Automation in Manufacturing
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Week - 11
Pneumatic systems
Lecture – 33
Basic concepts and air compressors

This week that is week 11, we will be studying the Pneumatic systems (Refer Time: 00:43). In the previous weeks, we have seen the hydraulic systems and hydraulic energy is one of the prime movers being utilized in the automation.

Pneumatics are also utilized as one of the prime movers in automation in manufacturing. In the lecture 1, we will be studying the Basic concepts related to the pneumatic systems and we will also study the air compressors.

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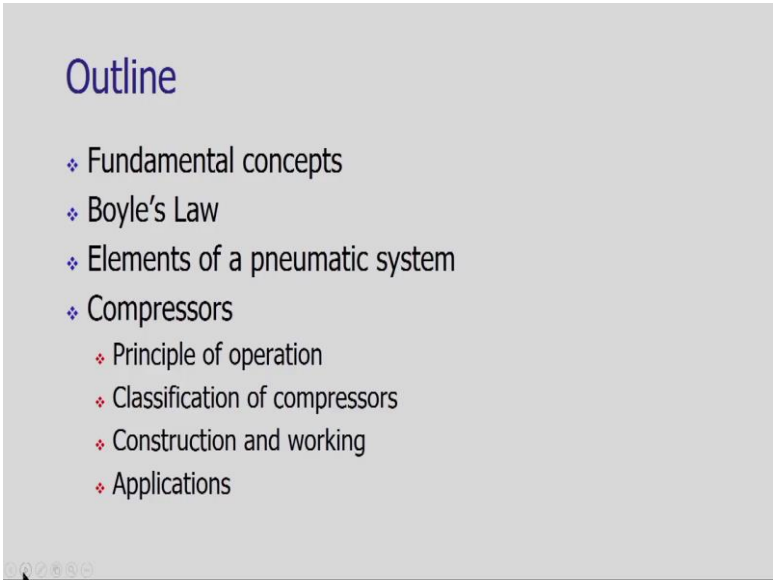

At start of the lecture we will study the fundamental concepts; we will have a discussion on the Boyle's law on which the pneumatic systems are working. Then we will study various elements of a typical pneumatic system.

After that we will have a detailed discussion on the compressors, the principle of operation of a typical compressor, a detailed classification of compressors, their construction and working.

And, we will also have a look at the applications of various compressors in automation in manufacturing.

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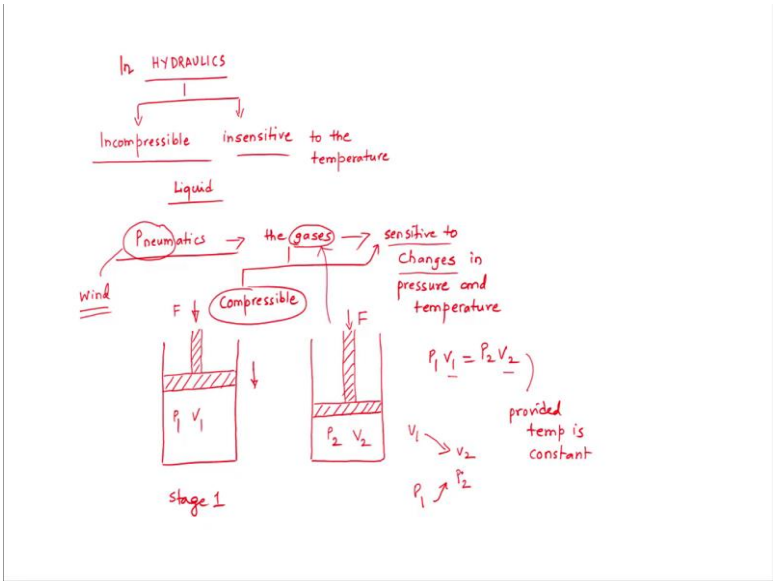

For all practical purposes; we are considering the liquid in hydraulics as incompressible and it is insensitive to the changes in the temperature. Fundamentally, in hydraulics, we are considering the liquid as incompressible and insensitive to the temperature.

With this basic assumptions we consider the liquid and we utilize the liquid for the variety of hydraulics related operations. But, in pneumatics we deal with the gases and here we consider the gas as compressible. Compressible fluid and the gas is sensitive to changes in pressure and temperature.

The systems which are using the pneuma, pneuma is in Greek is called as the wind, the branch of engineering which is dealing with the wind energy or the wind and the associated applications of the wind or the breadth that is called as the pneumatics. There are lot of gases are there in the wind which are compressive in nature. And, these gases are sensitive to the changes in pressure and temperature.

The behaviour of the gases is being governed by a certain law which is giving the relationship between the pressure and temperature. Let us consider there is a open container and that open container has certain gas. Now, we are closing that container by using a piston arrangement. Let us consider a piston.

In this stage 1 the volume inside the container is at pressure P 1 for the volume V 1. There is a gas with volume V 1 and at this situation the volume V 1 of the gas is experiencing pressure P 1. Let us consider that we apply a force F to the piston. When we apply the force F to the piston its volume will be reduced from V 1 to V 2. The piston is displacing in downward direction.

Due to the application of force F, the volume is changed to V 2, it is reduced from V 1 to V 2 and there is a change in pressure from P 1 to P 2. As per as the law of conservation of energy, we can write here P 1 V 1 is equal to P 2 V 2 provided temperature of the system is constant. Here we are considering that the temperature is not going to change during this operation. Due to the application of force F V 1 is reducing to V 2. As V 2 is reduced naturally the pressure inside the system will increase from P 1 to P 2.

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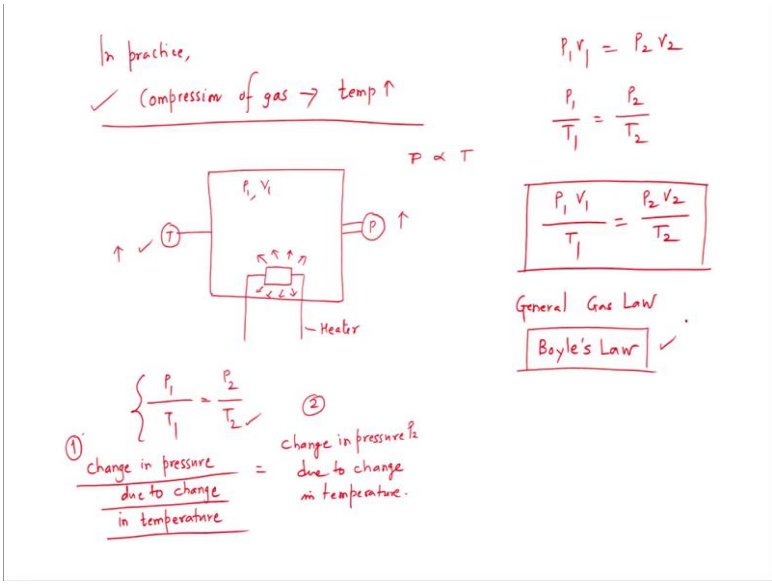

As V 1 is reducing to V 2, the P 1 will increase to P 2. In practice we always experience that the compression of gas is leading to or it is resulting in increasing temperature. Let us consider we are having a closed container, it is a sealed one and inside the sealed container there is a certain amount of gas is present. Volume of the gas is V 1 and it is having pressure P 1 and this container is also having an element which is radiating the heat. It is a heating element basically

We are continuously observing the temperature of the container by using a temperature sensor and we also observe the pressure of the system by using a pressure sensor. When there

is a radiation of the heat energy inside the container, the temperature of the container or the temperature sensor will show increase in the temperature.

As heater is heating up the gas inside the container there is increase in the temperature and due to that temperature increase, it is also observed that there is increase in the pressure of the system as well. We can consider

$$P \propto T$$
$$\therefore \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Therefore, the change in pressure due to change in temperature at condition number 1 will be equal to change in pressure due to change in temperature in condition number 2. P1 is the initial condition and P2 is the final condition.

We get two equations here which are as follows,

$$P_1 V_1 = P_2 V_2$$
$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Combine these two equations, we get

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

This is called as the general gas law. This general gas law has been given by the Scientist Boyle.

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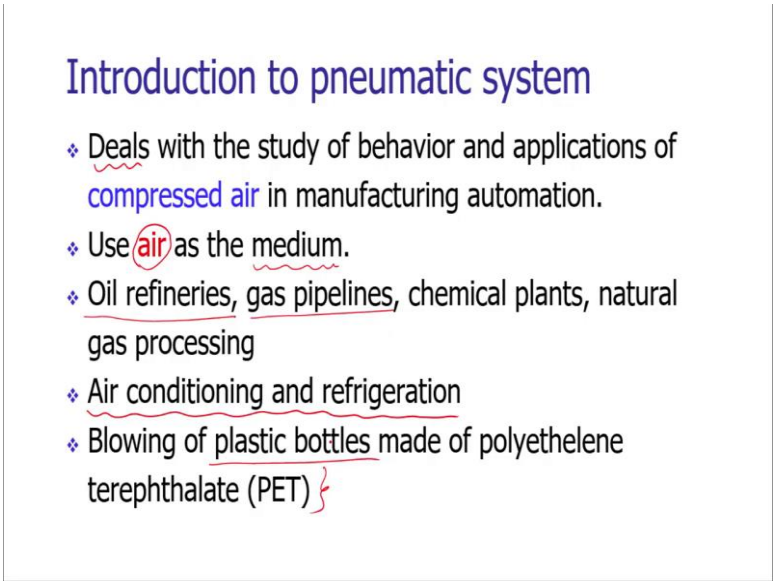

Here we are calling the general gas law as the Boyle's law. In automated manufacturing system, the compressed air or compressed gases are widely used to carry out variety of operation.

It may be the processing operation or it may be the painting operation or it may be the fastening operation that is the assembly operation, packaging, for cleaning, for sensing; for variety of purposes the pneumatic systems that is the compressed gas systems or compressed air systems are utilized.

The pneumatic system as we have seen it is basically it dealing with the behavior and application of compressed air in manufacturing automation. In general, air which is abundantly available in the environment is used as the medium for the processing.

Variety of applications are there such as oil refineries, gas pipelines, chemical plants, natural gas processing. Basically, in chemical plants and petrochemical industry, where it is very essential to have the safety aspects of the system and the human beings which are operating.

In petrochemical industry basically we cannot use the electrical energy; thus it may it may lead to generation of sparks and that may not be safe for the processing application. In this situation, that compressed air which is harmless, the chilled compressed air, but the compressed air at the normal temperature will be very much useful for the sensing applications.

In air conditioning and the refrigeration applications as well we are using the compressed air; particularly for the air cooling operations we are using you know the compressed air. In refrigeration also we are using the compressed air. One interesting and important application is to manufacture the plastic bottles of the PET; that is polyethylene terephthalate.

In the blow molding operation we are generating the hollow work parts or we are manufacturing hollow products such as bottles or the containers by sending a controlled compressed air inside the mold cavity. And, that mold cavity is already having the work piece material that is the PET material. When we apply or when we blow the material, that blown material will take the shape of the cavity which is provided. In this way we can utilize the compressed air for variety of its applications.

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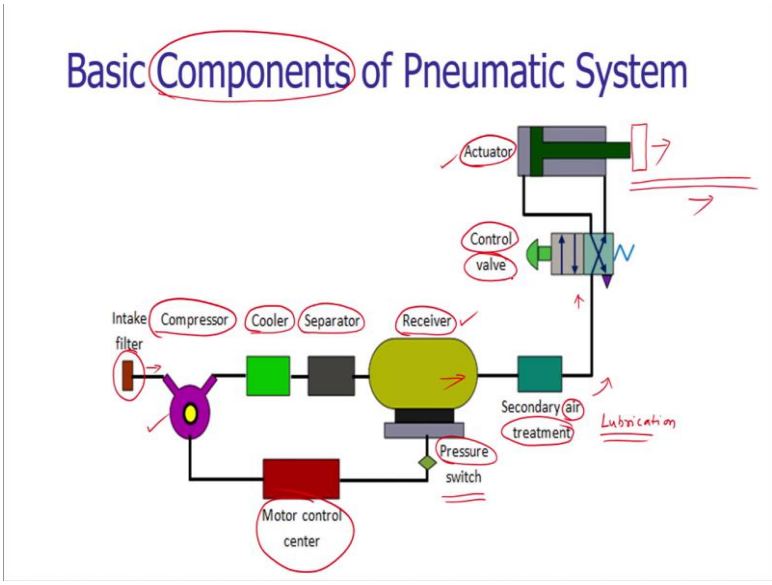

Let us see what are the various basic components pneumatic system has. The fundamental components of the pneumatic system is the compressor which takes the air from the environment and then it increase its pressure, it reduces its volume and it increases the temperature. When it takes the air inside for the increase in its pressure, it needs to filter.

The environmental air may have lot of impurities, may have solid particles. To protect the compressor unit and to have a pure air, the clean air we need to filter it out. As the compressor is compressing the fluid, it increases the temperature. As we have seen by Boyle's law, there is increase in the temperature when the volume is reduced pressure is increased and the temperature will also increase.

We need to reduce the temperature of that pressurized air. Once it is reduced to the normal temperature, there may be condensation of the water particles inside that pressurized air. Whatever the particles or whatever the percentage of watery inside the air that will get condensed when we are reducing the temperature and getting it to the normal ambient temperature, we need to separate the water from that cool air. And, then we have to store it inside a tank.

Now compressor, a filter, then cooling separation and then receiving or storing in inside a tank. The tank is getting continuous compressed air. We need to continuously monitor the capacity of the tank by using the pressure indicators and accordingly we can control the operation of the compressor. Thus, we need the continuous monitoring system of the receiver, and the tank by using the pressure sensors.

And, then we have to have a motor control center, a microprocessor based control system which will automatically operate the compressor unit. The receiver is receiving, it is storing the energy compressed air energy and that compressed stored energy or compressed air we will be utilizing for the actuation, for carrying out the operation. We need to use it for certain application, for actuation for carrying out certain work we need to have the utilization of this compressed air from the receiver.

To get it we need the actuator and to control the flow of this compressed fluid to actuate the actuator, we need the control valves. As we have seen in our previous lecture as well the direction control valves are essential. The compressed air is operating variety of mechanical elements. These mechanical elements are to be treated. The mechanical elements are working at a very high speed and there may be friction of the various sliding elements of these devices.

To lubricate or to reduce the friction between the sliding elements of the mechanical devices, we need to treat the air. We have to lubricate the air which is coming out from the receiver. Lubrication is called as the secondary air treatment. We need some device that will add and mix the lubricant with the compressed air and that will send to the pneumatic system application.

Thus, we can see there are various elements involved in a pneumatic system. These are the filters, compressors, coolers, separators, storage tank, sensors, the microprocessor based device, secondary air treatment unit such as lubricators, various control valves and actuators.

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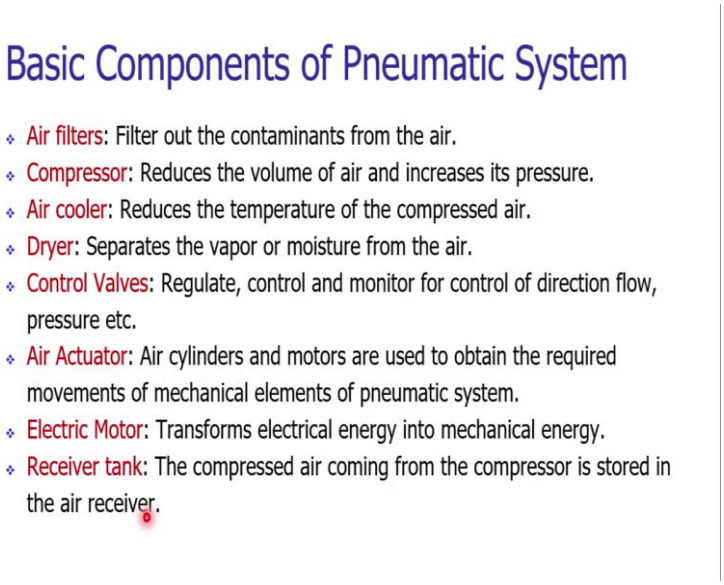

Before studying the construction and working, let us summarize all these components one by one. Air filters are filtering out the contaminants from the air. The compressors are reducing the volume of the air and they are increasing the pressure of the air. The coolers are reducing the temperature of the compressed air.

The dryers they are separating the vapor or the moisture from the air. There are various control valves and the control valves are carrying out their regular duties such as regulation, flow control and monitoring of the pressure or the compressed air. Air actuator these are basically cylinders, double acting cylinder or the single acting cylinder or we can have the pneumatic motors as well which are converting the pneumatic energy, pneumatic force into the rotational energy.

And, that rotational energy would be carrying out for variety of applications. The pneumatic cylinders and pneumatic motors are used to obtain the required movements of mechanical elements. Electric motor which is the prime mover for the pneumatic system; we need the DC motors which are transforming the electrical energy into the mechanical energy. And, we have seen that there is a need of a tank and the tank is a storage device which is storing the compressed air which is coming out of from the compressor.

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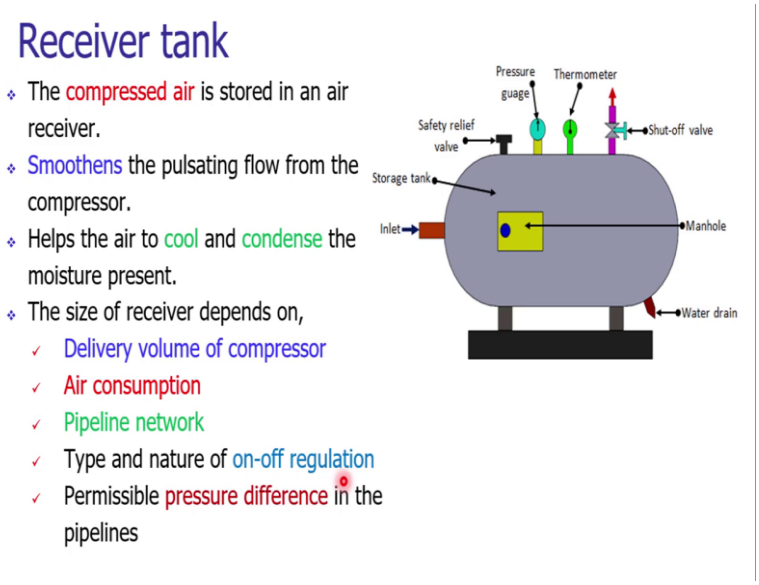

Well, first look at the receiver tank. A schematic of a typical tank is shown on the screen. It is a closed container, it is a sealed container and it has various mountings. It has the inlet and the outlet which has various mounting such as the relief valves, that is the safety relief valve. Pressure gauge to continuously monitor the pressure of the tank. There is a thermometer which is used to monitor the temperature of the compressed air which is stored inside the tank.

There is a water drain here. With the increase in pressure there is increase in temperature. When there is a decrease in temperature; now the temperature of the compressed air decreases, there will be condensation of the water vapors or the moisture inside the water. And, due to that we may get now water at the bottom side of the tank which need to be drained out.

So, we need a water drain. The reciprocating type of compressors are generating the compressed air in pulse mode and that pulsed compressed air or gas we need to store inside a common storage device. And, from that receiver or the storage we can utilize the compressed air for our application in smooth fashion. Smoothening is a very important function of the receiver tank, not only smoothening the receiver tank is also helping to cool down the temperature of compressed air.

And, it is also helping for condensation of the air inside the closed chamber. The size of a typical receiver tank, it depends upon the volume; the volume of the air it can store or it can

manage. The air consumption, the pipeline network, the various types of on off regulation units whether it is a semi-automatic or it is a fully automatic or it is a manual operation. Then we are having a important element of the pneumatic system that is compressor.

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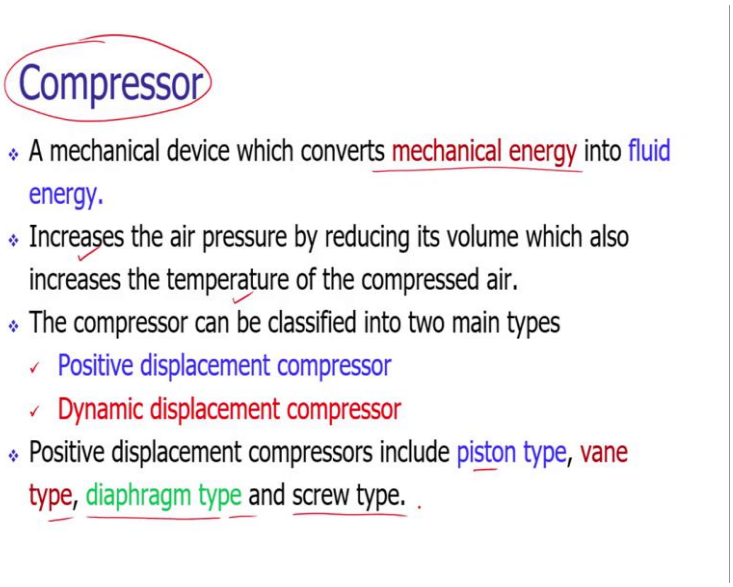

Compressor is a mechanical device which converts the mechanical energy into the fluid energy. We are applying the mechanical energy on the gas or air and then that applied energy would be converted into the fluid energy. Basically compressors are increasing the pressure by reducing the volume and it is purely based upon the Boyle's law.

During the application of the pressure there is an increase in the temperature; so, we need to further process that compressed air. There are various types of compressors are used in the industry and these are the positive displacement compressors and the dynamic displacement compressor. Positive displacement compressors are the piston type or vane type or we are having the diaphragm type and the screw type. Detailed classification of the compressors we will see in the next slides.

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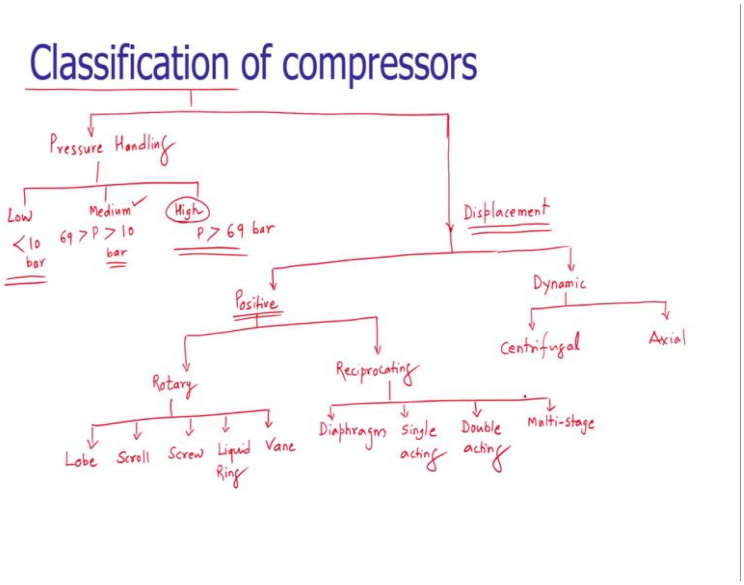

We can classify the pneumatic compressors based on two factors. The first factor is the pressure handling capacity, pressure handling. Here we can have the low pressure compressors, medium pressure compressors and the high pressure compressors. When a compressor is generating a pressure less than 10 bar, it is called the low pressure compressor.

When the pressure is in between 10 bar to 69 bar, pressure is more than 10 bar, but it is less than 69 bar that is called as the medium type of compressor. And, when the pressure which are generated they are more than 69 bar, then they then we can call them as the high pressure compressors. As far as the second parameter is concerned and that is the displacement; so, here we are using the methodology of displacement of the gas or the air.

There are basically two types of displacement in the compressed air generation, that is the positive displacement and dynamic displacement. In positive displacement again we can have two variants, that is rotary type of mechanism which is used to generate the positive displacement or reciprocating type of mechanism used to generate the positive displacement.

In rotary, there are five variants which are the lobe type of compressor, scroll type of compressor, screw compressor. We can have one interesting configuration that is liquid ring compressor and vane type of compressor. As far as the reciprocation type of movements are concerned; we are having diaphragm based compressors, we are having single acting compressor units, double acting and multi stage.

We are having double acting and multistage compression. As far as the dynamic displacement is concerned two types of compressors are used in the industry. These are centrifugal type of compressor and the axial type. We will be seeing these compressors, their function, their working and the operational details in the coming slides.

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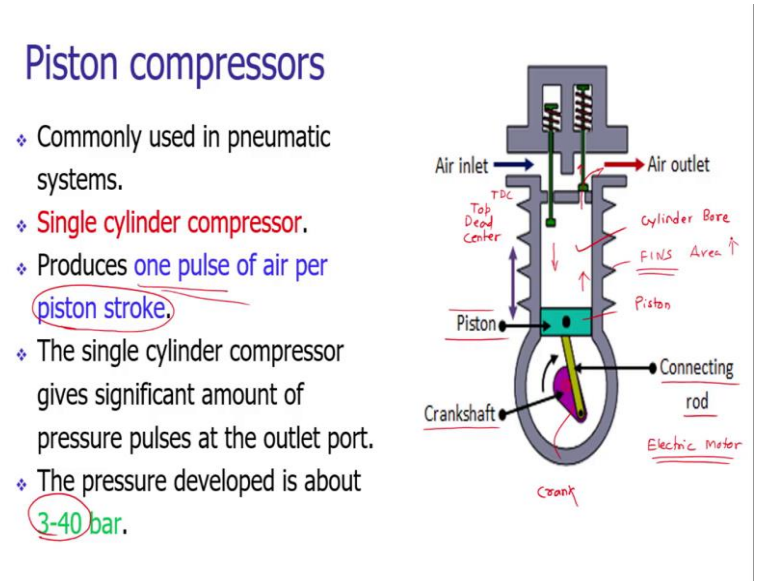

Piston compressors are widely used in pneumatic systems. A single cylinder compressor unit is shown which is generating the compressed air. The construction is very simple, there is a cylinder bore which is having the piston arrangement. The piston is connected to the connecting rod which is connected to a crank.

The crank is connected to the crankshaft which is mounted on the bearings which is supported on the bearings, that shaft is driven by the electric motor. A electric motor is required which is the prime mover for the piston type of compressors.

The rotational energy from the electric motor would be converted into the reciprocation motion of the piston. The crankshaft is rotating, the crank will also rotate; but the crank is connected to the connecting rod.

Due to the restrictions given to the movement of the connecting rod through the piston, the piston will translate or it will reciprocate inside the restriction given that is the bore. When the piston is moving away from the two valves which are there on the top dead center. This is

the TDC that is a Top Dead Center. There is the creation of a vacuum here, there is a creation of pressure difference.

The pressure difference from the atmospheric pressure and due to that the wall will get opened. And, when the wall will get open the air will be suck inside the volume for the half rotation of the crank. For the next half rotation of the crank, the piston will move in a upward direction. And during that upward direction movement, the wall, the inlet wall will get closed and due to the increase in pressure on the air, the outlet valve will get opened.

And, the pressurized fluid will come out of the cylinder bore in pulse mode. Basically the piston compressors are generating the piston strokes which are generating the air per pulse. These type of cylinders are manufacturing the compressed air within the range of 3 to 40 bars. There is a sliding friction between the piston and the cylinder bore.

It is a very high rate of the reciprocation motion, more and more amount of energy thermal energy will be generated. And, that thermal energy needs to be dissipated, its needs to be reduced to have the efficient operation of the compressor. For that purpose we need to have the fins. Fins are increasing the area for the heat convection.

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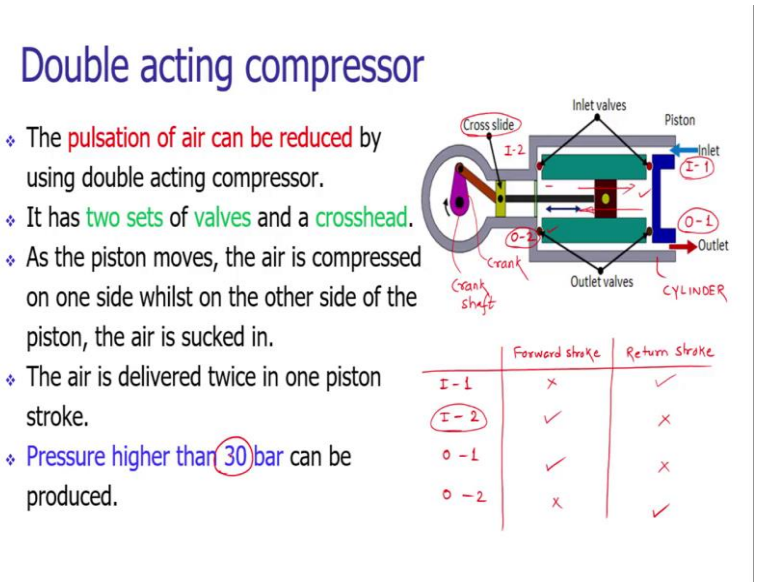

To increase the efficiency of the single acting cylinder, we can also utilize a double acting cylinder. In a single pulse or in a single reciprocatory motion we can generate 2 times of the

compressed air. For that purpose a typical arrangement can be seen on your screen. It is having the cylinder arrangement, the cylinder is hosting the piston.

And, that piston is having the connecting rod and that connecting rod is connected to the crank and we are having the crankshaft. The piston is connected to the connecting rod through a cross slide and here that cross slide is helping us to get the more efficiency of the system; how that you can see here. During the rotation of the crank, the piston is reciprocating inside the cylinder bore.

This type of arrangement is having basically two inlet valves and two outlet valves. Let us consider this as the inlet valve 1 and this is inlet valve 2; similarly we are having two outlet valves; outlet valve 1 and outlet valve 2 this is. Now, we will see how exactly we are generating the more compressed air in the typical forward or the return stroke. We are having the inlet valve 1, inlet valve 2, outlet valve 1 and outlet valve 2.

Suppose we are having a forward stroke and we are also having a return stroke. When the piston is moving from left to the right toward this direction that we call the forward stroke, pressurized fluid will come out from the outlet valve 1.

When it is pushing the fluid the piston is pushing the fluid inlet valve 1 will be closed. The outlet valve is open. But, during this forward stroke there is a creation of vacuum at the back side of the piston, at this side of the piston.

Here due to the pressure difference, inlet valve 2 will be open. There is a opening of inlet valve 2, there is a closing of outlet valve 2. In the forward stroke the inlet valve is closed, there is a pulsed output that we are getting from the outlet valve 1. During the return stroke from the top dead center to the bottoms dead center that is from right to the left, the outlet valve 2 will be opened.

Pressurized fluid or pressurized gas will come out from the outlet valve 2. As the outlet valve 2 is opened, the inlet valve 2 will be closed. This will be closed. As the piston is moving from right to left, there is a generation of pressure difference or the vacuum at the top dead center and due to that the inlet valve 1 will be open. Inlet valve 1 will be open and due to the spring force, the outlet valve 1 will be.

In this way in the forward stroke we are getting the compressed air and in the reverse stroke as well we are getting the compressed air. In this way we can have double action of the compression during the forward stroke and the reverse stroke, that is increasing the compression capacity of these cylinders. Generally these kind of compressors are manufacturing a pressure of up to 30 bar.

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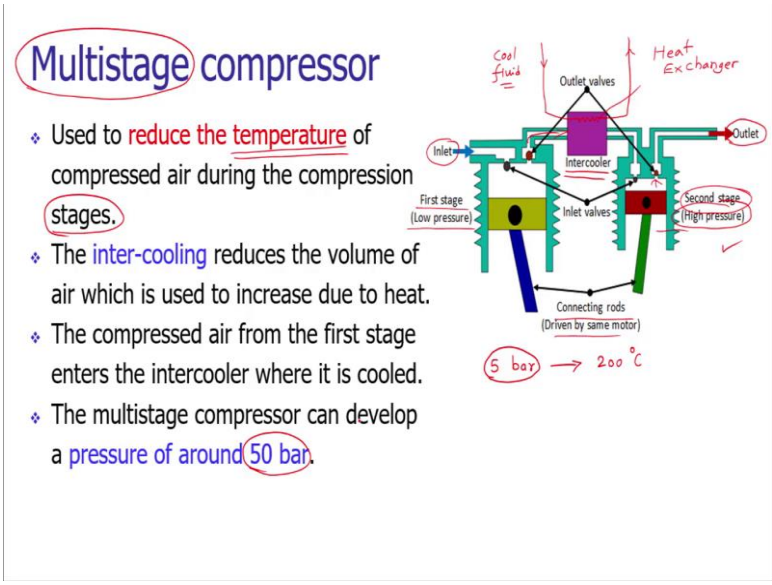

Well, in general the single acting cylinders to generate a pressure of about 5 bar, the temperature may go up to 200 degree Celsius. There is a huge increase in the temperature during the process of compression. To solve this problem and to increase the energy efficiency of these devices, we can go for the multistage compressing. We can use the intercoolers to enhance the efficiency of these systems.

The primary objective of the multistage compression is to reduce the temperature of the compressed air during the stages of the compression itself. For such systems we can have two cylinders which are connected by using a intercooler, that typical arrangement can be seen on your screen. We are having a low pressure stage that is the first cylinder piston arrangement, where we are generating the low pressure compression.

Through inlet we are getting the ambient air; the compression would be carried out here. The compressed fluid will be sent to the intercooler; so, intercooler is nothing, but a heat exchanger. This heat exchanger is having the outside supply of the cool fluid. It may be

another cold air or cold water which is circulating in the intercooler which will reduce the temperature of the compressed air.

As there is a reduction in the temperature of the compressed air which is coming out from the stage 1, its volume will be reduced. And, that reduced volume low temperature compressed air will be sucked in the second cylinder. In the in the second cylinder, in second stage; it will be sucked in and that will be compressed by using the second piston.

Already we are getting a compressed air which is cold which is having the low volume and we can further increase its pressure by applying the piston energy, by applying the mechanical energy in the second stage. And afterwards the pressurized air which is around 50 bar can be sent for the required operation. We can have the combination of these two stages together.

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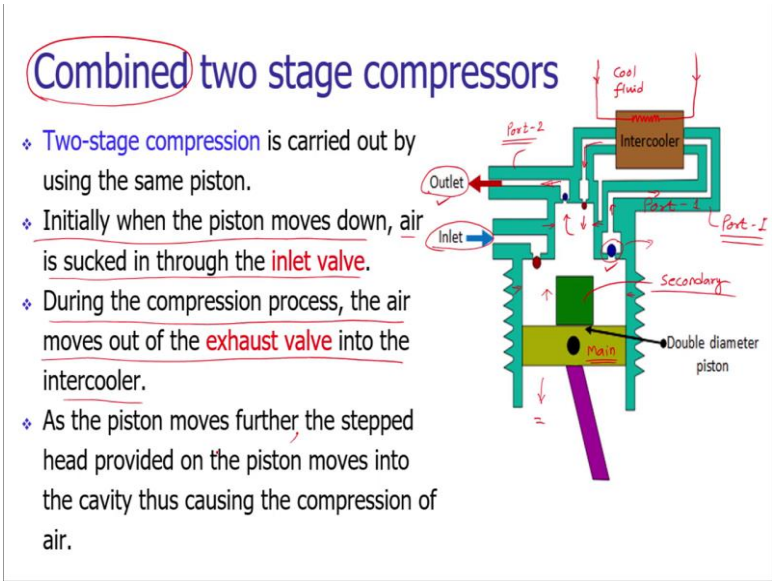

Now, the arrangement of the combined two stage compressor is there on your screen. In this case we are having two pistons. The diameter of the pistons is different. This is the main piston and it has a secondary piston as well. The diameter of the secondary piston is lower than the main piston and to accommodate the secondary piston, a secondary cylinder is also there which is having diameter lesser than the primary cylinder.

On the top side of the primary cylinder, we are having the secondary cylinder. There are two sets of inlet outlet valves. The ambient air will come, it will be sucked in during the return

stroke and that ambient air will be compressed in the forward stroke. During the compression of the forward stroke, the outlet valve 1 will be opened; during forward stroke the air will be compressed and that compressed air will be passed through two different ports which are connected to the outlet of the system.

There are two ports. This is the port 1 and the port 2. Port 1 and port 2 are connected to the outlet valve; however, the port 1 is connected to the outlet through the intercooler. The intercooler is nothing, but the heat exchanger. Now, during the process of compression, the outlet valve 1 will open.

And, the high temperature compressed air will pass through this passage, it will pass through the intercooler during the passage through the inter cooler its temperature will get reduced. And, that reduced temperature fluid will be further sucked in during the return stroke and its forward stroke that reduced temperature compressed air will be further pressurized and that will be sent to the port 2 of the outlet.

In this way the intercooler is reducing the temperature of the fluid which is coming from the outlet port 1 and that outlet port 1 fluid will be sucked in by the top smaller diameter cylinder; during the return stroke of the piston. And, further it will be pressurized to get the required pressure; required pressure would be quite high, with low temperature and with better efficiency.

Initially, when the piston moves down, the air is sucked in through the inlet valve and during the compression process the air moves out of the exhaust valve into the intercooler. As the piston moves further, the stepped head provided on the piston moves into the cavity thus causing compression of the air.

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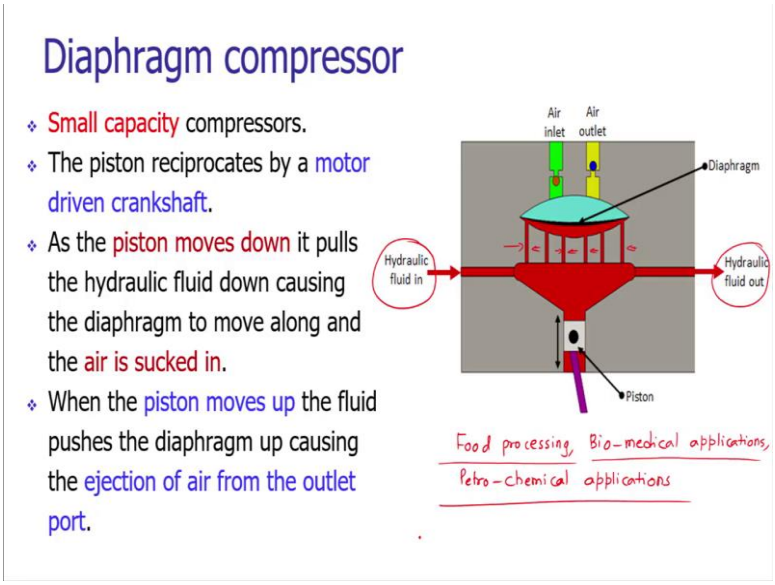

We are having one more interesting configuration based upon the reciprocation motion of the piston and that is the diaphragm compressor. The construction of the diaphragm compressor can be seen on your screen. It has the typical piston cylinder arrangement. This is the piston; there is a connecting rod, crank and crankshaft. The piston is reciprocating and it is driving the hydraulic fluid here.

The diaphragm compressors are utilizing the hydraulic energy as well. As the piston moves in downward direction, during its return stroke the hydraulic fluid will be taken inside this cavity and when the piston is moving in the upward direction, that hydraulic fluid will be pushed into forward direction.

There are number of passages to the hydraulic fluid and there is a chamber. Through these number of passages or the channel, the pressurized hydraulic fluid will come to this particular chamber and that chamber is having a diaphragm. It is a metal diaphragm, it is a metal plate thin plate that is called as the diaphragm.

And when the hydraulic fluid is pushed against this diaphragm, the diaphragm will be displaced in forward direction. When it is displacing in the forward direction; so, whatever the air inside this particular cavity above the diaphragm, that will be compressed and that air will be pushed through the outlet valve. There are two passages for the air: one is for the inlet that is input and the other one is the output.

When the piston is moving in downward direction, the fluid is moving in downward direction. Naturally the diaphragm also move in downward direction and due to pressure difference we are getting the ambient air inside the passage. And, during the upward motion the hydraulic fluid is pushing the diaphragm in upward direction and that is compressing the fluid, that is the air ambient air and through the outlet valve we are getting the compressed air.

In this way the diaphragm compressor are used or there is no contact of the processing air with the piston cylinder arrangement. The advantage of the diaphragms compressor is that it generates the clean compressed air. For applications in the food industry, the food processing industry, biomedical applications or in the petrochemical applications, where we required the clean compressed air; for this purpose these kind of diaphragm compressors are used.

However, the construction of the diaphragm compressor is quite complex and its cost is also quite high, because we need to have the hydraulic power pack. We need to have the hydraulic system which is having its own piston cylinder arrangement for by pumping the pressurized hydraulic fluid inside the system; it will have its own the prime mover electric motor, it will have its own passages.

The construction features are also quite complex, we need to manufacture the channels. These are the channels that to be manufactured. However, for the critical applications or for the biomedical applications, it is worth to develop such kind of facility and utilize it for our intended purpose.

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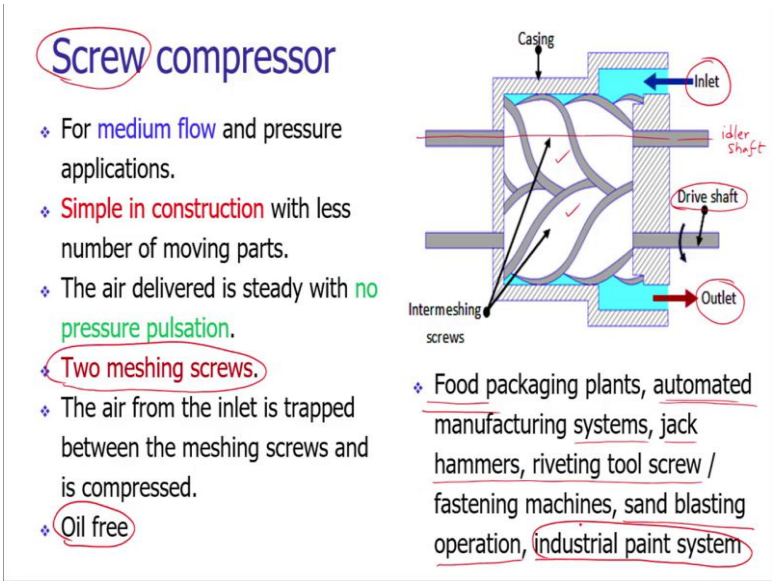

We can also have a arrangement with meshed screws. We are using two meshing screws, a compressor with the screws is shown; that typical arrangement can be seen on the screen. These are the two intermeshing screws and one screw, this screw is on a idler shaft and the other screw is on the drive shaft. The drive shaft is operated, it is governed by the electric prime mover.

As the shaft is rotating this drive shaft is driving the drive screw and that drive screw is driving the other meshed screw. During the process of rotation of these screws, the gaps in between the screw faces will pressurize, will reduce the volume of the air. As it is reducing the volume of the air, it is increasing the pressure. It is increasing the pressure on the air and that compressed air will be taken out from the outlet valve.

During the opening of the meshing, there is a decrease in the pressure and due to that decrease in the pressure the ambient air will be taken inside through inlet valve. This process oil free; so, that is why it is utilized for the food industry. The screw compressors are utilized in automated manufacturing systems; they are used in jack hammers and riveting tool screws.

A lot of pneumatic tools are utilized for the fastening operation. The automobile screw fastening operations are done by the compressed air. The screw compressors are also utilized for a sand blasting operation and they are widely used in the industrial paint systems. For painting operations as well we need the compressed air and the screw compressors are providing the same.

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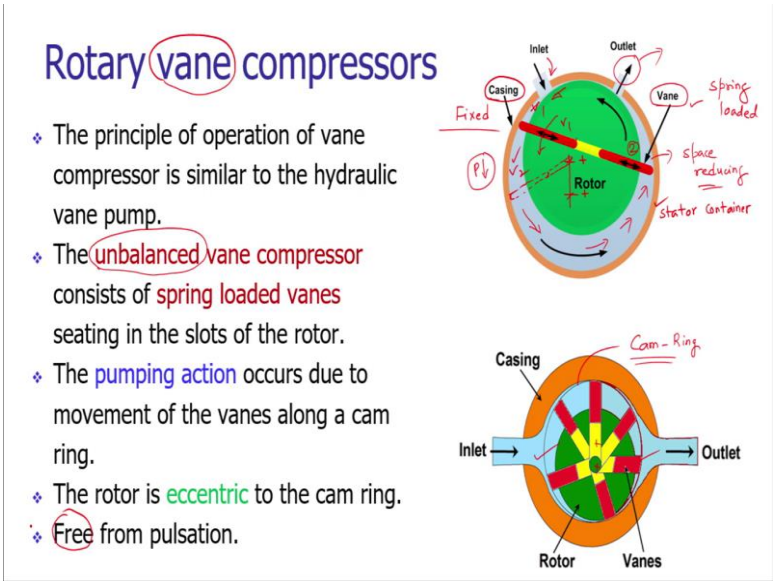

We can utilize the vanes, very similar to the vane pump which we have seen in our the hydraulic pumps section. We can have slots in a rotor and this rotor disc is eccentrically assembled with a stator container. This is the stator container. There is eccentricity between the axis of the rotor and the axis of the stator or the casing. The casing is fixed, it is not moving, it is stationary.

The rotor is moved by the prime mover and as the rotor is moving the prime mover, the spring loaded vanes are reciprocating inside the slots. The slots are having the spring loaded vanes. As the rotor is rotating; this vane number 1 if it comes over here. The length of the vane is the same, but it will pushed due to the spring force in outward direction.

As it is moving in outward direction; there is generation of the volume here. There is increasion of the volume; here you can see the volume V 1 has been increased to volume V 2. As there is increase in volume from V 1 to V 2, the pressure is reducing; pressure will be reduced and the ambient air will be sucked inside the cavity.

During the further rotation of the rotor, the vane number 2 will just push that sucked in air and it will take that air to the outlet valve. As it is approaching the outlet valve, the volume or the space is getting reduced; the here you can see the space is getting reduced. And, due to reducing in the space there is increasing the pressure and that pressurized gas will be taken out from the outlet valve or from the outlet port.

Instead of having two vanes or a pair of vanes, we can have multiple pairs of vanes which you can see on your screen here. This is the rotor which is offset and we can have the multiple vanes to carry out this kind of rotary compression action. To have the eccentricity a cam ring is used. This is a cam ring which is generating the offset between the axis of the rotor and the casing.

This is basically the unbalanced the vane compressor. The balanced vane compressor is also available, and the construction and the working is very similar to the balanced vane pump. The advantage of the rotary vane compressor is that they are free from the pulsation; they are free from that pulsating action which is obvious in the reciprocation type compressor.

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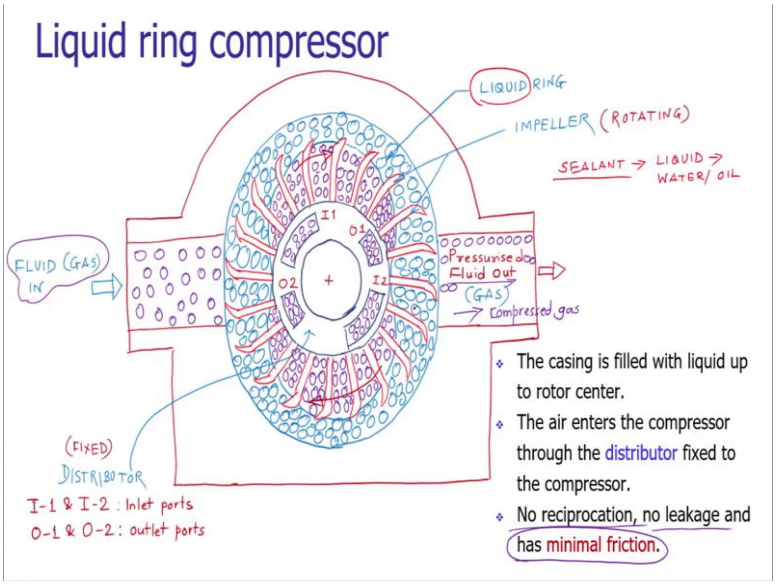

Now, let us study the next positive displacement compressor that is the liquid ring compressor. The technology is very interesting and the reason is very important. In reciprocating type of the compressor, we have seen that there are many mechanical elements and they are sliding. Due to the sliding, there is a friction, due to the friction there is wear and tear of the mechanical parts and due to the wear and tear of the mechanical parts there will be gaps.

These gaps are creating leakages of the compressed air inside the mechanical system. These leakages are affecting the efficiency. We need to have a leakage free or the system which is providing minimal leakage during the operation. For that purpose, a liquid is utilized as the

sealant here. We need to have an efficient sealant and the sealant which is used here is a liquid only.

That liquid is water or oil, by using this liquid sealing we are creating the compressed air during this operation. The construction of the liquid ring compressor can be seen on the screen. It has the casing or the chamber; this is the casing of the liquid ring compressor. Inside the casing there is obround kind of cavity or a space which has a shaft inside it.

And, on the shaft we have mounted a impeller, set of impellers are mounted and this impellers are rotating about this axis. The shaft is rotating by an electric motor and as the shaft is rotating, the impellers are also rotating. At the end of the shaft we are having a distributor, but note that the distributor is fixed.

Distributor is not rotating which is mounted in separate, it is mounted on the casing and it is not rotating. The distributor is a mechanical element and it has four openings: I 1, I 2, O 1, O 2, I 1 and I 2 are the inlet ports, and O 1 and O 2 are the outlet ports. The casing is having the main inlet port or main opening inlet opening through which we are getting the gas or the air at ambient pressure.

And, the casing is having the outlet port or main outlet port through which we are taking out the pressurized. The liquid ring compressor is having a certain liquid and that liquid maybe water or oil. As the impellers are rotating, the impellers are rotating we are pouring in a liquid inside the casing. Due to centrifugal force this liquid will try to move in a radially outward direction.

But, due to the shape of the casing they will not move out and we are getting a ring of liquid during the rotation of the impeller. Continuously impeller is rotating and due to that continuous rotation we are getting a ring of liquid at the periphery of the obround space. Due to the formation of the liquid ring and the vanes we are getting various chambers. These are all the chambers and these chambers are made up of the vanes.

This surface of the vane, this is the surface of the shaft or the body and this entire space has been sealed by the liquid ring. In this way we are getting multiple number of confined spaces which are sealed by the liquid ring. But, you notice that the volume or the sizes of the spaces is varying. It is increasing in this direction and then it is reducing.

These variable spaces, variable volumes are utilized for the suction of the air and compression of the air during the operation. How it is possible? We are getting fluid at ambient temperature through inlet port. Here the volume is less and as the impeller is moving, the volume is getting increased, the space is getting increased. There is a creation of negative pressure and due to that the fluid will come inside.

Due to the impeller motion this fluid will be moved further, the impellers are pushing the fluid. But, as they are pushing the fluid further their due to the restriction in the space, the pressure on the fluid is getting increased. You just notice here the pressure is getting increased and due to the increase in pressure, their volume is getting reduced.

This low volume high pressure fluid will come out from the outlet opening O 1 and that will be sent to the pressurized fluid out. Thus, the cyclic variation of the volume enclosed by the impeller vanes and the ring is creating the pressure on the fluid which is coming in. The liquid ring is acting or it is performing the functions of the piston in reciprocation type of compressor that we have seen.

The piston is taking the fluid in and it is compressing the fluid. The same operation would be done by the variable space created by the liquid ring along with the vanes. The advantage of such kind of operation is that there is no reciprocation, there is no leakage. And, thus it has a minimal friction that is lead to increase in the efficiency of the system. Simultaneously, to the I 1 the fluid at ambient temperature will also get into the inlet port I 2.

Here the fluid is sucked inside. Then it will be pushed and during the pushing of the fluid as the space is getting reduce, it will be compressed. And, ultimately through the outlet port O 2, it will be taken out to the pressurized fluid output that is the final output and then it will be pass for the desired application.

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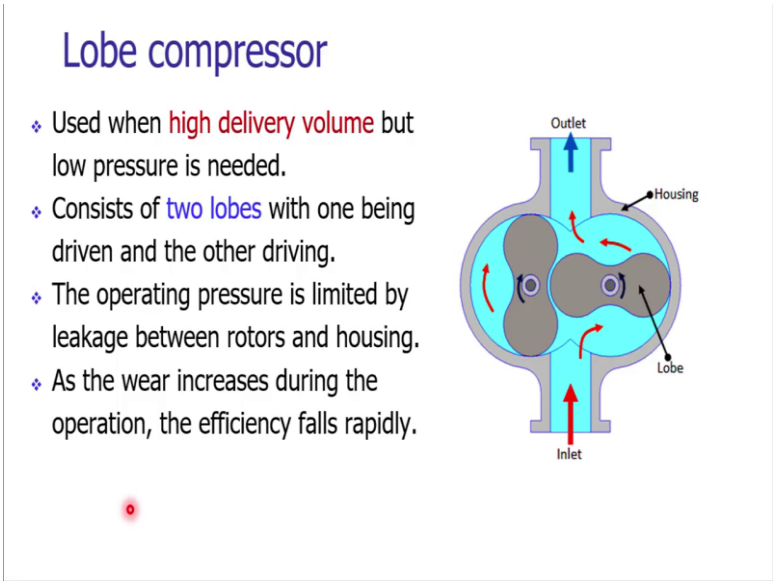

Well, the next type of compressor is the lobe compressor and it is generally used when we want to have the high delivery volume at low pressure. It has two lobes and they are mesh together. One is the idler lobe the other one is the driving lobe. The driving lobe is driven by an electric motor. When they are getting unmeshed, when they are getting disengaged; there is a creation of negative pressure.

And, due to that negative pressure the gas or air which is at ambient pressure will get sucked in inside the housing. The lobes are pressurizing, they are carrying, they are pushing the fluid inside the gap. As the volume of the gap is getting reduced, then there is increase in the pressure on the fluid that is air or the gas.

As the lobes are moving further that compressed gas or the fluid will be taken out, it will be pushed out through the outlet. Due to the continuous contact or rubbing of the lobe surface over each other, there is lot of wear and tear of this lobe compressor elements.

And, due to that there is a problem of leakage in the lobe compressor. Therefore, the efficiency of lobe type of compressor is quiet less. They are not that widely preferred, when we want to have you know high pressure fluid for our applications.

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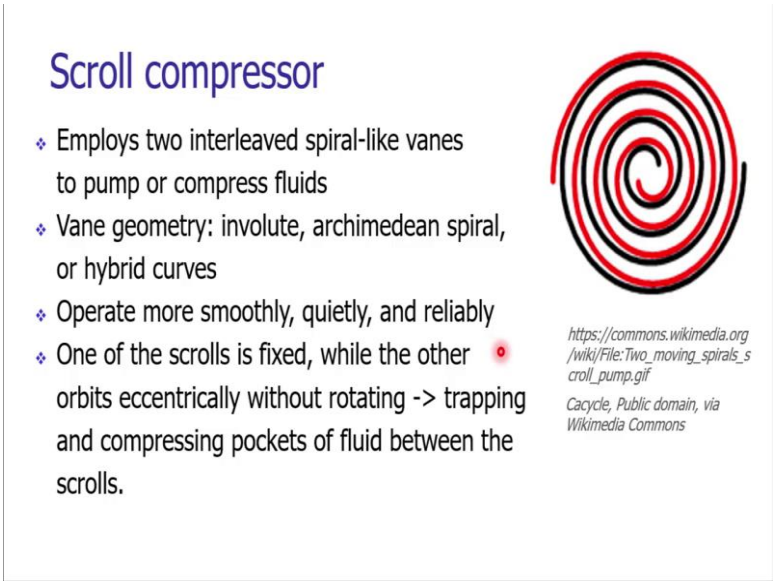

The next type of compressor is the scroll compressor and it employees basically two interleaved spiral like vanes which you can see on your screen. There are two spiral like vanes, out of these two spiral like vanes one is stationary. One is stationary and the other scroll is orbiting eccentrically; due to the this eccentric orbiting process there is generation of variable volume between the fixed scroll and orbiting scroll.

As we can see here the volume is getting changed, it is getting varied, it is getting reduced. When there is an increase in the volume whereas decrease in pressure the fluid will be sucked inside.

And when the volume is getting reduced, the pressure will be increased. The principle of reciprocating compressor of the general principle which we have seen in the previous pumps, the same principle has been employed over here; only the mechanism is different.

The vane geometries are in general the involute type or archimedean spiral type or we can have the hybrid curves as well. The operation of the scroll compressor is smooth, the operation is quiet and the reliability of the scroll compressor is quite high.

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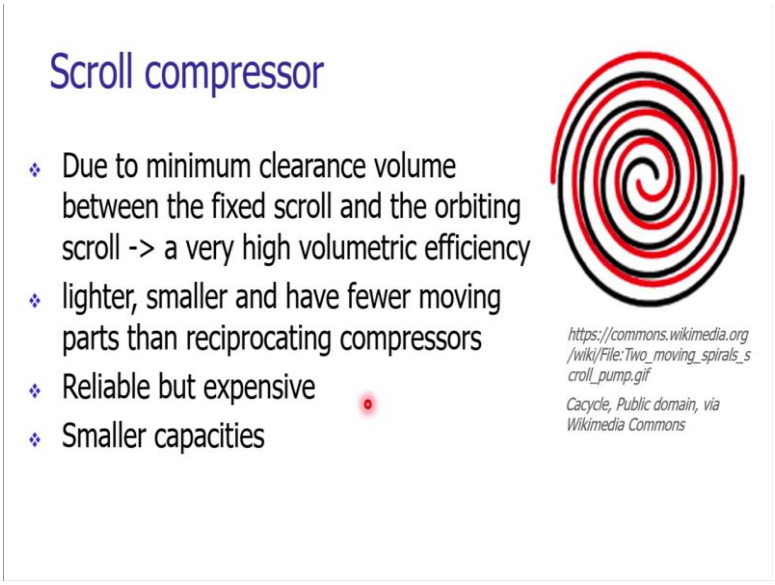

Due to the small clearance, due to very less clearance volume between the fixed scroll and the orbiting scroll, the scroll compressors are offering us high volumetric efficiency. As the clearance is less the leakage is less therefore, the volumetric efficiency of the scroll compressor is quite high. As far as the construction point of view, we are having a fixed scroll and there is a orbiting scroll.

The construction is very compact, they are very small, there are very few moving parts. Reliability quite high, but the cost of the compressor is quite high as well. They are quite expensive because of the precision in manufacturing of this various mechanical elements. The assembly is little complex, though the working is simple, but manufacturing of the exact spirals of the required dimensions, assembly of that and the generation of the orbital eccentric motion; it is its quite difficult.

Therefore, due to the construction complexity, the expense that we need to incur for scroll type of compressor is little high. The capacities of the scroll compressor is low because, of the area or the volume of compression is low; that is why we are getting small capacities pressurized fluid.

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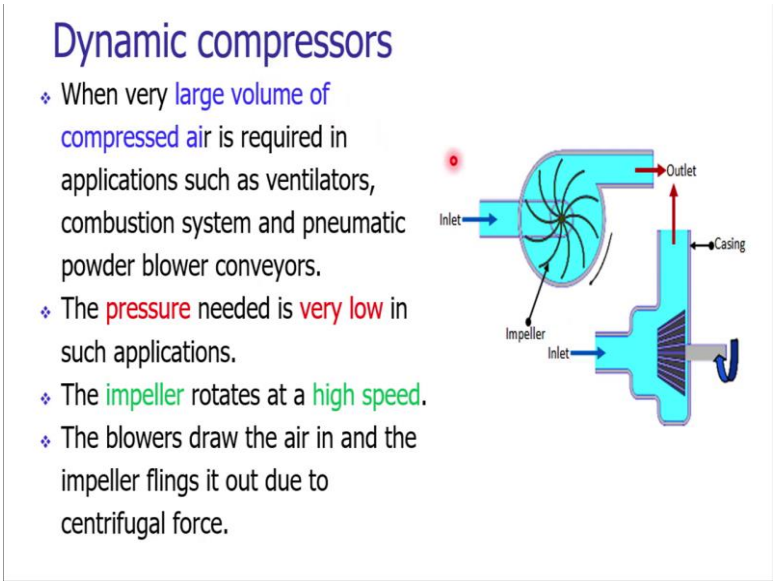

The next category of the compressor is the dynamic compressor. They are non positive type, where we are getting large volume of compressed air which is in general required for the ventilation operation. For combustion systems to provide the oxygen to the furnace, we need the air; for that operations we need the large volume of compressed air; we may not required very high pressure, but the volume should be very large.

For the blowing operations, when we want to have the blowing of the powder for that as well we need very large volume of compressed air. The operation is very simple; we have seen the principle of the centrifugal pump in our previous section. The principle of operation is very similar to that, there is inlet and there is outlet. These are connected to a casing; inside the casing we are having an impeller.

The impeller is mounted on a shaft and the shaft is being rotated by a electric motor. As there is a rotation of the impeller and as we are getting the input air at ambient pressure, the impellers are pushing airs and that pushed air with increased pressure will further lead to the outlet. As the impellers are rotating at a high speed, the fluid which has come out that would be you know pushed in a radial outward direction due to the centrifugal force.

Air will try to move in a radial direction, but there is a casing and that casing will restrict its operation of movement in a radial outward direction. The impellers are further applying the force on that radially moving air and that is increasing its pressure. In this case basically we are taking the fluid at a high volume and we are pushing it at a high speed to the application.

The pressure increase is not that high; there is a moderate increase in the pressure by using the dynamic type of compressors.

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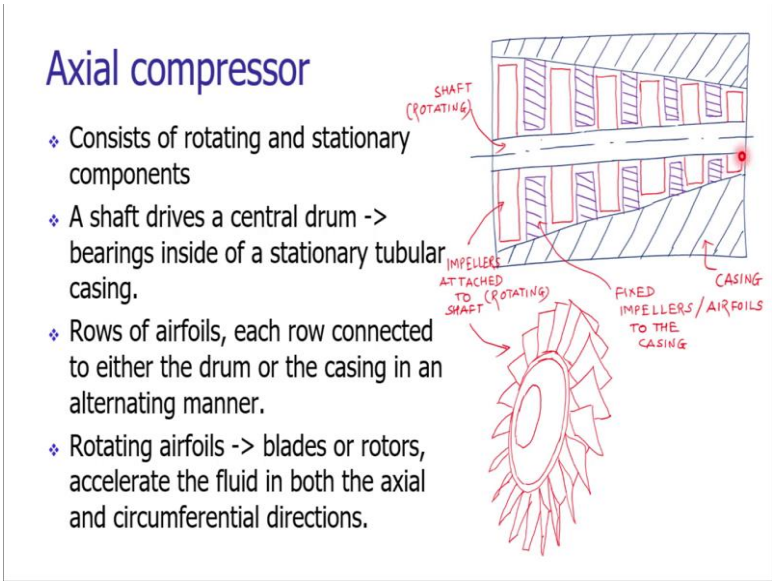

The next type of dynamic compressor is the axial compressor. The axial compressor is widely used. It has the rotating and stationary components. The typical construction of an axial compressor can be seen on your screen. It has a casing, the casing is housing a shaft, the shaft is supported in the bearings which are there in the casing. The shaft is being rotated by an electric motor.

The shaft is having a rows of airfoils, this there are many rows of impellers or airfoils which are attached to the shaft. In between these airfoils which are attached to the shaft, there are rows of airfoils as well which are fixed to the casing. The casing is shown on the screen. It is having the purple colour fixed impellers which are housed in the casing.

And, the red colour are the impellers or the airfoils which are connected to the shaft. These impellers are rotating along with the shaft. However, these impellers, the purple colour impellers are fixed to the casing.

As the shaft is rotating, the airfoils are also rotating. This is a typical shape of the airfoils which are there on the shaft. The blades or the rotors, they accelerate the fluid which is coming inside; both in circumferential direction, both in circumferential direction as well as in the axial direction.

But, as you can see that the volume of the cavity is getting reduced from left to right. There is a gradual reduction in the volume available for the passage of the fluid along the axial direction. Due to that gradual reduction in the volume available, there is increase in the pressure of the fluid or the gas or the air. As the shaft is rotating, the impellers are rotating, they are pushing; the gas or the air which has entered inside the cavity.

The air will try to move along axial direction, but the space is the restriction. But, still the air it is pushed, it is compelled to move along the axial direction and due to that space restriction there is increase in the pressure. In this way we are getting compressed fluid, compressed air at the outlet of this axial compressor.

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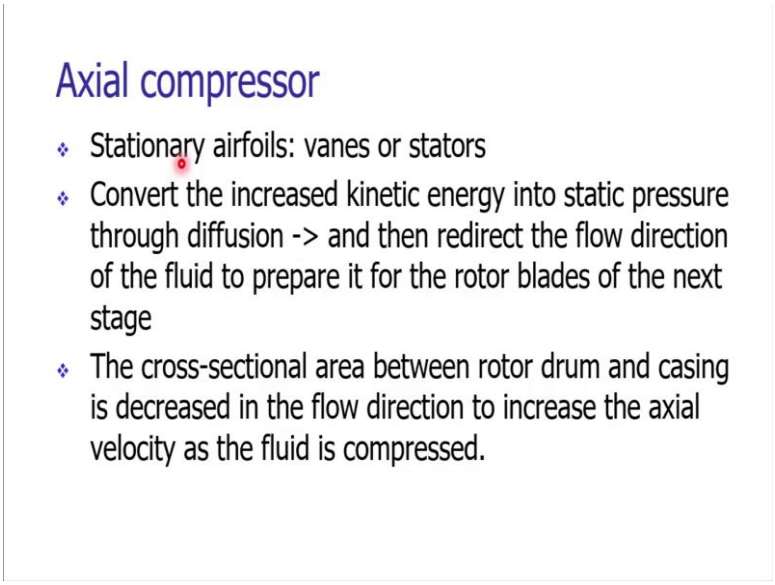

Basically the axial compressors are converting the increased kinetic energy into static pressure through diffusion. And then they are redirecting the flow, direction of the fluid to prepare it for the rotor blades of the next stages. Basically the gap between a fixed row of the impellers and the rotating row of the impeller is called as the stage.

Thus, in this way the axial compressor works and it is widely used in the industry. The construction of the axial compressor is quite complex and it requires many mechanical elements, many rotating elements. The cost of the axial compressor is quite high, but it is giving high volume with high pressure.

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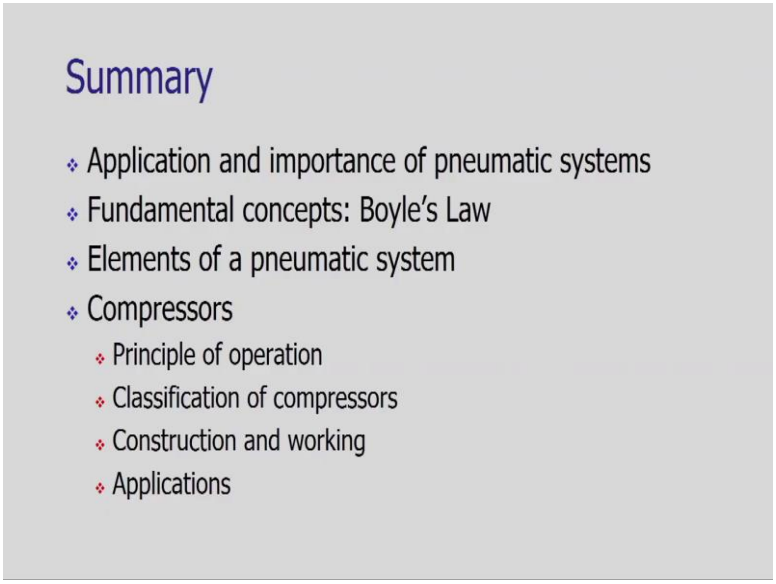

Well, let me summarize the lecture 1 of week 11. In this lecture we have seen the importance of pneumatic systems in automation, in manufacturing. We studied the basic concept such as the Boyle's law, on which the pneumatic systems are working.

There are various elements of an typical pneumatic system, that we have seen at a preliminary level. And, we discussed in detail about the compressors, we studied the principle of operation, classification and construction and working of various compressors which are used in manufacturing industry. We also learnt various applications of the compressors in automation.

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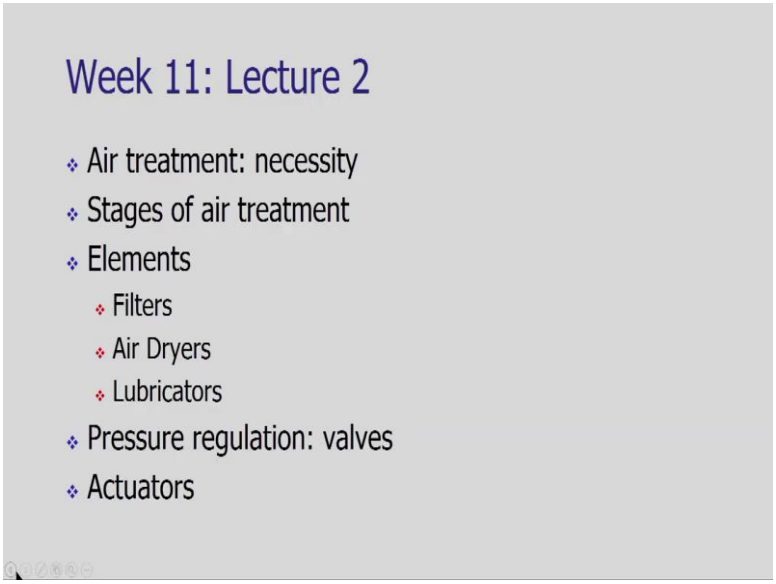

In the next lecture, that is lecture 2 of week 11; we will be studying the air treatment. What is the necessity to carry out or what is the necessity to treat the compressed air, what are the various stages of the air treatment. And, in that stages we are using variety of elements and these are filters, air dryers and lubricators.

We will see their configurations, construction working and applications. Then we will have a detailed discussion on the various valves, control valves, direction control valves which are used in the pneumatic systems. At the end of the lecture, we will have a discussion on various pneumatic actuators which are used in the industry.