Bulk Material Transport and Handling Systems
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Lecture - 15
Design Calculations for Pneumatic Conveying

Welcome back, in our last class, we introduced, what is a pneumatic conveying?

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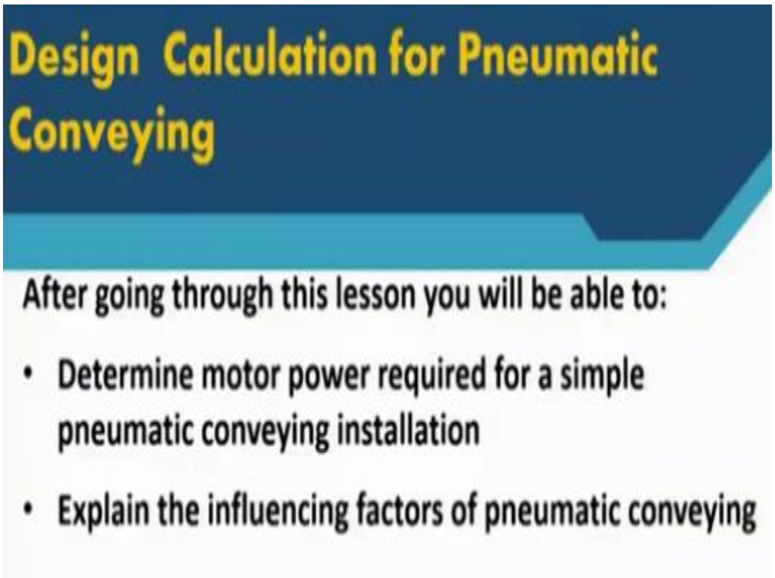

We will today further discuss on this pneumatic conveying so that you can determine the motor power required for a simple pneumatic conveying installation and so that you can explain the influencing factors of pneumatic conveying. Whenever you are going to select a particular conveying system, what are the main points or that main influencing parameters you must consider so that the behavior of the transportation system goes according to your will.

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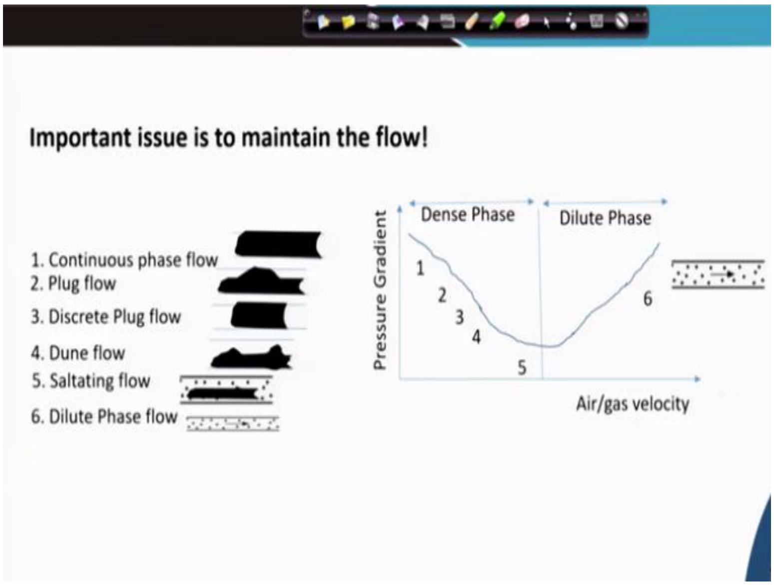

So, for that, one thing you again recapitulate. In our last class, we told that this different types of flow like your dilute phase flow, your this different dense flow and dense phase flow. In that we discussed about that how pressure gradient and velocity are very important. And then, in which (()) (01:25), the different type of flows will be there. We just very briefly told about this continuous phase flow.

As a dense flow, it can be within a particular pressure gradient. As the pressure gradient goes down and then with the increased velocity, how we can come up to a dune flow where this is still becoming and then after the velocity increases that particles from there will be again taken up. And then, a saltation will take place. And, it will start flow. But, again, when the velocity is further increased with that we get the particles suspended and then we get a dilute phase flow.

This we discussed. But, the important parameter is there that what is a slip ratio? What is your that material factors that is how much exactly the concentration. How it will behave.

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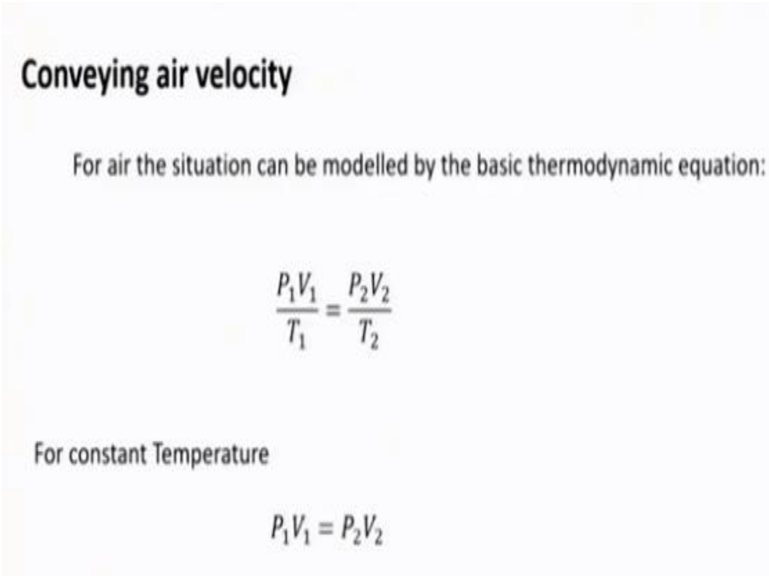

Those things, we will be discussing today. But, for doing this, you know that whenever you are conveying they are transporting the material with a, in a pipeline with some gaseous material, this universal gas law that from the thermodynamics is replicable. And, you know this is a very all of you know this formula P 1 V 1 by T 1 equal to P 2 V 2 by T 2. That is from that law, (()) (02:50) law.

We consider and in designing, it is the starting point we will have to do. But, saying is that the pressure gradient or that pressure differences which you will have to maintain between the two ends of the pipeline so that the material or that gas will be flowing along with the material. But, during the time, if the temperature changes the whole flow phenomena will change.

So, in normal cases, in one room, or in a particular distance, when you are designing a system, we consider the temperature working conditions is remaining constant so that we can use only that PV equal to constants. Boyle’s law will be followed over there.

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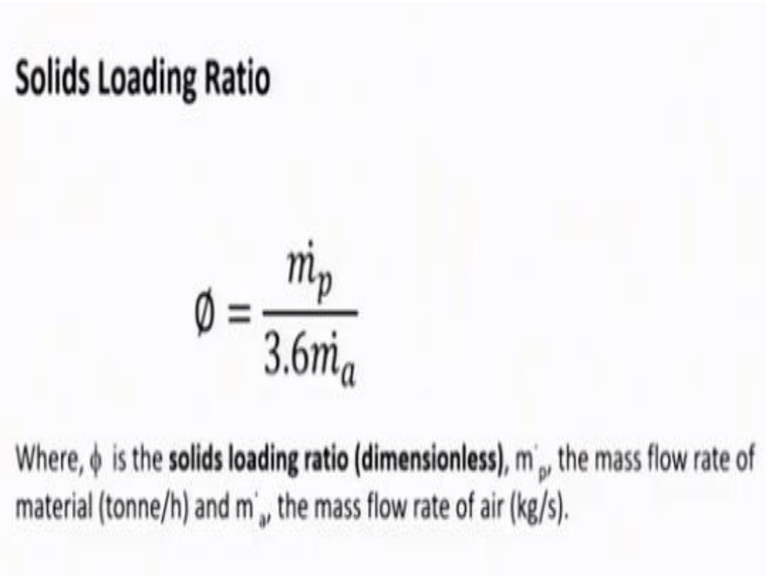

And then, this is another important parameter that you need to know about the solid loading ratio. That is where your this ratio we have determined here as a phi where your m dot p is the mass flow rate. That means how much material is flowing. So, there again, this material mass flow rate whether that same thing what you have introduced into the pipeline from your the rotary feeder or your venturi feeder.

And then, what exactly you are getting it may not be the same. But, thing is that at any particular area, any particular length of a pipe, what is the total content of material? How much tonne of material is exactly flowing per hour? And then, this, what is the mass flow rate of the media? That is you are using air or in some cases nitrogen or other gases you can use. So, that flow rate is normally the, a gaseous media. That flow rate is given in kg per second.

And then, the material that is given in tonne per hour so that to bring it to a, that is a dimensionless number. We convert that tonne by multiplying by 1,000 and then hour into second by 3,600. That is why that 3.6 is coming, you know about it.

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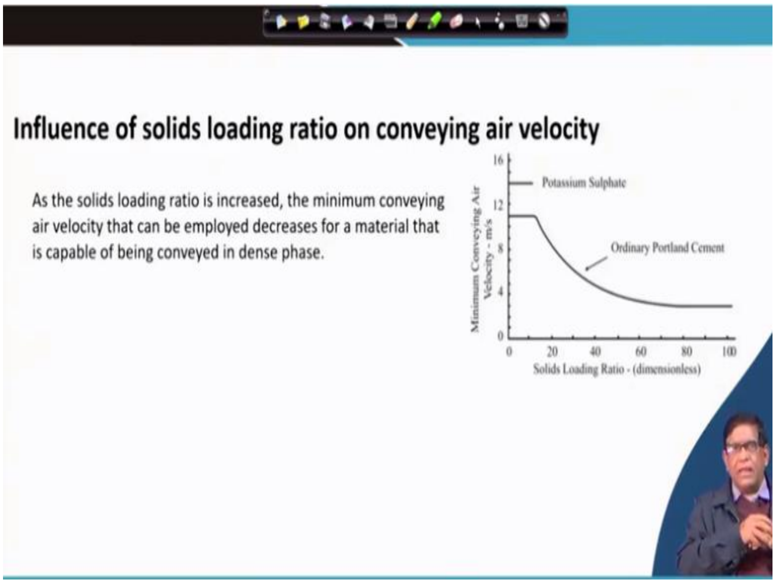

Now, that your solid loading ratio it exactly plays a very important role in pneumatic conveying. Exactly as the, that your loading ratio is increased, the minimum conveying air velocity it gets decreased. You can see here. That is, your, the main velocity here is less but that your solid ratio is coming more. That means if you want to increase your solid ratio and then you want to increase the, this velocity also, it will be giving certain problems.

Particularly with that your the time of type of your wear and tear of the pipe will take place. The particle particle the collision will increase. Your energy required will be being more and so many other things. So, it is very important while designing that for the particular material which you have selected that one their solid loading ratio will be working how or how it will be changing with the air velocity.

Now, the solid ratio that loading ratio event is coming as a tonne per hour you know that it is the density of the material it is very important. So, that is why that velocity at which you will be say transporting a food grain or if you are thinking of transporting a oxides, metal oxides which can has got a higher density of the particle that will be exactly varying.

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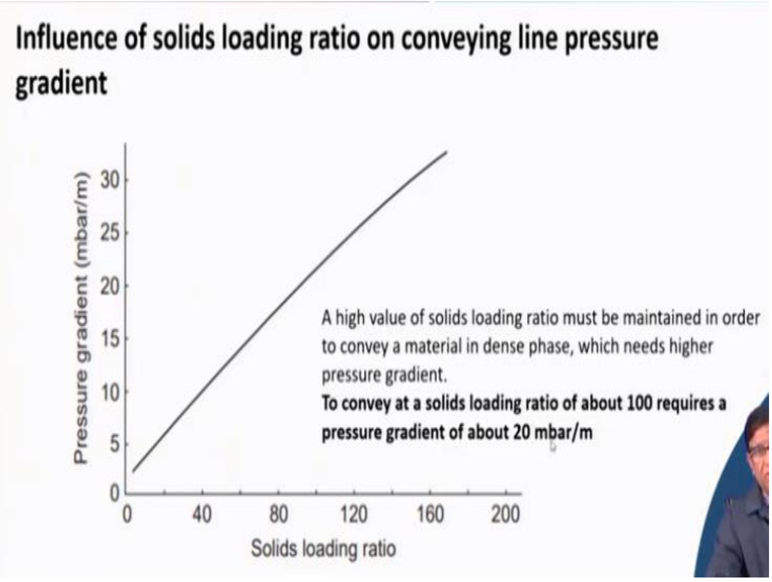

We will have to look into that how density matters. Moreover, another thing is there if your solid ratio solid loading ratio is higher, you will have to maintain a high pressure gradient. When you have to maintain a high pressure gradient that means more energy will have to be introduced into the system. So, that is why you will have to optimize while selecting your system that exactly how much particle and how what concentrations you will be exactly getting.

So, that means your delivered concentration, delivered rate will have to be considered on the basis of this pressure gradient. Now, again that pressure in a, cross sections of a conveying pipe, it will be depending on the diameter of the pipe also. So, whether you will be having only in a uniform diameter or at the loading point and at the near in certain curves how exactly the dimensions of the pipe will be changed.

That also will be an issue while designing. So, normally, that is for a solid loading ratio of about 100 it required that pressure gradient up to 20 millibar per meter. So, that type of pressure to be maintained. And, for that, what type of compressors capacity and how will you select that motor power for running that compressor.

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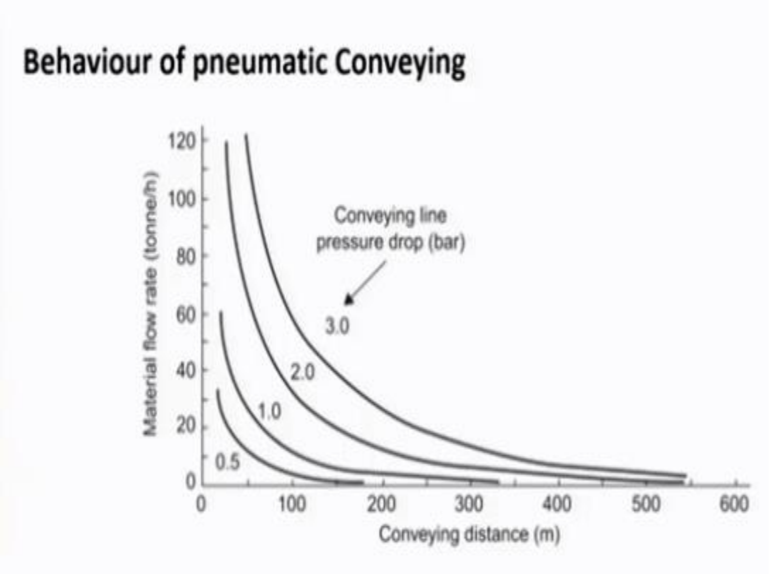

So, one thing is there. Again, this graph, you can see that your conveying distance you remember in that earlier class I told you that in your hydraulic conveying we can go 100 kilometers. But, in our pneumatic conveying, we do a very less say one of the longest one of the very long conveying of flyers is there I told you about the roper this electricity super thermal power stations where they have got about the more than 2 kilometer.

About 2 kilometer, they have doing (()) (08:33) pneumatic conveying. But, you can see here when the distance increases, the flow rate material flow rate that need to be maintained very less. When the material flow rate is to be maintained less that means your productivity that will be again a matter of your concerns while designing. But, only thing is that this relationship of your material flow rate and the conveying distance is also your related to your conveying line pressure drop.

That pressure drop is a very important aspects in a pipeline transportations. Now, when we say the pressure drop, you will find that this pressure variations in hydraulic also. You say that we say sometimes it is a head hydraulic head. We can, we say sometimes it is that exactly gradient. Now, all the things are the same.

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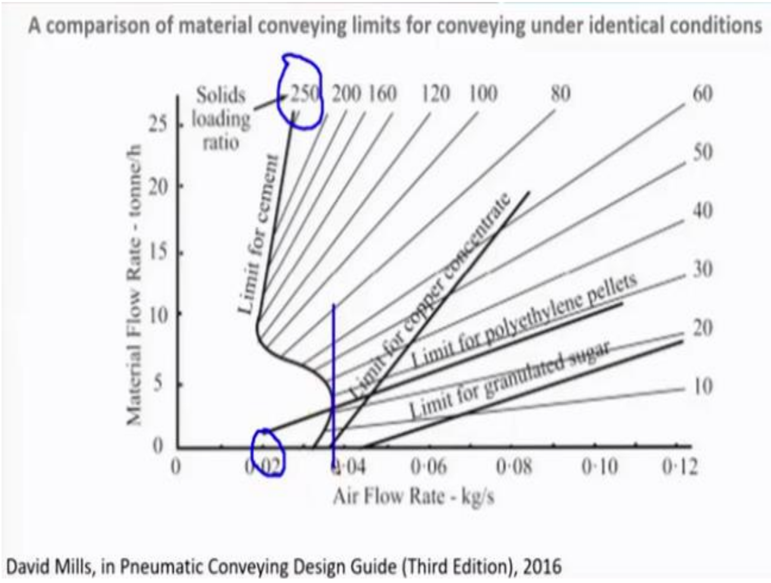

The concept wise you will have to know that exactly your that material flow rate will be depending on exactly how much air flow rate you will be maintaining. That air flow rate and the material flow rate but there exactly if your solid loading ratio is changing you can see here that when your you are having this solid loading ratio you can see at this you are having a very high solid loading ratio.

And, you can see here, the air velocity for this is coming only up to here 0.02 kg per second. So, that means now if that same solid ratio is your reduced to say 80, at that time, what happens? You can see the material flow rate is reduced up to here. And then, you can see here that (()) (10:27) you cannot even bring that at such a low (()) (10:33) ratio will not be giving your air flow rate. For this ones, you can see here. You will have to take up to here.

So, this is the way how the design graphs will have to be used. Now, coming to this point that exactly how you will be designing it you will have to follow the guide books. There are number of pneumatic conveying design guides are there. You will have to follow. And, many a times, whenever any new installation is to be made, at that time, what they do? There is a experiment laboratory experimentations are carried out.

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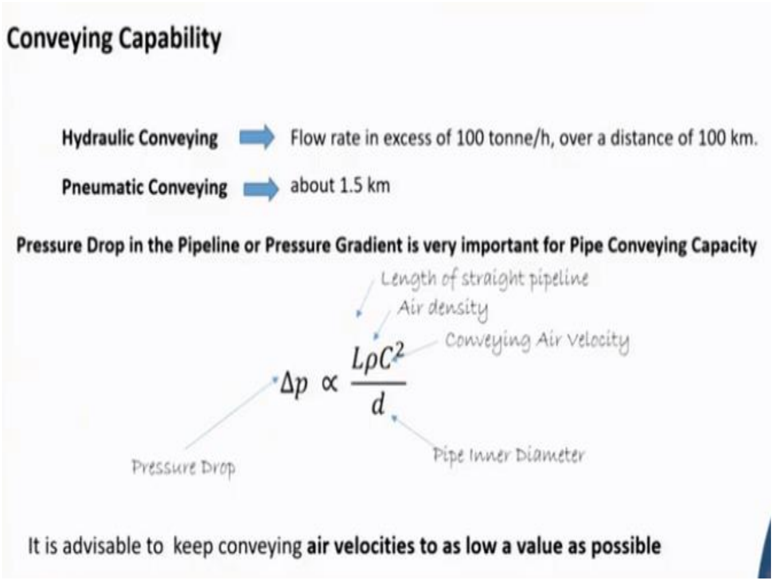

And then, they determine. Now, what you exactly do that experimentation. It is for the your in case of hydraulic conveying, the flow rate you can get at about say excess of 100 tonne per hour for a distance of 100 kilometer it can go. But, in case of your pneumatic conveying, as I said, it is a, for very less distance because that pressure gradient in a pipe conveying follow this one. So, that means you can see that this velocity is squared.

So, that means if your the pressure gradient to be maintained for a particular velocity will significantly change. If you want to increase the velocity rate by say 1 meter per second but that when your that total value will be squared. That means, your, you will have to maintain a very high pressure ratio. Similarly, if your length increases, for there also, you will have to maintain a high.

That is your pressure gradient that your pressure drop will have to be maintained which is also a dependent on the density and also the diameter of the pipe. So, if you see here that the pressure drop will be directly proportional to your this length of the straight pipe. The air density that particular media density and then your this conveying air velocity and the pipe inner diameter they will exactly affect it.

And, that is why for your maintaining the energy efficiency and also for the convenient of that you are getting the proper floor design, you will have to keep the velocities as low as possible. At a higher velocities again, you know that sometimes in fluid flow, if the higher velocities the things will become turbulent. When turbulent, there will be (()) (13:12) and there will be the particle to particle collisions.

That particle will start hitting the wall. And, with that exactly, the frictional resistance from that particle and the wall will increase. And, as a result, there will be more drop. And, that means you will have to maintain a more energy more (()) (13:28) power will have to be put.

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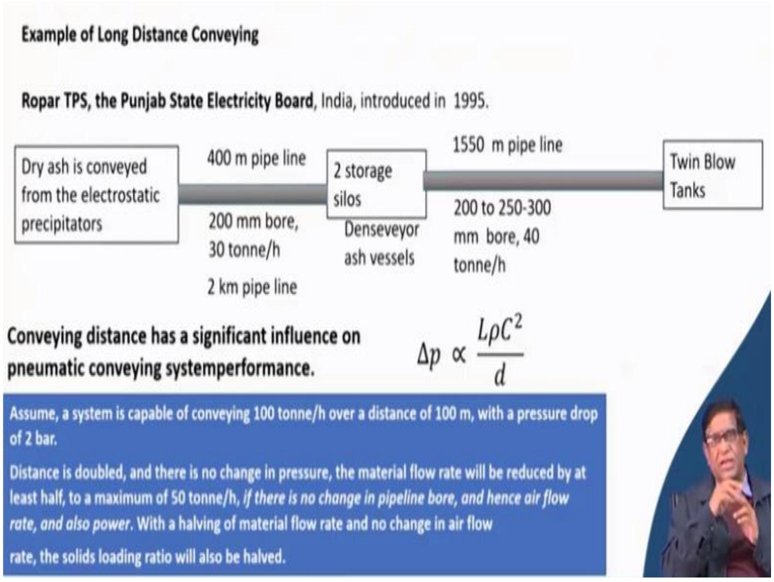

So, this is the basic concept from where exactly you need to even how when we talk about we have talked the Ropar Thermal Power Stations, their flyers transportations. They do in a 2 stage. What they have done? For there, this is a very old installation in India. In 1995 itself, at Ropar, Punjab State Electricity Board they did it. The first 400 meter pipeline they are using a 200 millimeter diameter and they are giving a 30 tonne per hour flyers for a distance of 2 kilometer.

They are storing it in a silo. After that there is a denseveyor ash vessels as particular type of ash carrying vessels they load from there. And now, because there is a cement plant that cement plant at a distance of about 1.5 kilometer, 2 kilometer, there, they have got a twin blow tanks, the specially designed your vessel or that container on which they will be stored. And, from there, they are transferred to the steel plant.

So, there, again, the diameter it is up to 250 to 300 millimeter and because here that capacity is 40 tonne per hour. So, they have designed such type of systems which is working in India. Now, this conveying distance that will exactly influence the whole design of the system because you can see here if you consider any value and by that go on varying and you see by dropping and you can yourself draw some graphs from that value.

And, you can find out that what is that exactly significance of each of this parameter. So, that is an exercise you can do. Take some your just representative values. Draw a physical graph. And, you see that how exactly if you double the diameter, what will be happening? If you double the distance, what will be happening to the pressure drop? Now, while all are changing, your 2 are changing, 1 is changing. Under different conditions, you can draw some graphs and check, how it is.

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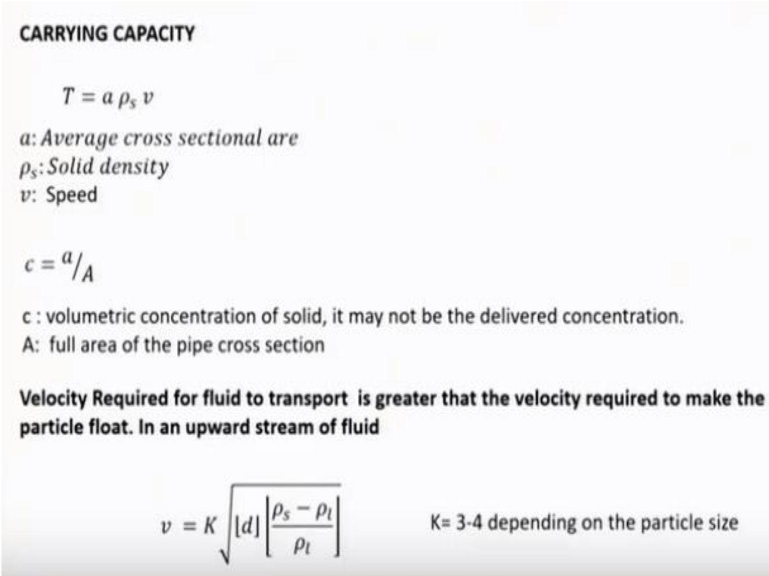

Now, let us see how we will design exactly a system. For designing, you will have to first know that what will be the total carrying capacity. That is how much material it will carry. Now, one thing again, here, you must say that what is your introducing rate and it may not be the, your, the delivery rate because in between there may be depositions there may be other things may coming.

So, that average how much it will be there, at a, if we consider whatever you have introduced whatever the cross section of the material is coming over there in the pipe that will be continuing over there for a distance. Then, you need to know, what is that cross sectional area of the material inside the pipe? And then, if you know the density of it and you know the speed then you can find out that this much material tonne per hour you can calculate.

Then, this concentration that will be what, exactly, it will be depending on that what is the material cross sectional area if you consider those material only compact together. And then, how much area it will be taking? And then, overall the whole pipe area, their ratio is the concentration on a cross sections. And then, you can find out that velocity of the fluid for transporting this one, it must be the velocity required for floating the material.

That one thing is there that your 2 phenomena is going. You will have to make the material to float in the pipe and then it will have to carry. That velocity it will be depending on what is that exactly the solid density and the liquid density. Their ratio and then the diameter of the pipe and that particular these are proportional. This velocity is proportional to these 2 vectors square root of that. And, this K value, it depends on the particle size.

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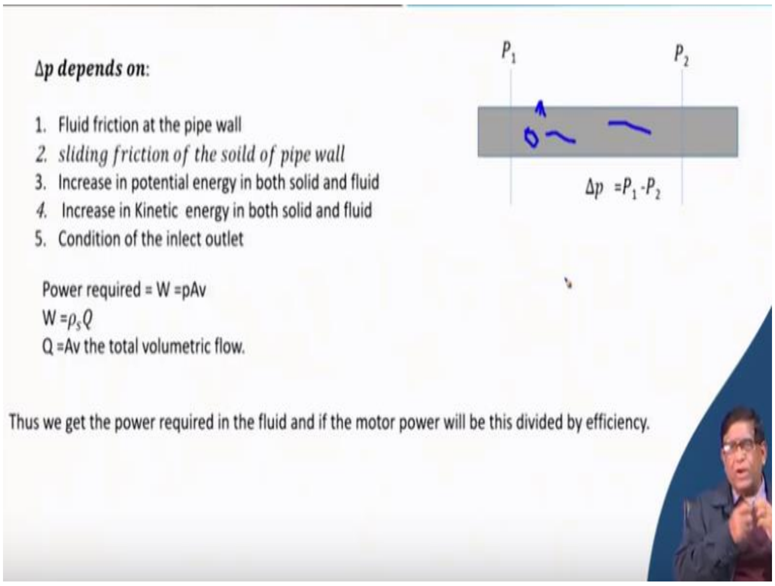

So, if you just think of there that in a pipe at a 2 separated distance. Here, the pressure is P 1, air pressure, the P 2. That means a pressure drop has taken place over there. And, it will be depending on that number of factors. First 4 factors are very important. That is fluid friction at the pipe wall. When this fluid will be flowing through this, at that time, they will be giving a, exactly here the flowing fluid.

When it is flowing like this in this direction, they will be having on the pipe wall a friction will be there. Then, this solid particle which will be here those solid particle they will be also heating this wall. At that time, they will be also dragged and moved. So, those part also will be giving a friction of the solid on the wall. Then, what is happening? The potential energy of this whole material that is your particles as well as (()) (18:46) over that your fluid.

Their potential energy over here is raised. Sometime, it is increased. So, that increase of potential energy is again a pressure. There will be a pressure. You will have to put it there.

That is why also a pressure drop will be coming over here. Then, your increasing in kinetic energy that is when you are introduce the material, this material will get a kinetic energy. So, that also will have to that extra energy will have to come.

That is also responsible for giving a, you will have to apply that so that the pressure gradient can be maintained. Other than that, that is your, the, what is the condition of the inlet and (()) (19:26) on that also? It will depend. So, that power required to make these things. How much energy will have to be there how much work will have to be done on that. That is the rate of doing that work it will be depending on this density that this pressures that cross sectional area and the velocity.

If you do that then you can find out that power required is also that is density and the flow rate that will be giving your that in newton per that is your second. That will be giving your watt unit. So, here that quantity is nothing but cross sectional area into velocity. So, if you know this parameter it is the basic design or basic calculations that will give you how you can go to towards designing a motor power.

Now, the normally, if we know this power after calculating this power which will be there but that motor will be have to have some additional extra. Because, there will be some loss in the gearbox from the motor going to the compressor. And, the compressors also from their shaft when it is coming to that air there also will be a efficiency. Normally, a, the motor and compressor unit together it will be about 60 percent 70 percent within that efficiency will be there.

So, if you divide by that efficiency that will give you exactly what will be the motor power required.

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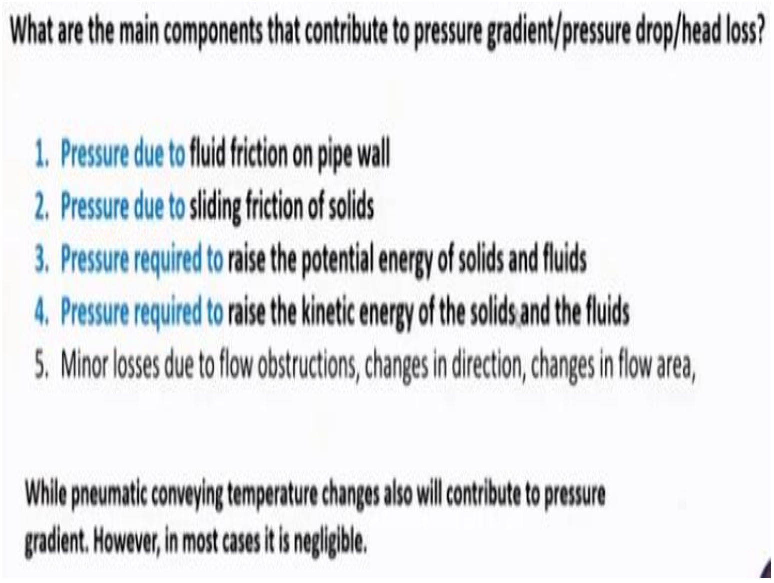

So, if we see over here coming to this the 4 items to be considered for designing or for determining what will be the motor power required. But, here some minor losses are also there. Those minor losses are because of some obstructions, there could be a change of directions; there could be bend, there would be some accumulations in the bend. These things will be they will be changing the area of the cross-section sometimes.

And accordingly, there will be a pressure drop for the initial preliminary discussions. We will be neglecting that. But, the first 4 things will have to be designed.

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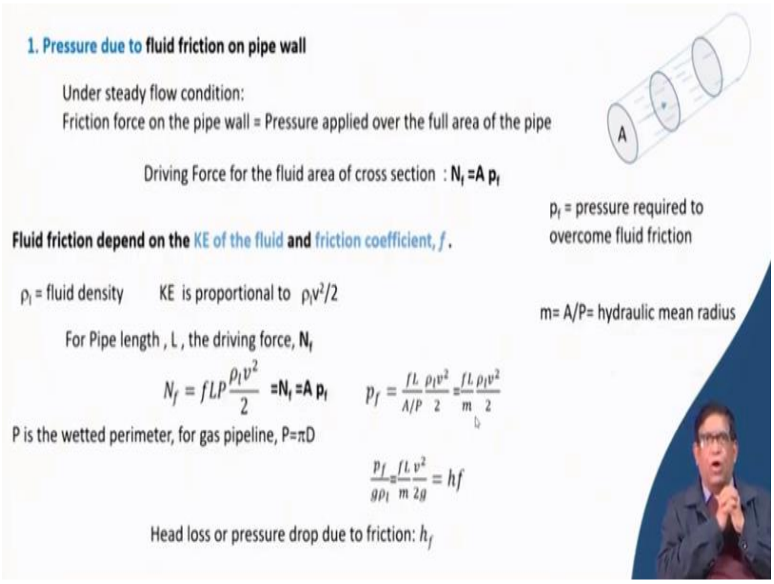

Now, how will you, the pressure due to the fluid friction on the wall. When the fluid is flowing through this pipe at that time, how exactly will be determining the pressure. So, we will have to consider said let there be a steady flow. So, that is your friction force it will be due to the total pressure applied over the full area of the pipe. That is very important. Now, in case of your, that pneumatic conveying, your whole pipe is exactly occupied because that it will be as a you know that is a compressible fluid.

And, it is a, because that container whole container it will be (()) (22:27). But, in case of your hydraulic that is your, it will not be touching the whole pipe also. It may be half filled in a horizontal pipe it may sometimes may not go the full run. But, here, that the force will be your, the pressure required to overcome the full fluid friction whatever will be there. And, if you know that area that it will be you can find out the frictions.

That area will be depending on if your within a particular length then this length into the perimeter that will be giving you the whole area. So, pi D into L will be giving you the total area. And, on that, if you know this pressure difference then you can find out that force so that the fluid frictions will depend on the kinetic energy of the fluid and friction coefficient. These 2 are the very important factors to be taken.

If your density of the liquid you can take at that gas as a raw, L, we have taken. And, that kinetic energy you know is a proportional to the density and the v square by 2 where v is the flowing velocity. So, if you take of this length L from where from one area to another it is going, at that time, what you will do. That is your, the, you will have to do one thing here your this driving force which will be coming. That is equal to your this formula.

That means length, pressure, density that is your kinetic energy and this f which is our coefficient of friction which can be determined. And, from there, you find out this equations where your, the total that your pressure drop can be calculated.

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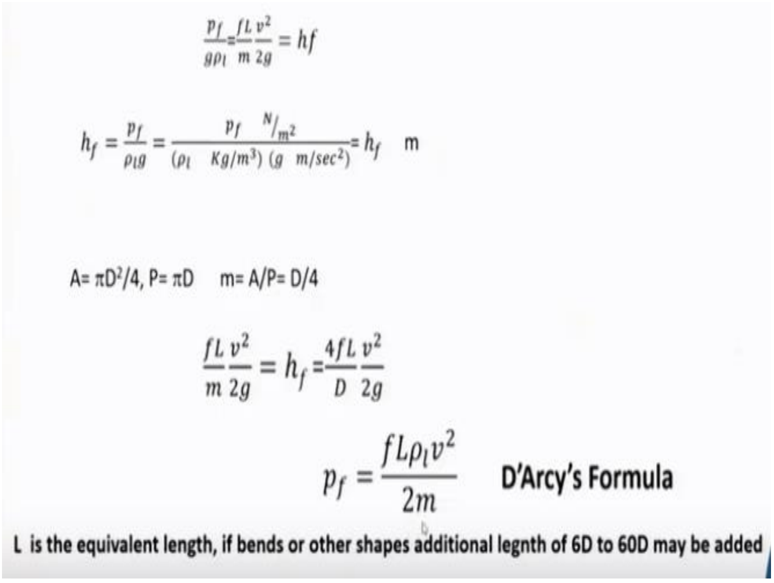

And, this one, if you do a little bit of that manipulations or that by changing it so that we can put it in terms of p f. That is your total loss coming. The pressure drop we can find out this equation which is exactly D'Arcy's formula and which in your fluid mechanics you study. So, that means the pressure drop it is, it can be calculated by applying the D'Arcy's formula. For this, a length is a exactly a equivalent length will have to be taken.

Because, that equivalent length means what will have to do. This, their bends and all will have to be taken over here.

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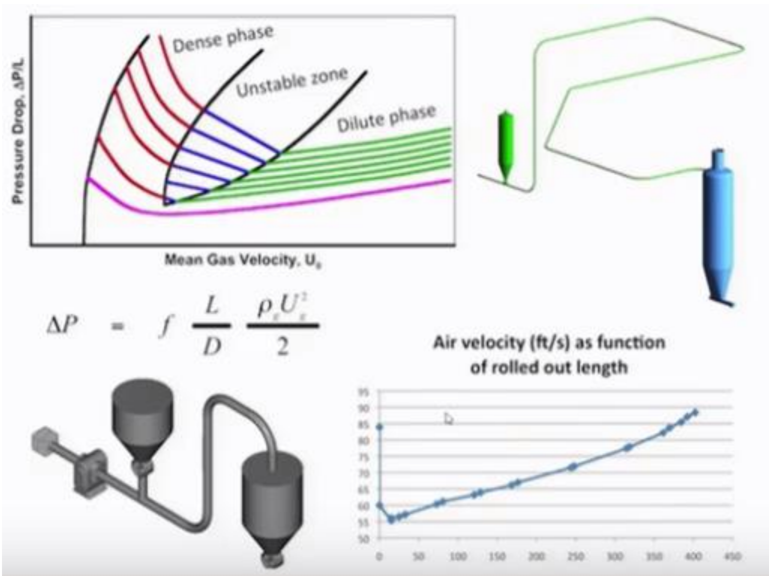

So, one thing is there that pressure drop which we can we are measuring by D'Arcy's formula, it will be depending on the type of flow. In a dilute phase, it will be working over here in an unstable zone and also in the dense zone. And, as your loading factor is increased, you can see that this pressure drop will increase. So, this one and that total air velocity as a function of the rollout length that can also be found out. You can get it from the design data book.

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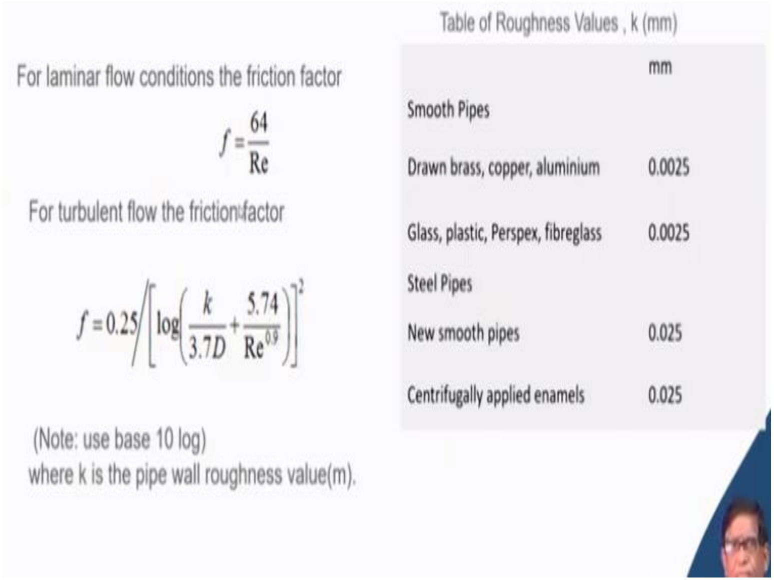

Now, for our laminar flow, that coefficient of frictions can be determined by Reynolds number. And, that coefficient of friction is also can be found out from this equations. This is given in the guide book. That is your the pipe roughness, depending on the pipe roughness that can be value and that pipe roughness which are available in the standard guidelines in terms of millimeter for different types of pipe.

So, while designing, you will have to consult these things. And, from there, you get this value determine this value.

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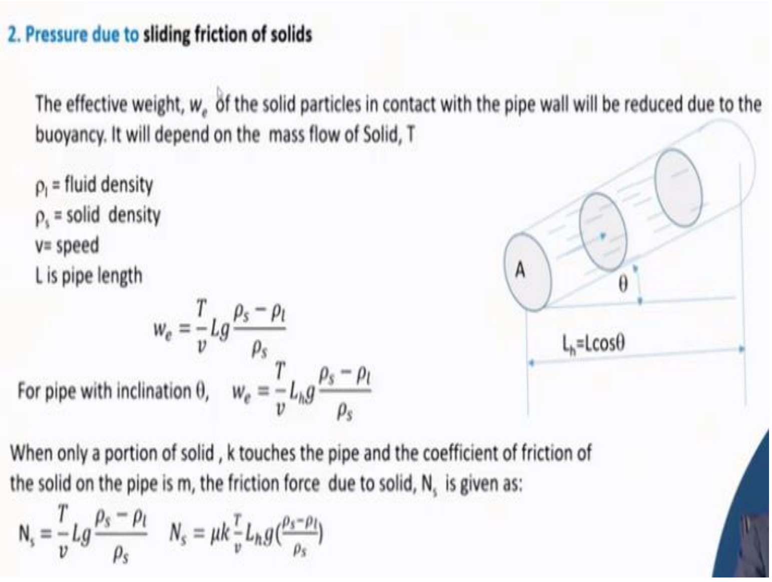

Then that another thing is their pressure due to the sliding friction of the solids. Now, when the solid will be touching over here, at that time, this solid force that also that is the frictional force also will have to be taken out. Now, it will depend on that mass flow rate of the solid. That is your total tolerance. That is how much tonne per hour it is going. On that basis, will be calculating it out.

Now, if we see that our, this rate it is that your effective weight which is exactly the material is getting carried. That effective weight is calculated from this formula where v is your velocity at that speed at which the air is moving and that rho s is your solid density particle density and that rho l is that your liquid or the fluid density. So, if we take for a distance L and that weight is found out.

Now, if that is pipe is at an inclination theta then this length will be your L cos theta which can be taken as the horizontal length of it. Now, once we know that thing from here the frictional force due to the solid can be calculated out by this formula. So, you are having it. That is once you know this force you can calculate out what will be the pressure difference.

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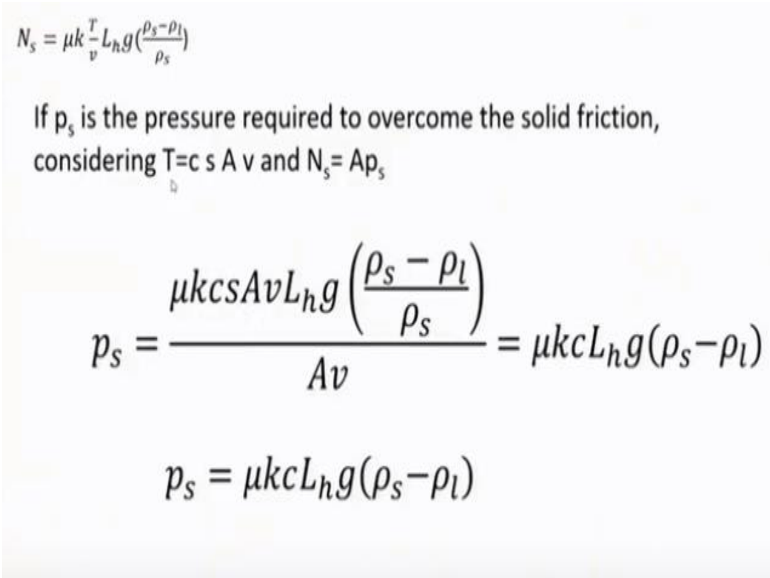

That is if your p s is the pressure due to the overcome the solid frictions consider that your the total flow rate you can find out that concentrations that your the density multiplication by the area and the v. And then, your, that force is also area into pressure combining these 2 you can get down what is the pressure coming over here. And, it ultimately, it gives into this coefficient frictions, your, this factors taken into consideration.

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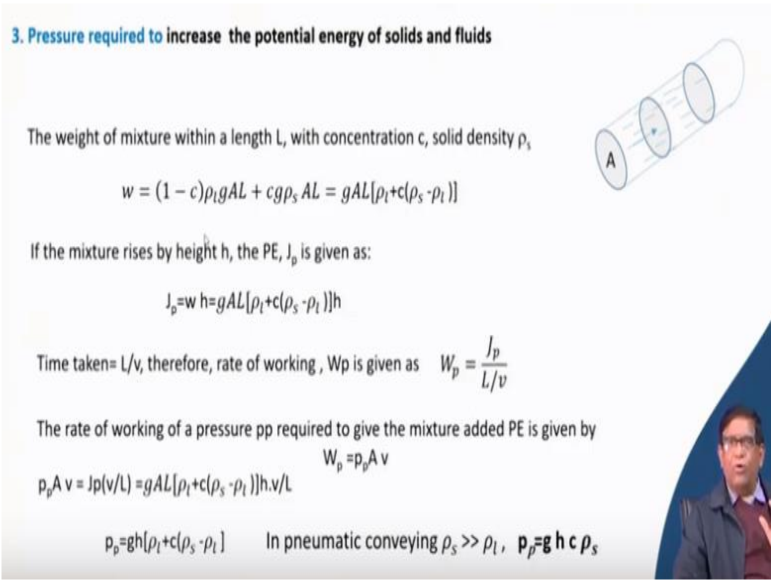

So, this is the way how you do also for increasing the potential energy of the solid and fluid. Now, that whole solid and fluid is moving from one point to another point. At that time, the total pressure required can be calculated by and from there you can find out this pressure. For, that is your what will be coming for the increasing the potential energy.

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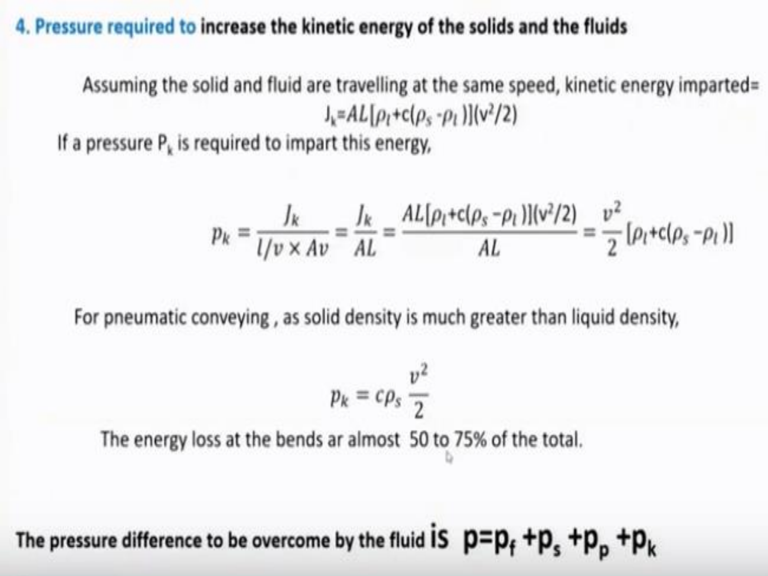

Similarly, you can do it for the kinetic energy. Kinetic energy also, you get this pressure. So, once you find out all this pressure by applying this formula from the design guide book, I request you, you can just derive it. It is very simple. And then, their sum total, this gives the total pressure.

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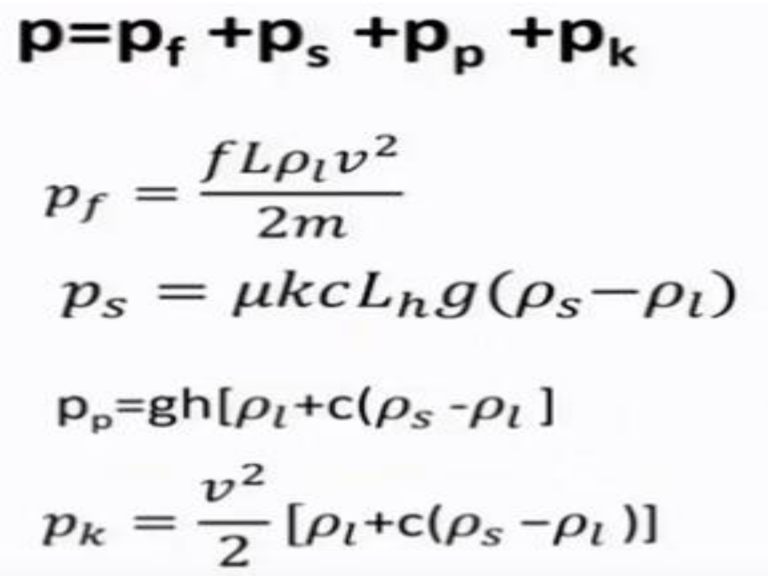

Now, once you know this total pressure that means, your, from the D'Arcy's Law, you get exact your fluid friction, solid friction, potential energy pressure and then (()) (29:00) and kinetic energy. These 4 factors will have to be calculated.

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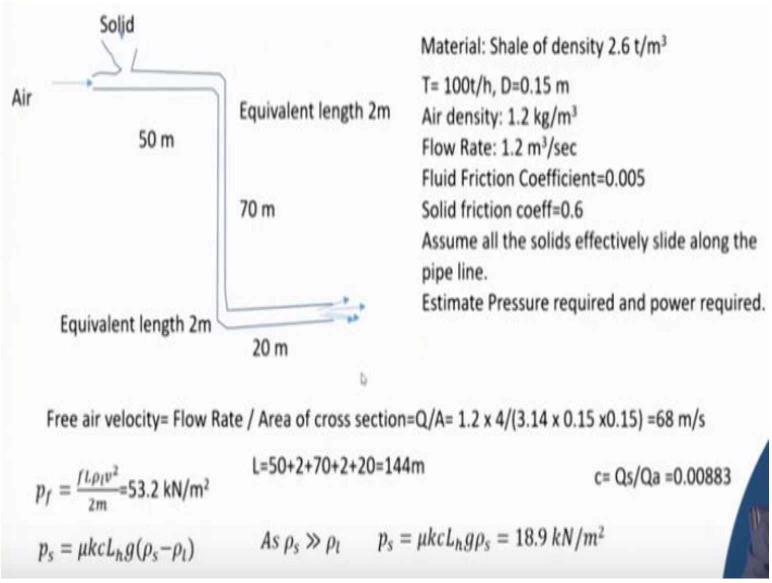

Now, you can take up a small problem. Say, for example, your air is introduced over here. Compressed air may be pressurized or by vacuum creation positive or negative pipeline you can take it over there. Solid is introduced here. Let us say 50 meter it has gone. Then, there was a bend and then which can be considered as an equivalent length of 2 meter. Then, you have got a path for 70 meter. Then, you have got another part for 20 meter.

So, 2 bends, some equivalent length you can take it up. And then, if you are given the, we are transporting shale where density is 2.6 tonne per meter cube. Your total tonne is rate is suppose given 100 tonne per hour and the diameter of the pipe you have considered let us assume it 0.1 5 meter. Then, air density, if we take it 1.2 kg per meter cube and the flow rate of air 1.2 meter cube per second.

Then, the fluid friction coefficient from the design data we get is a 0.005 and the solid friction coefficient 0.6. So, let us consider that is a, solids are effectively sliding over the pipeline. And then, you need to estimate the pressure drop. So, for free air velocity, flow rate and the area of cross sections you can find out. That is as these 2 values are given, you can find out what is that flow rate of the material will be 68 meter per second.

Then, you put this D'Arcy's law. You find out what is that for the pressure. Same applications of the formula, it will give 59 3.2 kilonewton. For a distance that L here which you are taking is a total length that means equivalent length. Here, you should take care of. That is while doing your designing that what is your depending on the number depending on the route your that L will be changing.

And then, for the solid frictions, this also you can just put it over that value. And, it is gives you ultimately you just I have done the calculations it comes over here like this.

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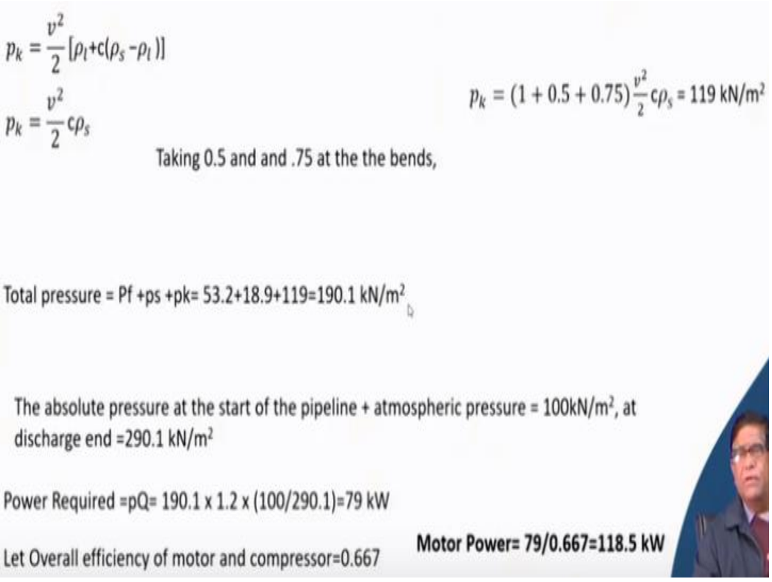

So, by similar way, you calculate all the values. And then, your total pressure some of them will be getting in kilonewton per meter square as given over here. So, this will lead to your what is the absolute pressure at the start of the pipeline. If it is outside atmospheric pressure is equal to your 100 kilonewton then you will have to get this much pressure exactly (()) (31:31) introduced into the system. At the delivery end, your pressure will be then 290.1 kilonewton.

So, that means your power required will be that your if your pressure and that your this multiplied it gives 79 kilonewton. Now, if you are finding out this as a power required then the motor power considering your overall efficiency is 66.7 percent. We can calculate the motor power as this. So, does it give you an idea about how exactly a design is to be taken. So, some of the points we may continue later on.

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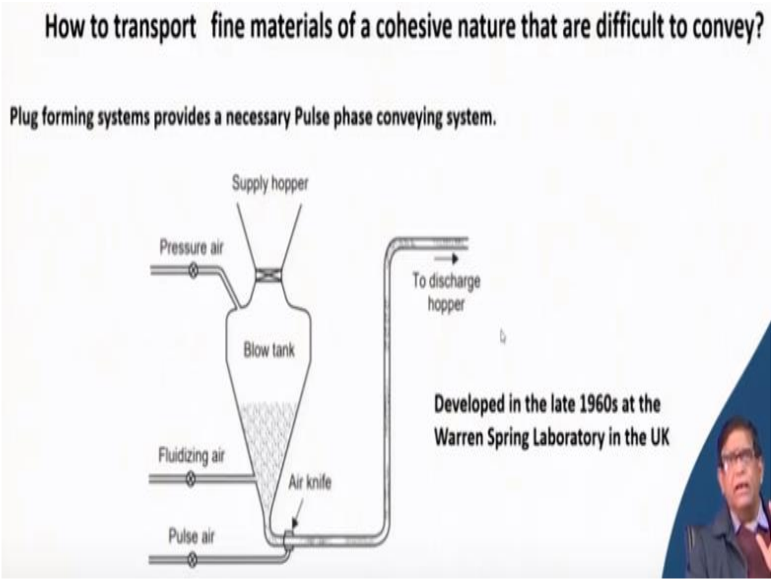

But, if we want to get how to transport fine materials of a cohesiveness or that are difficult to convey. You can find here a fluidized air is given, pressure air is given and also a pulsating air so that this will be giving making them to flow as a plugs. It will be flowing over here. So, like that many different types of systems can be there.

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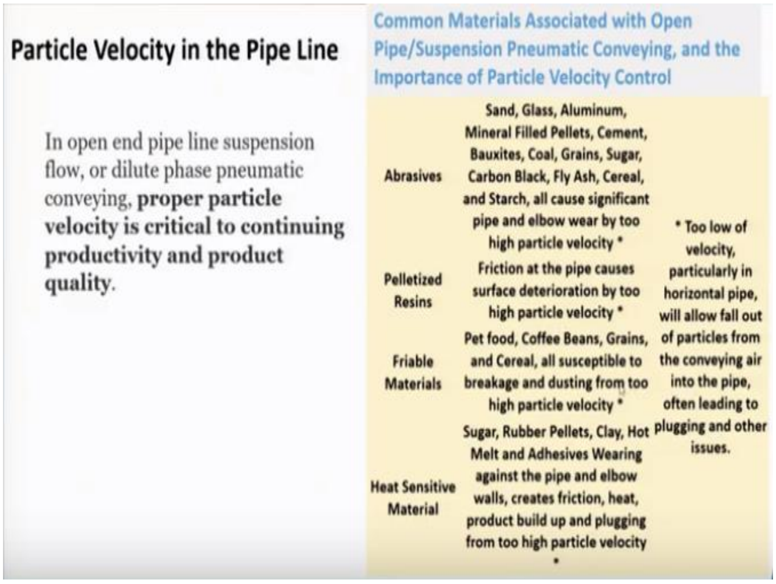

That the particle velocity in the pipeline that can also be for different particles. How they go, their things are also there. This you will have to study that what are the common materials that can be flowing and then what will be the effect of the particle velocity. Nowadays modern instruments are available. And, you can easily buy electronic devices exactly particle velocity can be determined. And, this will be leading to a more optimal design.

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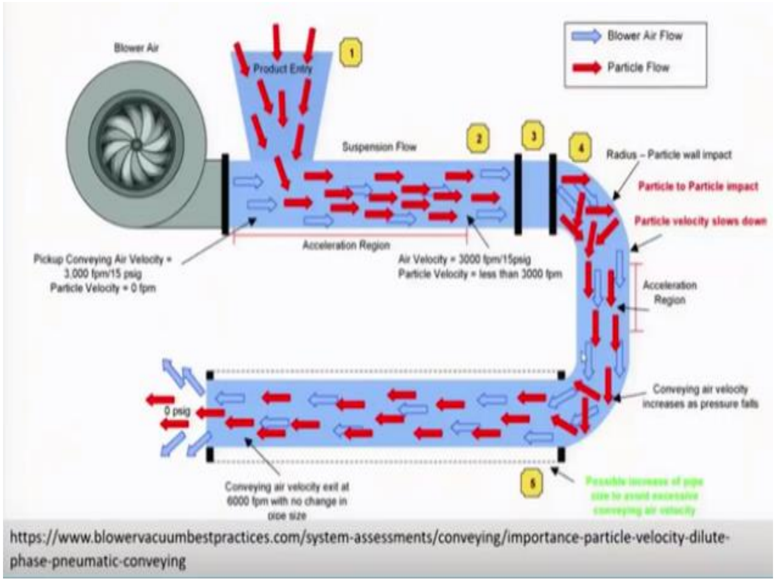

That particles when a blower is going you can see that the particle will be flowing a differently at the bends, they will be striking each other and then it will go. So, now, here, that means at the bend, your diameter may be increased. So, that type of design idea can be taken up by measuring the particle velocities.

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And, there are many installations are there. This dome technology is another one which is latest coming for this that when you are storing it over there these type of systems you will have to design and in a thermal power stations how the fly ash will be stored. These are the things where you will have to apply.

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So, there are many references are there.

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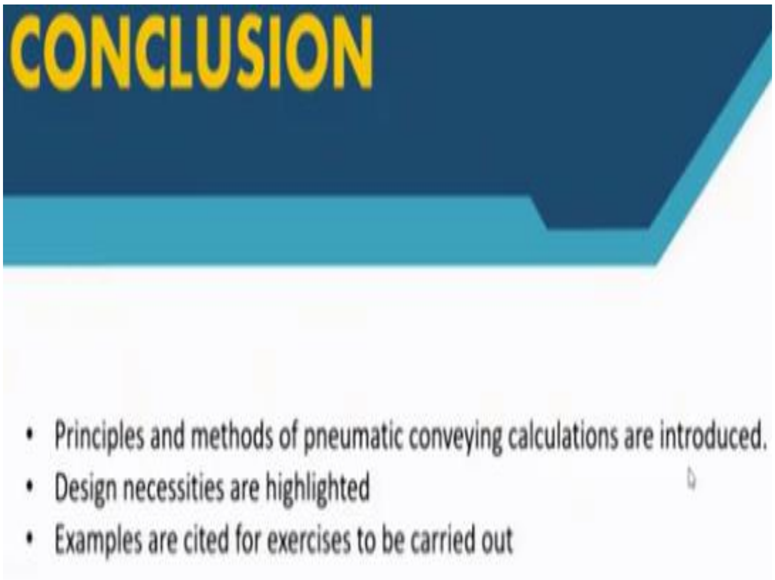

So, to conclude here, we have just very briefly said the principle and methods of pneumatic conveying. And, there is a, what are the basic important factors that need to be considered. That 4 pressure drops due to the fluid friction due to the, your particle frictions due to the pressure energy that is your potential energy increase and due to the kinetic energy increase. How they will have to taken into consider on has been given over here.

An example is there. Maybe we will be giving you some more assignments as a, for taking up and your practice on this. So, I hope you have learnt about it, thank you.