that can be a different one.

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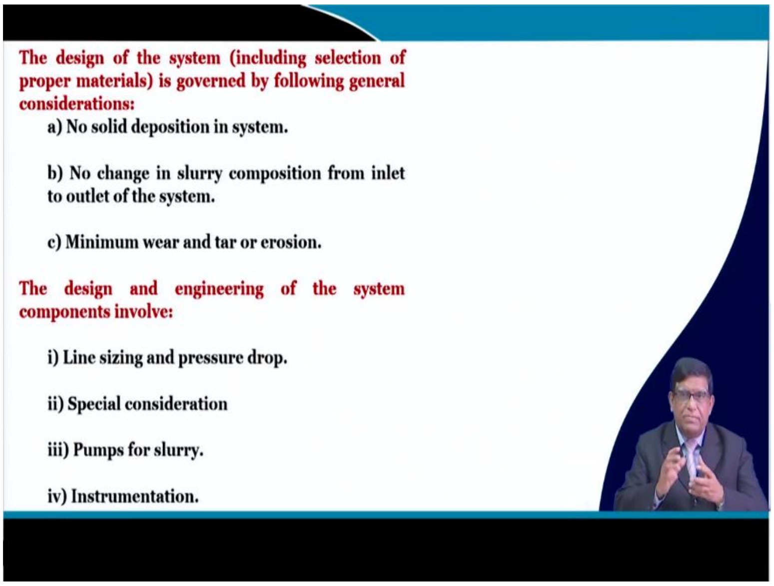

Now, the design of a system that is exactly it will be based on what type of flow resign you are going to consider. And then how in the pipe the particles will be behaving the response of the particles to that particular flowing system there you can find out one thing is there that the design and engineering of the system components involve line sizing and pressure drop. That means, what should be the length, what should be the diameter of the pipe.

And then how exactly the pressure is dropping that pressure gradient because only on the based on the pressure gradient you will be getting the velocities. So then some of the cases you may have to get some special considerations because, if it is the particular is wearing with abrasive in nature, if the mixture that oil and that water and particular mixture, if it is highly corrosive and then there will be a different type of situations.

So that slurry pump you will have to select there the design also depending on what type of pump, what will be the pump size and how many number of pumps will have to be there and then you will have to while you are doing the whole total design, how you will be doing the instrumentation also will be coming into picture.

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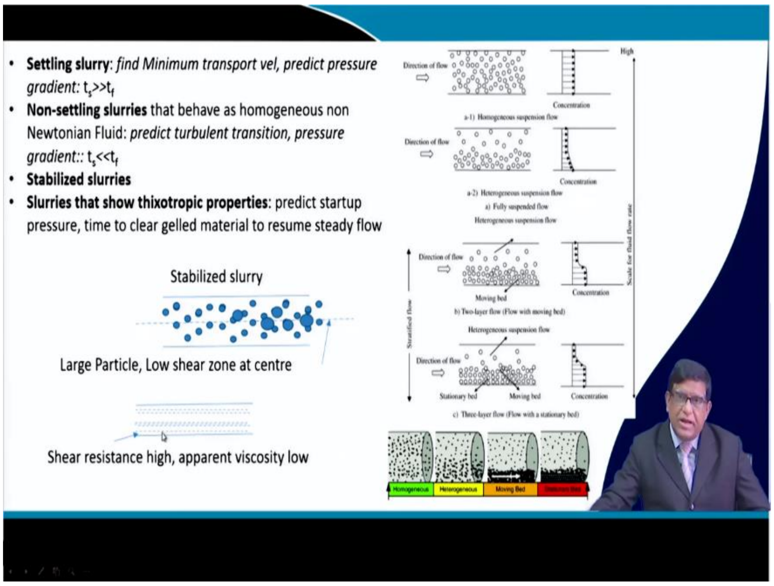

Now, for that one very important thing is you will have to consider what type of flow is taking place. Now that could be a settling slurry or it could be a non-settling slurry or it could be a; that is your stabilized slurries or non-stabilizing slurry. Now, you can see over here that is a when you see this particular type of pipeline of where the particles are very uniformly that is almost a homogeneously.

But sometimes it is a heterogeneous the particles are not properly distributed within the pipeline then sometimes there is a total thing getting concentrated in the bottom they are getting a settling. So, it is a celebration or there is a moving bed this whole thing is moving slowly over there at that and sometimes they get deposited over there only one layer will be permanently sticking to it just like here they will be having a stationary bed.

So that means at least 2 that in a stationary bed that whole shearing is taking place above the stationary bed. This is also called your saltation has taken place. Now, sometime when you see over there that whole pipeline design your destabilizing of the slurry for that you will find that the larger particles they will be in the centre portions then sometimes very small fine particles will be around that.

And then you can find out that near the wall there the apparent viscosity will be very low but the shear resistance will be very high. So, depending on these systems, you will have to have that exactly how you will go for designing the whole system.

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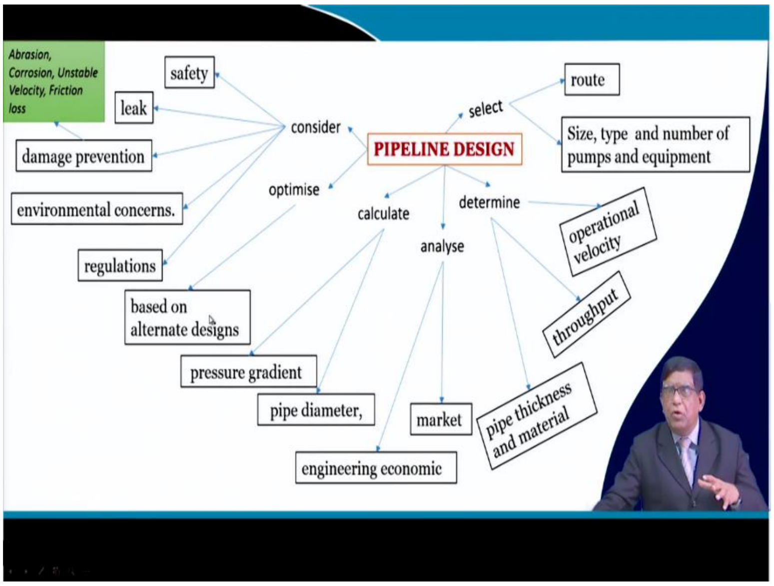

Now, if you see here, the pipeline design it involves your selecting the route and then what is the size type and number of pumps and equipment required for that. That is what exactly will have to seal it after the pipe design. But for that you will have to determine that is what will be the operational velocity and what will be the throughput and then what will be the pipe thickness of the material.

That is your that this is the basic determinations on the basis of your demands in the site. This is the throughput the demand once you load the demand then you will have to find out that at what operation velocity you will have to work and that is to do that you will have to first do a little bit of analysis of the engineering economics and the market. That is you have good number of alternative mode of transportations then why you will go for this slurry?

That is another type of analysis that is done in the design team. But you will have to calculate for pure design you will have to calculate what will be the required pipe diameter for this particular throughput and then what will be the pressure gradient depending on this route you have on a different route, different type of pipe layout can give you different pressure gradient. Then you will have to optimize that is you may have a different type of route.

You may have that different bend you may have different types of diameter of pipe at you may have different sections, you may have different feeding section, you may have different locations of the drivetrain. So, for that different alternative designs are developed and then you will go for optimizing to select which one you will be using for that and for that you will have to make a number of considerations.

That is your safety first that because, if the pipeline it must not burst. Where will be putting a wall where we will be what type of joints will be making what type of control will be there, if it is a highly corrosive material that pipeline will get thin and by that, if the by side some other obstructions come, if it bursts then whole problem will be coming. Because pipeline bursting and then at that time to control it becomes a very big problem.

It is whether it is a gas pipeline, your water pipeline or your oil pipeline or slurry pipeline that you must not get into a situation where there is a pipe burst takes place. And the leak is many times the joint click of the valve leak now that say the selecting the valves, wherever you are to control over there that is very important. Damage prevention is that is the damage or the safety or the leak may come by abrasion your corrosion your other that unusable velocities.

Their friction losses and all that dose damage prevention studies will have to be carried out. And of course, there are some environmental concerns, whether you are going to be a buddy pipeline whether you are getting overhead pipeline or your roadside pipeline. How it will be affecting near the dewatering part? At that time the water which is separated, if it is going to exactly pollute because it may take some of the lead sheets.

If there are source of pollutions those things will have to be seen and of course, the regulations will make. So, does it give you an idea that whenever you want to take a pipeline design, it is designed is always an integrated work.

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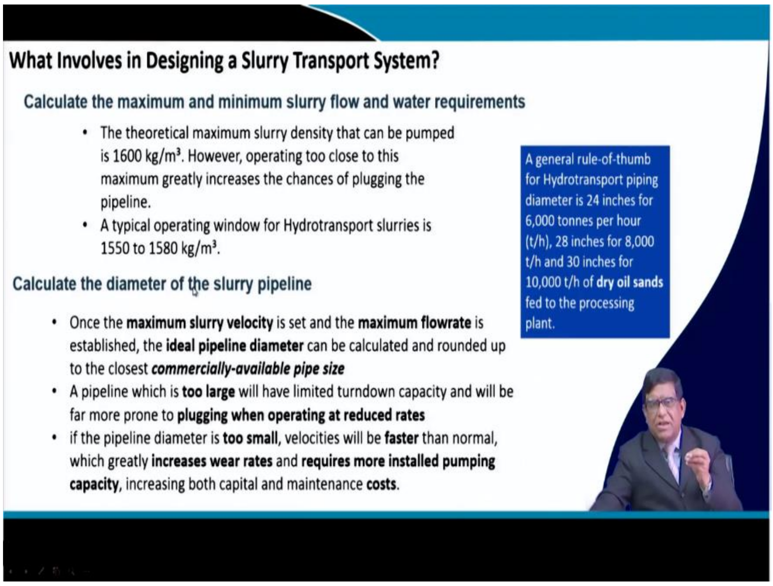

Now, when you go to real doing a selecting a thing, what are the things it involves? It involves your calculate the maximum and minimum slurry flow and water requirements because how much solid will have to be given how much water will have to be given and then how it will be pumped. So, you can see some of the thumb rules that is your a maximum slurry density what material it can be there that is exactly 1.6 tonne per meter cube.

They say that, if that is the materials density is very good but it can be with a higher also depending on taking into. These are all the typical value you can find out that operating that your dependent hydro-transport slurries you are up to 1580. This is considered as an optimal but then you will have to based on your this velocity you will have to calculate the diameter of the slurry pipeline.

Now that maximum shallow slurry velocity once you determine it then you know that what is the maximum flow rate. And then the floor it will be giving you what will be the diameter. If you remember in our first class, we did that how exactly the continuity equation and that gives to our deciding on the diameters. Now, if you take a particular flow rate and then you just find out a number something say 22.5 went to 2.3 or 22.4.

But thing is that you will be selecting whatever is commercially available because, if you want to go a you do not become an odd man out in the industry, so that your benefits are in for your case only it will be very costly. So, now, the pipeline, if it is too large that will be very limited turndown capacity and will be far more prone to plugging is a very big diameter 1, if it is not properly operated.

It may give a plugging and also a work will be there it will reduce rate. If it is very small pipeline then what happened to get the throughput capacity? You will have to run at a very high velocity, if you run into very high velocity then what may happen the particles, if it is getting a rubbing of both sides on the wall and then the your pipe may get thinning and which may lead to a damage.

So, one thing is there a general-rule-of thumb for that slurry transport system a pipe diameter of 24 inches for a capacity of 6000 ton per hour that is that type of values are typical for oil sand. Similarly, you can find out from the design handbooks, what are the typical values being used for different things.

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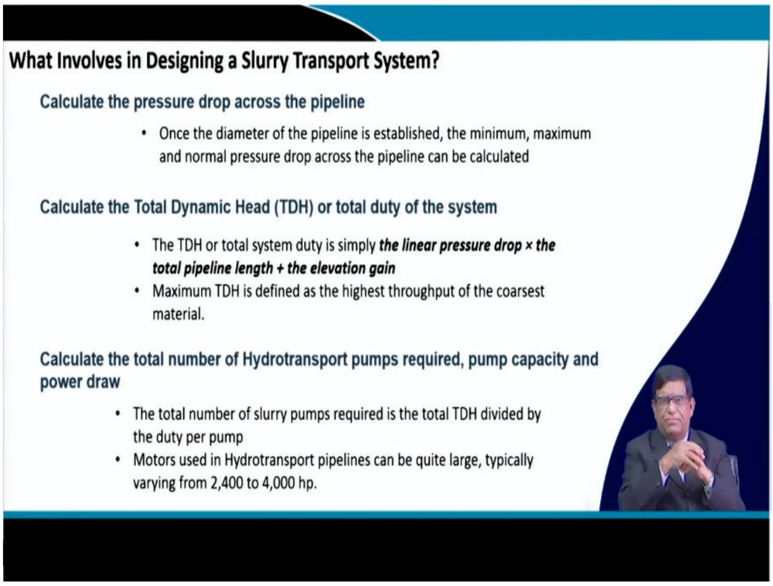

Now, when you are going to design over there, you will have to calculate the pressure drop across the pipeline. How exactly pressure drop is taking because that will be determining what will be the total dynamic head or the duty of the system that means total pressure which will have to be maintained. Then this one exactly once you know that will lead to your design of the pump.

Or that considering or selecting the pump from different pump alternatives as we also discussed few points in the past class. Now, calculate the total number of pumps and then the pump capacity. These are coming based on these 2 things.

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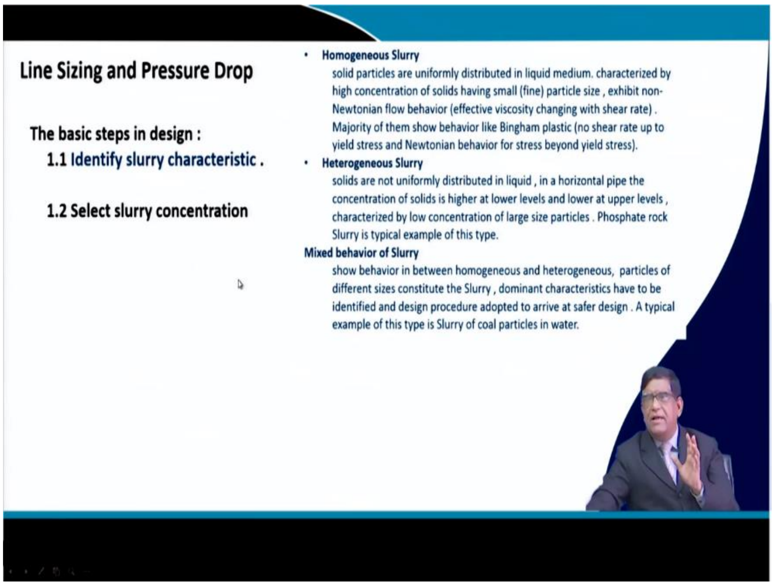

Now, what will be the basic steps in doing these calculations first you will have to identify the slurry characteristics that whether you are taking a homogeneous slurry, heterogeneous slurry and mixed behaviour slurry. As we have said in a homogeneous the particles are there. These will be very important in selecting the slurry concentrations.

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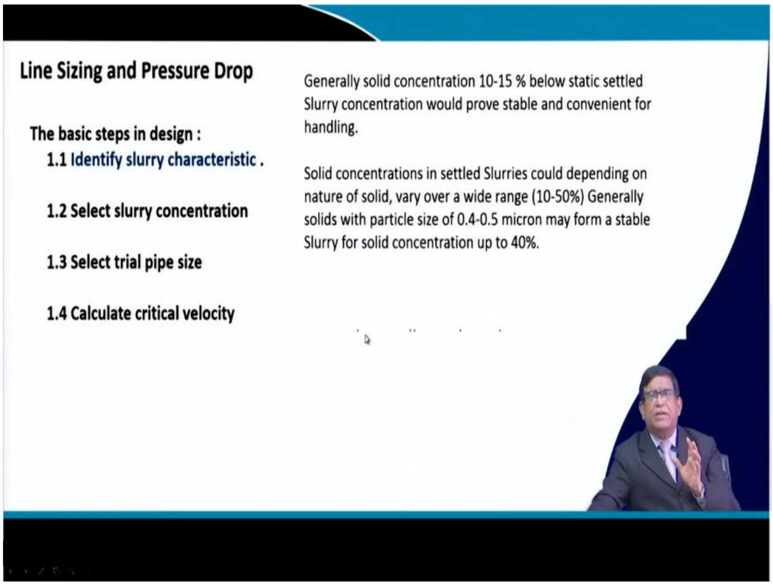

Now that such slurry concentrations normally, so that solid concentrations would be 10 to 15 percentage below static settled slurry concentration that will be giving a stable and convenient handling. Then solids concentrations in settle slurries could depending on nature of the solid vary it can vary with a wide range 10 to 50 percentage and then typically some value of 0.4 to 0.5 micron sizes are used.

But some of the slurries as we say the whole slurry and all there could be that lump size bigger and that concentration can go even up to 70, 80% concentrations. But a slurry solid concentration up to 40% it becomes very stable because that with the water it could be flowing well.

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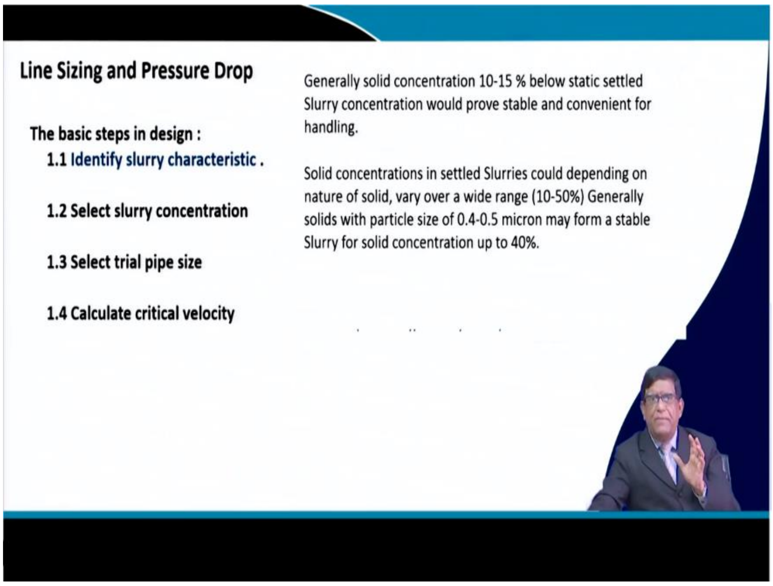

And then you will have to first find out what is the pipe size that pipe size and then you will have to decide what is the critical velocity because the critical velocity will be finding out that what is the volume flow rate? Our velocity and area of cross sectional will be area cross sections and the velocity will be giving you what is the CUSEC that is how much cubic meter is being traveling per second multiplied by density will be giving you the tonnage.

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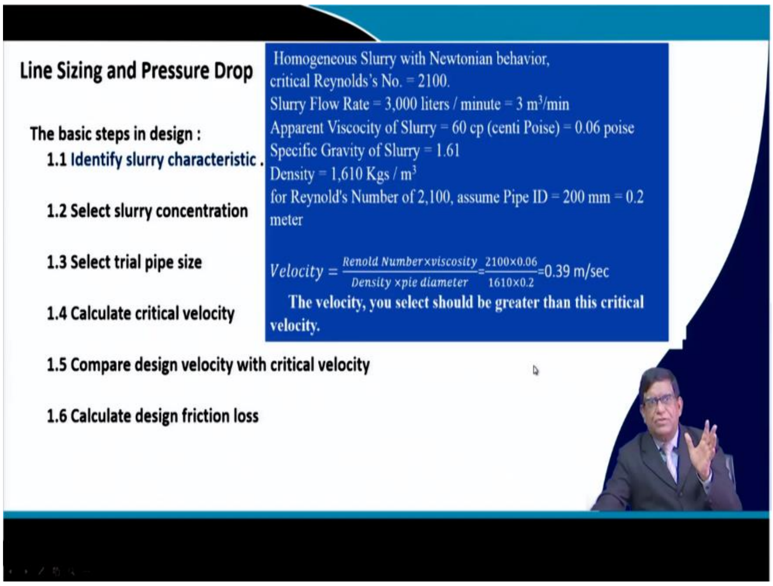

So, this critical velocity is again another important point we have told you over there. That is when the particles will be moving over there because of due to gravity it will be having a settling velocity we did not set that is it will be a tendency to settle down. Now that is very important. Now, they say when the slurry will be having a you are just taking a simple example here.

If you are a Newtonian slurry behaviour that Reynolds number yesterday we told you that there is a it will be a linear flow up to 2100 this Reynolds numbers value. And now, if we are considering a slurry flow rate for a particular case is a 3 meter cube per minute that is your 3000 litter per minute you are carrying. And then the viscosity of the slurry is taking say your 0.06 poise.

Then the specific gravity of the slurry also will have to be taken let it be 1.61 because the density it is given 1600, 10 kg per meter cube. These are the site conditions which are given. Now, here the pipe diameter it is for different flow commercially available, we can start with this wider that 200 millimeter pipe diameter that is 0.2 meter pipe diameter is taken. Then from here you can find out that from the Reynold numbers.

You can get the value of the velocity at which the flow in the pipe will take place. So, this is how the velocity is calculated. So, in this particular case you have got 0.39 meter per second. Now, this is to be checked, whether at that velocity that particularly settle down or it will flow. That is what exactly once you calculate out it does some preliminary basic informations given you get a particular velocity then you need to check whether this velocity is okay or not.

Because it should be you are more than the critical velocity. Now, the critical velocity and the friction loss and then the pressure gradient that will effect.

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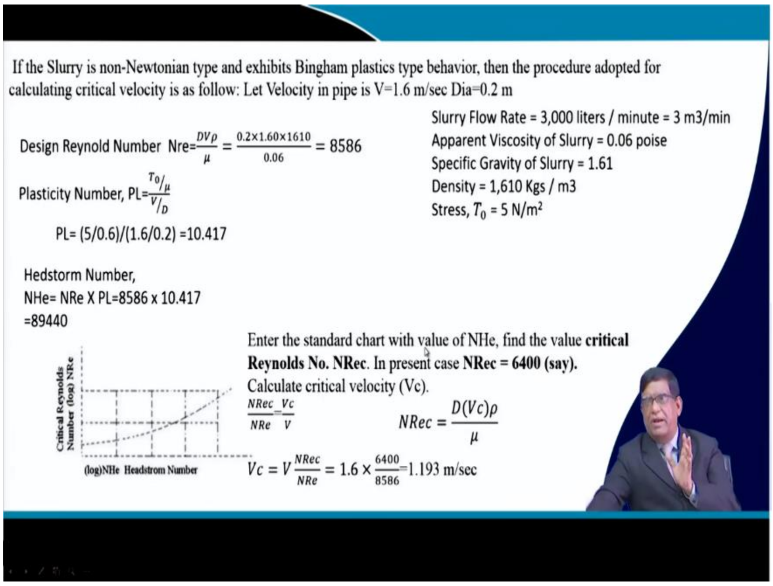

Now let us continue with the discussions that once you have got the same value, so, your to find out whether it the critical velocity it will prove or not. We will have to follow a procedural things in case of non-Newtonian type and there could be a plastic flow at that time. Exactly your that same Reynold numbers will not do you will have to take a non–Newtonian Reynold number.

This formula is given where you are the these that your diameter of the pipe. We are having this flow rate v rho is the density mean is the viscosity for these given situations where your slurry flow rate and then your viscosity is given specific gravity is given density is given and then also the stress is given then you can find out that this is your Reynold number coming.

Now, 8586 for this Non-Newtonian definitely will be having a turbulent flow over there not a plasticity number. Why you need the plasticity number? Once you know the plasticity number, you can find out a handle Number, Angstrom Number another non dimensional number used in the fluid mechanics which is exactly the plasticity number is your space over your viscosity velocity over that your diameter it gives you this number.

Now, there are a chart once you get this Armstrong number from there that from the design chart you can calculate out what is the critical Reynold number. Now, in this case, when you have got this 89440 is your Armstrong number for that the Reynold number found is 6400. Now, once you find out this that you can find out this is your non–Newtonian Reynold numbers formula, if you take these 2 Reynolds number ratio.

That gives the ratio of your critical velocity and this velocity in the rate. So, now, what you are getting over here that your critical velocity is coming to be 1.193. So, this is the way you calculate the critical velocity.

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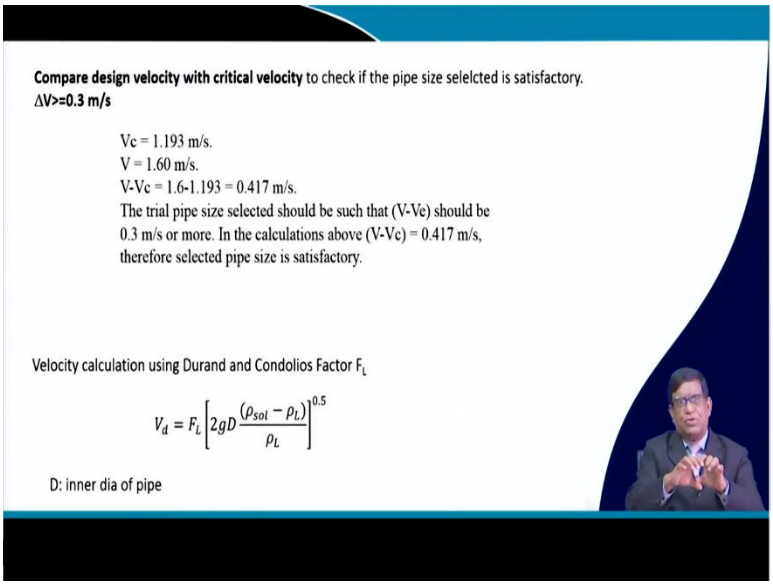

Now, what will be here that is your design velocity and the critical velocity will have to be compared. Now, you can find out your critical velocity is coming this much but your flow velocity it was 1.6. So, you find out this delta V difference between the critical velocity and the your flow velocity, it is 0.417. Now, normally your design in designing a pipeline you consider that, if it is more than 0.3 meter per second.

This division that is it is that your critical velocity is one 3 meter per second less than the flow velocity then your particles are going to move. If it is not there, there will be a chances that after some time that is your some your the calculation will take place or the bid permission will take place that scaling will take place and a lot of problems in the pipeline will be coming.

So, this is what exactly you need to do in a design calculation. Sometimes that your velocity it can be calculated by the Durand and Condolios number F L. There also again your charts are given in the design, what will be the value of that and you can find it out. Now, only thing here as I said in this there are a number of workers have worked on and they have found out a way of expressing it.

And then coming to a at least a engineering work that is engineering work can be carried out so that the problem will be solved. But there is no exactly you cannot use an exact design cannot be again implemented that part you will have to keep it your mind.

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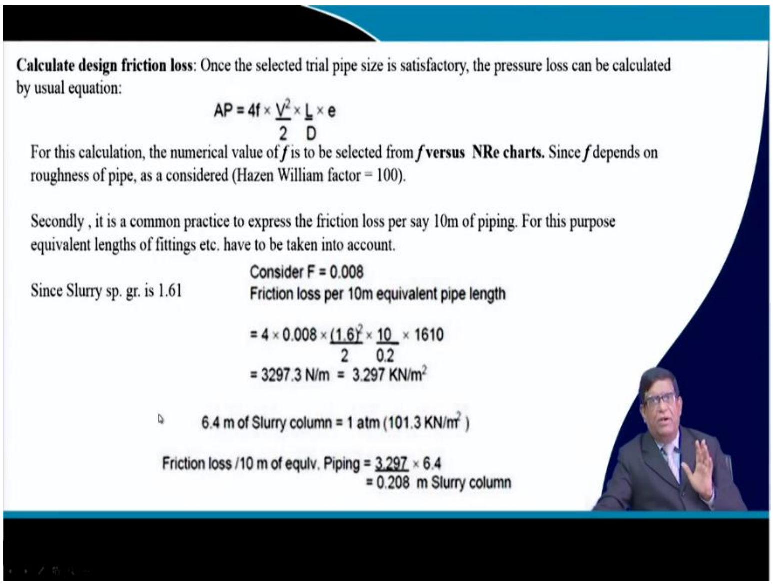

Now calculating the friction loss, there are also these equations are used which will be depending on that what will be the length and then velocity. Now, by using this formula, if you calculate this then this friction value that is your it will have to be obtained from the again the chart which is available. That is your Non-Newtonian Reynolds number and frictions their charts are given.

And this friction it will be depending on what is the roughness of the pipe and many times that is exactly the in the manufacturing of the pipe and the pipe design. They take a different type of how the liner even sometimes so that the settling velocity, if there is a high concentration slurry you are taking even inside the pipe, you can give a helical groups are given over there.

So that it can it just help in flowing the material at the which are in the boundary layers conditions. So, now, it is common practice to express the friction say for a 10 meter of piping for this purpose that you need to find out what is the friction loss over there. Now, if you are getting this frictional loss for a 10 meter equivalent pipe, you are calculating depending on that friction is point 0.008 you are getting that 3.297 kilo Newton per meter square is coming over here.

So, if you find that normally 6.4 meter of slurry column will give one atmospheric pressure. So, under this pressure, you need to find out the friction loss per 10 meter you can calculate it out in this is the way how you calculate the friction loss in the pipe.

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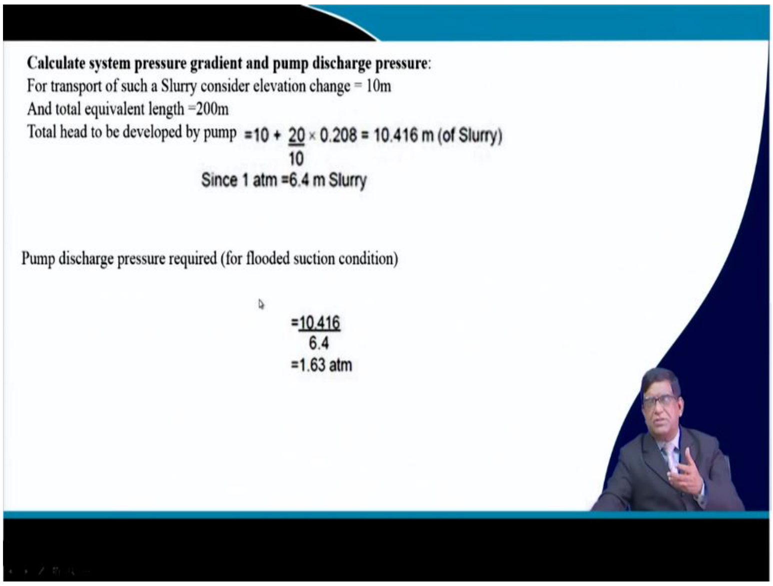

Similarly, you can calculate the system pressure gradient and the pump discharge pressure from the slurry transportations. Your; what is the total equivalent length for that the total head developed by the pump can be calculated out and from here you can find out what will be the pump discharge pressures required. So, once you know the discharge pressure required for the pump and then you can find out exactly how many pumps may be required then you can calculate up.

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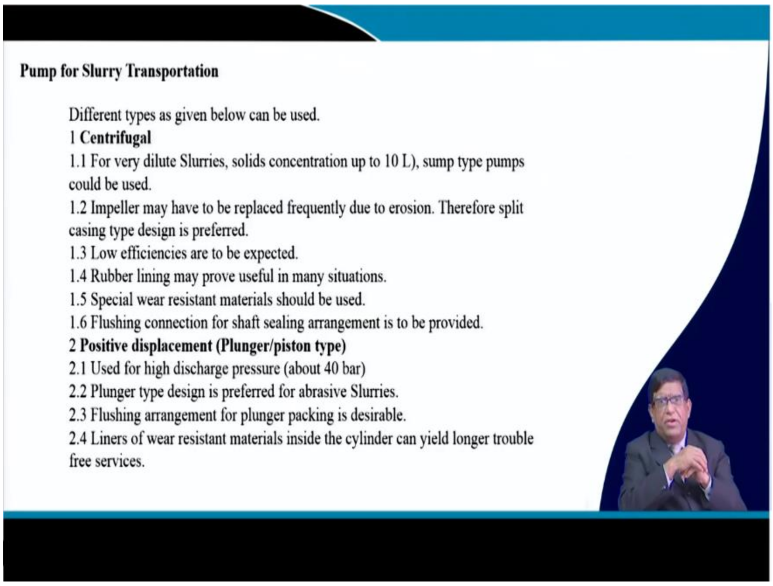

So, the pumping purposes there could be a centrifugal pump or positive displacement pump. Different type of pumps can be used. Normally the centrifugal pump you will be selecting for very dilute slurries solid concentration up to 10 litter than your sump type pump could be used you are keeping in a sump and there from it will be pumping and impeller may have to be replaced frequently in slurry pipeline.

One of the problems while using your centrifugal pump is your impeller will be wearing out because of the erosions and all. Now that is why sometimes within the pump casing there could be a rubber lining maybe provided and also special wear resistant materials are used this to increase the pump life. So, for example, while some carrying a coal slurry and or the mud from an underground mine which is a Shinnick mine.

Some of the pump impeller even it was running only 6 hours 7 hours. So, there had been a lot of things that your metal get worn out so, they are different ever Willis to Mars impeller whether they can be used or not there are a lot of pump design for handling over here. But the positive displacement pumps basically the plunger pump and piston type of pump they are used for very high discharge pressure and for abrasive slurries they are very good.

And then the flushing arrangements and then your can give me a plunger picking and also the liners can be used. So, there are wide varieties of pump. Last class also I introduce you how mono pumps are used in mining industry.

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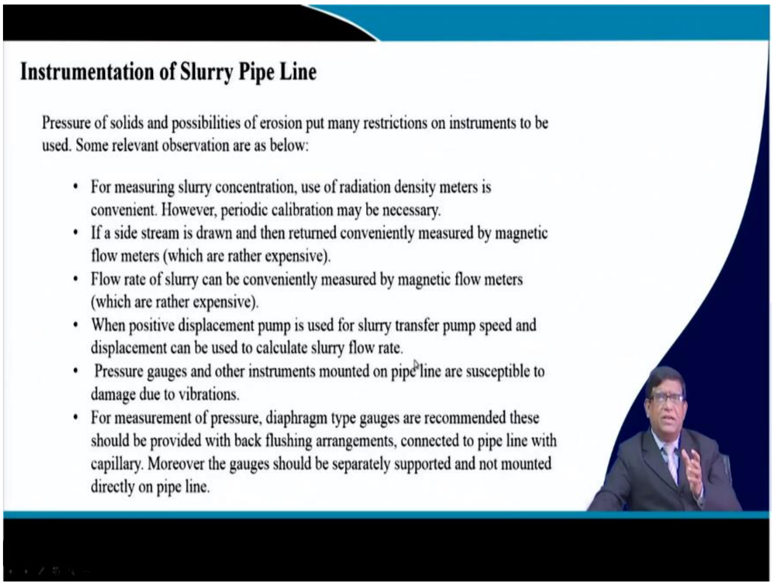

In the instrumentation side also you can find out there are different type of instruments can be used for measuring the slurry concentrations sometimes for the that you need to get to what is the flow velocity then you will have to use sensors in the pipeline to you can measure how the pressure differences are coming. Now, it is very advanced Mechatronics sensors are available and the whole study pipeline instrumentation as an another subject in the oil industry and pipeline transportation industry.

Now, normally put the measurement of pressures, lot of a different type of pressure gauges, different type of pressure instruments are there, now, many directly also you can be inserted and done, but there are many indirect methods have also developed.

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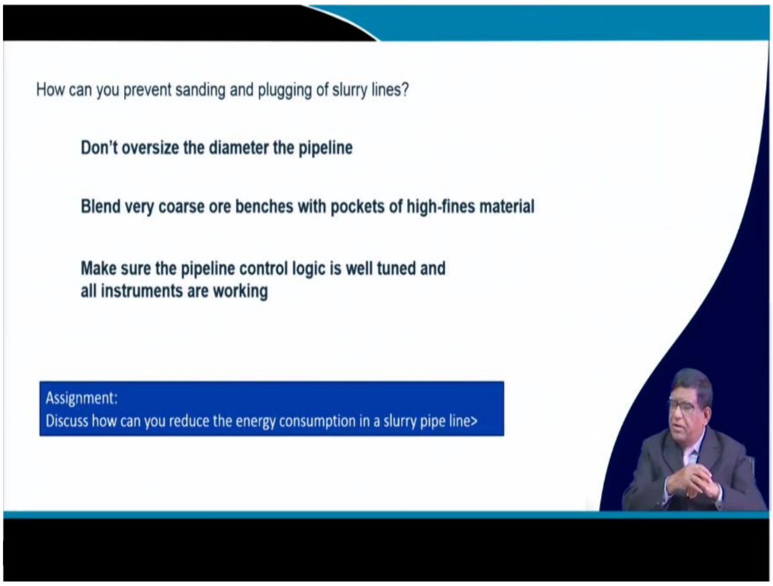

So now, one thing is there that the problem was within the study pipeline that teach your deposition takes place and then sometimes it may happen that it has got totally blocked. Now, depth when it is having a plugging then to the reason is you, if you make your oversize pipe diameter at that time it will be contributing more to the shuttling and then your for this purpose so that your plugin does not take place material remain suspended.

If you take some very fine particles along with the coarse particles then also it runs better way. But nonetheless keep some materials are getting deposited in the pipe and it is getting plugged. How do you do it? The operations which are done in the pipeline industry is called pegging the peaks are used for cleaning the pipe. Now, what are the peak is a small device which can be made to move along the pipeline by pushing it can take up all the material.

In the oil industry that for crude oil and then it does the pegging particularly, if you see in Canada or in Alaska in oil pipelines are there during that that many times this get plugged they get them sometimes in the winter season then they will have to do the pigging operations frequently. So, similarly, there is a separate pressures people have developed different types of peak to clad do the operation.

So here is an assignment I would like that you should do it that is discuss how to reduce the energy consumption in a slurry pipeline. That energy consumptions can be in your for non settling liquid there could be a different type of problem and settling liquid. There could be different type of problem but for that your by reducing the slurry concentrations your energy requirement will become because your resistance you are reducing.

Now, if you increase the particle size then also your overall energy reductions may take place. So, there are many way you can do in case of your settling the type of slurry you sometimes add sump so that your energy because flow become better and then your energy consumption become less. Sometimes they add some fibers also. Then there are also the flocculants are also used in the slurry pipeline for better energy utilization. So, those aspects you try to study over here.

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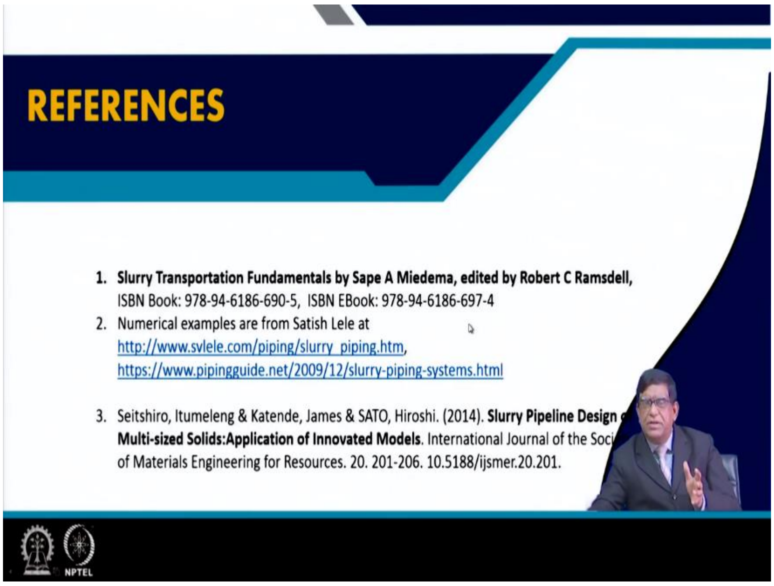

And then there are wide range of literatures as available but I have given few things which you can study.

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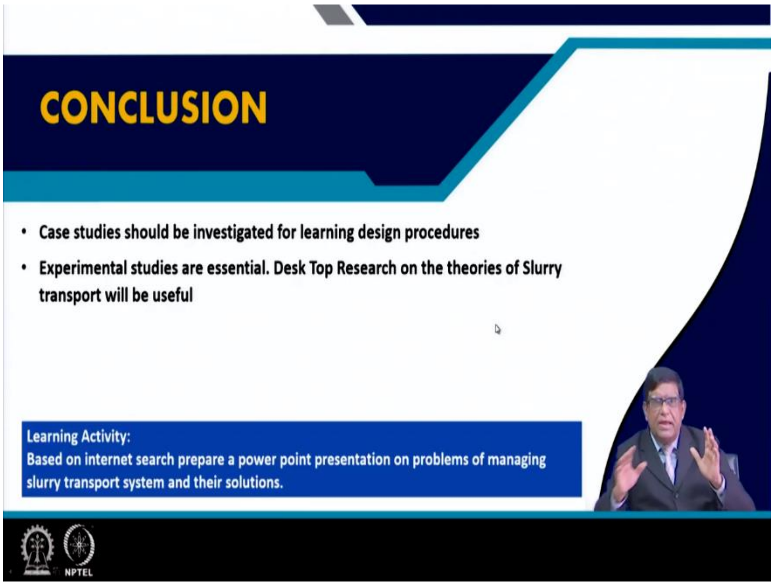

But a case study should be investigated that is what is a because such type of things you will have to learn from what is there over here. So, as I said I have given some examples like black my circle slurry I have said about the; could remove iron slurry, or zinc mine in the river mines slurry or that your Odisha mining. Still that is arsenal metal they are now, having those study pipelines they are just being erected so, you can see their design.

And then in the operational what type of problems come. And then you can study from the literature some of the experimental study how they have done and that will be giving you can do a desktop research find out categorically that how that slurry transportation have been designed and used. So, a learning activity you can take up as a based on the internet research prepare a power point presentation on problems of managing slurry transport system and their solution.

So, because in a slurry transport system how you exactly prepared a material for putting into slurry study pipeline? How it is inserted into the pipeline? How it is exactly pumped from the whether you are having a sump or whether you are having as in some of the tailing disposals you can find from a thickener you are pumping it over there. So, different type of ah industry has got a different type of slurry transportation system components.

Now how they are managed? How it is monitored for managing? You will have to measure something when you measure, if you can measure then you can manage. So, for managing of the Trans study transportation system what are the things measured? That is how you keep record of the pressure gradient how the pump readings you want to measure or by monitoring the motor energy consumptions level you can know about the health of the slurry pipeline.

So, these are the things you will have to study and then I think you will be able to take up some work related to slurry pipeline design. So, I hope the basic understanding of what is a slurry transportation system in the bulk material handling it is there. So, with this I have completed about the introducing to the slurry pipeline with water that is liquid slurry maybe in the next class we will be talking about pneumatic conveying how air can be used. Thank you very much.