Chemical Process Utilities
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Lecture – 31
Air

Welcome to the new chapter of air under the edges of chemical process utilities. Now you see that we are in the process of learning about that what are the different utilities, attributed to the chemical processes and air is one of them. So, let us have a look that what we are going to study in this particular lecture.

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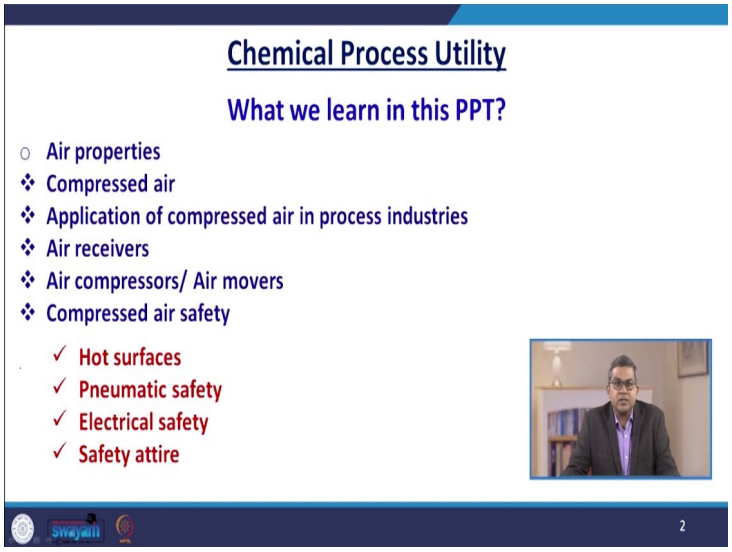

We will discuss about the air properties, various aspects of all air properties, discuss about the compressed air. Application of the compressed air in various process industries, we will have an outlook about air receivers and then we will discuss about the air compressors and we will have a talk about to the compressed air safety including hot surfaces, pneumatic safety, electrical safety, safety attires etcetera. So, all these things we are going to study in this particular lecture.

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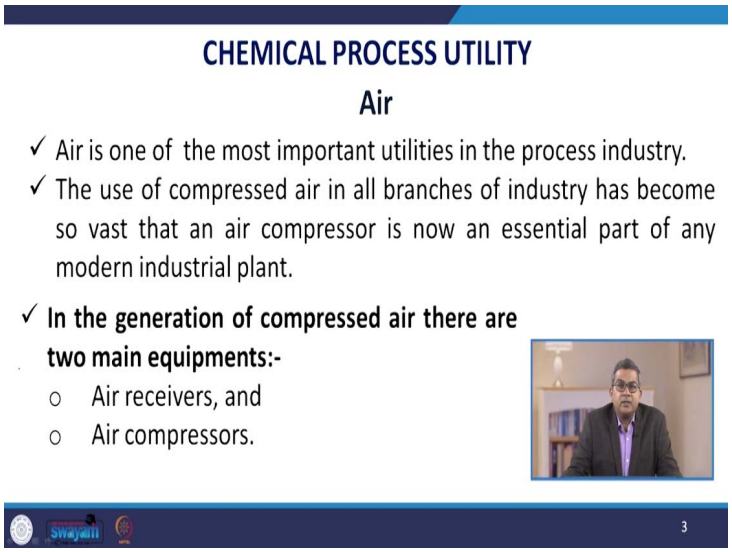

Now see what is air? Air is one of the most important utility in the process industry. We can use air in variety of spectrum. The use of compressed air in all branches of industry has become so vast that an air compressor is now an essential part of any modern industrial facility. So, obviously when we are using the compressed air then definitely the question may arise that how we can compressed the air.

Now see before we go for this compression aspect let us see that why air is so important in the chemical process industry? See first and foremost important thing is attributed to the economics. Air is available in abundance I mean you are surrounded by air. So, air supply is you can say very much available for all parts of chemical industry. Moreover, air is very much versatile.

So, based on this particular aspect there are two major equipment used in the compressed air aspect. One is the air receiver and second one is the air compressor.

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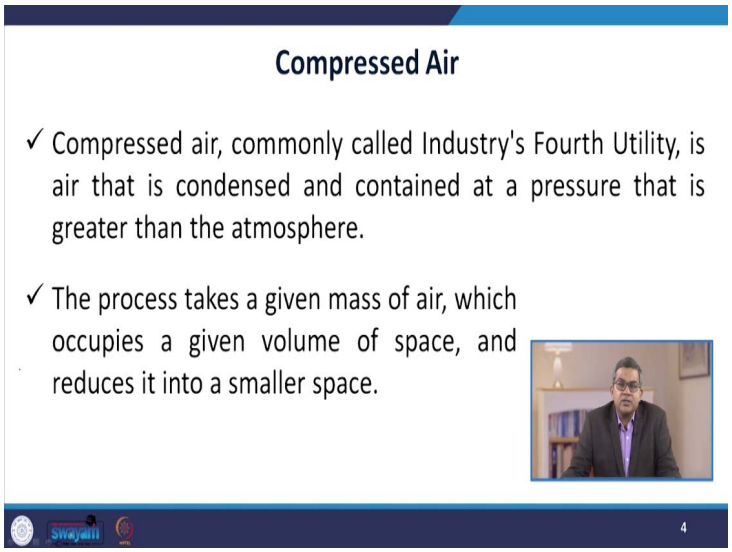

Now compressed air commonly called as industries fourth utility. This is the air that is condensed and contained at a pressure that is greater than the atmosphere. Now the process takes a given mass of air which occupies a given volume of space and reduces it into a small spaces. Now there are wide varieties of application of compressed air in the process industry. One is that to transmit the power as in the compressed air system for operating pneumatic tools like pneumatic controllers etcetera.

It can be used for the agitation of a liquid and slurries in the slurry reactors. It can be utilized to transport the solids. Compressed air is sometimes used for the cooling purpose also. In grinding mills like fluid energy mills where the solids are pulverized by less consumption of power, transportation of liquid or semi solid substances and sometimes it is used in blending of solids.

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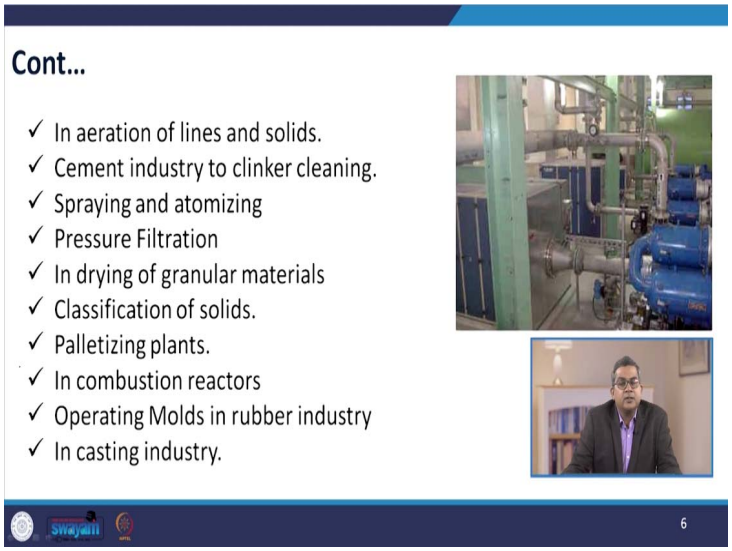

It can be used in aeration of lines and solids, flushing of lines, cement industry to clinker cleaning, spraying and atomization, it can be used as a pressure filtration device, in drying of granular materials the compressed air can be used. Segregation of solids the more frequently uses the compressed air, palletizing plants are foremost user of compressed air, it can be used in the combustion reactors where you require the oxygen supply because 21% oxygen is available in the air.

It can be used in the operating molds in the rubber industry, in casting industry. So, see the purpose of this application is to know that how air is versatile. Now, when we talk about the versatility of the air then obviously one thing is coming in our mind is that it should be supported by the various properties of the air.

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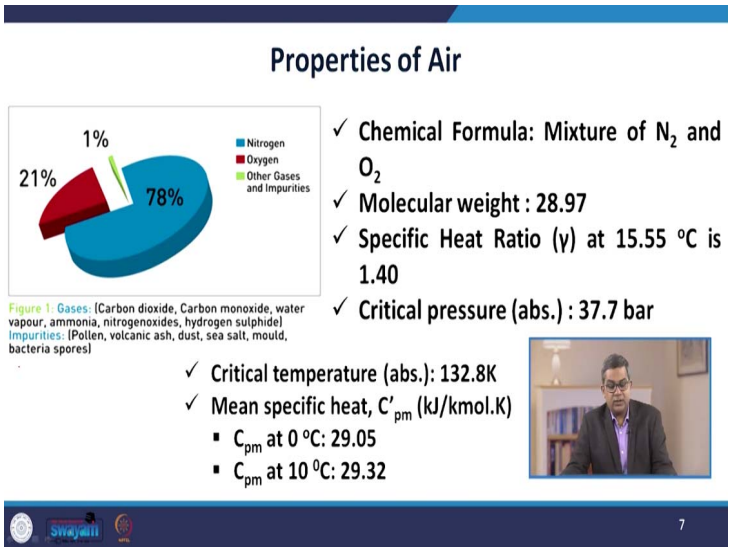

Now the properties of air if we talk about it is having the chemical formula, I mean that is attributed it is mixture of nitrogen and oxygen having the molecular weight of 28.97 then the specific heat ratio at 15.55 degree Celsius is 1.40 and a critical pressure is 37.7 bar whereas the critical temperature is 132.8 Kelvin having the specific heat is equal to at 0 degree Celsius 29.05 and at 10 degrees Celsius it is 29.32.

And of course, we are utilizing its percentage of oxygen that is 21% and 78% nitrogen and 1% the other gases and impurities. So, we were talking about the compressed air the integral part of compressed air production facility is the air receiver.

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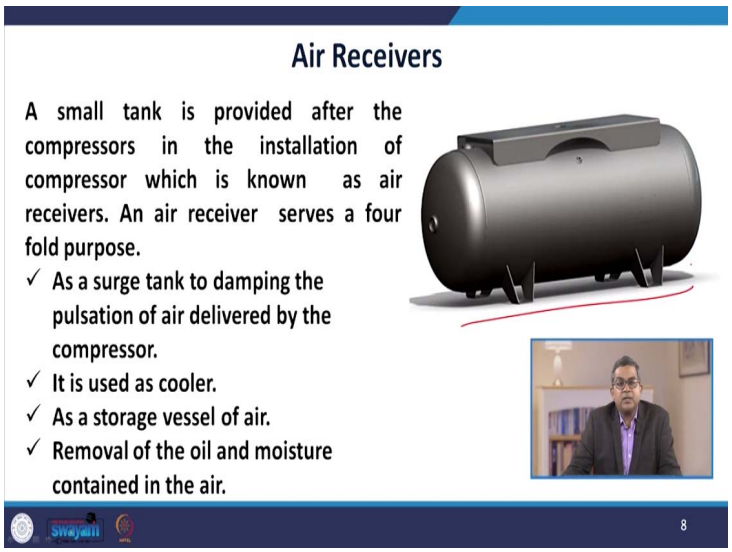

This is a small tank provided after the compressor in the installation of the compressor which is known as air receiver. An air receiver serves the four-fold purpose. As a surge tank to damping the pulsation of air delivered by the compressor it is used as a cooler because after compression the temperature of the air may go up. It can be used as a storage vessel of air. It can be used as a removal methodology or removal services of the oil and moisture contained in the air.

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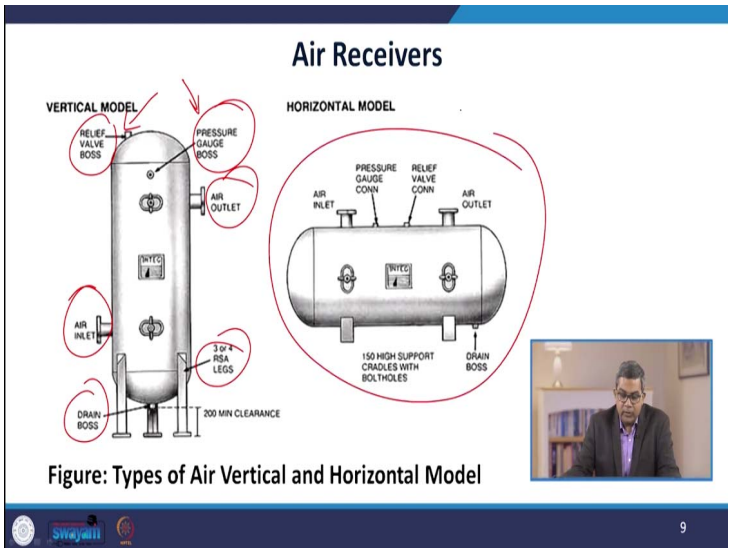

Now this is the basic anatomy of air receiver and these are the two types. One is the vertical one and second one is the horizontal one. The integral part of air receiver the relief valve, the pressure gauge, the air outlet as well as air inlet then drain and RSA legs. Now see because it is duly attached to the compressor and it contains the pressurized air that is why these are the safety devices or pressure gauge which indicates that the pressure of air receiver or tank. Now similarly you see this is a similar type of a structure attributed to the horizontal model.

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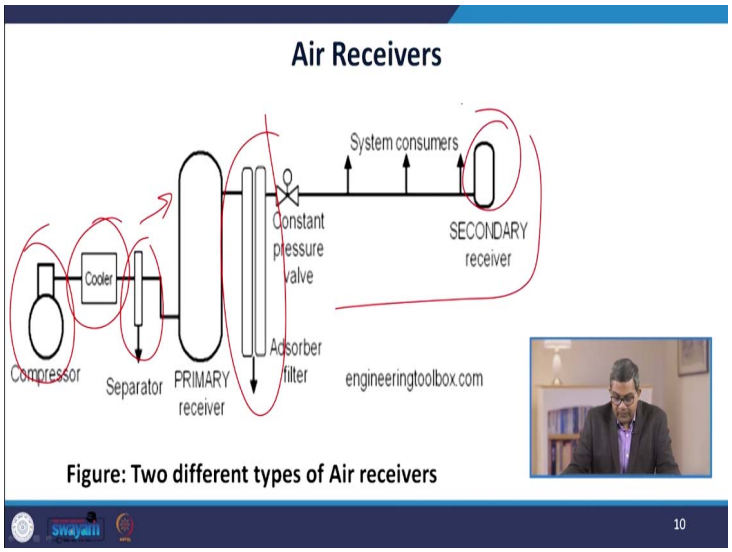

Now when we talk about the basic phenomena here you see that compression unit and after compression because I told you that there is a slight rise in the temperature then it is attached with a cooler and then there are separator which is attached to the primary receiver. Now there may be certain oil or other debris in the compressed air. So, these are removed in this adsorber filter and thereafter it can go to the secondary receiver for that use in different processes.

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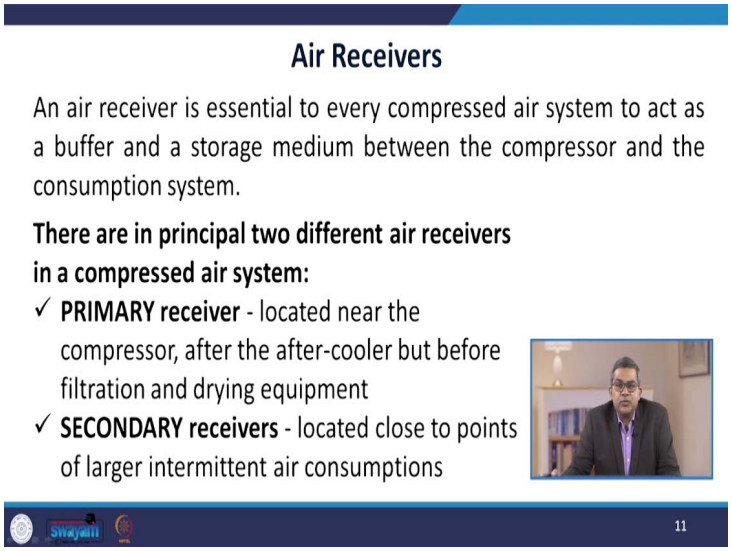

Now an air receiver is usually is extremely essential for every compressed air system to act as a buffer and as a storage medium between the compressor and the consumption system. Now as per the previous figure you see there are two different type of air receiver. One is the primary receiver and second one is the secondary receiver. So, the primary receiver this is located near the compression unit if you see over here after cooler, but before the filtration and drying equipment.

And the secondary receiver this is located close to the point of larger intermittent air consumption you see this is situated over here.

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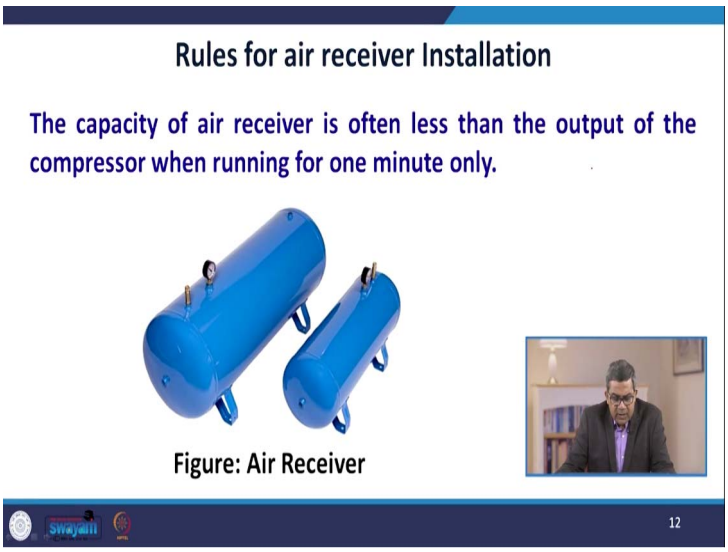

Now there are several rules which are related to the air receiver installation. Now the rule is the capacity of the air receiver is often less than the output of the compressor when running for one minute only.

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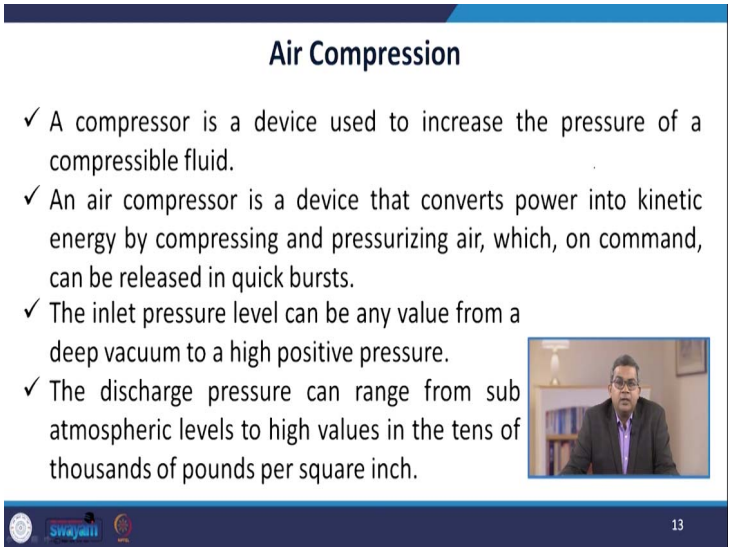

Now we have talked about the air compression system as well as the air receiver. Now as far as the air compression is in question then air compression is a device used to increase the pressure of a compressible fluid. Now air compressor is a device that converts the power into kinetic energy by compressing and pressurizing air which on demand can be released in a quick burst.

The inlet pressure level it can be any value from a deep vacuum to high positive pressure. The discharge pressure can range from say sub atmospheric level to high values in the tens of thousands of pounds per square inch.

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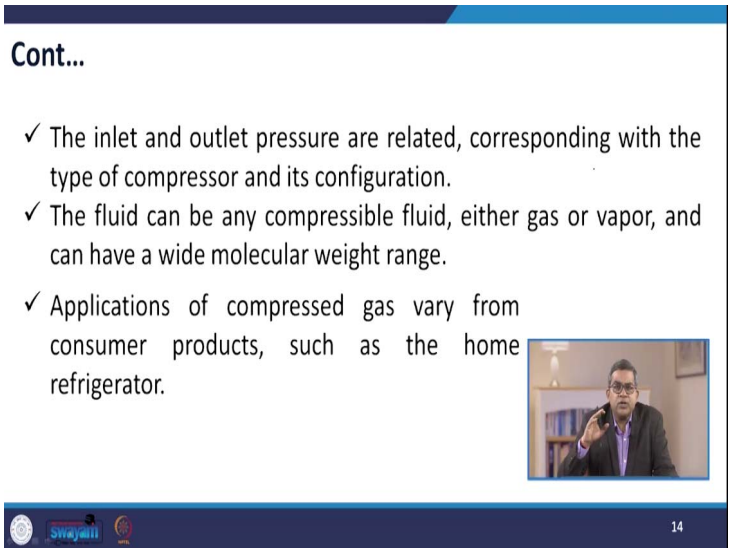

The inlet and outlet pressure are related corresponding with the type of compression and its configuration. The fluid you can say the fluid can be any compressible fluid either gas or a vapor or it can have a wider molecular range material. Application of compressed gas it can vary from consumer products such as the home refrigerator to some other products like this.

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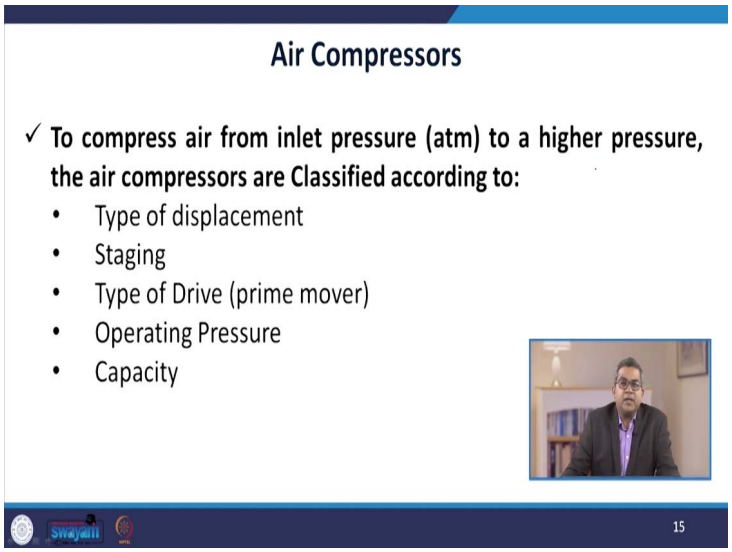

Now to compress air from inlet pressure to a higher pressure the air compressors are classified as per the type of the displacement, it may have a different number of stages so based on staging. It can have a different number of drives. So, it can be classified on the basis of type of drive that is the prime mover. It can be classified based on the operating pressure and capacity.

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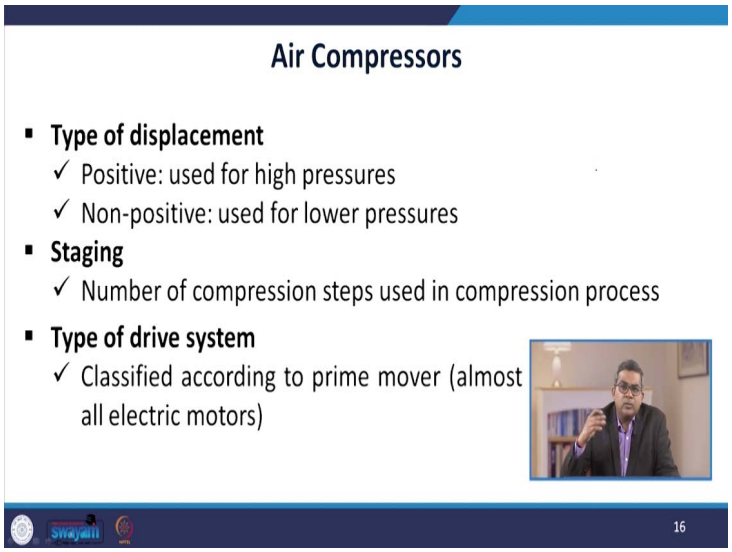

Apart from this the type of displacement also contributes towards the classification scheme. It may be a positive that is used for a very high pressure and non positive that is used for the lower pressure and above all staging that is the number of compression steps used in the compression process may be two stages, three stage, four stage and so on. The drive system also is a main contributor in classification of the air compression.

This is classified according to the prime movers almost all you can say compressors they are driven by the electric motors.

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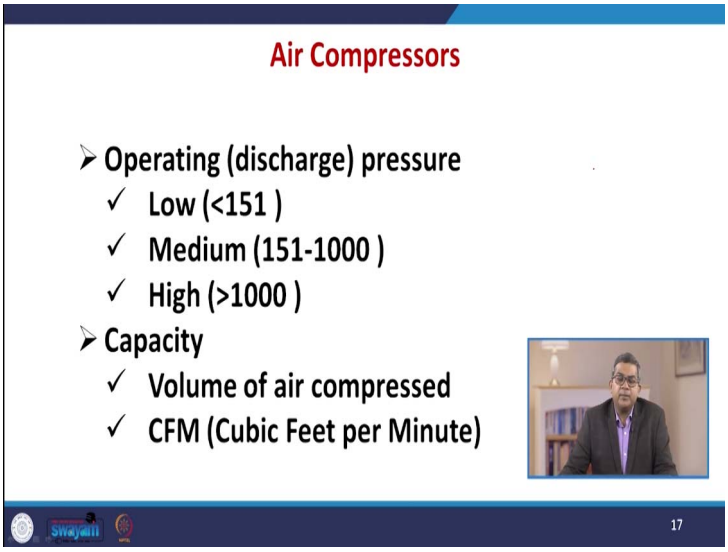

So, when we talk about the operating or discharge pressure. So, it can be classified based on the low, medium, high. Low is less than 151, medium is 151 to 1,000 and high is greater than

1,000 bar. Now capacity that is purely based on sub classified on the basis of a volume of air compressed with respect to the CFM that is cubic feet per minute.

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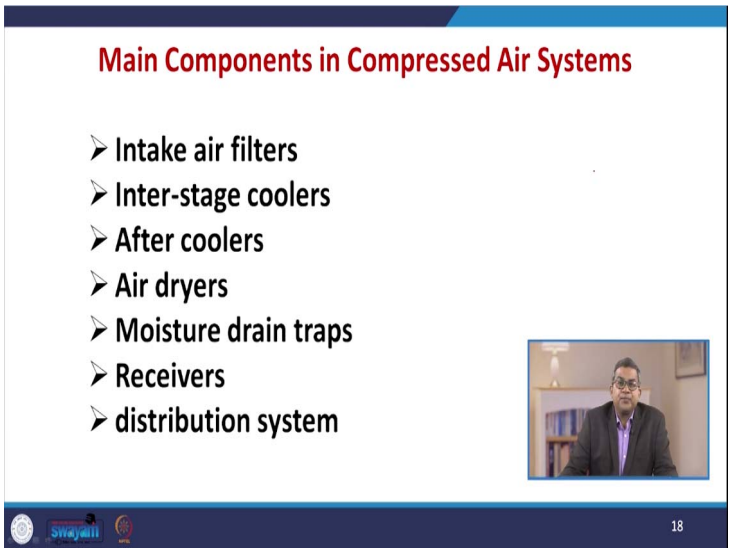

There are various components in the compressed air system. One is the intake air filters another one is the inter stage coolers then after coolers air dryers, moisture drain traps, receivers' distribution system.

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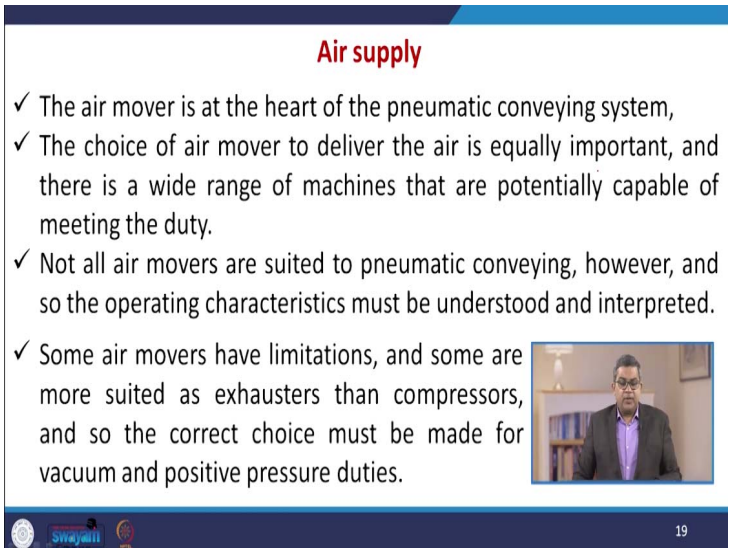

Now let us talk about the air supply the air mover is the heart of the pneumatic conveying system. The choice of air mover to deliver the air is equally important and there is a wide range of machines that are potentially capable to meet the duty. Not all movers are suited to pneumatic conveying. However, if we are operating characteristics in taken into the consideration it must be understood and interpreted based on the knowledge of air supply.

Some air movers have a very limitation and some are more suited as exhausters than compressors and so the correct choice must be made for vacuum and positive pressure duties. Now, let us talk about the types of air movers. All movers available for pneumatic conveying application range from fans and blowers producing high volumetric flow rates are relatively low pressures to positive displacement compressors usually somehow reciprocating or rotary screw machines.

They are capable of producing the high pressure required for the long distance or dense phase conveying system. The main features of some air moves typically employed for both vacuum and positive pressure pneumatic conveying duties are outlined. The available air movers are classified according to their duties as per this particular figure.

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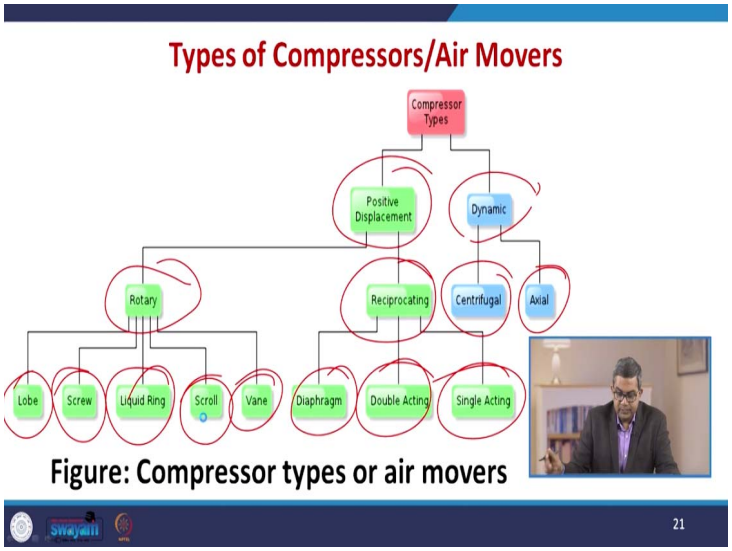

Now, let us talk about this different type of compressor or air mover. There are two different type of a compressor positive displacement and dynamic one. Dynamic are further divided into centrifugal and axial whereas the positive displacement again broadly classified into two aspects. One is the rotary and second one is the reciprocating and again these reciprocating types is divided into three different aspect diaphragm, double acting and single acting.

Similarly, a rotary one the low type of compressor screw type, liquid ring, scroll and vane type.

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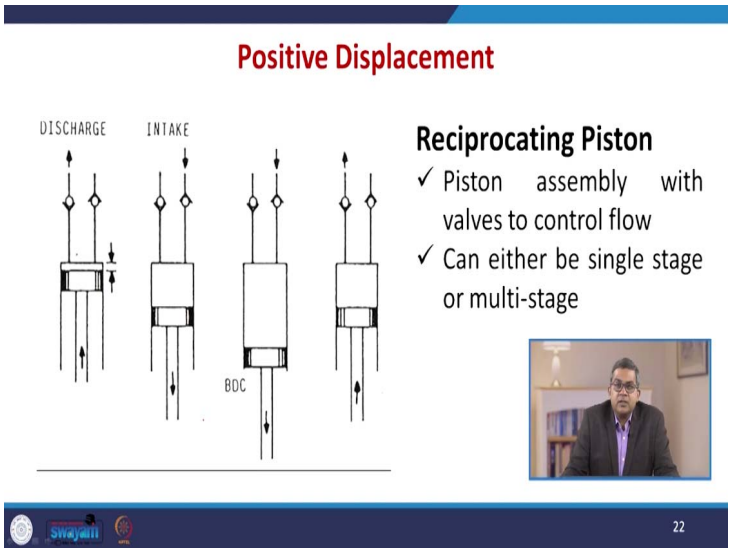

Now, let us talk about the positive displacement system. When we go for the reciprocating piston the piston assembly with valve to control flow, it can either be a single stage or multi stage.

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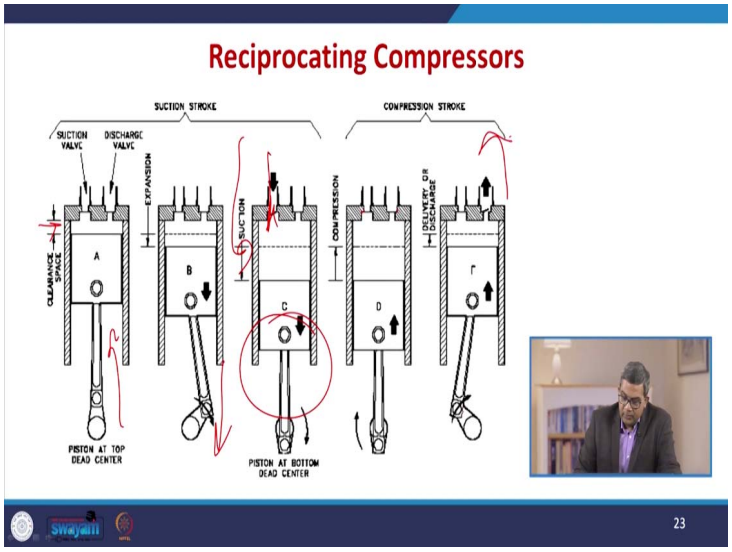

Now here you see those different stages of reciprocating compression. There is a suction valve and a discharge valve and this is the cylinder piston assembly and there is small clearing space. So, during the expansion this piston goes down and at the bottom up to the dead center here you can see and the suction starts from here and during the compression both the valves are initially closed and later on this valve is open for the upward movement of this cylinder piston assembly.

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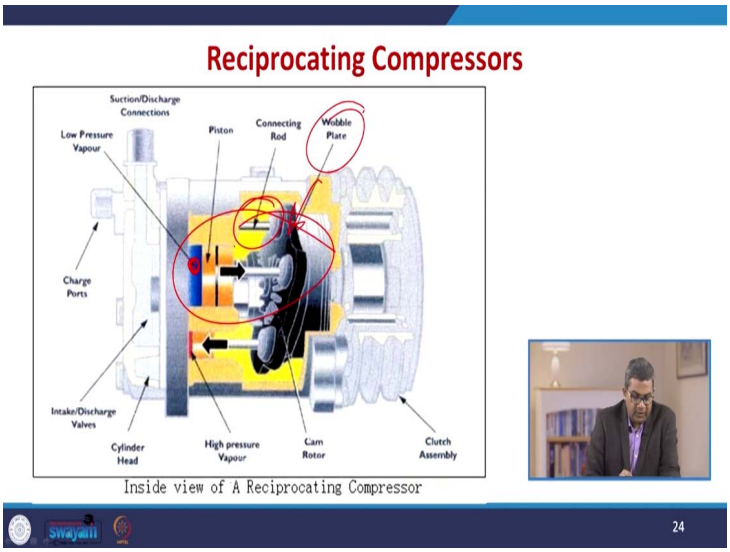

Now here you see the inside view of reciprocating compressor there is wobble plate here. You can see this is the connecting rod, this is a cylinder piston assembly and you see here the low-pressure vapor's joining here. These are the charge ports and this is the intake and discharge valve and cylinder head and here you see the high-pressure vapor.

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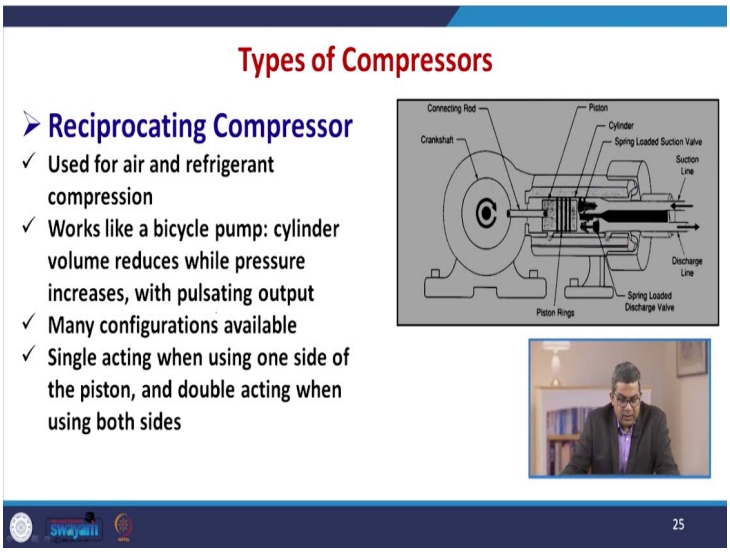

Now this reciprocating pressure they are used for air and refrigerant compression. Works like bicycle pumps, cylinder volume reduces while the pressure increases with pulsating output. There are many configurations available for this type of compression units single acting when using one side of the piston and double acting when using both sides.

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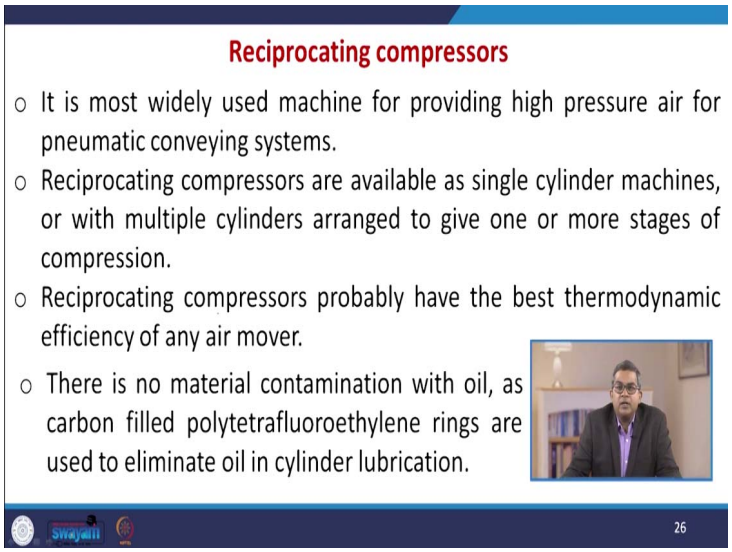

Now it is most widely used machine for providing high pressure air for pneumatic conveying systems. These reciprocating compressors are available as a single cylinder machine or with multiple cylinders arranged to give one or more stages of compression. Now reciprocating compressors probably have the best thermodynamic efficiency of air mover. There is no material contamination with the oil as carbon filled polytetrafluoroethylene rings are used to eliminate any kind of oil in the cylinder lubrication. Now this oil can be entrapped in the atmospheric air maybe because of the variety of reasons.

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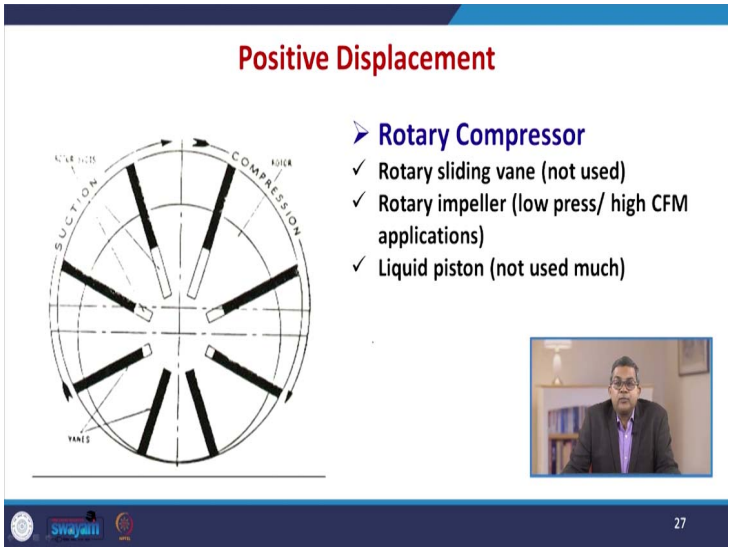

Rotary compressors; so, there are different type of rotary compression units, rotary sliding vane they are not much popular nowadays, rotary impellers they are having the low pressure or high CFM applications, liquid piston they are not used much.

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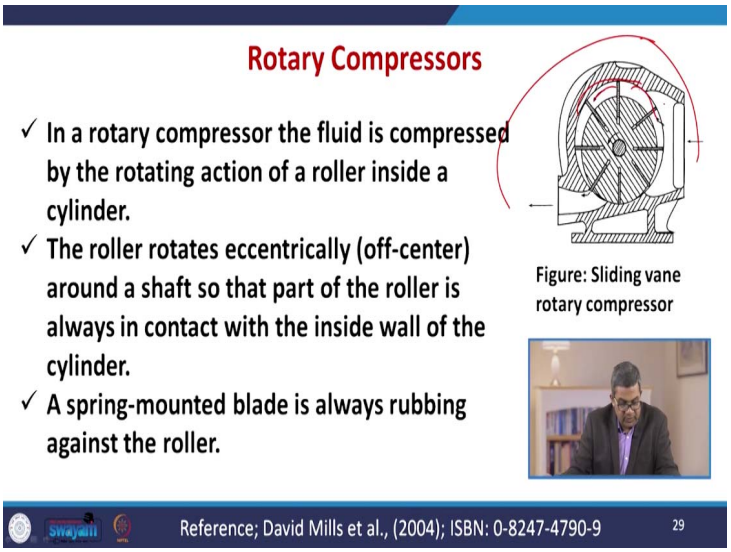

Now the rotary compressor portion of the positive displacement families made up of several compressor configurations. The features these compressors have in common like they part energy to the gas being compressed by way of an input shaft moving a single or multiple rotating elements. They perform the compression in an intermittent mode and they do not use inlet and discharge valves.

Now in rotary compressors the fluid is compressed by rotating action of a roller inside the cylinder. The roller rotates eccentrically that is off center around a shaft so that the part of the roller is always in contact with inside wall of the cylinder. You can see this is the inside wall of the cylinder and this is part of this one. Now as spring mounted blade is always rubbing against the roller.

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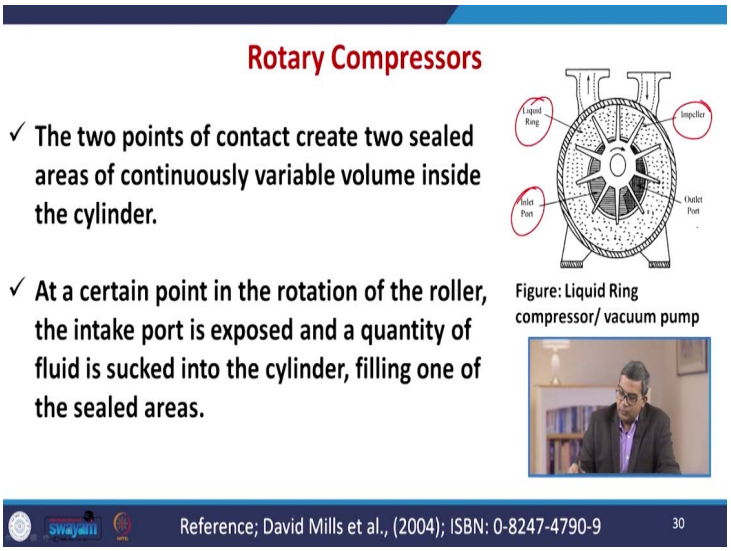

Now the two-point contact creates two sealed areas in continuously variable volume inside the cylinder. At a certain point the rotation of the roller the intake port is exposed and a quantity of a fluid is sucked into the cylinder filling one of the sealer areas. Here you see that the liquid in compressor impeller liquid ring inlet port outlet, outlet port etcetera.

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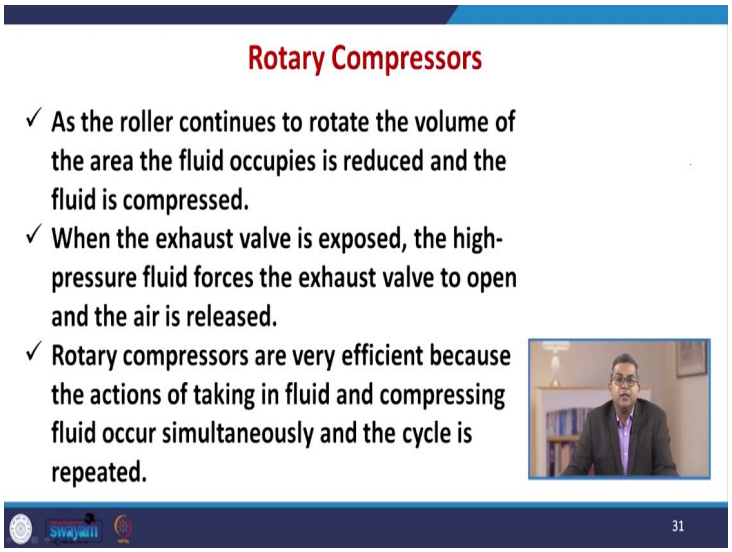

As the roller continues to rotate the volume of the area the fluid occupies is reduced and the fluid is compressed. So, when the exhaust valve is exposed the high-pressure fluid forces the exhaust valve to open and the air is released. Rotary compressors they are very efficient because the action of taking in fluid and compressing fluid occur simultaneously and the cycle is repeated.

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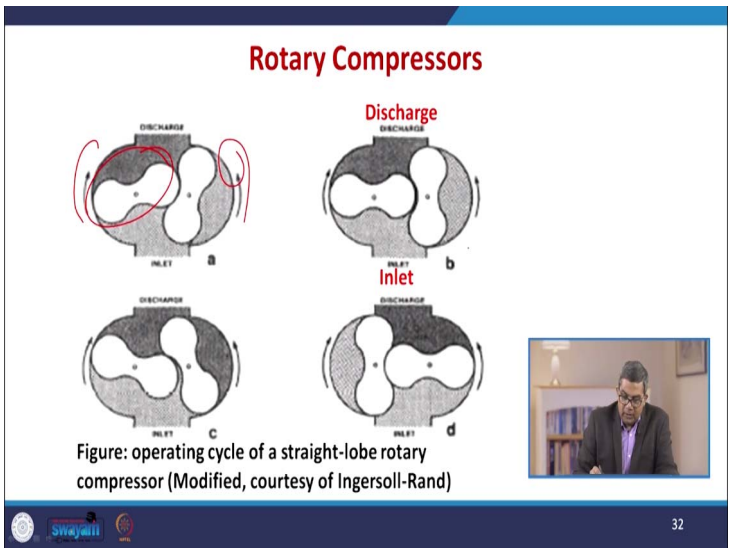

Now here are some of the operating cycles of the straight lobe rotary compressor. Now here you see that discharge you see that the motion this one is moving this direction. Now here you see this is the inlet, this is the discharge motion and this is the inlet you see this is the compressed fluid.

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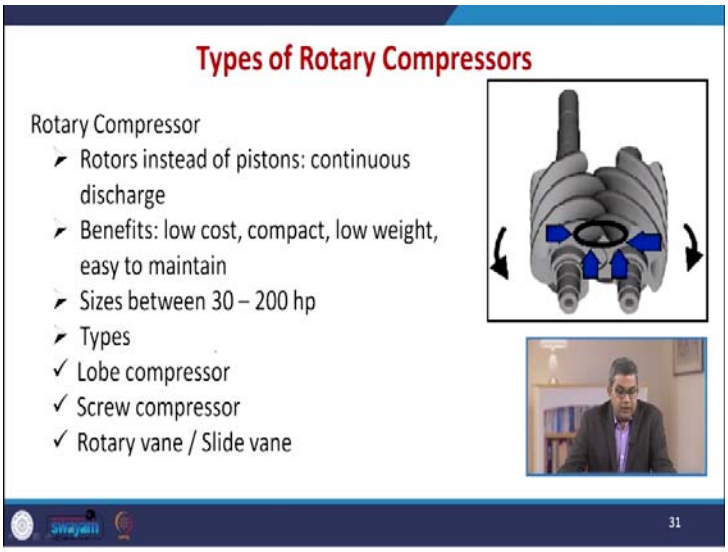

In rotary compressor we are using the rotors in instead of piston and that is for the continuous discharge. Now there are so many benefits associated with this kind of arrangement that is the low cost, they are very compact is nature, low weight and easy to maintain and they are having the sizes between 30 to 200 hertz power. There are different types of these rotary compressors one is the low compressor, one is screw compressor, rotary vane or slide vane compressors.

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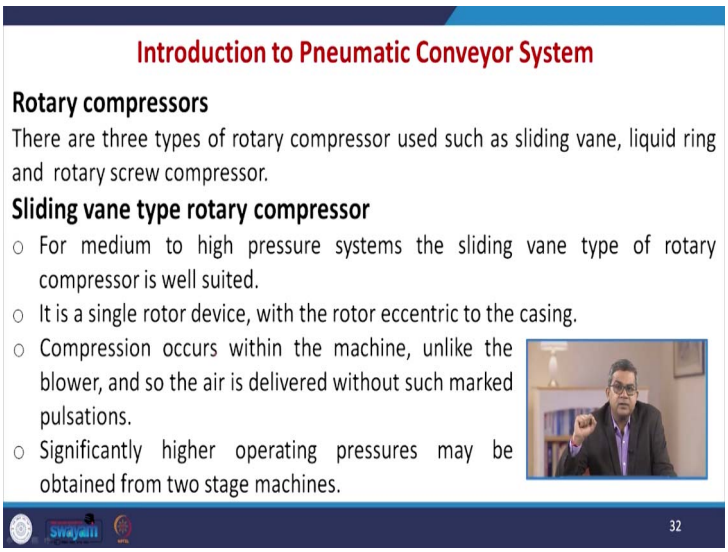

Now there are three different type of rotary compressors which we used earlier that is sliding vane, liquid ring and rotary screw compressor. Now, when we talk about the sliding vane type rotary compressors these are applicable for medium to high pressure system. The sliding vane type of rotary compressor is usually well suited. Now it is a single rotor device with the rotor eccentric to the casing.

Compression usually occurs within the machine unlike the blower and so the air is delivered without such marked pulsation. Significantly higher operating pressures may be obtained from two stage machines.

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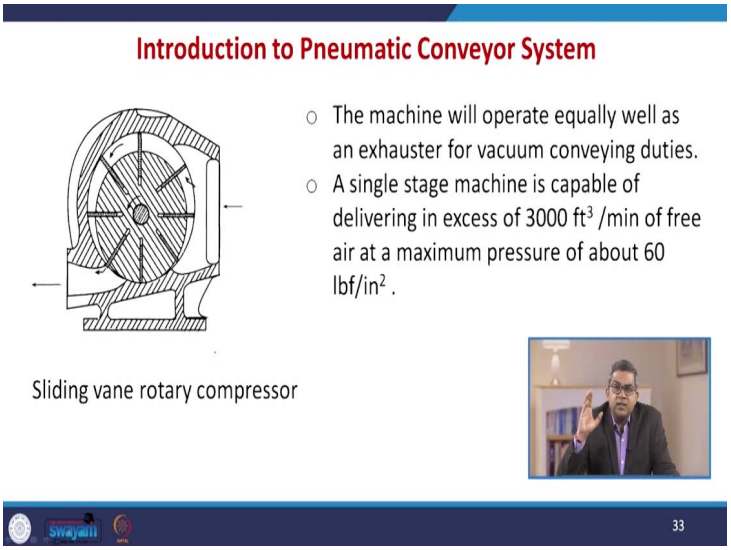

Now when we talk about the pneumatic conveying system the machine usually will operate equally well as an exhauster for vacuum conveying duties. A single stage machine is capable of delivering the excess of 3,000 cubic feet per minute of free air at a maximum pressure about 60 pounds fuse per inch.

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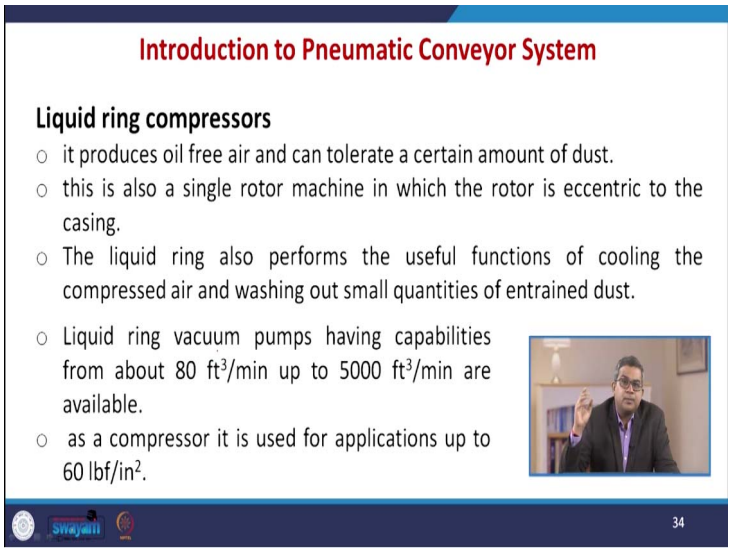

Let us talk about the liquid ring compression. It produces oil free air and can tolerate a certain amount of dust and this is also a single rotor machine in which the rotor is eccentric to the casing. The liquid ring also performs the useful function of cooling the compressed air and washing out small quantities of entrained dust. The liquid ring vacuum pumps having capabilities from 80 cubic feet per minute up to 5,000 cubic feet per minute they are available. As a compressor it is used for application up to 60 pounds per square inch.

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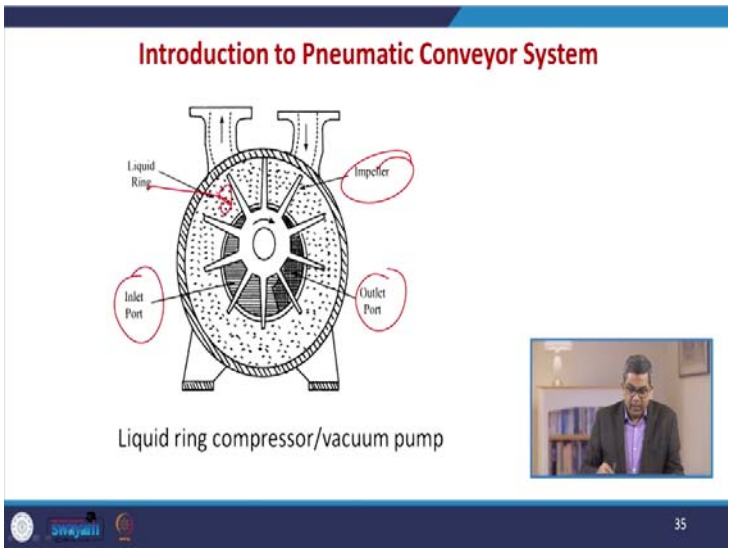

Now here you see the liquid ring compressors there are integral part like impeller, outlet port, inlet port and the most important this is your liquid ring.

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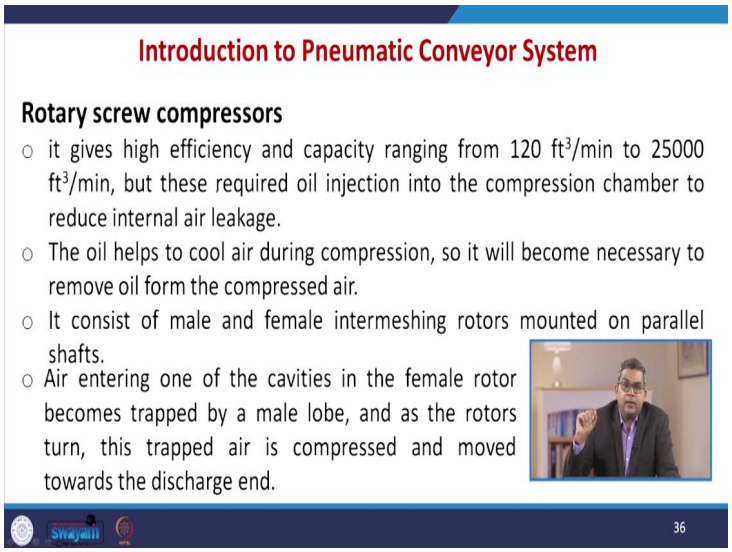

Let us talk about the rotary screw compressor. It gives high efficiency and capacity ranging from 120 cubic feet per minute to 25,000 cubic feet per minute, but these require oil injection into the compression chamber to reduce the internal air leakage. Now this oil helps to cool air during compression so it will become necessary to remove oil from the compressed air. It consists of male and female intermeshing rotors mounted on a parallel shaft.

The air entering one of the cavities in the female rotors becomes trapped by male lobe and as the rotor turns this trapped air is compressed and moved towards the discharge end. Now when we talk about the positive displacement compressors the constant speed operating characteristics for positive displacement machine provides basis on which the design of heavy-duty conveying system take place.

Now a pressure surge is the very common phenomenon pressure surge in the conveying system will result in only in a small decrease in the air flow rate delivered by the compressor and this can be incorporated into the safety margin for the system. With the positive displacement compressor, the percentage reduction in conveying air velocity due to constant speed characteristics will be no more than that caused by the compressibility effect.

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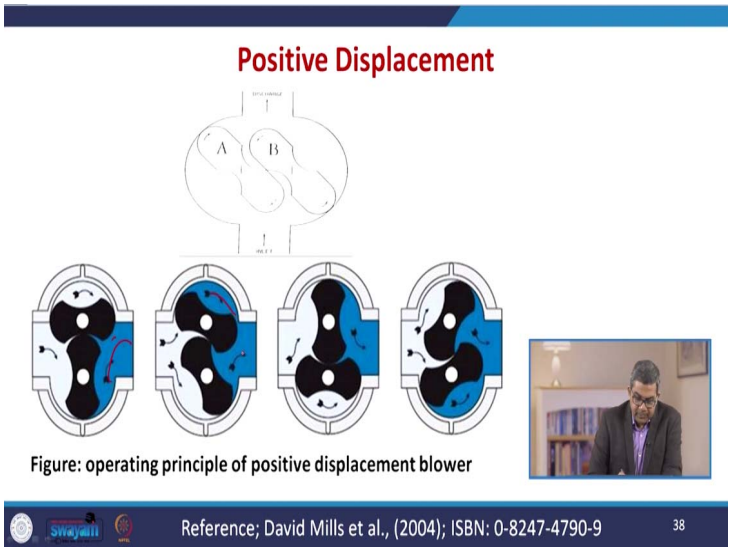

Now here you can see there are the operating principle of various positive displacement blowers you can see can observe the movement here. You can see now this is the discharge port and this is the inlet port and you can see their air is coming out and the rotor motion is in the clockwise direction and you see that how this positive displacement blower works.

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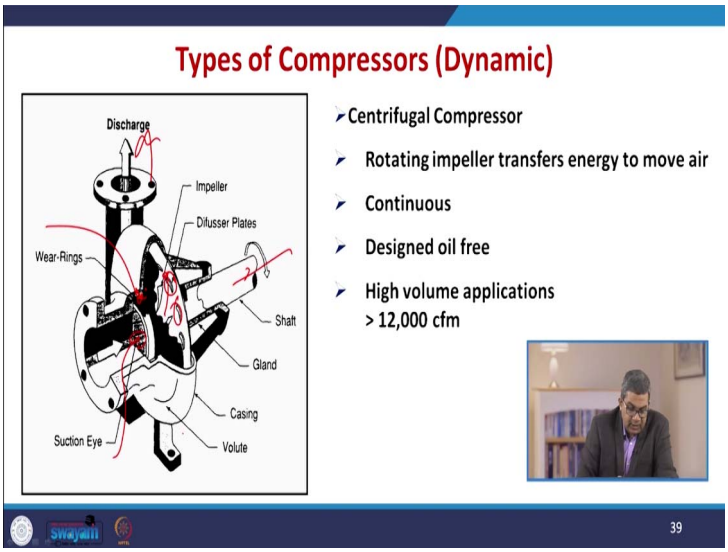

Now let us talk about the dynamic compressor system. This is centrifugal compression system; rotating impeller transfers the energy to move the air and its continuous in nature and it is designed for the oil free operating with the high-volume application of 12,000 cubic feet CFM. Now here you see there is a suction eye here with the supported by wear rings and here this is a discharge one.

And you see the impellers are situated over here with the diffuser plates here small just you can see the diffuser plates with a shaft and gland casing and volute.

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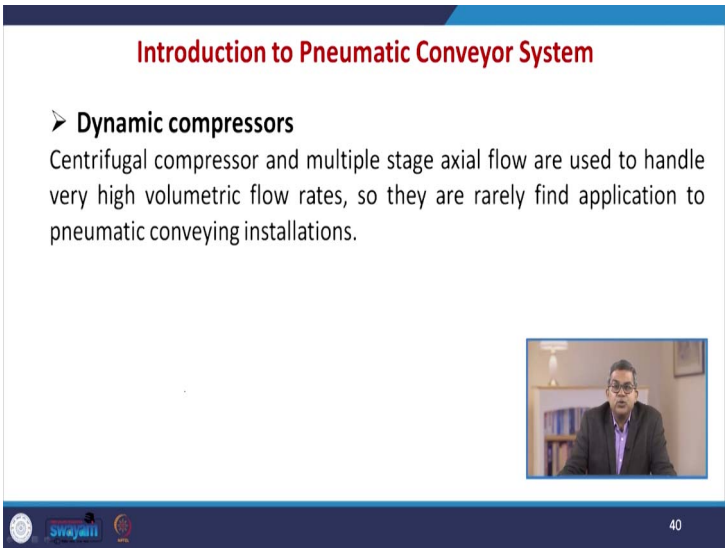

Now, centrifugal compressor and a multiple stage axial flow they are used to handle very high volumetric flow rates. So, they are rarely find application to pneumatic conveying installations.

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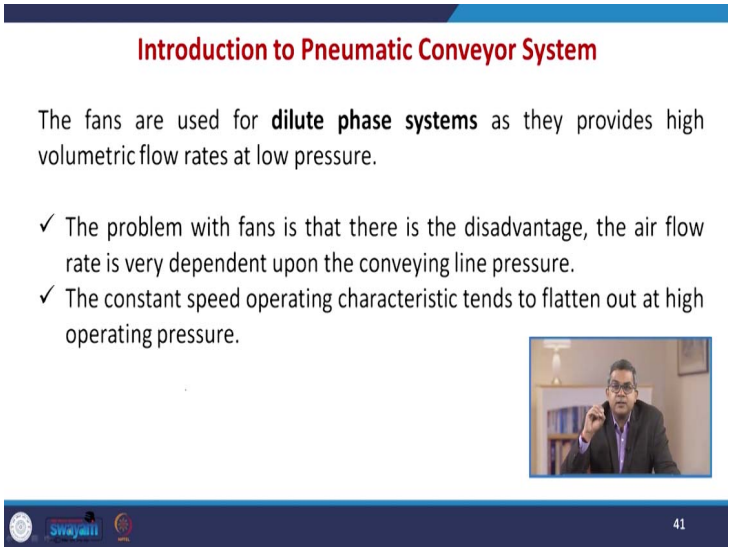

The fans are used for dilute phase system as they provide high volumetric flow rates at low pressure. Now the problem with the fans is that there is a disadvantage the air flow rate is very dependent upon the conveying line pressure. The constant speed operating characteristics tend to flatten out at operating pressure.

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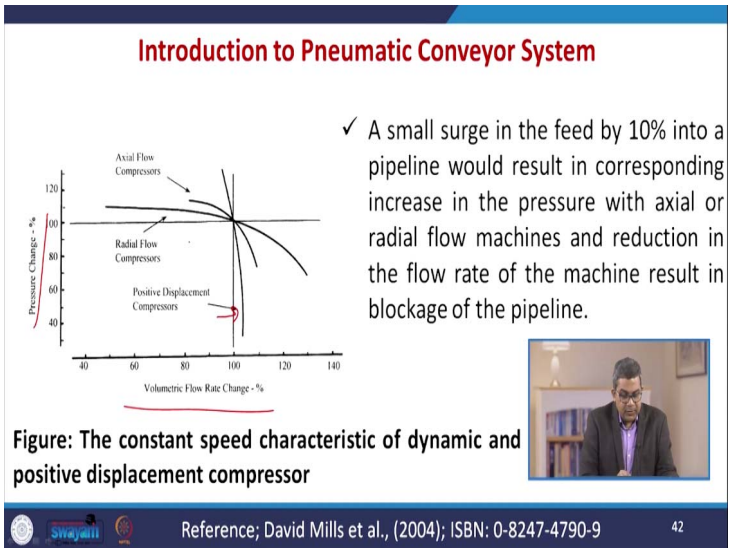

A small surge in the feed by say 10% into a pipeline would result the corresponding increase in the pressure with the axial radial flow machines and reduction in the flow rate of the machine results in the blockage of the pipeline here you can see in this. This is the percentage of the pressure change and the volumetric flow change. You see that here you may observe the positive displacement compressor and here the radial and axial one.

So, this is the constant speed characteristics of dynamic and positive displacement compressor.

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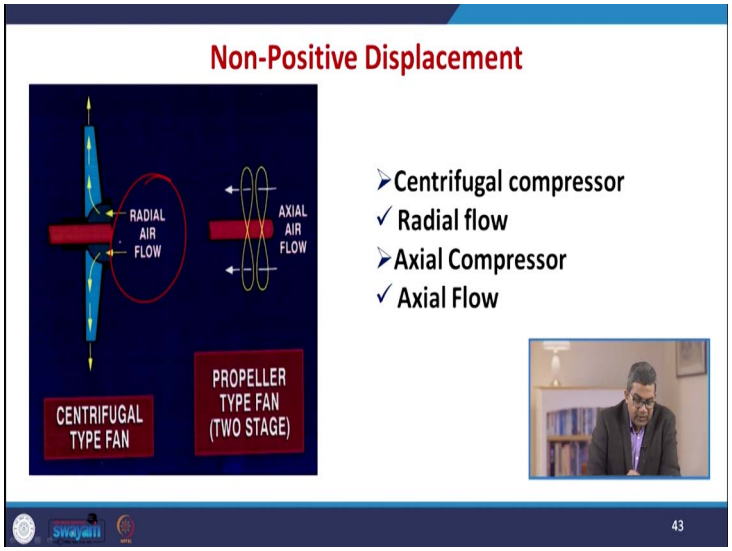

Now there are certain non-positive displacement again the centrifugal compressors, radial flow compressors, axial compressors with the help of axial flow. Now here you see this is the pictorial difference between these two the centrifugal type of fan and the propeller type of fan.

When one is utilizing the radial air flow you see the path of air. Here you see the axial air flow you can observe that this is the movement or air is moving like this.

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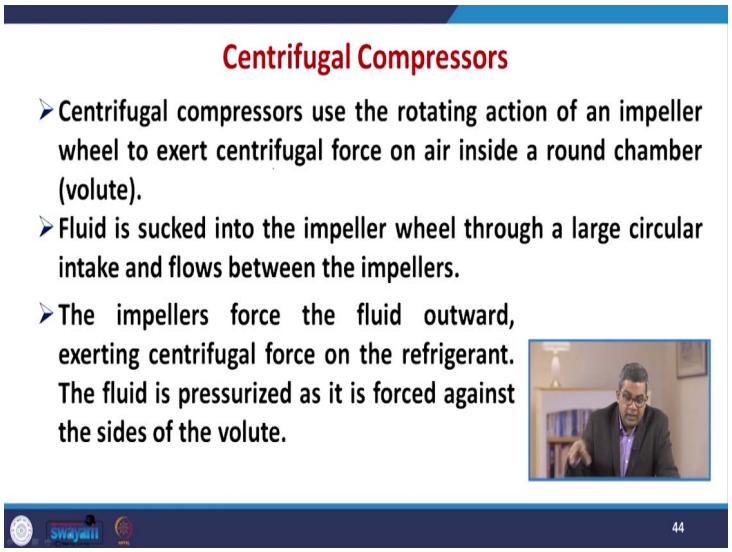

So, let us talk about the centrifugal compressor. The centrifugal compressors use the rotating action of an impeller wheel to exert the centrifugal force on air inside the round chamber and that is called the volute. Fluid is sucked into the impeller wheel through a large circular intake and flows between the impeller. The impeller force the fluid outward exerting the centrifugal force on the refrigerant and the fluid is pressurized as it forced against the sides of the volute.

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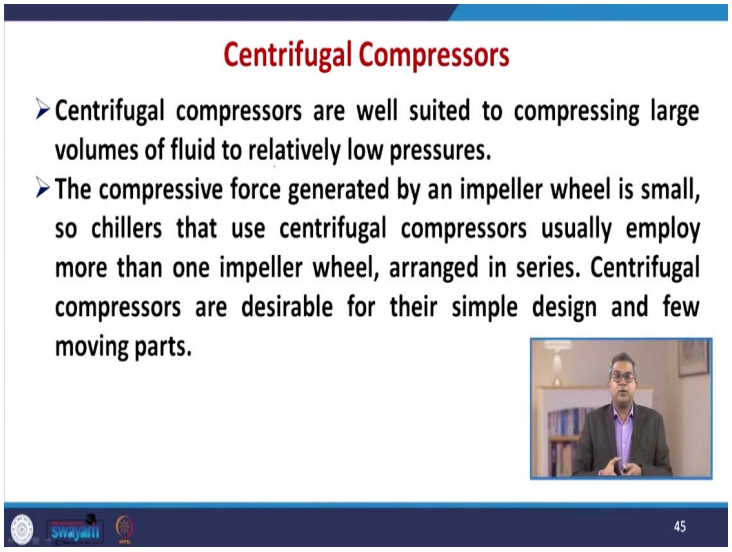

The centrifugal compressors are well suited to compressing the large volume of fluid to relatively low pressure. The compressive force generated by an impeller wheel is small. So, chillers that use centrifugal compressor usually employ more than one impeller wheel arranged

in series. Centrifugal compressors are described for their simple design and the few moving part.

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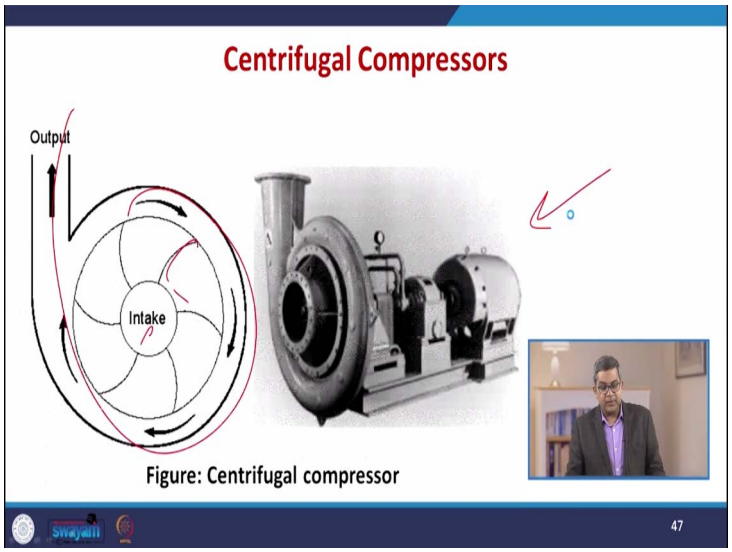

Here you see the basics of the centrifugal pump. This is the intake and then there is a movement and you can see these are the impellers and this is the real photograph of the centrifugal compressor. So, at the outset in this particular lecture we had discussed about the various properties of the air, we discussed about the importance of air in the process industries.

Apart from this we discussed about the various aspects of the air compression including the basic anatomy of air compression units including the receivers. We discussed various classification scheme of air compression system.

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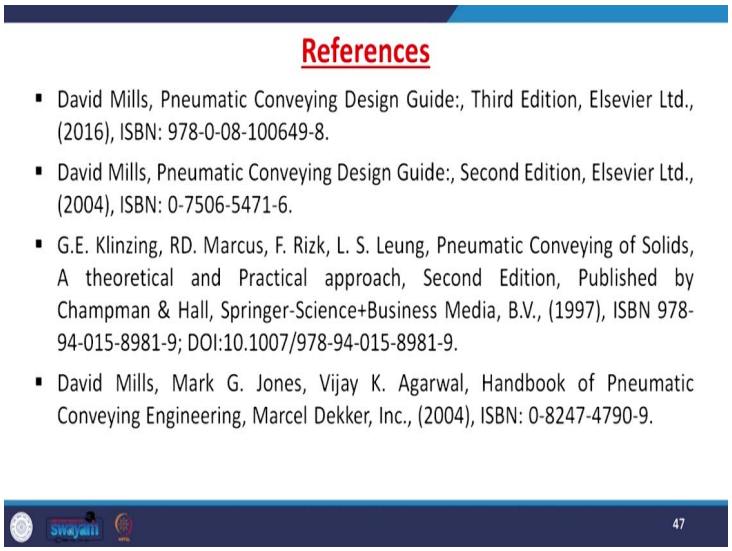

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- David Mills, Pneumatic Conveying Design Guide:, Second Edition, Elsevier Ltd., (2004), ISBN: 0-7506-5471-6.
- G.E. Klinzing, RD. Marcus, F. Rizk, L. S. Leung, Pneumatic Conveying of Solids, A theoretical and Practical approach, Second Edition, Published by Champman & Hall, Springer-Science+Business Media, B.V., (1997), ISBN 978-94-015-8981-9; DOI:10.1007/978-94-015-8981-9.
- David Mills, Mark G. Jones, Vijay K. Agarwal, Handbook of Pneumatic Conveying Engineering, Marcel Dekker, Inc., (2004), ISBN: 0-8247-4790-9.

Now, if you wish to have a further study, we have enlisted couple of references for your convenience you can go through. Thank you very much.