Chemical Process Utilities
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Lecture – 33
Introduction to Pneumatic Conveying System

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Welcome to the introduction to the pneumatic conveying system. Now, let us have a brief look that what we discussed in the previous lecture. We had a discussion about the various air filtration system because separation is an integral part of conveying system because solid is being conveyed with the help of pneumatic media like air in this case then at the port of this engagement it needs to be separated out from the solid and gases system.

So, we discussed about various separation techniques. We had a discussion about the compressed air safety because it is a pressurized vessel and sometimes pressure vessel may create a problem as well as because of the temperature engagement in the compressed air than the high temperature surfaces again may create a problem and because of various other chemicals being conveyed they are using various processes.

They are using the compressed air then we discussed briefly about the various kind of a safety devices or safety approaches to be used in the compressed air system. Apart from this since all these things are electrically powered so we discussed briefly about the electrical safety. Then we started the pneumatic conveying system a brief introduction we had given about the pneumatic conveyors and how it can be used in the various kind of the process industries.

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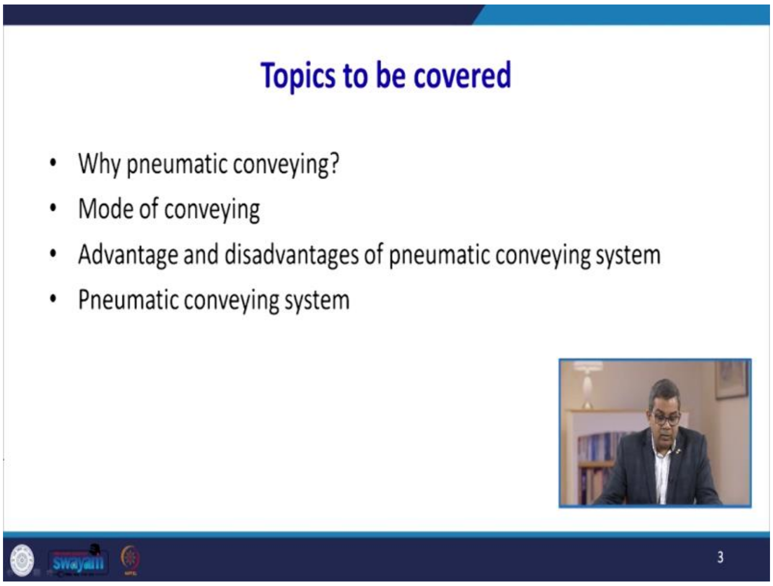

In this particular lecture or in this particular topic we are going to discuss about why we are using this pneumatic conveying, what are the different modes of the conveying system since it is having a prominent place in the conveying system then what are the various advantages and disadvantages associated with the pneumatic conveying system and then we will start about the basic concept of the pneumatic conveying system.

Now why pneumatic conveying? Now it is attributed to the fluid dynamic; the concept of fluid conveyance by the pipeline is far from new. It has a very long history using getting back to antiquity like Romans they utilized led pipe for water delivery and sewage disposal. Our Chinese they employed the bamboo tubes to transport the natural gas. Now with the invention of the fans to activate the first systematic pneumatic conveying was introduced in 1866.

And the history of the pipeline transportation of solid and air is more recent. Now the vacuum conveying of grains was the first large scale application of pneumatic conveying in late 19^{th} century sometimes negative and a positive pressure grain conveying which was popularized in the 1920 etcetera. Since then, the pneumatic conveying has evolved tremendously and has expanded to include a wide range of particle solids. Now why it is so important? First and foremost, thing is that it provides system flexibility.

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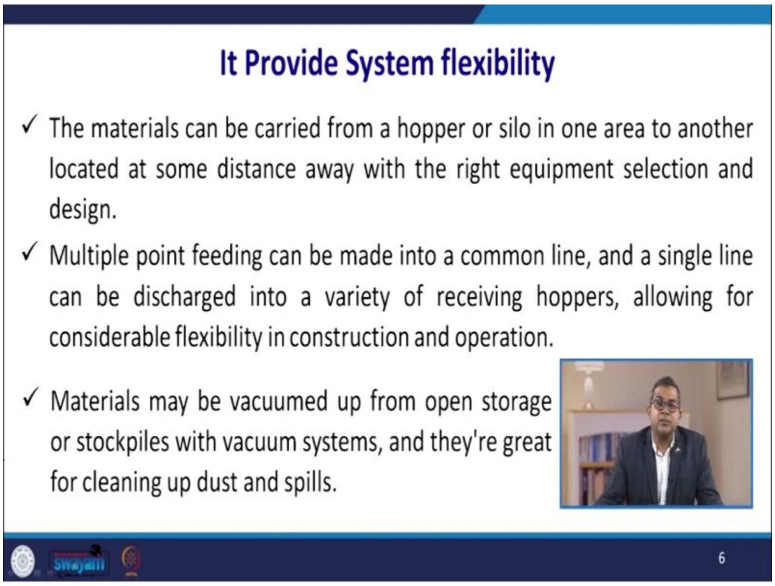

The materials can be carried from a hopper or silo in one arena to another located at some distance away with the right equipment selection and design. Multiple point feeding can be made into a common line and a single line can be discharged into a variety of receiving hoppers allowing for considerable flexibility in construction and operation. Now materials can be vacuumed up from open storage or stockpiles with the vacuum system.

And they are great for cleaning up dust and spills. These pipelines of course it will be with the help of pipeline.

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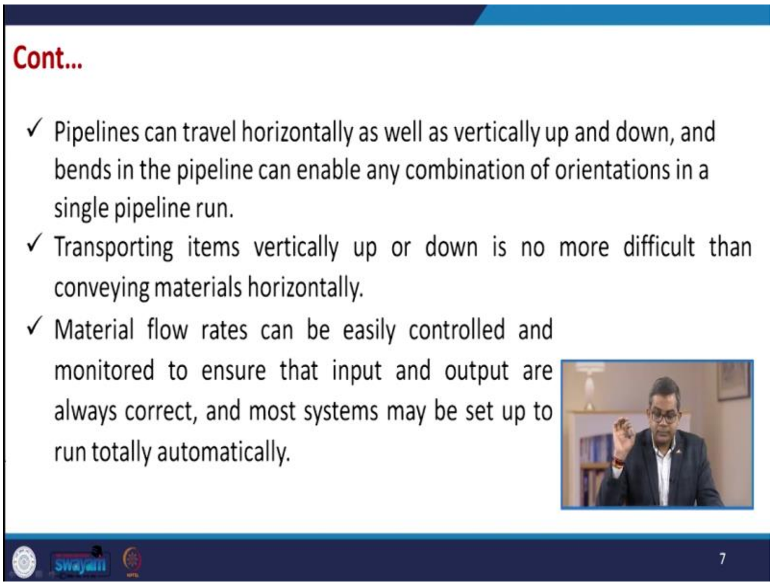

So, pipeline can travel horizontally as well as vertically up and down and bends in the pipeline they can enable any combination of orientation in a single pipeline run. So, when we talk about the transportation the transporting item vertically up or down is no more difficult than conveying material horizontally. Now material flow rate you can easily control and monitor to ensure that input and output are always correct and more system may be setup to run totally automatic.

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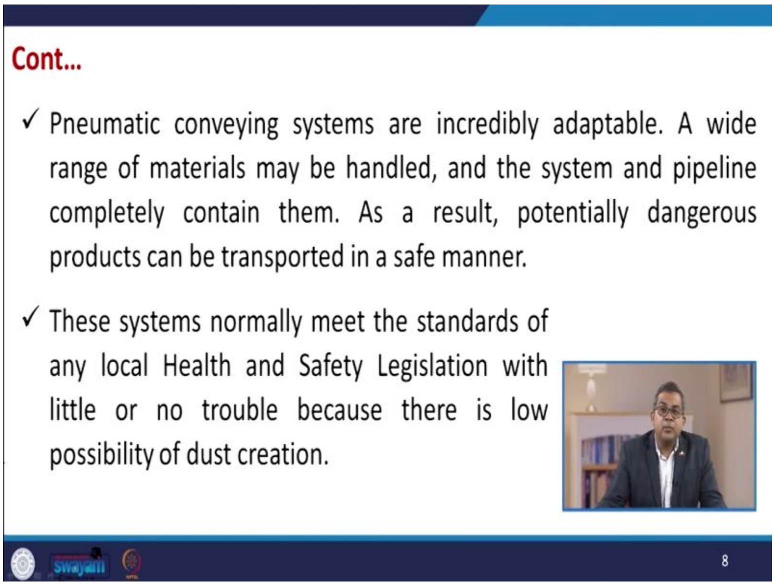

Now pneumatic conveying systems they are incredibly adoptable. A wide range of materials may be handled and the system and pipeline completely contain them. Now as a result to potentially dangerous products can be transported in a safe manner and that is very plus point I will tell you this is very important point because the transportation of the dangerous material is always offer a wide attention.

Now these systems normally meet the standards of a local and health and safety legislation may be some your state may have some different legislation, federal or central level you may have different legislation with the little or no trouble because there is a low possibility of dust creation.

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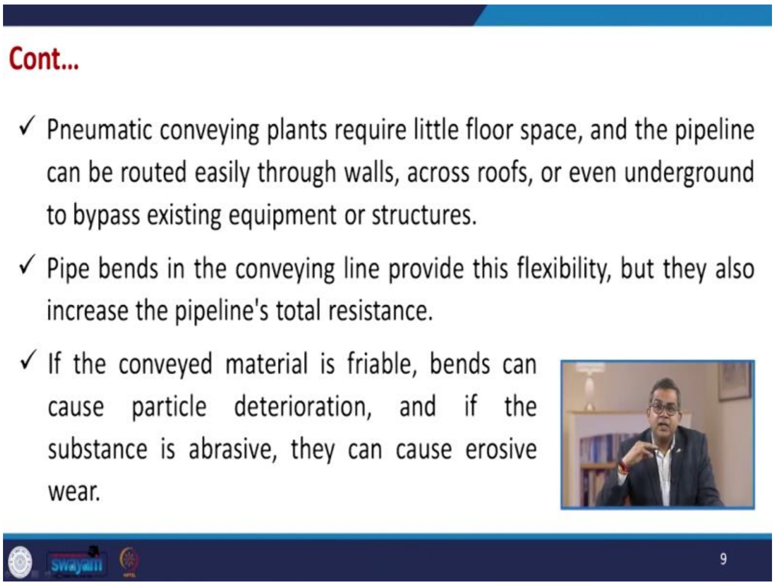

Now these pneumatic conveying plants they require a very little floor space and the pipeline can be routed easily through walls across roof or even underground bypass existing equipment or structures. So, there is no need to alter the existing layout of the plant. Now pipe bends in the conveying line usually they provide this flexibility, but they also increase the pipelines total resistance.

So, your usual fluid dynamics or fluid mechanics law always prevails and resistance when there is large amount of resistance then you need to have more and more pumping expenditure. Now, if the conveyed material is friable, bends can cause particle deterioration sometimes a deposition may take place and it further reduces the overall available area and sometimes if substance is abrasive, they can cause erosive wear and tear.

And it can react with the pipeline material and sometimes the effect may be more and more catastrophic.

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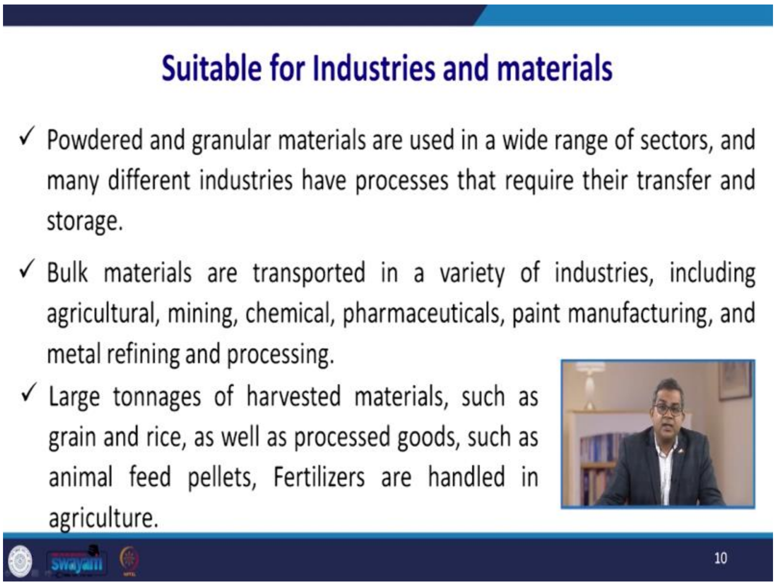

Now it is suitable for various industries and materials. So, the powdered and granular materials are used in wide range of sectors and many different industries they have processes that require their transfer and storages. Now the bulk materials are transported in variety of industries including agricultural, mining, chemical, pharmaceutical, paint manufacturing and a metal refining and processing.

Large tonnage sometimes large tonnage of harvested material such as grains and rice as well as processed goods such as like animal feed, pellets, fertilizers those who are handled in the agricultural industries.

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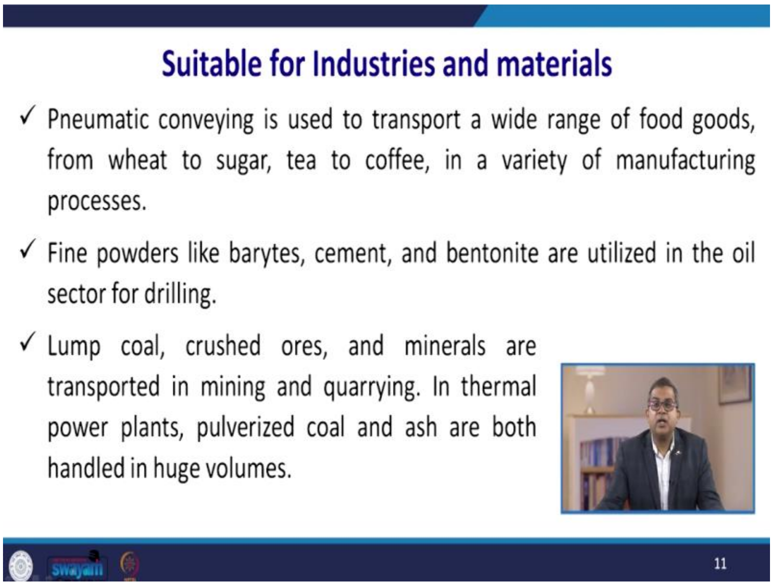

The pneumatic conveying is used to transport a wide range of food goods from wheat to sugar, tea to coffee in variety of manufacturing processes and the beauty of this particular pneumatic conveying is that you can install these pneumatic conveying process onsite easily. Some fine powders like cements, bentonites they are utilized in the oil sector for drilling you can easily convey through this pneumatic conveying.

Lump coal, crushed ores, minerals they are transported in mining, quarrying, in thermal power plants, pulverized coals and ash they are both handled in a huge volume. So, it can handle a huge volume of these materials.

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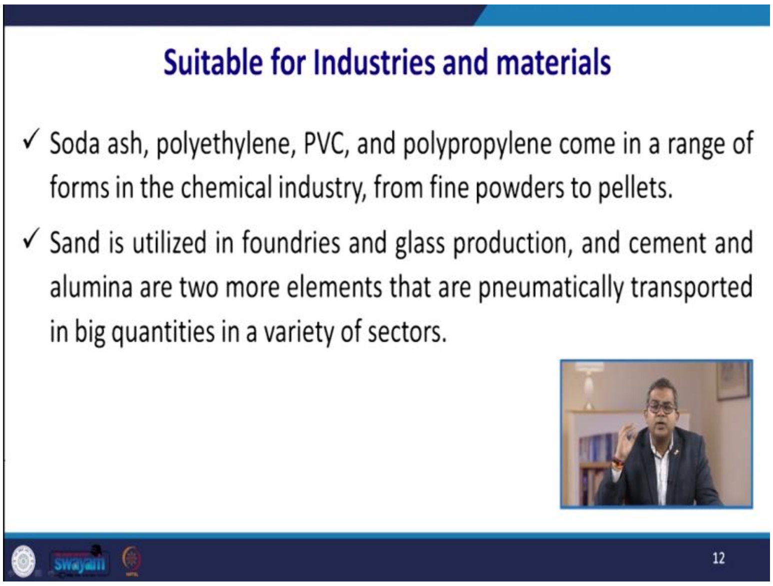

Soda ash, polyethylene, polyvinyl chloride, polypropylene they come in a range of the form in the chemical industry from fine powder to pellet if these industries can utilize this pneumatic conveying. Sand which is utilized in foundries in popular manner. It is also used in the glass production, cement, alumina these are the other elements that pneumatically transported in a big quantity in variety of sectors.

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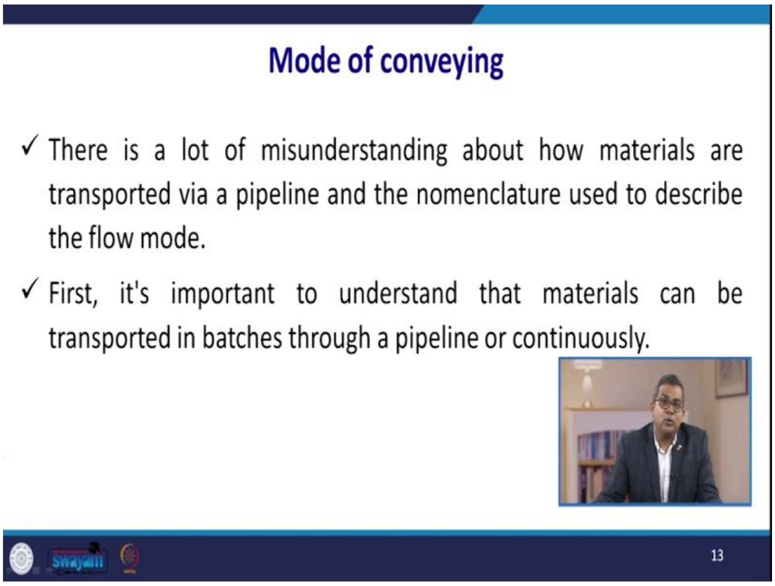

Now let us talk about the mode of conveying. Now there is lot of misunderstanding about how materials are transported via a pipeline and the nomenclature used to describe the flow mode. First it is important to understand that materials can be transported in batches through a pipeline or sometimes in the continuous pressure. Now, if batch size is small the material can be carried as a single plug-in batch conveying.

Now two forms of conveying there are recognized in continuous conveying and batch conveying if the batch size is large that is the dilute phase conveying and the dense phase conveying. Now, let us talk about the dilute phase conveying.

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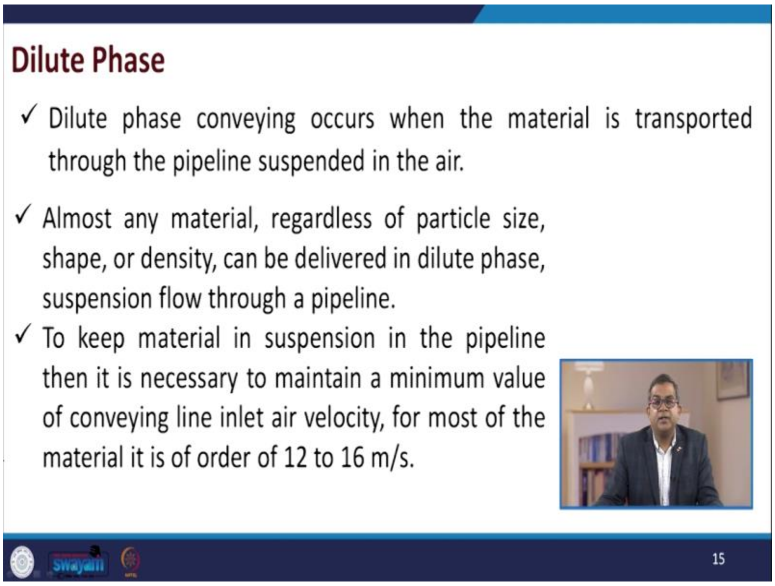

Now dilute phase conveying occurs when the material is transported through a pipeline suspended in the air. Almost any material regardless of particle size, shape, density it can be delivered in dilute phase, suspension flow through a pipeline. Now to keep material in suspension in the pipeline then it is necessary to maintain a minimum value of conveying line inlet air velocity. For most of the material it is in the order of say 12 to 16 meter per second.

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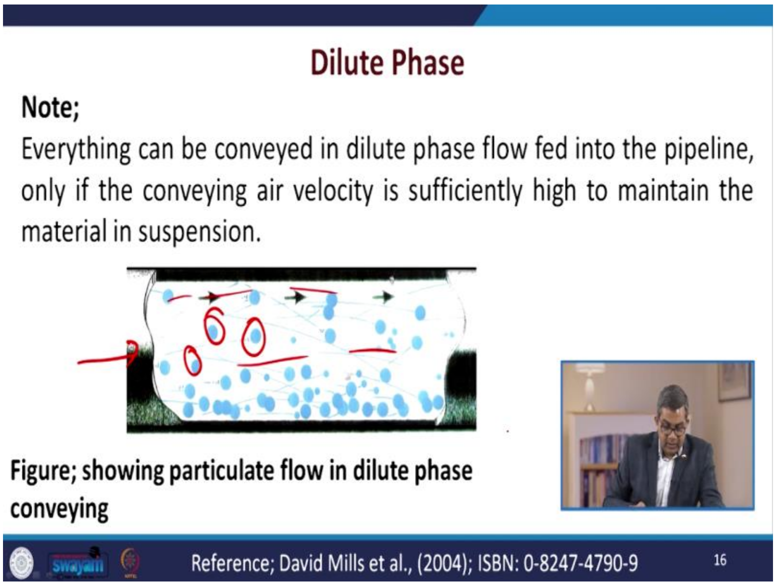

Now everything can be conveyed in dilute phase, flow fed into the pipeline only if conveying air velocity is sufficiently high to maintain the material in suspension. Now you see the basic anatomy of the particulate flow in the dilute phase conveying. You see these are the particulate and air so you see that discrete particles reflects that we are under the dilute phase.

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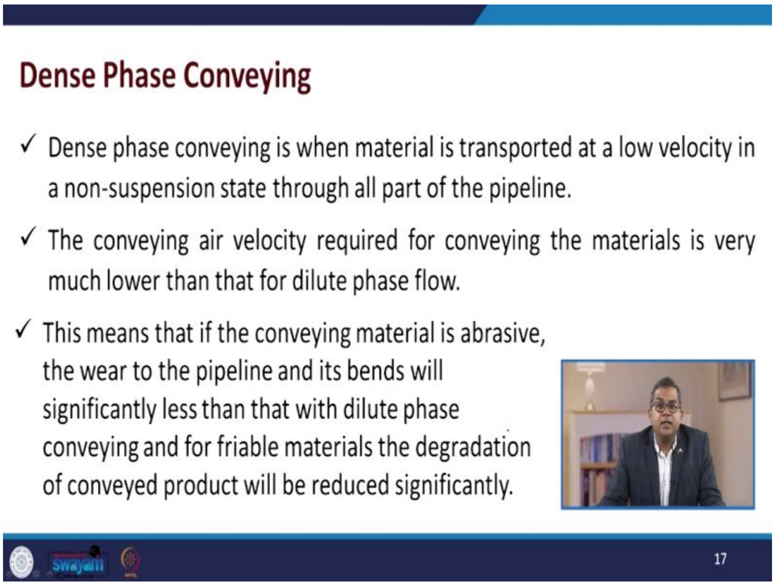

Now, let us talk about the dense phase conveying. Now dense phasing is when material is transported at a low velocity in a non suspended state through all parts of the pipeline. The conveying air velocity required for conveying the material is very much lower than that of dilute phase flow. So, what does it mean? It means that if conveying material is abrasive the wear to the pipeline and its bend will significantly less than what with the dilute phase conveying and for the friable materials the degradation of conveyed product will be reduced significantly.

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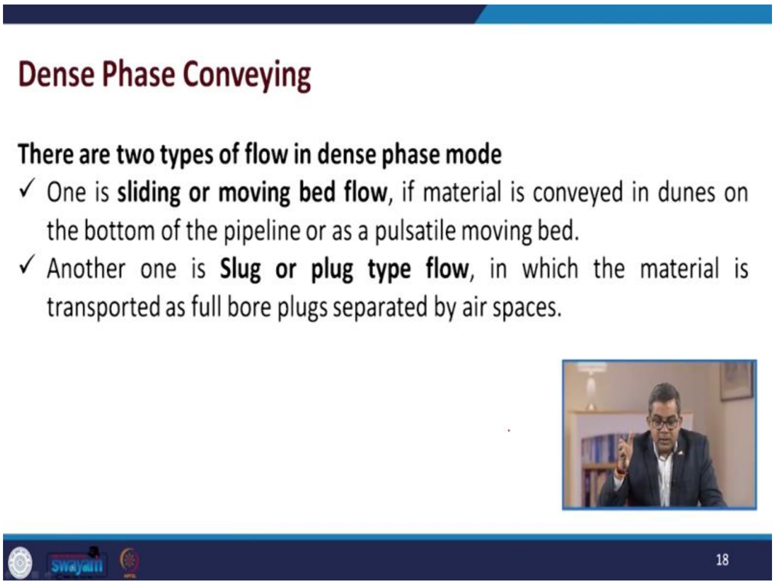

Now again there are two types of flow in dense phase mode. One is sliding or moving bed flow. Now, if material is conveyed in dunes on the bottom of the pipeline or as pulsatile moving bed. Another one is the slug or plug type of flow in which the material is transported as full-bore plugs separated by air spaces.

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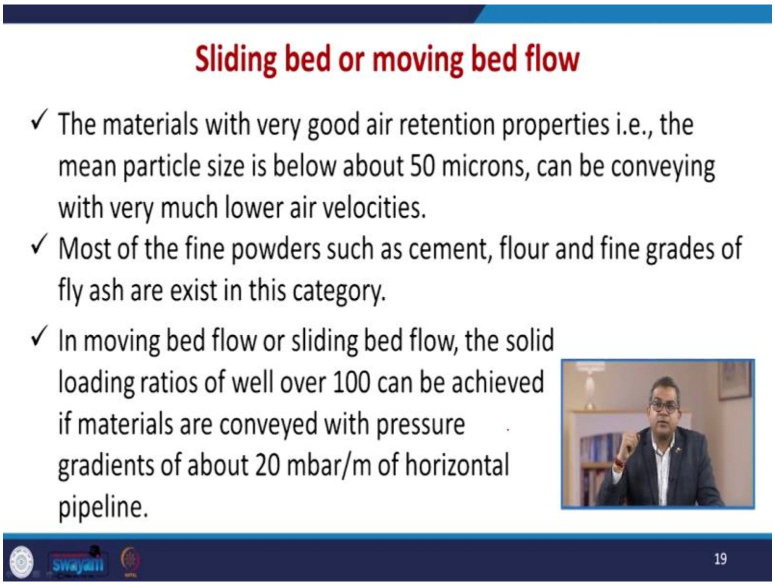

Let us talk about the sliding bed or moving bed flow. The material with very good air retention properties that is the mean particle size is below about say 50 micron it can be conveyed with a very much lower air velocity. Most of the fine powders such as cement, flour and fine grades of fly ash are existed in this particular category. Now in moving bed flow or sliding bed flow the solid loading ratio of well over say 100 can be achieved.

If you can say the materials are conveyed with pressure gradient of about say 20 millibar per meter of horizontal pipeline.

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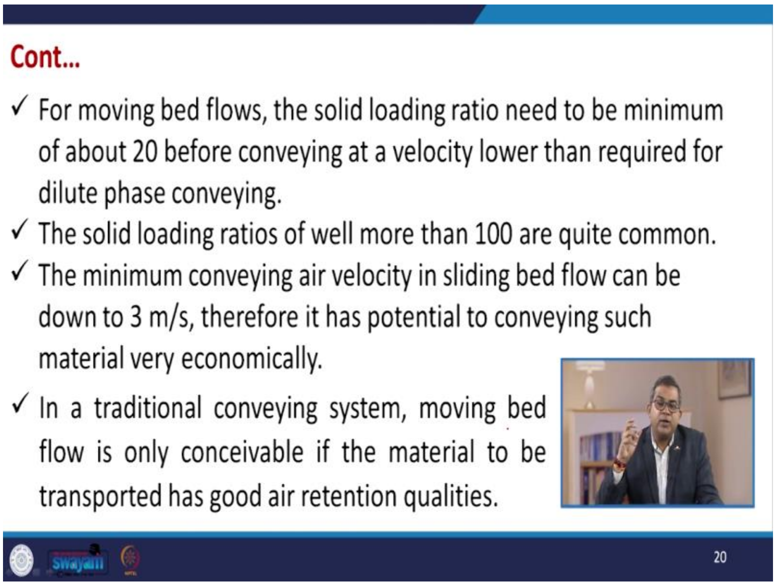

Now for moving bed flows the solid loading ratio needs to be maintained about 20 before conveying at a velocity lower than require for the dilute phase conveying. The solid loading ratios of well more than say 100 are quite common. The minimum conveying air velocity in sliding bed flow it can be down to say 3 meter per second. Therefore, it has potential to convey such material very economically.

So, when we are looking for economical aspect or economical feasibility this type of approaches are quite favorable. Now, in a traditional conveying system moving bed flow is only conceivable if material to be transported has a good air retention quality this is the foremost requirement.

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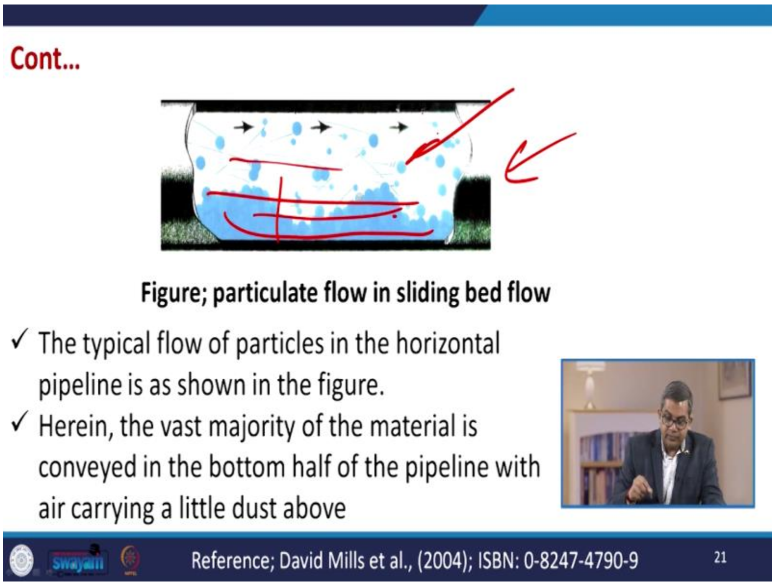

Now here you see the particular flow in a sliding bed flow you see the difference. Now the typical flow of a particle in the horizontal pipeline we have depicted in this particular figure the vast majority here you see that the vast majority of the material is conveyed in the bottom half of the pipeline with air carrying a little dust above. You see that this is the little dust and the major part is being at the bottom.

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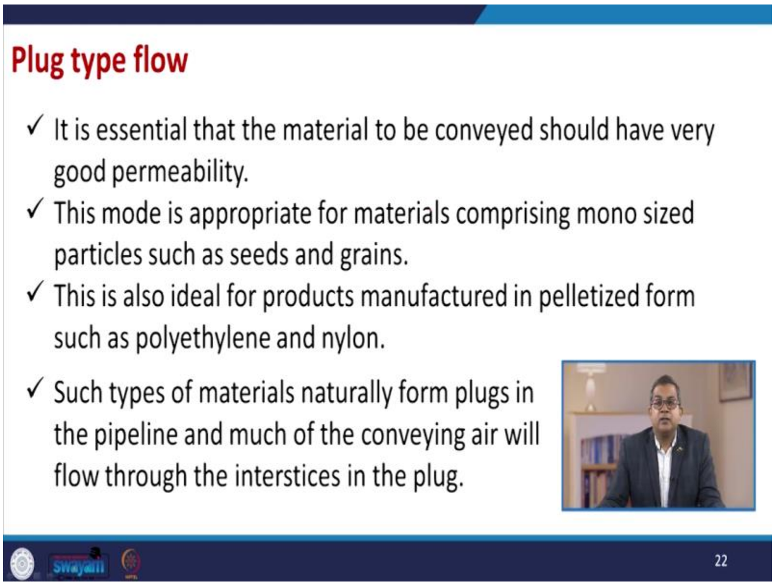

Let us talk about the plug type flow. Now, it is essential that the material to be conveyed should have a very good permeability. This mode is appropriate for materials comprising mono sized particle sometimes referred as seed or grains. Now this is also ideal for product manufacturing in a palletized form such as polyethylene pellets or nylon. Now such type of materials naturally form plug in the pipeline and much of the conveying air will flow through the interstices in the plug.

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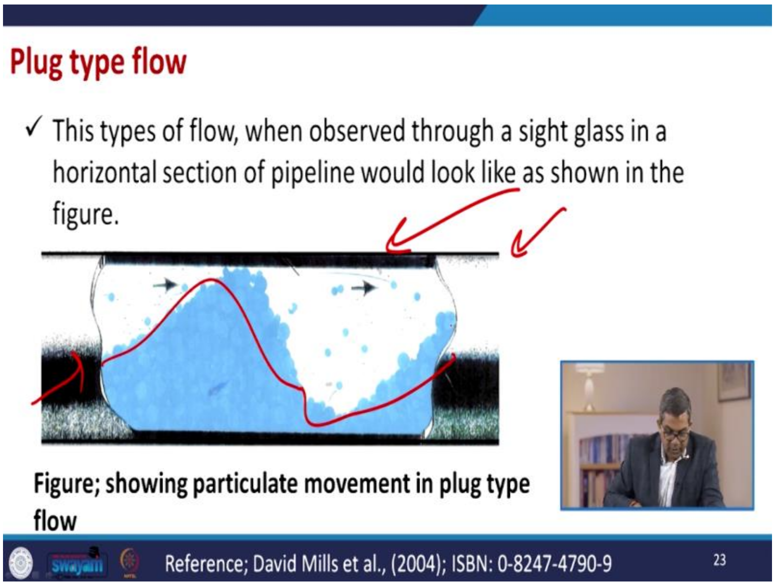

Plug type of a flow. Now this type of a flow when observed through a sight glass in a horizontal section of pipeline like shown in this particular figure here the particulate movement you see in a plug type flow.

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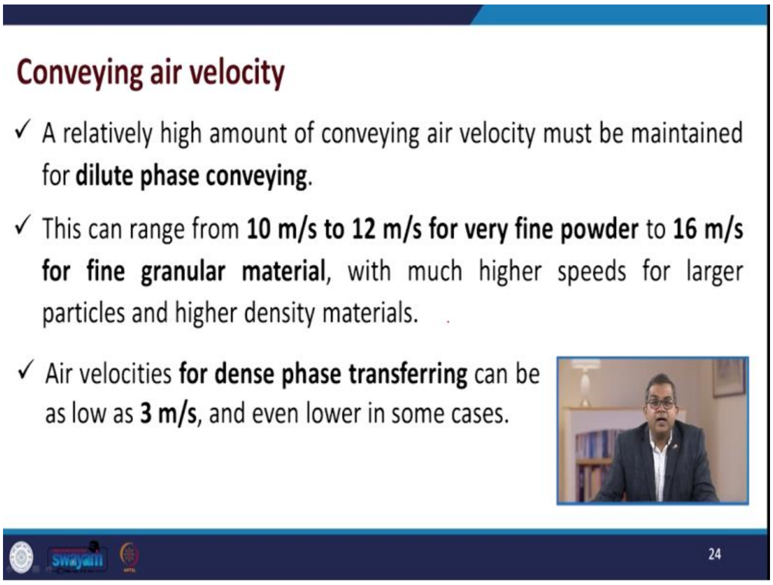

A relatively high amount of conveying air velocity it must be maintained for dilute phase conveying sometimes this can be ranges from say 10 meter per second to 12 meter per second for very fine powder to sometimes 16 meter per second for a fine granular material with much higher speed for larger particles and higher density materials. Now air velocity for dense phase transferring this can be as low as say 3 meter per second and even lower in some cases.

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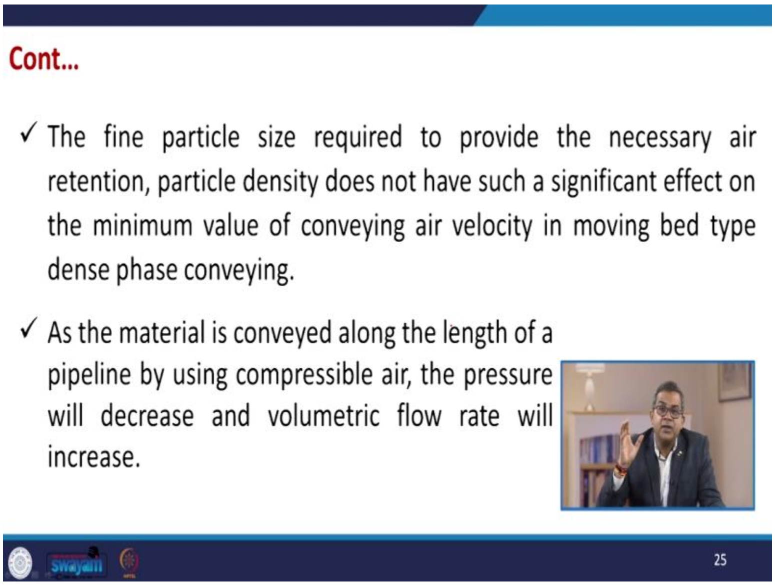

So, the fine particle size they require to provided the necessary air retention. Particle density sometimes does not have such significant effect on minimum value of conveying air velocity in moving bed type dense phase conveying. Now as the material is conveyed along the length of a pipeline by using compressible air. The pressure will definitely decrease and the volumetric flow rate will increase.

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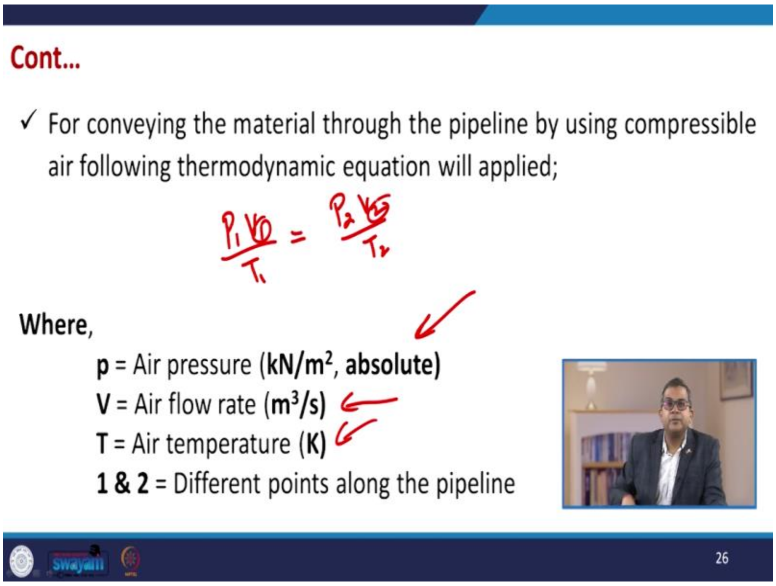

For conveying the material through the pipeline by using compressible air you can use the ideal gas law with the Charle’s and Boyle's Law in question and thermodynamically we can represent P 1 V 1 / T 1 = P 2 V 2 / T 2 where p is the air pressure and it is in the Kilo Newton per meter square absolute. V is the air flow rate in meter cube per second and T is the air temperature in Kelvin and usually 1 and 2 they are the different point along the pipeline.

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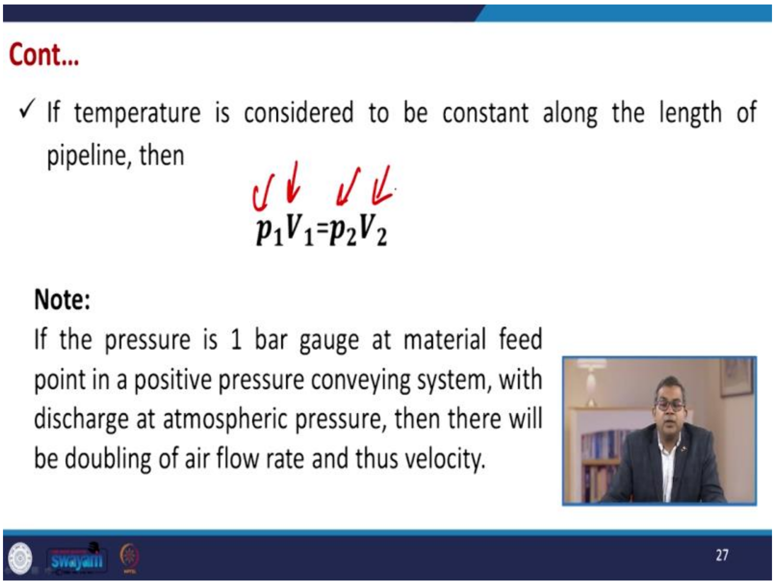
$$\frac{p_1 V_1}{T_1} = \frac{p_1 V_1}{T_1}$$



Now, if temperature is considered to be constant our isothermal along the length of pipeline and this is a very common practice and since we are using the ideal gas law it is purely an assumption that we are adopting the isothermal concept then it has become the p 1 V 1 = p 1 V 2. Now, if the pressure is 1 bar gauge at material feed point in a positive pressure conveying system with discharge at atmospheric pressure, then there will be a doubling of air flow rate and thus velocity.

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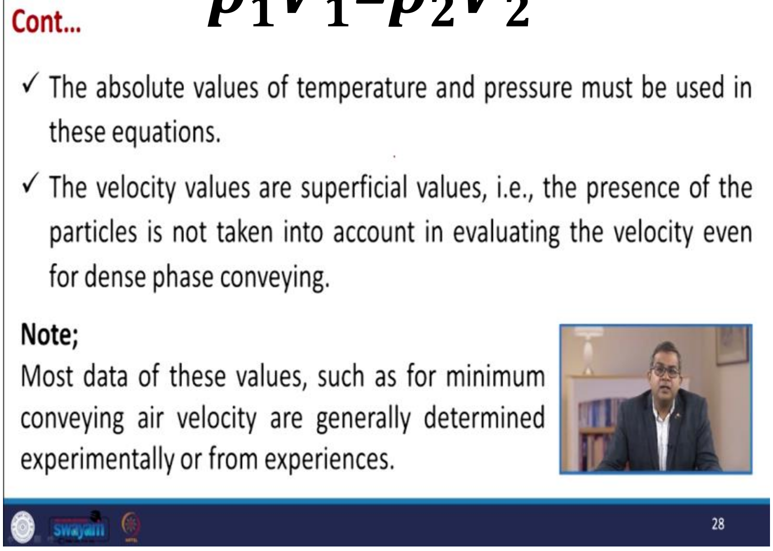
$$p_1 V_1 = p_2 V_2$$



So, the absolute value of temperature and pressure must be using this equation. The velocity values they are superficial values and obviously because we have taken the assumption that is the presence of the particle is not taken into account for evaluating the velocity even for dense phase conveying. Now most data of these value such as minimum conveying velocity they are generally determine experimentally or from the past experiences.

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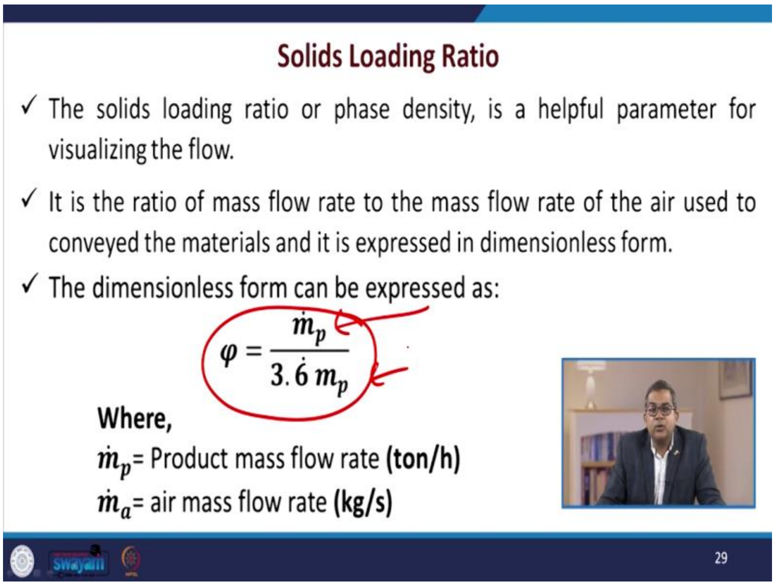

When we talk about the solid loading ratio and it is a very important phenomenon. So, the solid loading ratio or phase density this is a very helpful parameter for visualizing the flow. Now, if the ratio of mass flow rate of air used to convey the materials and expressed you can say in the dimensionless form. So, the dimensionless form can be expressed as phi = m p / 3.6 m p.

Now this is the product mass flow rate usually represented in tons per hour and m a is the air mass flow rate that is kilogram per second.

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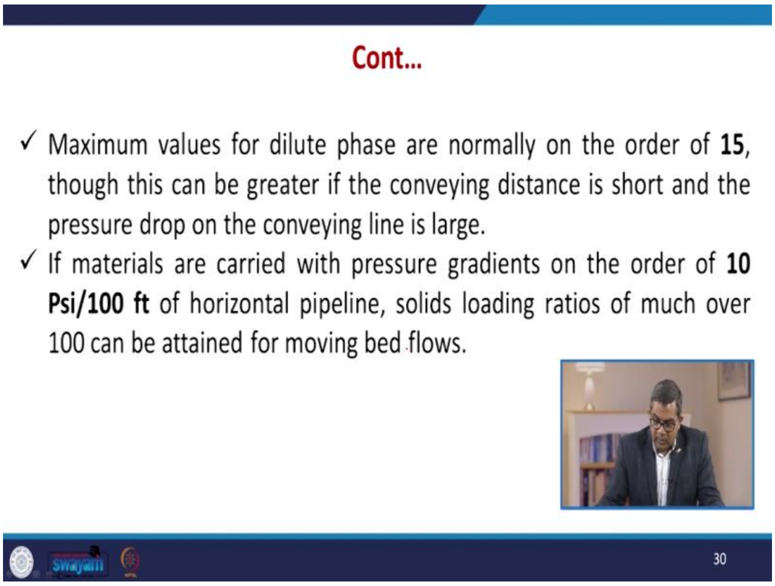
$$\varphi = \frac{\dot{m}_p}{3.\dot{6}\, m_p}$$



Now, the maximum value for dilute phase is normally in the order of say 15. Though this can be greater if conveying distance is short and the pressure drop on the conveying line is very large. Now, if materials are carried with a pressure gradient in the order of say 10 Psi per 100 feet of the horizontal pipeline solid loading ratio of much over say 100 it can be attained for moving bed flows.

For plug flow its value is not appropriate as a material have to be very permeable and maximum values are only of the order of say 30, materials obviously this can be reliably carried at a velocity of say 600 feet per minute and below in the plug flow type despite of low value of solid loading ratio.

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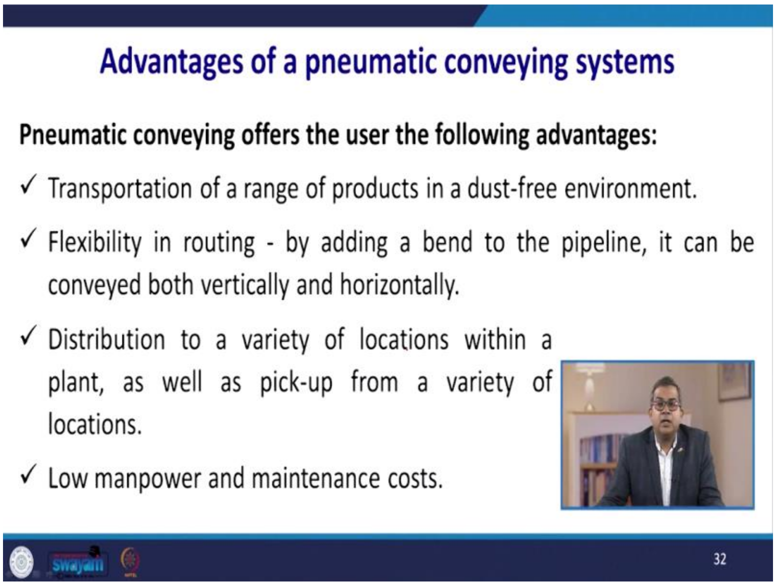

Now, let us talk about the advantages of pneumatic conveying system. Now pneumatic conveying offers the user various kind of advantages. One is that transportation of a range of products in dust free environment. Second is that flexibility in routing by addition of a bend in the pipeline it can be conveyed both vertically and horizontally, but remember when we are using the bend than we are compromising with the pressure as well as there are certain issues with the available area in question.

Then third point is that distribution to a variety of location within a plant as well as pick up from the variety of the location. So, it offers a very wide spectrum. The fourth one is that it enjoys the low manpower concept and maintenance cost. So, the economics of your plant can be in a good arena.

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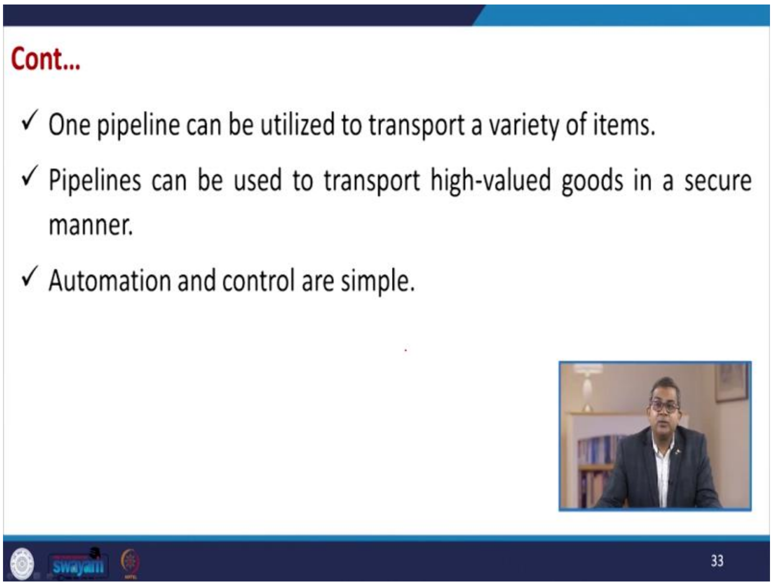

Another advantage is that one pipeline can utilize to transport a variety of item only thing is that you need to flush it out the old material. Now these pipelines can be used to transport high valued good in a very secured manner and for this pneumatic conveying system the level of automation and controls are very simple. See we discussed various advantages of this pneumatic conveying system, but simultaneously there are so many disadvantages. They are also associated with the pneumatic conveying system.

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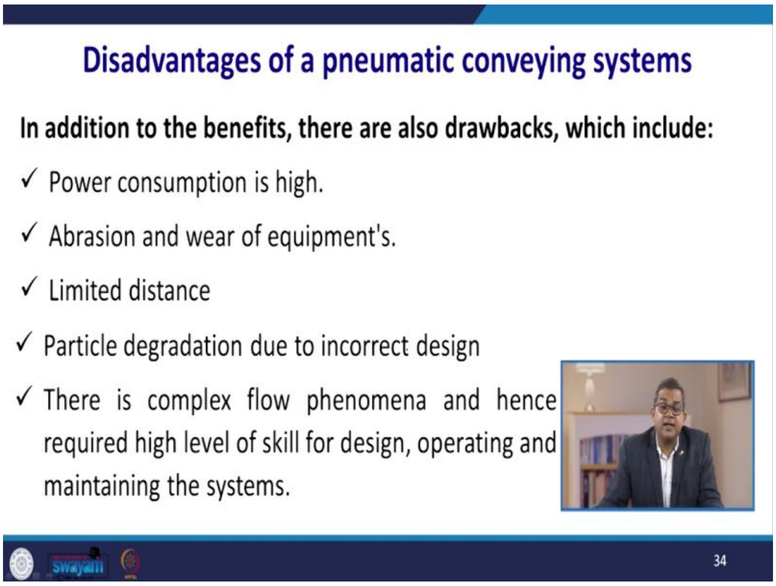

Now these drawbacks are one is that you require a very high-power consumption because you need to build up the pressure, you need to have a separation, you need to have other things then there may be a chance of abrasion and wear and tear of the equipments because of the high pressure as well as the accumulation of the material. Since, it is consuming very high power and the chances of abrasion etcetera are there.

Then you are having a very limited option with respect to the distance so you are having a very limited distance cover up. Now the particle degradation may occur due to the incorrect design. So, the designing factor is again very important. Now there is a complex flow phenomenon therefore it requires a high level of skill for design operating and maintaining the system.

Now due to higher power consumption the pneumatic conveying system are generally suitable for the transportation of very fine particles for a very shorter distance may be say 100 meter or little bit plus minus. The major existing system they have the capacity from 1 to 400 tons per hour over the distance of less than say 1,000 meters with average particle size of say 10 mm.

For transportation of solid materials this particular system should be considered as a prime option and should be evaluated against other mode of transportation.

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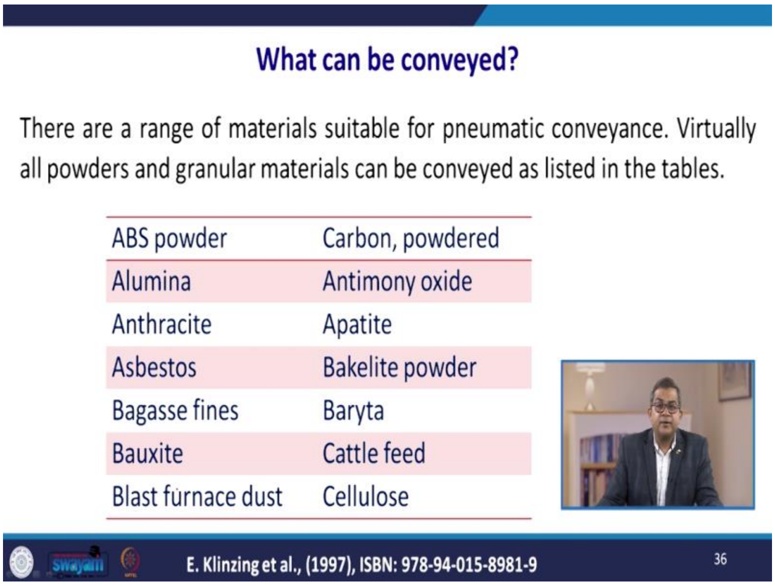

Now question arises that what can be conveyed. There are range of material suitable for pneumatic conveyance virtually all powders and granular materials these can be conveyed and we have enlisted like several of them like ABS powder, carbon powder, alumina, antimony oxide, anthracite, apatite, asbestos, Bakelite powder, bagasse fines, bauxite, blast furnace dust, cellulosic material, cattle feed etcetera.

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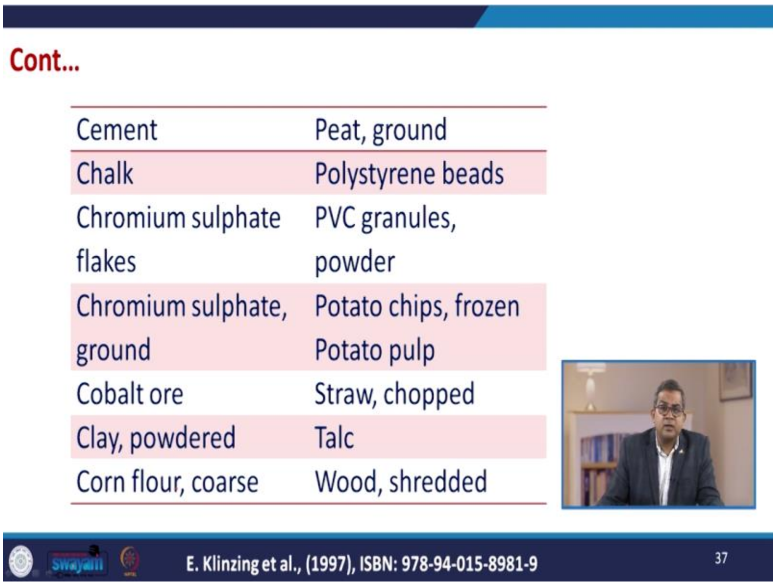

Apart from this the cement, chalk, chromium sulphate chromium sulphate grounded then cobalt, clay, corn flour, polystyrene beads, PVC granules, potato chips, frozen potato pulp, Talc, straw chopped, shredded wood.

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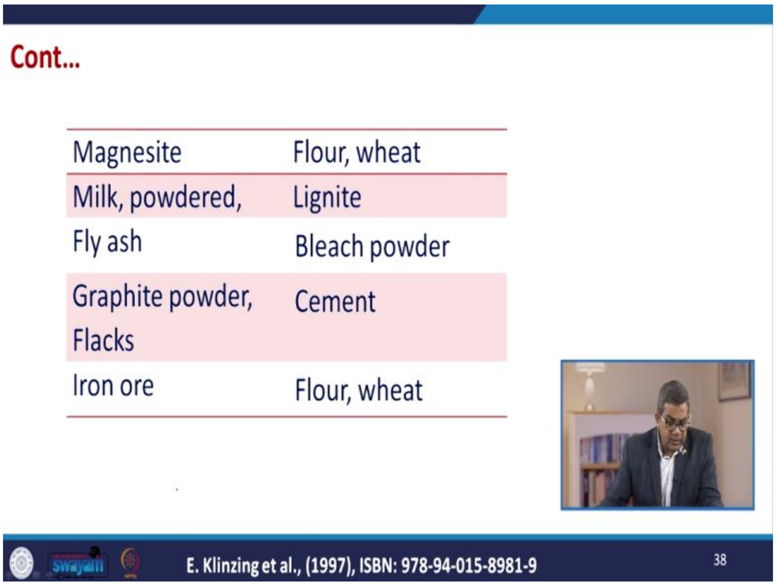

Then we can use this system for the magnesite, milk powder we can use it for the fly ash then graphite powder flacks, iron ore, flour wheat, lignite, bleaching powder.

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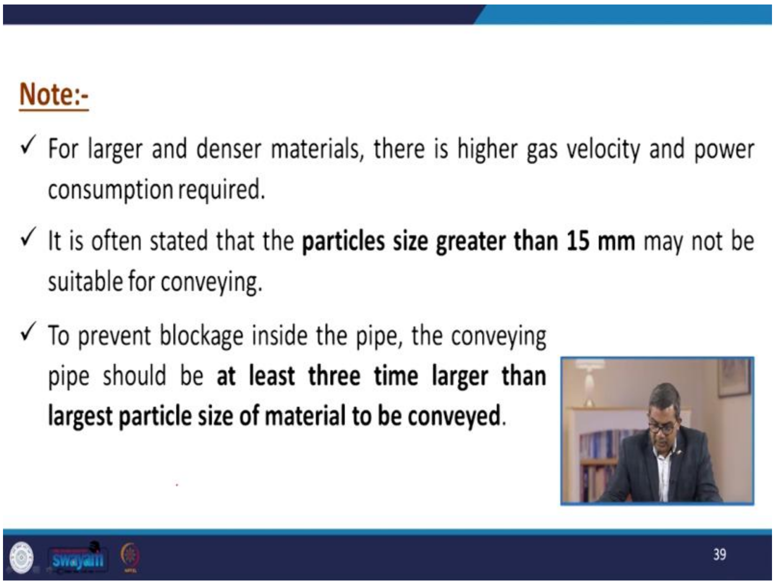

Now for larger and denser material there is a higher gas velocity and power consumption required because these materials they do posses some mass etcetera. Therefore, you require a gas velocity to convey and then power consumption would be on the higher side. It is often stated that those particle size greater than say 15 millimeter may not be suitable for conveying because you may convey it, but the thing is that it will not all economical because of the higher velocity requirement. So, therefore you need more and more power consumption.

Sometimes blockage may create a problem. So, to prevent the blockage inside the pipe the conveying pipe should be at least 3 times larger than the largest particle size of the material to be conveyed so that is very important and during the course of designing it must be properly addressed. So, the last in this particular segment we discussed lot about the pneumatic conveying system.

We discussed the basic aspect of pneumatic conveying, how we can use, what are the different materials can be use, what are the different type of pneumatic conveying systems, what are the advantages and disadvantages of this pneumatic conveying system.

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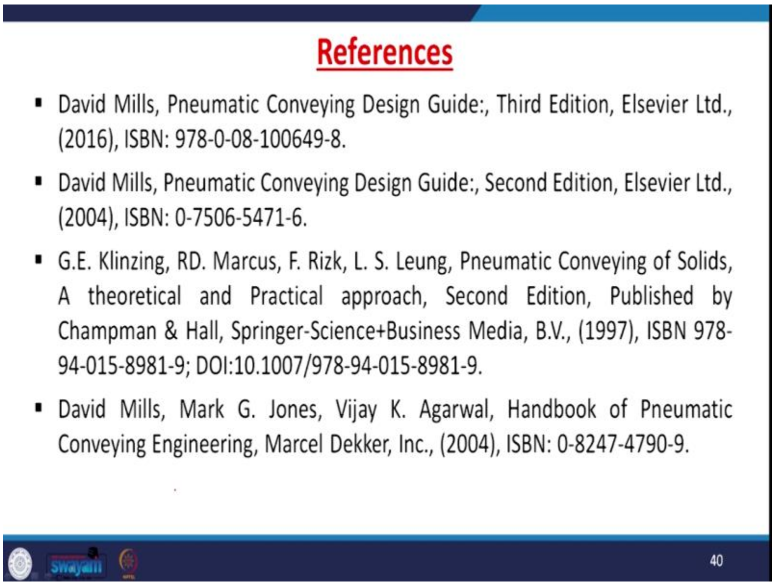

And if you wish to have further study or further knowledge about this pneumatic conveying system you may look to the various references which we enlisted in this particular slide. There are four references you can utilize these references for further reading. Thank you very much.