Bulk Material Transport and Handling Systems
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Lecture - 14
Introduction to Pneumatic Conveying Systems

Welcome back to our discussions on this bulk solid handling and transportation system. Today, we are going to discuss another mode of transportation that is the pneumatic conveying. You might have seen that there are the power of air or gas to carry material. You might have seen that how the dry leaves in the winter they are carried away by wind from the garden to your house.

You might have seen that how the dust particles from the road are brought to your house and it make your courtyard dirty. So, that means there is a power of the air or that gas to carry material. So, that is where we can use this air for transportation purposes. So, we will be discussing today that how this pneumatic conveying is carried out and so that, after this discussions you will be getting the introduction to this system.

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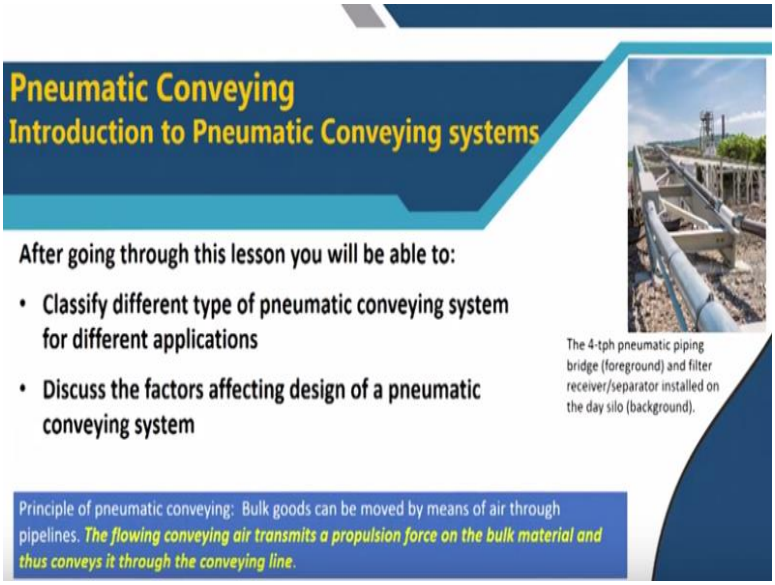

So that you can classify what are the different types of pneumatic conveying systems and how they are applied. And also, we will be discussing that what are the different factors that influence the whole operations? So, that while you are going for designing or selecting a system, you can take care of it. And then, you can go for doing certain calculations which we will be discussing in the next class.

So, the basic principle is the bulk goods can be moved by means through pipeline. And that, in that pipe, your, the main carrying material carrying force is coming from moving air. That is the basic principle. So, the flowing conveying air that transmits the, your propulsion force. So, anything is to be carried from one place if you want to take it to another, we are applying certain force to get it over here.

So, that force we are now giving into the material by means of air. So, that is why, but, when we talk of the bulk material, loose, that is the powder, then your, the heaps of coal or the minerals that will have to be carried out. Now, this type of conveying it is necessary particularly in the food industry in the chemical industry and also in the mineral industry where certain things must be kept.

That is we must kept free from water or moisture that when you have to carry that as a dry there is nothing can be better than carrying it by air. And a diagram here, you can see. There is on that bridge you can see this pipeline which is exactly carrying the bulk material by air. Here, fly ash is going. And, there at the background, you can see, there is a storage system which exactly separates out this material which is coming over here. And, store it over there for the next thing. So, we will be discussing about this system.

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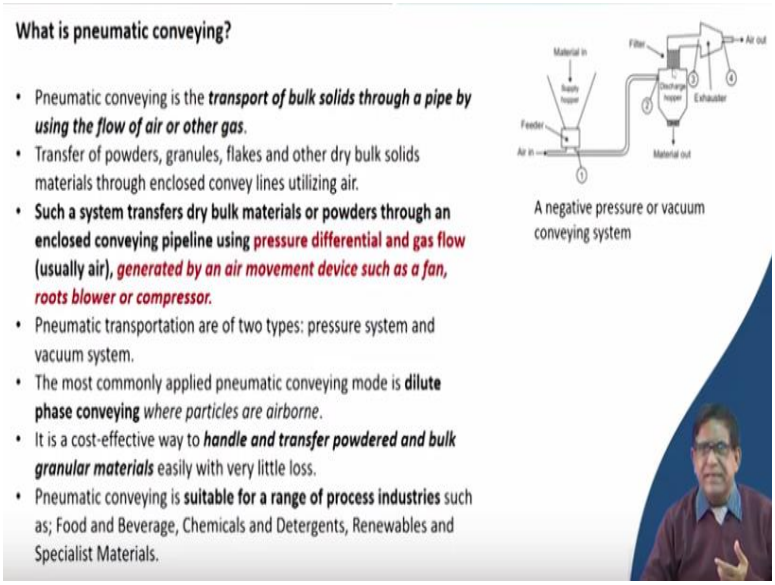

How it work? So, we have learned this now. What is pneumatic conveying? You will be able to tell it that it is a conveying here that is a transport of the bulk solids through a pipe by using the flow of air or other gas. That is very simple definitions. But, it exactly by this

method, it sometimes not for a very long distance, sometimes there could be a transfer of for a short distance also.

Normally, as we have discussed in our hydraulic on transport or the conveyor belt transport, it can go for 100 kilometers. But, for the pneumatic conveying, normally, it is less about 1.52 kilometer, 3 kilometer. You can very easily do. But, in plants, few hundred meters that transfer by pneumatic it is done. In the port, you may find out that when the ship is evacuated they are evacuated by using a pneumatically collected material and transferring through pneumatic means.

So, they are very suitable for powders, granules, flakes and other type of bulk material that which can be conveyed through a closed conduit. And so, you have very clear, that means, it will have to be dry material. It can be, that is a, it can be granule. It can be powder. It can be flake and that you have seen that there should be a pipe and there should be the flowing gas. And, this transportation system are normally of 2 type.

If it is a gas is going or air is flowing through a pipe, it can be just you can blow from one end and with pressure you can make the things to move. Or, you can suck by creating a vacuum and you can get it. So, depending on that we can have the whole transportation system whether it is a, your positive pressure system or a negative pressure system. And also, it can be that your particles which are to be carried out, it can be in a very its concentrations can be very less or it can be very dense.

Depending on that, we can have a dense phase or a dilute phase. So, we can have classify our pneumatic conveying systems also in that way. So, one thing is there. We will have to separate them out. So, that means, our main purpose of transferring or transporting is whether we are spending how much for doing the job. So, that means, to get it as a competitive with other mode of transportations, it will have to have less expenses.

So, for cost benefit, you can get if you judiciously select that what material at what concentration at what flow rate can be taken out. That is why when you will be doing the design calculations you will be going into that how that flow rate how that pressure how that velocity how you will be maintaining into it in a cost effective manner. So, it can be, this is by now, you now know that this pneumatic conveying is a, it is practiced in different places.

And, it has got a system. It can be going as a negative pressure system. You can see here. It is a, that it is sucking the air from here and then the material is inserted here. We are having a feeder. And then, when it has come from this location, it has brought over here. There it is separated out. It is collected for the storage and then it is going.

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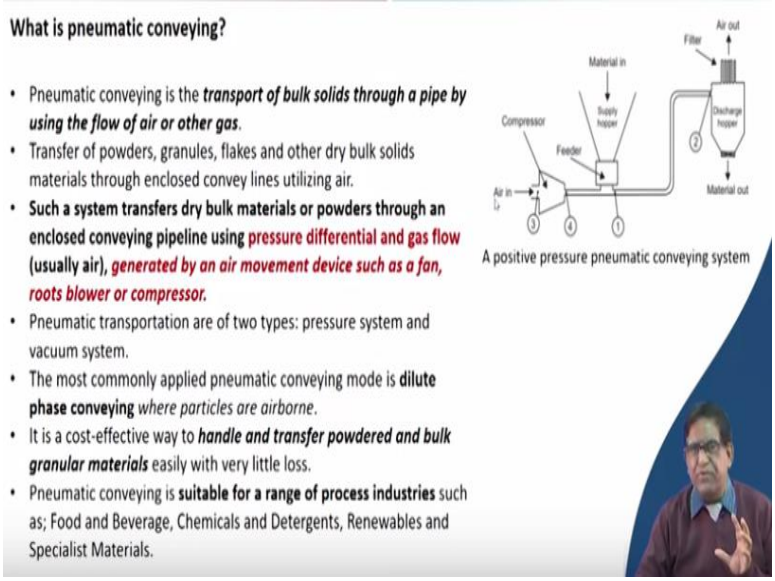

That or sometimes, you can see that the pressure is blowing out here giving a positive pressure from that feeding point to the collecting point. This is a very simple system how exactly your conveying takes place.

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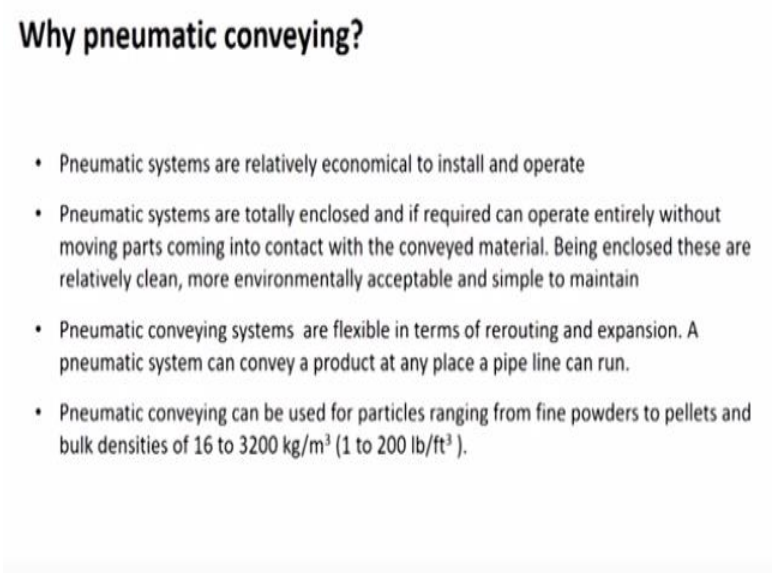

So, it is, it has got certain advantages over the other systems. Say, for example, it is very clean. You can say that because in water or slurry, if there is a (()) (07:50) and all that thing it

will be making a lot of things. But, here normally, it is a cleaner and it is economic. If you are judiciously selecting the system rate and all, it can be designed to be a very cost effective or economic. And, there is, it will be in any case totally enclosed because that air must not leak out.

If the air leaks, your system will not work. So, we will not create any air pollution problem. If you taking on a conveyor belt with the wind comes the material dust will be going away. So, that type of system is (()) (08:23) more environmentally friendly it can be made. And then, it is flexible in the sense you can design your pipeline installations and wherever you want to you can get it.

You can change where you will be loading it where you will be putting it. So, it is not like that. Say, for a railway line, you will have to all the time the line will be there but sometimes here we can have certain flexibility. Particularly, in the small plants, when you want to make it because it is not a very big installations. It can be dismantled. It can be placed over there. So, there is a flexibility over there. And then, it can be, it can carry different material.

But, there is a limitation. That is if you are very big particles or very high density particle it may not be carried. That is one of the thing is there. So, that means that pressure on which this by which the air will be taking up for transportation purposes. There is the limitation. You cannot go for a very big size as it is known in any pipe transportations. You cannot go for a very big size.

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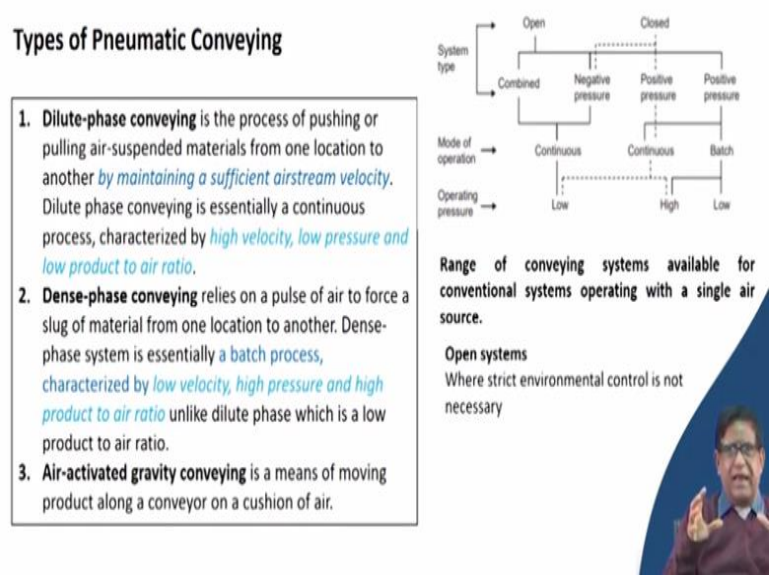

So, by now, I think you can (()) (09:38) whatever we have said. You have said these words in between. You here again make it a note of it. That is, it can be a dilute phase conveying. It could be a dense phase conveying. And, there could be a air activated gravity conveying. Different type of conveying is there. So, what is there in a dilute phase conveying? Exactly, pushing or pulling that air suspended material from one location to the another by maintaining a sufficient airstream velocity.

So, that means your air is going so much and then the, we have got the particles are uniformly distributed. The concentration is not very high. But, in case of your dense phase conveying, what is there? That your whole tube is having a very high concentrations. A lot of materials get packed over there. That material if you take any particular length of a pipe in that the total amount of material is much more. That is why it is called your dense phase conveying.

And then, so, that is air activated gravity conveying is another type. Exactly, what is there? We will be discussing sometime. That in a conveyor belt, you have seen that conveyor belt is supported on rollers. But, instead of roller, if we can make this conveyor belt to move on a cushion of high pressure air, it will be putting pushing over there. Then, there will not be friction. So, energy will be fully utilized over there.

And, there is a new and the different type of innovative system is there which is called your air activated gravity conveying. We can do it. There are number of such type of innovative systems are there. Now, when we talk of this conveying systems, then we are having a number of them we can classify as a open and closed. Open is exactly strict environmental control is not there.

In an open system, of course, it is not when in the pipeline your pneumatic conveying it is always going through a closed conduit. But, it may so happen that you are sucking from a heap of material outside is there. One side is totally (()) (11:49). But, otherwise, when you are inserting the material from a closed systems to the pipe that is a open and closedness. And then, they can be combined of different.

And, this, as we said earlier, that is a, your negative pressure and the positive pressure type. Or, the mode of operations can be continuously. That means the material is going continuously you are pouring and inserting that material. You are feeding continuously. And,

you are collecting continuously. Or, it can be intermittent rather batch wise. Sometimes, there are packet materials also. That is not non bulk material in a packet form it can be inserted.

And, it can go batch wise. So, there are different type of systems could be there. And then, the operating pressures that can be low, high or medium. That way, we can go having classified this pneumatic conveying systems into number of types.

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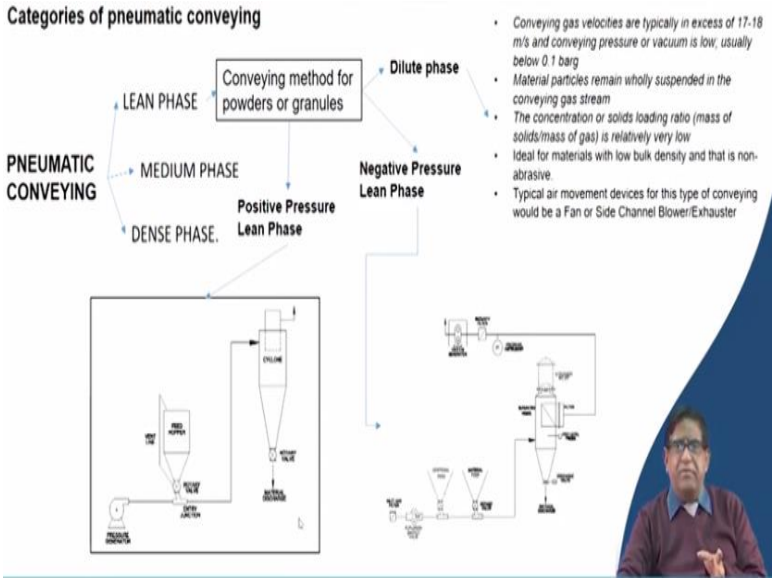

So, coming again, recapitulate what you have learnt so far. That is pneumatic conveying can be basically this lean phase, medium phase or dense phase. Lean phase which could be exactly conveying methods for the powders or granules they are used. And then, this lean phase is basically it can be a dilute phase or a negative phase or a positive phase. These are the, whatever there.

And, the medium phase means where that exactly the dense density that is your how much particle is there in that line. So, in case of your this dilute phase where your conveying gas velocities it will be normally 17 to 18 meter per second. That is that means a high speed material is going over there. And, the barometric pressure that is gauge pressure it is below 0.1 bar. And, material particles remain wholly suspended in that concrete.

When it is going through a pipe, there may be different situations coming in. That the material instead of remaining airborne, it may get settled down or it may whole thing is settling and then you are pushing. In a dense type of flow, there is one thing is there. Say, you

can think of some very that some dense liquid. In the liquid form, when the whole (()) (14:12) is full of that liquid but air is pushing that and taking over there.

Some type of very high dense liquid in the pharmaceuticals or in the chemical industry they can use that type of system for pneumatically conveying. Then, the concentration of the solid loading is generally low. If it is in a dilute phase that means you take any cross section, there the material per unit area inside the pipe will be less. That is the basic things of a dilute phase conveying. And, that is your, it can be, both it can be pressurized or it can be in a vacuum.

You can work over here. That negative pressures and positive pressures when we say over here. You can see that the location of the blower or the fan where you are putting it on that basis you can say that whether a system is positive pressure, negative pressure, vacuum or that is in an open storage or a shared negative.

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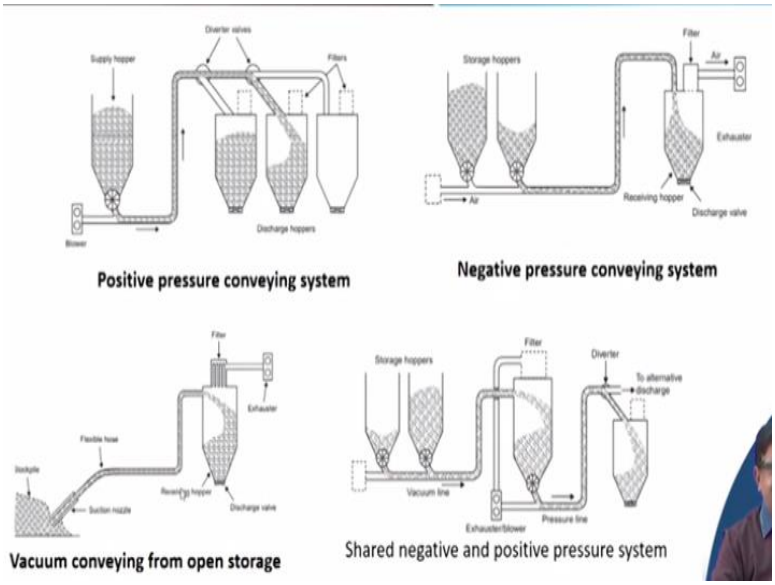

So, there could be all these things possible. You can see here. It is the blower is blowing. That feeder from here it is getting feeding. And then, from there, it is collecting to the material like that. This is a positive pressure. And, this is a negative pressure. And then, here, you can see that they have combined both. There is some positive portion as well as some negative portions they can be combined together.

And here, this is a, your, a vacuum your negative is created. But, you are collecting from an open storage. So, they are different mode of transportations can be there.

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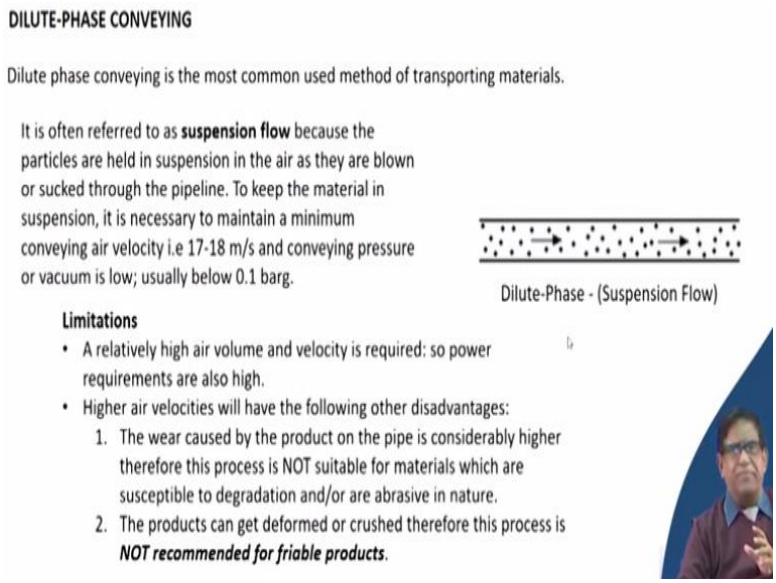

So, once again, you see we have (()) (15:54) that dilute phase. This diagram will be get clearing you the doubt if you have got anything. Say, the particles are very, that is your, that the concentrations are less. That is why all the particles are in the suspended form. Nothing is going over there. But, if there is a high concentration and then this velocity it cannot suspend. Some of the materials will be putting over there and that will be dragged away.

So, that will not be then a suspension flow. That suspension flow in a dilute phase is a, it is as shown in the figure. Now, this dilute phase has got certain limitations. Finally that air, more air volume is there. And then, your velocity will have to be higher. And, if these 2, your conditions, that means power requirement is more. That means that cost will be more. Now, when there is a high velocity, what will happen?

The particle, they will be having more force if they are highly abrasive particle if they are making in contact whichever is going near the boundary layer. When it is touching the pipe more wear and tear will be taking place. Then also, there is one thing. The products can get, that products mean that material which is being carried they can get crushed. Say that the particle size whichever is there then they are going at a very high speed.

When there will be particle to particle that your friction or attacking each other, they may break and then more fines will be generated which may be that your product (()) (17:38) your next processing may not require. So, those are the some very differences or minute things that you will have to consider when you are going for designing.

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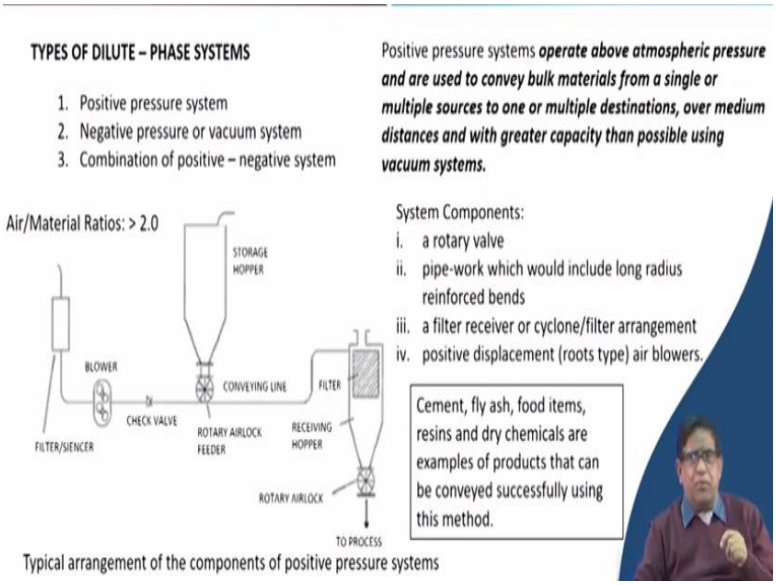

So, that as we have said you will be designing a system as a dilute phase or as a positive pressure or negative pressure or combine pressure. Now, what you will have to consider for such designing. That will be exactly what are the things in this particular systems you will have to provide for. First thing is, as you say will be you keep this always in mind that will have to have a feeder that rotary wall feeder.

There are different type of feeders are there that is when your dry bulk material powder or flaky material which could be your say in the (()) (18:32) that when it is (()) (18:34) manufacturing people they are keeping the (()) (18:37) over here for they are taking it to the packaging unit or some other they can put it over here. So, this will have to be inserted to the pipe.

The pipe is having the air at a pressure maintaining a pressure gradient at a, it is moving at certain velocity. At that time, you are inserting the particle for that you are having this is a rotary feeder. It has got a gate. That gate get open and as it will be rotating whatever the, at what rate it will be feeding that can be controlled over here. So, then, there will have to be the pipeline. That whole pipeline, how it will be designed those pipes also important.

Whether it will be, all along it will be uniform size pipeline or the pipe will be having a curve or where the pipe will be having how it will having a bend or exactly that whether the cross section of the pipe with different places will be different so that your flow can be maintained. So, those are the things comes in the system component or system designing. Then, when

they will be collecting, at that time, there should be certain filter that what exactly will be taken up for your as a product and what will be discarded.

And also, that how you will be introducing the air, those are the things will have to be considered. And then, this positive pressure systems, they operate above atmospheric pressure. This is what is known. And then, they are conveyed the materials from a single or multiple sources to one or multiple destinations. This whole thing will be now how you design the system whether your as a single point loading, multiple point loading or your delivery at a single point or at different point.

So, accordingly, your that feeding and receiving sections will have to be designed. So, these systems, a dilute phase systems with this provisioning, they are there in the cement industry for transportation of flyers, food. As I have already said, these are available there. So, there is one very important factor. That is, what is the material flow rate? And, what is the air flow rate?

That is when you are collecting at the end, you are getting some particles or that your, how much tonne per hour it is coming. But, the air which is moving when there is no particle inserted. At that time, it is moving at some velocity per that is a meter per second velocity. This tonne per hour to meter per hour this once when we consider as a non-dimensional number that as a factor which exactly is very important in designing.

That because, that will decide, how much will have to be velocity maintained? How the feed rate will have to be maintained?

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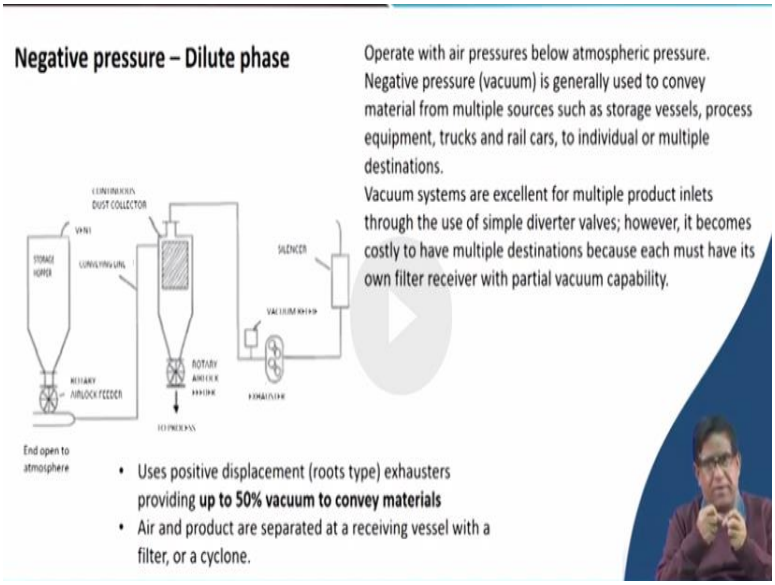

How the, this, and then, in a negative pressure system, what is happening? In a negative pressure system, your only the whole pipe it is exactly air is getting sucked at a with this your with that, your, the devices your pneumatic devices are placed over here. Unlike a compressor, you can just having a exhaust fan which will be collecting the material. Now, this the, when you are using this negative pressure or a vacuum systems, your, at any time, you can get.

Your entering material into the system is very easy. But, that your, how much percentage of material will be normally that as a positive displacement exhauster provide up to 50 percent vacuum to convey material. If your sufficient vacuum pressure negative pressure is not created, the material introductions will be problematic.

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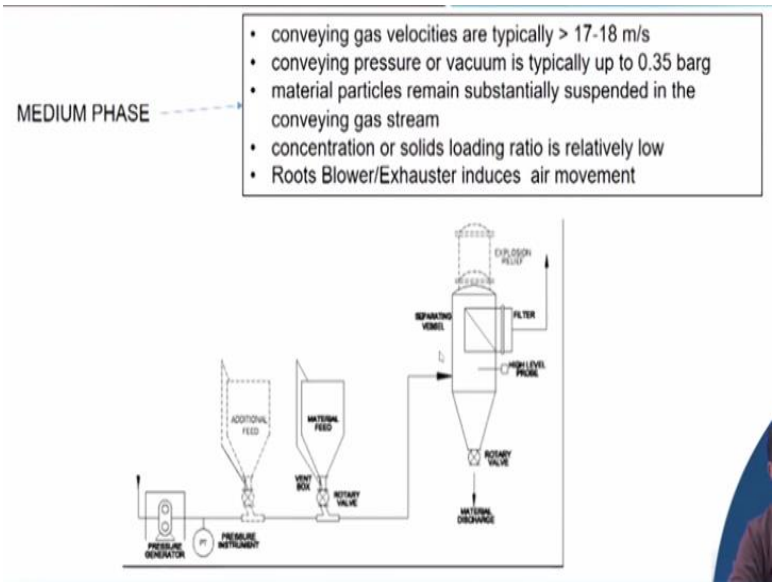

So, now, coming, when we talk about a medium phase that is we are talk we have talked about the dilute phase. Here, the conveying velocity it is more than 17 to 18 meter per second. And the pressure, it is also up to 0.35 bar. In dilute phase, it was 0.1 bar only. And the material particles remain substantially suspended in the conveying gas system. It will have to be.

And, concentration of solids loading ratio is relatively low. And, the, you can use both the type here also in medium phase.

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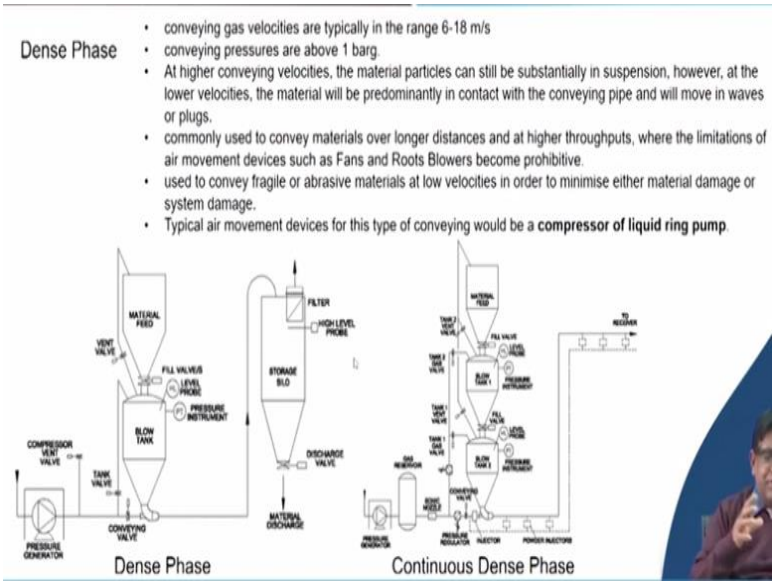

And, in case of your dense phase, there they conveying velocity are typically within your 6 to 18 meter per second. And, the conveying pressure is also 1 bar. And then, at higher conveying velocities, the material particles can still be substantially in suspension. However, at the lower velocities, the materials will be predominantly in contact with the conveying pipe.

Here comes of these things when you are putting this dense phase, certain particles sometimes, it can plug. A plug flow will be there. There can be even the materials are settling down over there and that has dragged out. A drag flow could be there. So, in a dense will have to be very careful in selecting the pipe that diameter and then the doing this your calculation design calculations will have to be very carefully carried out.

So, here, the dense phase, it could be a continuous dense phase. Number of them can be put it over there. Or, it can be intermittently dense material that is going as a pulsating flow it may

go. Sometimes, what may happen inside the pipe? They form sampling small dunes. And, the dunes will be moving over there. So, these are the different way.

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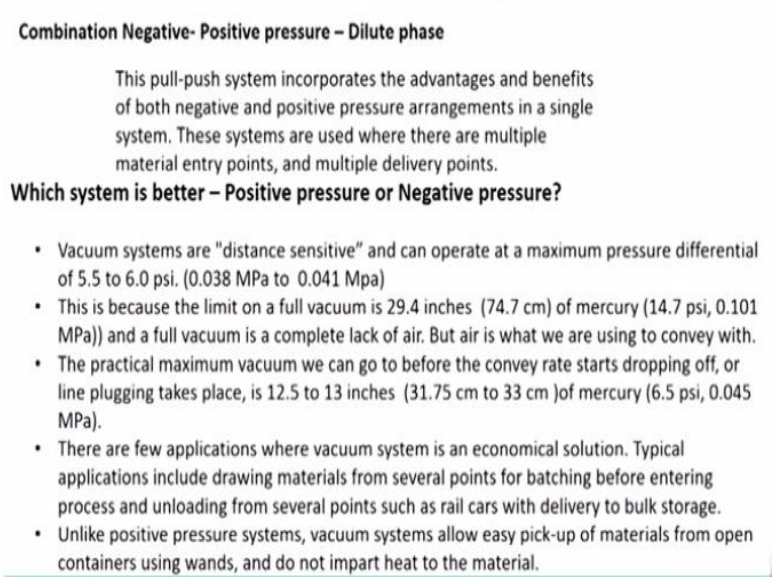

The material that whole thing the material properties also is a very important thing that how the response of a particular material to a given velocity and pressure gradient that need to be checked while going for the designing. Now, the other phase is your, a combination of your negative and positive. It is a push pull system. You are pulling as well as you are pushing that both negative and positives your the forces are given to the pipeline.

Now, if it is coming to a question that which one will be better. What will you be selecting? Now, the vacuum systems are distance sensitive. So, it can operate at a maximum differential pressure of that is your 0.38 megapascal, 0.41 megapascal. And your, how exactly you will be considering your the pressure selection. That is your, in a very high pressure, if you are requiring over there, then maintaining that within that diameter of the pipe, you need to calculate it out.

Similarly, the, what is the practical maximum vacuum which can be exactly will be allowing your particle size to be moved. So, while you are selecting a positive or negative, you will have to see the material size, material volume to be done and the economics of the system. When you do the calculations, then it will be determining and then selecting.

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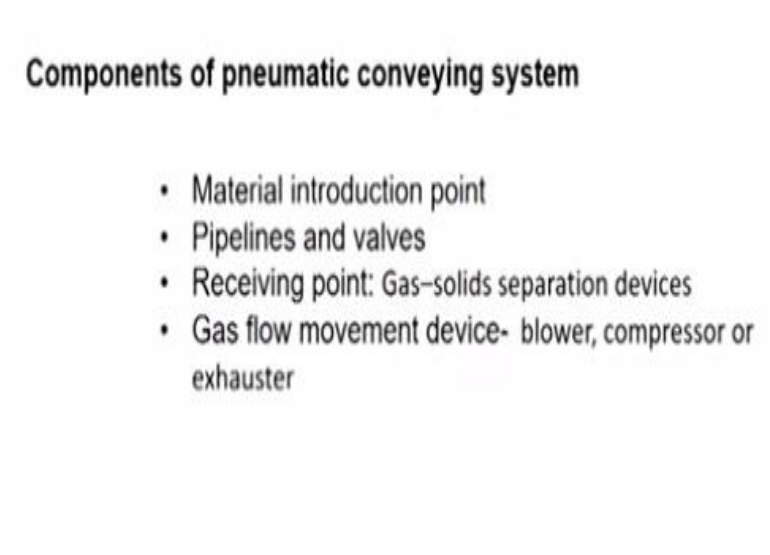

So, a basic preliminary things you have now understood that there we can design a system depending on the material and any of the available technique can be adopted. So, in, when you are thinking of say transporting coal or transporting say cement through a pneumatic pipeline, you will have to how will you introduce the material to the pipe and then what are the, what type of pipe and what type of valves you will be using.

And, how the separation will be taking place? And, how your the whole air flow movement will be given.

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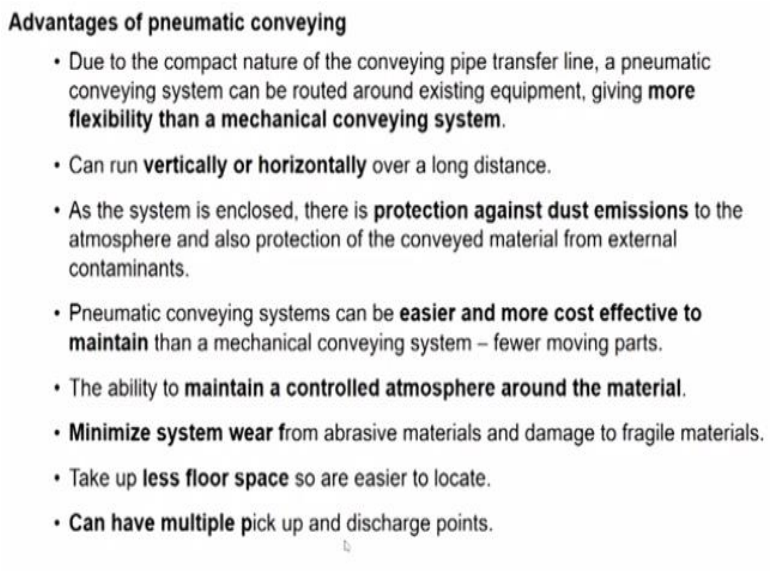

So, that is what exactly will have to be designed. And, there the advantages as I have already told you that is your it could be flexible. It can be, you can have negotiate bend. You can have a vertical one. You can (()) (27:35) with horizontally. And then, it could be, you can

have a very controlled systems very clean system. And then, if you are properly designing that your frictional wear and tear of the tube also can be controlled.

And then, this will be requiring very small. Say, for example, transporting that quantity of material by other means will require more space. (()) (28:02) space economy also can be done.

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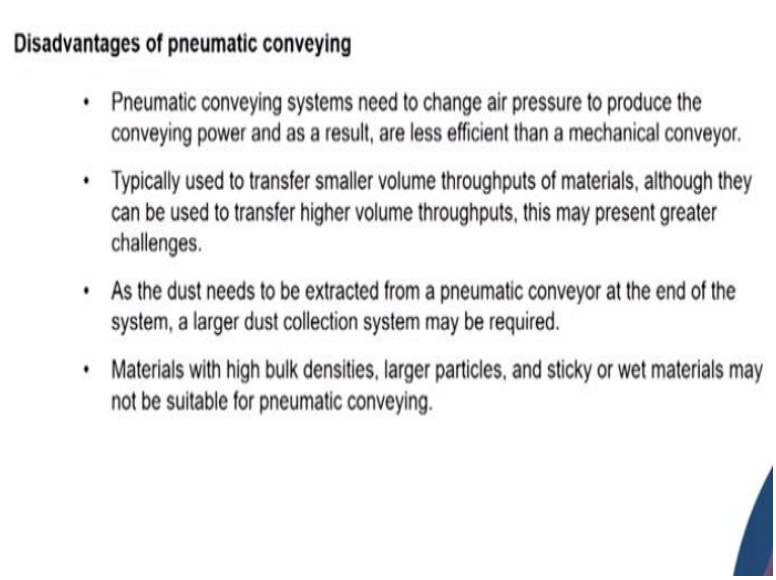

But, at the same time, it is a comparative to the other conveyor it is less efficient that is your, in terms of energy requirements and all. Then, typically, you transfer volumes throughout the material although they can be used to transfer higher volume throughputs. This is at present is a big challenge that say for example in the cold transportation for a thermal power stations is in million tonne per year.

So, such type of throughput whether by an inventive conveying you can ascertain or not. That is a issue need to be seen. And also, that the airborne dust at the time of where you are separating it out at that time very fine dust can be given if it is your spm 2.5 or 10 micron. At that time, it can be respiratory dusts will be released which could be an environmental problem.

So, this, a, you cannot make a sticky particles. You cannot make wet particles. There conveying is a problem.

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So, those are the challenges. So, when you are going for a designing an applications, you will have to see that what type of particle size distribution. What is the air humidity? What is the moisture content? What is that your angle of flow? How many bends? How many your, this, how many your angles need to be negotiated? Whether there is a, the, what type of that is your drag can be carried out. What will be the density?

What, up to what density of material can be done. So, whether there is a fluidisation should be taking place or not. Then, your, that materials hardness and friability if a friable, they can that is your by collisions they may become more powder, hard will be making more damage to the pipeline. So, these different factors like concentration, system throughput, system distance, they are taken into consideration for designing it.

And, by that when you will be going for the designing, you will have to know that what will how will you calculate the air flow rate air only. That is your only air it is to go through the pipeline. At that time, what should be the, your compressors or the blowers or fans requirement? Then, what are the conveying characteristics? Whether there will be any temperature variations in these things that because it is a gas.

So, that temperature variations will be bringing in your volume changes and that whole pressure regime can be changing. So, those in material property, so, these are to be looked into.

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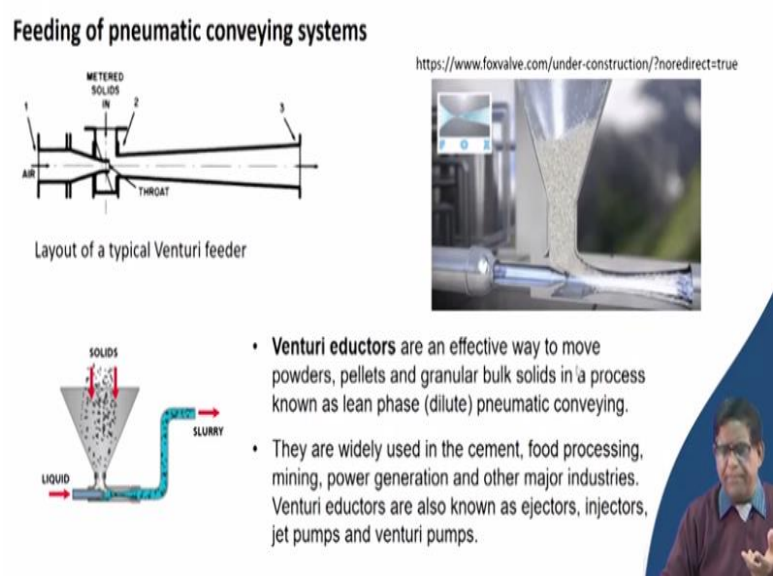

And there, you will find when we go for designing that feeding it can be done by a venturi feeder. It is a very old technique still there. Your, that is, when air is going out in a venturi point, your metered solid will be entered into over there. So, this venturi eductor that is your solid is coming, the liquid is flowing or the, that your gas is flowing and the material is allowed to go like that.

(Video Starts: 31:19) So, you can see here if it is either in a liquid form or in a gas that any fluid when it is introduced to a pipeline through a venture, what is happening here? The velocity is very high. At that high velocity, this material is getting pushed. That is the very basic principle of having a feeder of this type. **(Video Ends: 31:43)**

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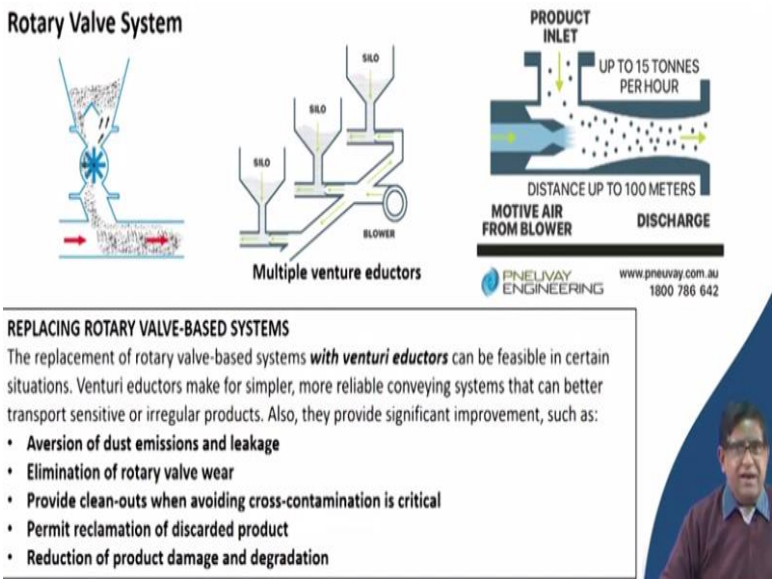

So, there is a rotary valve type. You can see here that the material dry particles are coming over here. And, it is the system with the fluid. It is the same type of feeder is in the hydraulic transport also. So, here, the, this gas will be now taking up this material and carry away. So, this is what is called your rotary valve. We are making the material to flow. So, does the venturi and rotary, these 2 are the most commonly used.

And sometimes, there will be multiple number of feeders. And then, as because this your sometimes one system if it is to be shifted to retrofitted by another advanced system. At that time also, the, how you can do it. Sometimes, you need to look into over here because many of the old systems they need to be. If you can develop a better system and retrofit it over there, a new business can come.

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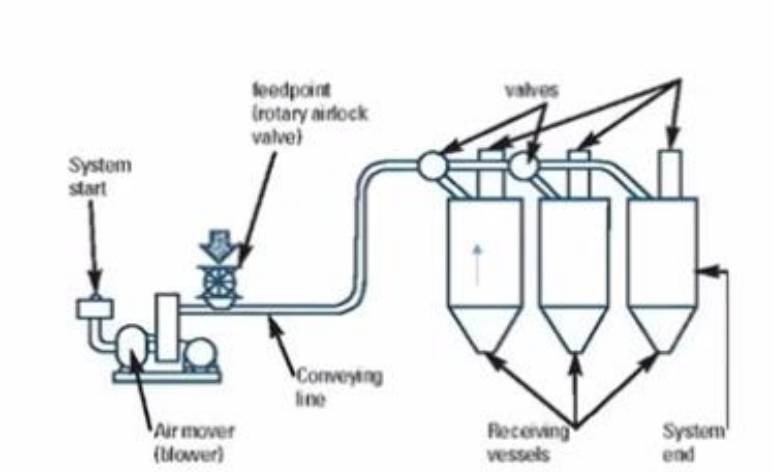

So, you can see overall that there are so many different type of systems.

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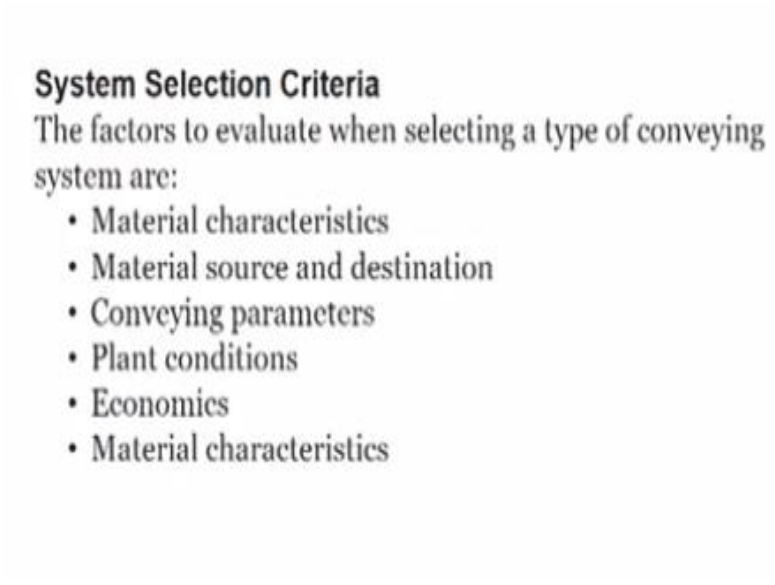

You will have to know the system selection criteria based on the material characteristics, their destinations, their route, their other conveying parameter, the plant conditions. All these things are taken whether you are going to have an application in a ship unloading, in a processing plant, in a food processing plant, or for making a warehouse, or you are taking it the system for a dispatch sections.

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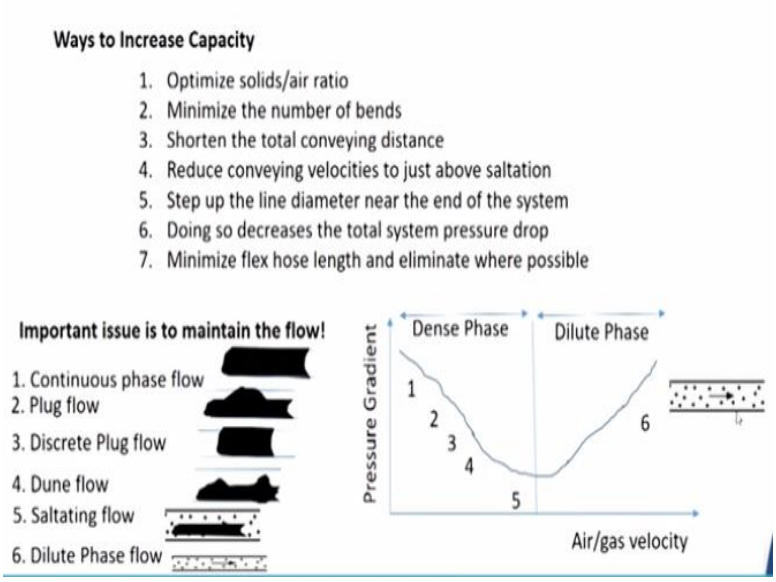

So, depending on that and as we said that the most important thing is the flow. And that flow is maintained by your pressure gradient. And that there is a, the gas velocity and the pressure gradient at different in a, if you put them in a log graph you will find that there in a dense phase and dilute phase, they have got a different type of flow phenomena may take place. For example, your, when it is a continuous phase flow, the whole material it is just like in a pipe as a dense media it is going over there.

Sometimes, it is a plug flow. In between, it gets plugged like that. And then, sometimes, it is a discrete plug flow. It will be there in between some gap. And then, the material will be going through that. That phenomena may happen and that in some locations, there could be your, that stratifying it is a saltation taken place. It is now being dragged. But, the, one thing is there when it is going in a dilute phase your free and that you are getting a good uniform all material suspended. So, these are the things, we will be discussing in our forthcoming class.

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And then, we will be doing some basic calculations.

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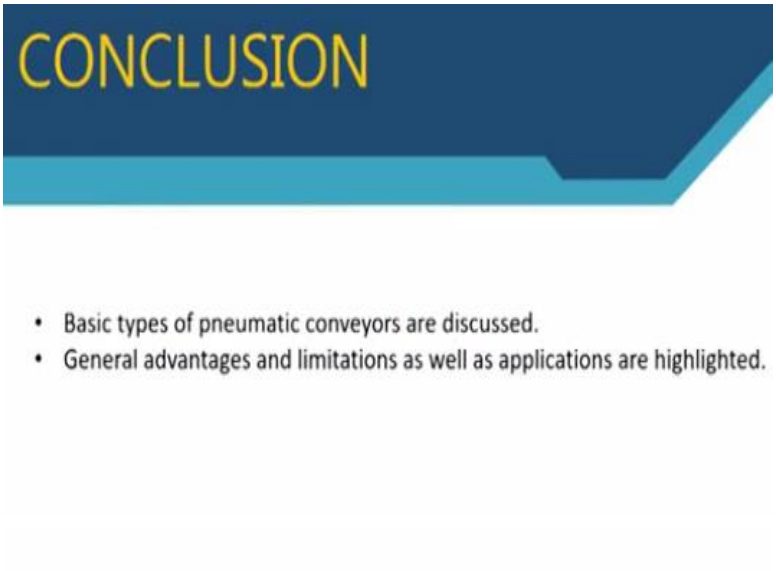

So, today, basically, we have that the basic introductions of your pneumatic conveying. You have understood that the air in a pipe can be used for transporting bulk material. And, for

that, the basic design will have to understand the fluid mechanics and will have to design the pipeline that what should be the diameter, what should be the capacity of the pump and how much exactly the flow material we can deliver.

And then, once you go for a real designing, you can do a cost benefit analysis and take out because that what type of problems will be there how will we maintaining. So, this itself is a subject combined with this pneumatic conveying itself is a subject. But, here, we will be introducing you that only the basic. And, maybe you know next class, will do some basic calculations so that if any one of you are interested you can take this to study further, R and D. And then, exercises got always a wide area of working. Thank you very much.