Automation in Manufacturing
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Week - 11
Pneumatic systems
Lecture - 34
Air treatment and pressure regulation

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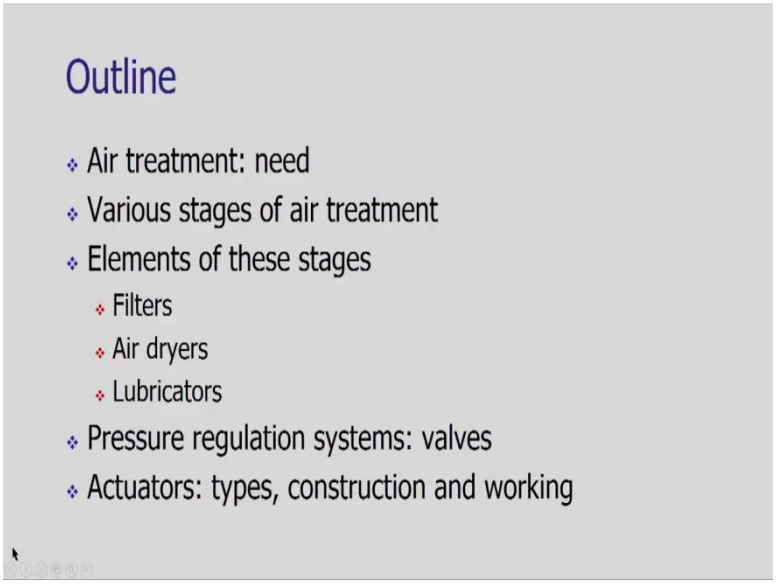

In lecture 2 of week 11, we will be studying various Air treatment technologies and the pressure regulation technologies used in pneumatic systems. The outline of the lecture 2 is there on the screen. At start of the lecture, we will have a discussion on the air treatment, what is the meaning of air treatment, its necessity and importance.

Then, we will have a discussion on various stages of the air treatment and to carry out these stages, we need certain elements and devices. These devices are filters, air dryers and lubricators. We will have a discussion on these elements, their construction and working and various types. Then, we will have a discussion on the valves, various control valves which are used in regulation of the pressure in the pneumatic systems.

At the end of the lecture, we will study the actuators, various types of actuators being used such as single acting cylinder, double acting cylinder and pneumatic motors that we will be studying in the last phase of this lecture. Let us begin the lecture 2.

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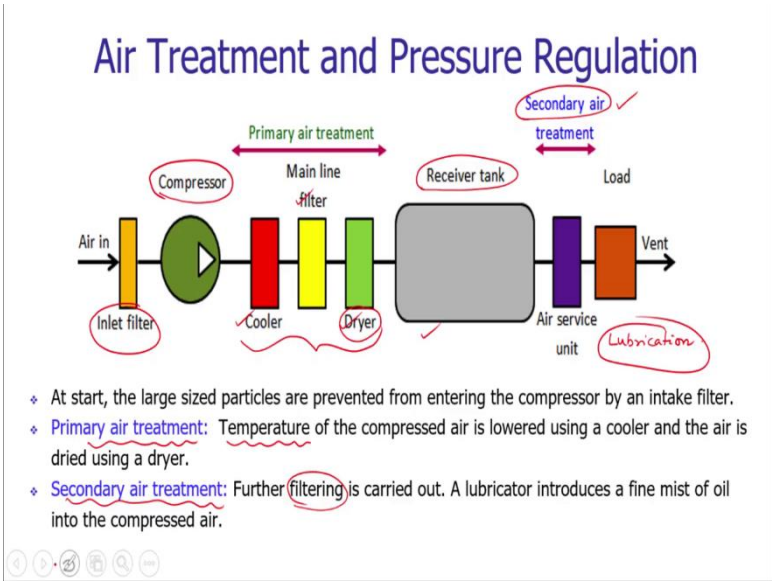

In our previous lecture, we have seen various types of compressors which are used to generate the pressurized air or the gas. After getting that compressed air, we are storing the compressed air in a storage device that is a tank and when we store the compressed air in the tank, we are processing, we are treating that air.

There are various processing elements involved in the air treatment and these are the coolers, filters and dryers. After storing the compressed air in the tank, that will be utilized for the load applications. Before sending the compressed air for its utilization, the air is treated and we are using the lubrication operation and lubrication process.

Let us see what are the various elements which are involved in this air treatment. At start of the compressor itself we are also using a filter which will remove the hard particles and very large size particles to protect the compressor. In the primary air treatment stage at the start of the air treatment, the temperature is to be controlled.

In compressor, the pressures are increasing very high and due to that increased in pressure, there is increase in temperature as well. We need to cool down the compressed air.

During the cooling operation, there will be condensation of the vapors or the water particles inside the; inside the air. That condensed water or the vapour need to be filtered out, we need to separate it so, for that purpose the dryer application is needed and then, it would be stored in the receiver tank.

In the secondary air treatment, we need to further filter the compressed air. In a receiver tank also, there may be certain impurities and that impurities need to be filtered out when the compressed air is utilized for the application.

For food processing applications, for pharmaceutical applications, biomedical applications where very pure clean air is required, there the secondary air treatment is very much essential. Even for painting of the automobiles as well, the purified or the clean air is very much essential.

Afterwards, the air has been added with certain lubricants that lubricants are utilized for the lubrication of various mechanical devices; which are on the way towards the application from the tank to the application there are many mechanical elements some of the elements are say the directional control valves itself. To lubricate these elements, we need to have the lubrication process that is part of the secondary air treatment.

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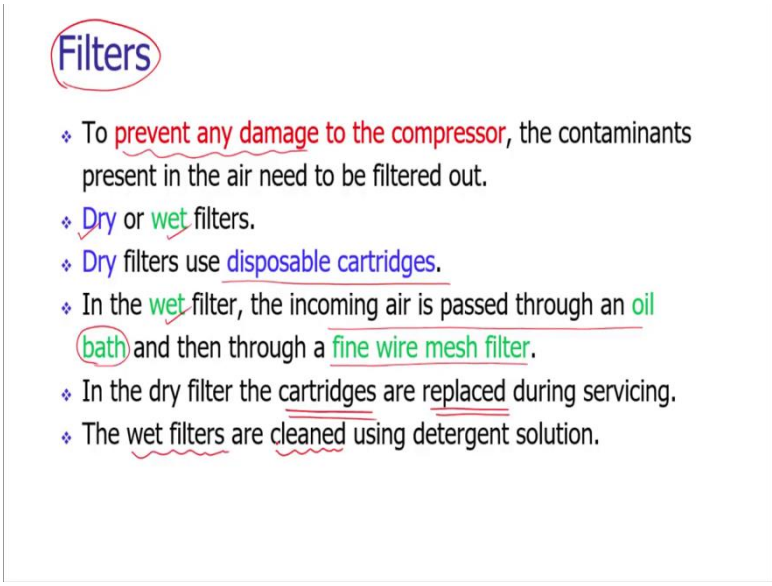

First element is the filters. Filters are basically used to prevent the damage to the compressor. We are having the dry and the wet filters, basically the dry filters are utilizing disposable cartridges.

There is the certain chemicalin the cartridges whichis removing the water vapors from the compressed air. In the wet filters, the incoming air is passed through an oil bath and then it is

passed through a fine wire mesh. During the passage through the oil bath, the air will get dried.

After utilization of the cartridges, we need to replace the cartridges and these cartridges are disposable cartridges. While the wet filters are to be cleaned using the detergent solution regularly to remove the dirt and to reuse the filters for multiple number of times.

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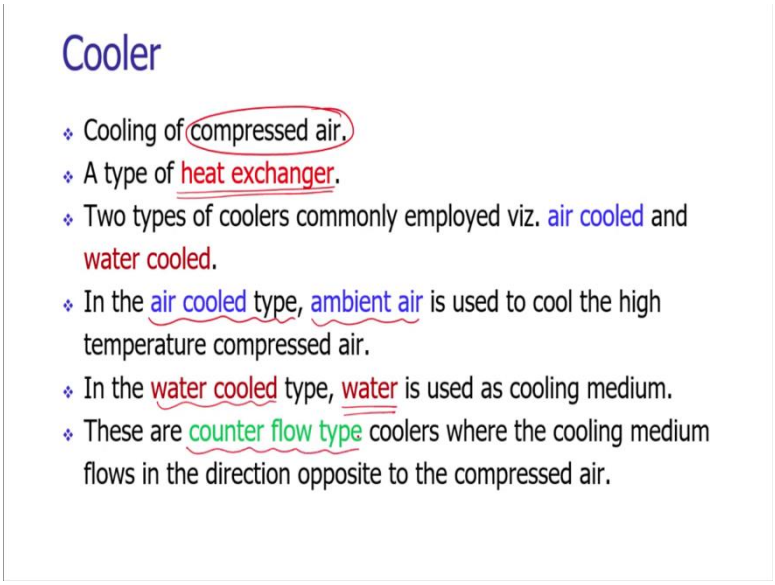

Coolers are essential as the temperature is very high after the compression and we need to store that compressed air in the storage tank so, we need to cool it down. For that purpose variety of heat exchanger arrangements are used, to cool down the air either cold air or cold water is used to reduce the temperature of the compressed air.

In the air cool type of the cooler, the ambient air is used to cool the high temperature compressed air whereas, in water cooled, the water is used. We can have either the counter flow type of the coolers or the indirection type of the coolers.

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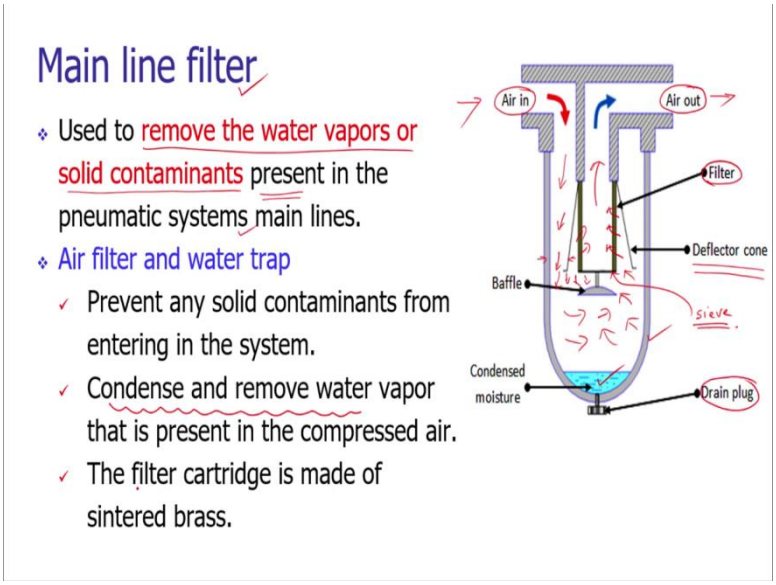

One typical filter is the main line filter and it just removes the water vapor or solid contaminants which are present in the pneumatic system main lines. The construction can be seen.

It is having a tube and inside the tube there is an inlet port through which the compressed air is coming in and there is an output port from which theair is going to the tank or to the load application. Inside the tube, we are having the filter and there is a deflector cone.

As the air is coming inside the tube, there is a restriction to it. The high pressure air as it is getting restricted, the pressure will reduce and the velocity will increase and during this process of increase in the velocity, high velocity fluids will come in this way and will try to escape. Thus, high velocity fluid will just pass through the filter and during the passage, the particles will be removed from the filter or the sieve.

During the process of filtering, some of the water vapors will also get condensed as the compressed air is passing through as the compressed air is passing over the deflector cone there is increase in the velocity. As the velocity is increasingand the fluid is passing through this constriction and then, there is the reduction in pressure as well. Due to reduction in pressure, the water vapors will get condensed as the temperature is getting reduced which would be taken at the bottom side. The filter cartridge is in general made up of the sintered brass.

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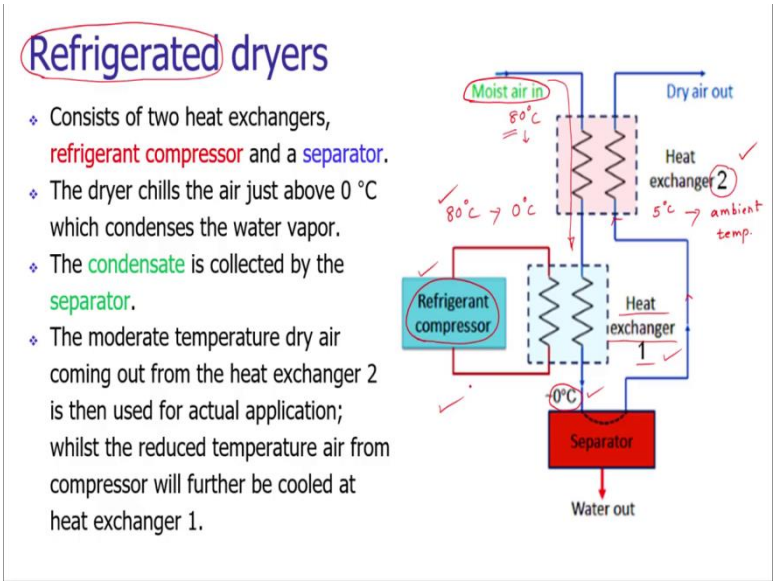

We can have variety of the air dryers. Mostly, the refrigerated dryer is used which is based upon the heat exchanger principle. We need to dry the air and that dry cool air will be utilized for the applications. In the refrigerated dryers, the cold air is used to reduce the temperature of the moist air so that the water particles will get condensed.

To achieve that very low temperature, the temperatureis gradually decreased. To reduce drastically the temperature from around 80 degree Celsius to the 0 degree Celsius, we need to apply more amount of energy. In this case, we are trying to regenerate the energy during the process of the drying operation itself.

It is having two heat exchangers, heat exchanger 1 and the heat exchanger 2. The moist air will come, and it will pass through both the heat exchanger 2 and heat exchanger 1. Let us consider we are having only one heat exchanger and through which the air is passing. A refrigerant compressor is producing the chilled air.

When the moist air is in contact with the chilled air, its temperature is reduced and we are trying to achieve around 0 degree Celsius. To reduce the temperature from say around 80 degree Celsius to 0 degree Celsius, a handsome amount of the energy needs to be appliedat the compressor. To reduce the energy consumption in heat exchanger 1, a heat exchanger 2 is used which is working based upon the input given by the heat exchanger 1 only.

For the condensation purpose, we are reducing the temperature to 0 degree Celsius, but the air around 0 degree Celsius may not be useful for us, for direct application. We need to increase its temperature so, we need to have the moderate temperature air or the ambient temperature dry air for our application. That chilled air can be utilized for the heat exchanger 2 to gradually reduce the incoming moist air in the heat exchanger 1.

For that purpose, the processed air which is not having any water particles is passed through the heat exchanger number 2. The heat exchanger number 2 is having a provision that is getting the moist air at the primary stage itself. If we consider the temperature is around 80 degree Celsius, the temperature of the air from the separator may be around 5 degree Celsius.

Due to the considerable difference in the temperature, there is a the heat transfer from the hot moist air to the chilled air coming out from the separator. The heat exchanger 2 is reducing the temperature of the moist air at initial stage itself. During this operation, the 5-degree Celsius chilled air temperature may be reached to the ambient temperature.

It is increasing up to the ambient temperature and the moist air temperature will reduce to the intermediate temperature level, it is may be around 60 degree Celsius or around the 55 degree Celsius, but that will certainly saves that will certainly reduce the load on the refrigerant compressor and we can save the energy. In this way, the regenerative type of arrangement is certainly helping to enhance the efficiency of the refrigerated dryers.

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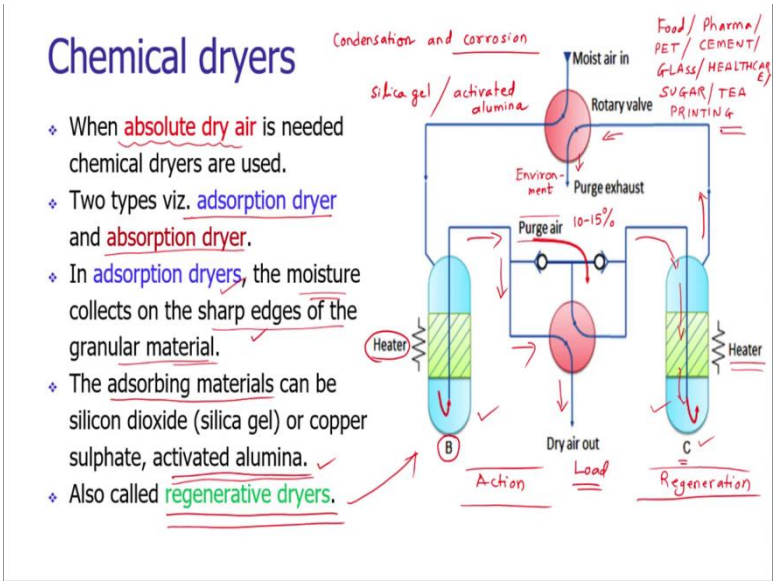

The next type of drying is based upon using the chemicals, variety of chemicals are used. Basically, the drying operation is used for the condensation and to avoid the corrosion. As we know that the moist air or the moist air which is having the water particles, water particles are promoting the chemical reaction and physical erosion. We need to remove the water particles to pass through the pneumatic systems.

The chemical dryers are basically used when we want the absolute dry air, complete dry air. We are having basically two types of the configuration and these are the adsorption type of dryer and absorption type of dryers. In the adsorption type of dryers, the moisture is collected on the sharp edges of granular materials.

In adsorption type of dryers, the moisture is passed over a material which is having very sharp edges and there the moist air will get separated out from the compressed air. In general, silica gel and activated alumina are used as these adsorption materials. These are silica gel or activated alumina. These type of dryers are also called as the regenerative dryer. Let us see the arrangement of the chemical dryers.

In general, the chemical dryers are having two tubes. One tube is basically used as the action tube; in this tube the basic action of drying is going on, the other tube may be considered as the regenerative tube. In this tube, the regeneration of the adsorbing material is going on. What is happening during the passage of moisture over this adsorbing material? The material will get saturated with water particles and after certain time, their adsorption capacity will get exhausted, after that particular material will not adsorb any water vapor and the entire the drying operation will be failed.

During that operation, we need to dry the material itself, which is removing the water particles so, for that purpose, we have to heat the elements. But after heating the moisture, how to remove the moisture? To remove the moisture, we need the air itself. During this process, the compressed air can be utilized which is getting processed during the operation for removing the moisture from adsorbing material of other tube.

If I consider the tube B as the cylinder or action tube in which the drying operation is carried out, the dry air will pass through the piping and from there it will take the load. But certain amount of the air may be around 10 to 15 percentage dry air will be utilized for the regeneration purpose. This is called the purge air. Around 10 to 15 percentage of the dry air

will be passed through the second tube or the cylinder in which the saturated adsorbing material is there.

Already, the heating operation is going on the from the granules, the moisture has been evaporated and that evaporated moisture has to be taken out from the passage. To have the dry granules, the purge air is passed over the granules which air is taking away the water vapors which are separated from the granules. The purge air will come, it will pass over the granules and then, it will be purged to the environment.

Well, after drying the material in the C tube, the passage of moist air is directed in the cylinder C by the time the passage of the air is passing through the cylinders C, the saturated adsorbing particles of the cylinder B will be relieved, they will be get processed by the purge air which is coming out from the cylinder C itself. On alternate basis, the cylinder B and the cylinder C will be utilized during the operation. Therefore, these type of chemical dryers are called as the regeneration dryers.

They are saving a lot of energy and they are commonly utilized in the industry like the food industry or pharma industry or the PET that is the plastic industry or the cement industry.

These are also utilized in the glass industry, healthcare and there are many more application such as the sugar processing, the tea processing and printing applications where we need the absolute dry air for efficient processing and manufacturing operations.

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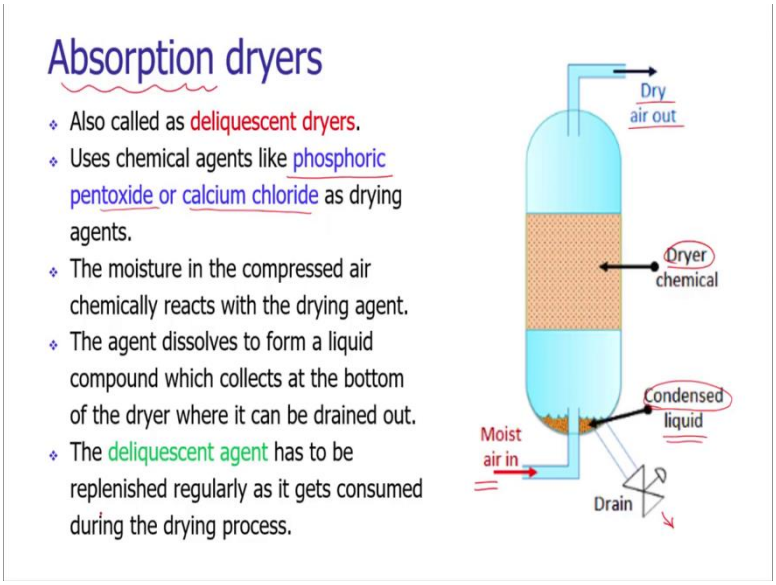

The next type of dryer is absorption dryer. In absorption process, we are using a material such as the phosphoric pentoxide or the calcium chloride, these are the drying agents. The arrangement is very simple, we are having a tube or a cylinder and there is an inlet to the tube through which the moist air is entering inside the dryer and there is an exit, through which the dry compressed air is taking out.

Inside the tube, we are having the dryer material. The compressed air is passing over the dryer material and during the passage, there is a chemical reaction between the water and these chemical agents and that chemical agents are just removing the moisture, they are drawing the air basically.

The agent is getting dissolved inside the liquid compound and that is getting collected at the bottom side of the tube that condensed liquid will be further drained out. We need to replenish regularly that deliquescent agent to have the efficient operation of the absorption type of dryers. Thus, it is required to have the regular maintenance of these kind of dryers.

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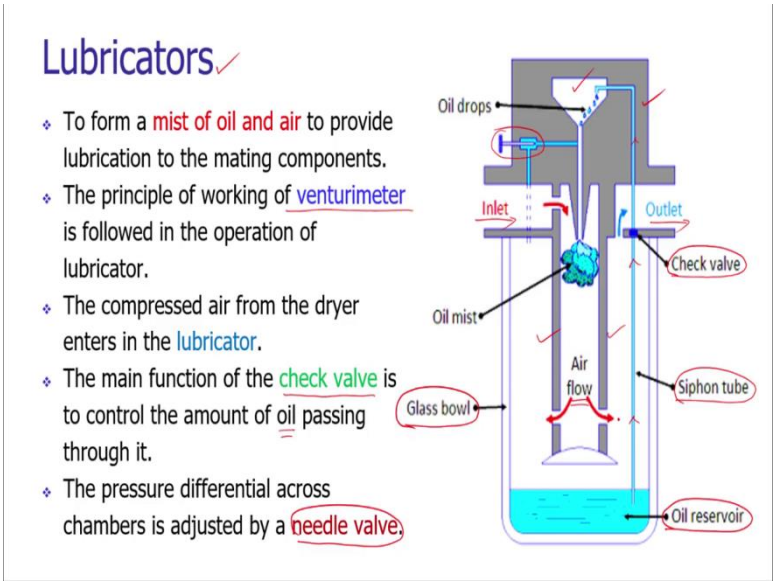

The next type of treatment of the air is lubrication, the lubricators. The dried air is stored in the tank and further it will be utilized for the desired application. During the passage, many mechanical elements need to be lubricated. For that purpose, we are deliberately adding the lubrication oil and creating a oil mist which is utilized for the mechanical operations of the valves or the actuators of the pneumatic system.

A typical lubricator arrangement can be seen on your screen. It is having a glass bowl and the at the top of the glass bowl, we are having an arrangement which is having variety of passages. This passage is provided to drip the oil to be mist or the oil to be mixed with the compressed air. At the bottom side of the glass bowl, we are having the lubricating oil which will be taken to the passage at the top through a tube that is called as siphon tube.

There is inlet to the tube and there is an outlet. Through the inlet, we are getting the compressed air inside the tube. It is having a typical arrangement with the passage of air flow.

Due to this constriction, there is increase in the velocity of the compressed air. Due to increase in velocity of the compressed air, there is uniform mixing of the oil and the compressed air. The dripping would be carried out by controlling the droplets that control of the droplets is done by using a check valve.

As the pressure inside the glass bowl is more than the pressure at the top side of the tube so, due to this pressure difference, the oil will get now taken at the top side due to this pressure difference and drop by drop it will be dripped inside the passage. When the fluid oil is coming, it will get mixed with high velocity, high pressure fluid and that mist will be taken for further processing. Basically it is working based upon the principle of the venturimeter.

In the venturimeter, we are using the gradual decrease in the passage. Due to the gradual decrease in the passage, the velocity of the particles or velocity of the fluid is getting increased. The same principle of the venturimeteris followed in the lubrication as well to have the proper or uniform mixing of the oil with the compressed air.

There is a check valve which is controlling the amount of oil which is passing through it and there is a needle valve which is basically controlling the pressure difference at the top side of the glass bowl and the bottom side of the glass bowl. Due to this pressure difference only, we are getting the oil from the oil reservoir at the top.

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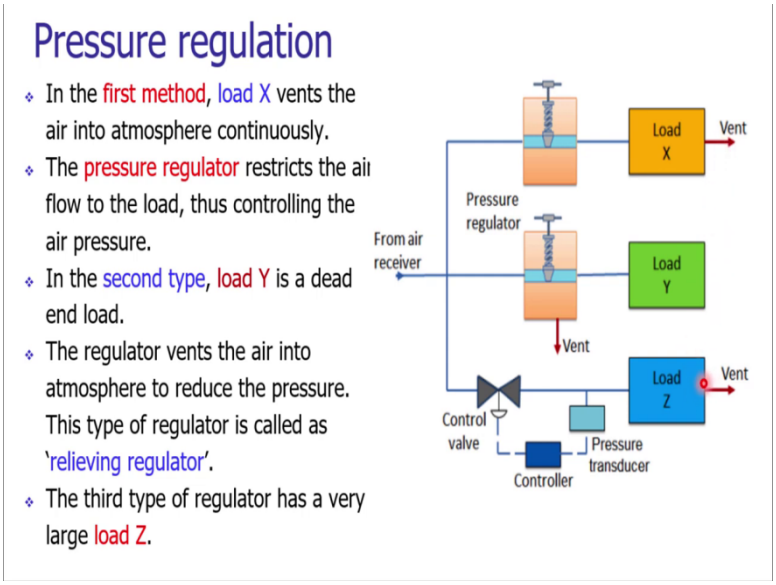

The compressed air is having variety of application in the industry. In certain cases, we need to have the continuous passage of the compressed air. Let us consider the ventilation purpose. During such kind of application, from the load itself, the compressed air is getting vented out. For such application, we are utilizing a simple pressure regulator which is regulating the pressure of the compressed air at the load.

But let us consider there is blockage of the compressed air at the load itself. For example, the compression operation or the clamping operation, pneumatic clamps so, after certain time, there is blockage for the compressed air, the compressed air will not be utilized, but there is continuous input from the tank or from the compressor towards the load. Thus, during the case of such dead end, it is called as the dead end of the load.

During this operation, there may be increase in the system pressure beyond the critical pressure. To protect the system from getting damage due to this enormous pressure, which is generated, we need to vent out the extra or the excessive compressed air. For that purpose, we need to have a pressure regulator which will drain out or vent out the compressed air to the environment itself.

There may be certain situation where we need to have very heavy loads or very large amount of compressed air is required. For these kind of operation, we are using a dedicated microprocessor based the controlling mechanism for application of the compressed air to the load.

Here as we have seen, we need to employ a set of sensors, a set of signal processing devices and based on the signals received from the signal processing devices, the microprocessor is controlling the actuators. We need a pressure transducer, a controller and the actuator or the control valve which is controlling the flow of compressed air at the load.

These are the various types of loads which are being utilized and for every type of load; we are having a different arrangement of the pressure regulation.

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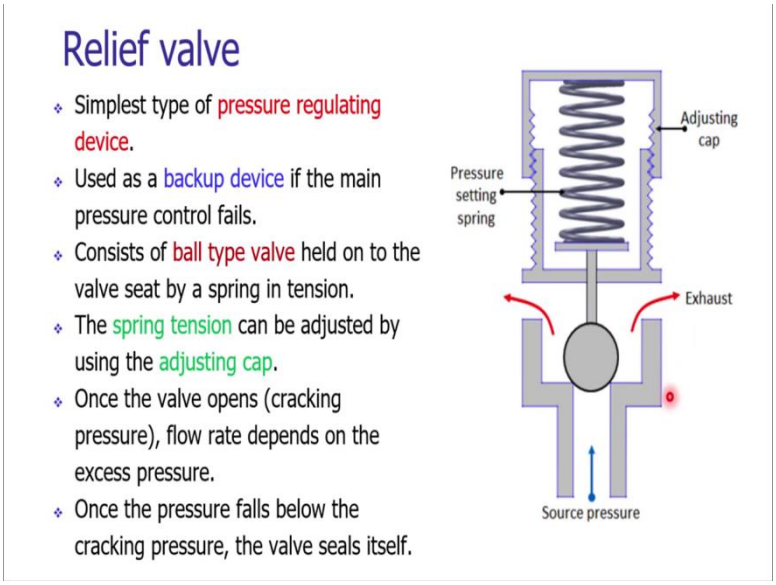

For the pressure regulation, simple relief valves are utilizing and the arrangement of a simple relief valve can be seen on your screen. It is having a steel body and inside the steel body, we are using a ball. The ball is spring loaded. Pressure has been set by the spring, stiffness of the spring and there is a an adjusting cap, that adjusting cap is controlling the pressure applied on the spring itself.

This is the source pressure port and through this source pressure port, the compressed air is applied over the relief valve. As the pressure, as the source pressure is more than the critical pressure of the relief valve or the set pressure of the relief valve, the ball will be displaced in upward direction and the excessive pressure will be relieved through the exhaust. This is a typical relief valve which we are using in the pressure regulation operation of the compressed air.

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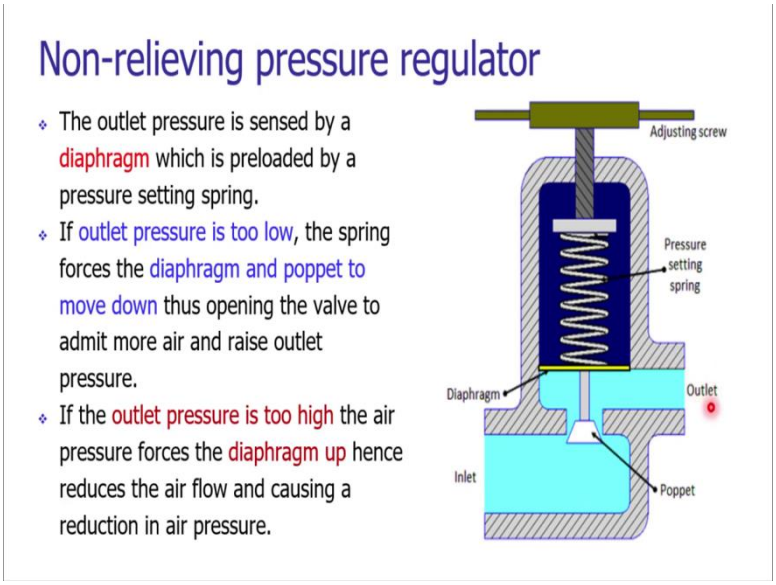

The second type is the non-relieving pressure regulator. In non-relieving pressure regulator valve, we are using a diaphragm, a diaphragm-based arrangement; so, here we can see a diaphragm which is having the spring loading as well. At the bottom side of the diaphragm, we are having a pin and that pin is attached to the poppet and poppet is blocking the flow of the compressed air in the passage of the inlet. This is inlet, and this is the outlet of the compressed air.

Now, let us consider the outlet pressure is reduced or the outlet pressure is too low. There is a constant spring pressure has been applied and due to the spring pressure, the diaphragm is being pushed in a downward direction, there is no load at the outlet. Due to the no pressure at the outlet, the spring will push the diaphragm in downward direction, the poppet will move in a downward direction and the valve will get opened.

From the inlet, the pressurized or compressed air will come and it will pass through the passage and it will be applied at the outlet. Now, let us consider the outlet pressure is too high that will be experienced by the diaphragm inside the valve body.

As the pressure applied over the diaphragm is very high, it will be pushed in upward direction and due to the pushing of the diaphragm in upward direction, the poppet will also moved in upward direction.

As the poppet is moving in upward direction, this valve will be closed and due to the closing of the valve, there is no passage of the compressed air through the valve. In this way, we are regulating the pressure based upon the load conditions.

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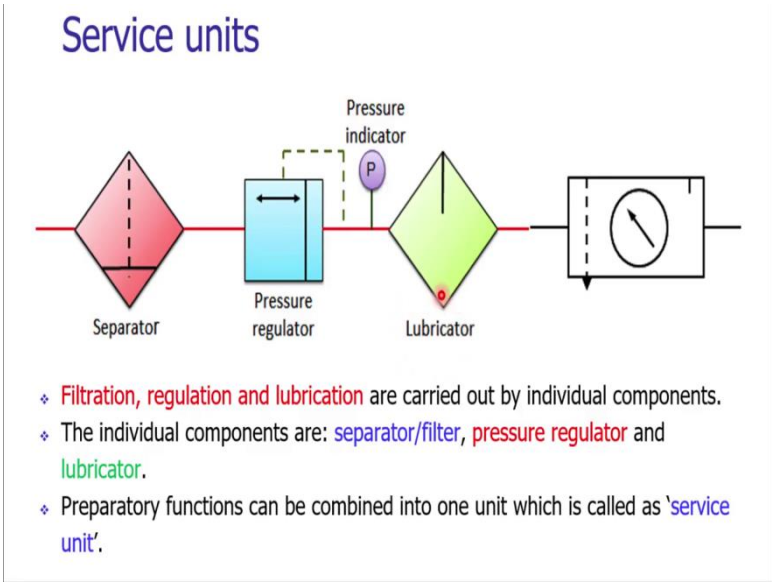

As we have seen that we need a separator, a pressure regulator and lubricator. These are the essential elements of the treatment of compressed air. In general, in the industry, the separator, pressure regulator or the lubricator, separator is also called as the filter so, filter, regulator and the lubricator that is called the FRL unit.

FRL unit it is a service unit and together this package is coming in the industry and these has been designated by using a graphical symbol which you can see on your screen. The separator is designated by using this symbol, this is the regulator, there is a pressure indicator and the lubricator.

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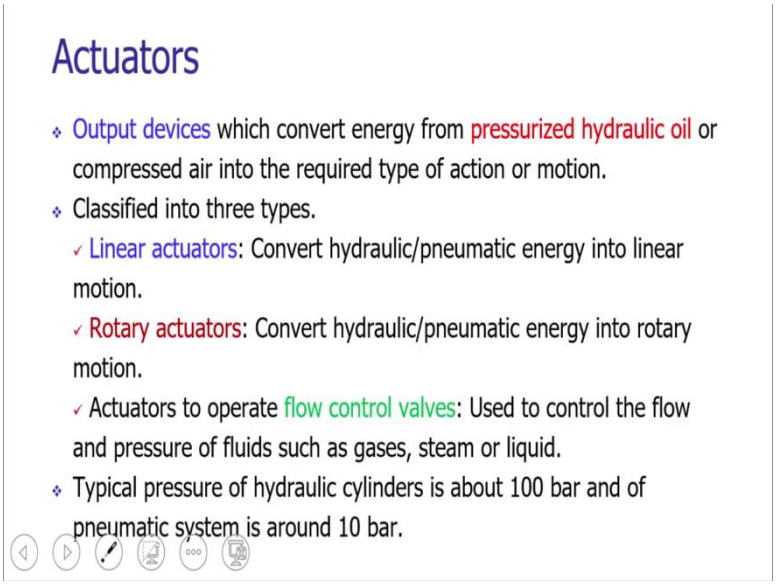

The pneumatic systems employ various actuators the actuators are the output devices basically. Tthey are converting the pressurized hydraulic oil or they are converting the energy from the compressed air into the required type of action or motion. We have seen the actuators pertaining to the hydraulic oil. Similar type of actuators are also used in the pneumatic applications as well.

We can have the three types basically and the linear actuators which are converting the pneumatic energy into the linear motion. We can have the rotary actuators which are converting the pneumatic energy into the rotary motion. There are certain actuators which are used to control the control valves, to operate the control valves, certain actuators are used and that is the third type of the actuator.

As far as the hydraulic cylinders are concerned basically 100 bar is being the limit of the pressure handled by the actuators, but in pneumatic system, it is around the 10 bar.

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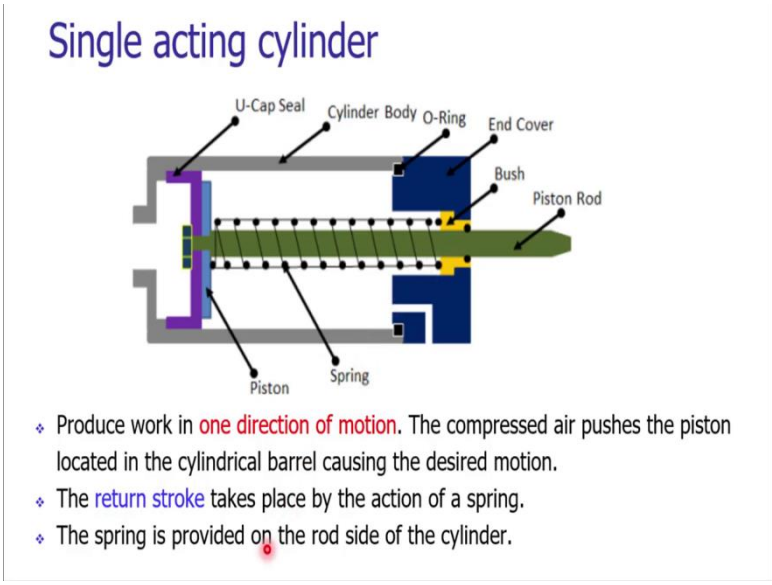

A typical single acting cylinder can be seen on your screen. It is single acting means it is producing the work in only one direction. The construction can be seen on your screen, it is having the cylindrical body. Inside the cylindrical body, there is the piston rod and at the end of the piston rod, there is a piston attached.

The piston and piston rod assembly is loaded with a spring. There is a bush, and this bush is protecting the rod continuously from moving inside the cylinder body. There will be friction between the piston rod and the end cover. The end cover is quite heavy, and it is having the passages for the fluid in and fluid out.

If we are putting the piston rod inside the end cover and due to the wear and tear if there are certain gaps, we need to the scrap the entire end cover. To protect the end cover from the friction or the wear and tear, we are using a bush. There is O-ring, it is the leakage prevention ring. At the top side of the piston, we are having U-cap seal, this is the seal which is not allowing the compressed air to go to the other side of the cylinder that is the piston side of the cylinder.

Well, from this port, we are getting the compressed air which is pushing the piston rod from left to the right direction against the spring force. As there is no pressure from the left side in the forward side, the spring will restore the position of the piston rod by acting the spring energy. In this way, the forward stroke is driven by the compressed air while the return stroke is controlled by the spring inertia.

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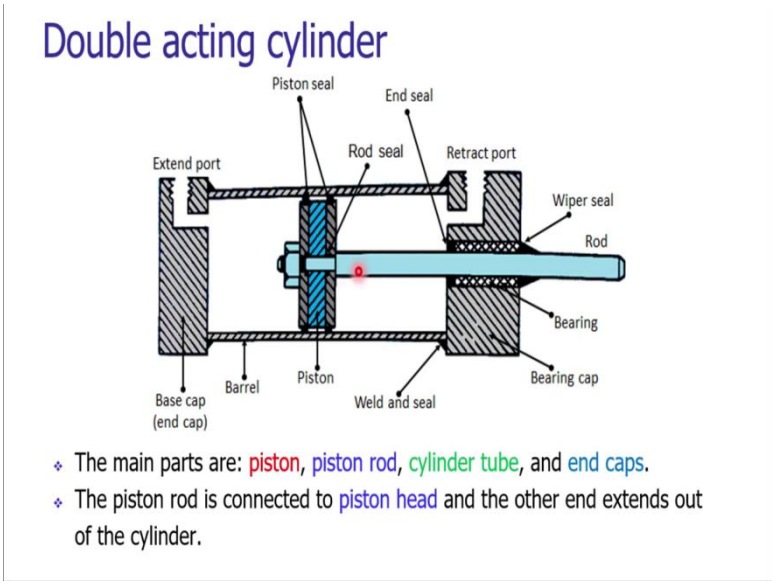

The double acting cylinder is providing us two; two-way action the forward stroke and the reverse stroke and both the strokes are being controlled by the compressed air only. The construction of the double acting cylinder is little more complex, but the elements are the typical elements.

Here also, we are using a cylinder and there is a piston rod and piston seals, the pistons are continuously moving inside the cylinder to avoid the direct contact of the piston surface with the cylinder bore surface. There are piston seals which are protecting, which are reducing the contact between the piston and piston cylinder. In case of wear and tear, we need to just replace the piston seals, and there is no need to replace the entire piston.

The rod is supported in the bearing, the same case at the same situation is at the rod side as well as the rods are moving in a faster rate, there is a wear and tear and to protect that wear and tear, we are using the bearing. There is extension port and there is a retraction port.

When the compressed air is applied in the extension port, the rod will be displaced in the right direction from left to right direction and there is extension of the piston cylinder arrangement. For the retraction, we have to apply the compressed air in this direction, then there is a retraction of the piston cylinder arrangement.

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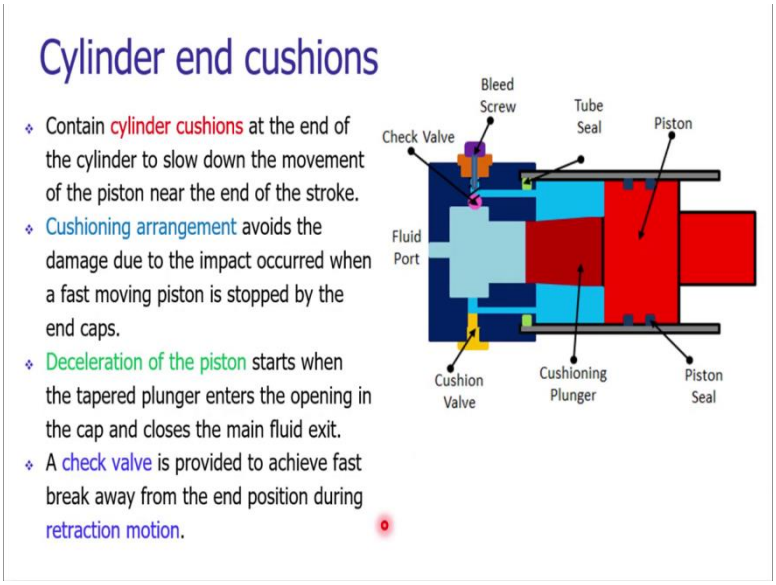

When the pistons are moving in a very rapid way, there may be chances of having the ramping of the piston at the walls and at the end of the cylinder, which are having various walls. Thus, to protect the ramping or the sudden impact of the piston at the end of the cylinder arrangement, cylinder cushions are used.

This is the cushion arrangement, we are having the cushion valve, the passage is provided, inside this passage the fluid is there and there is a cushioning plunger which is located over here. When the piston will come in a rapid way, it will come in contact with the cushioning plunger and that cushioning plunger will be displaced in right to left direction.

But due to the pressure or due to the fluid which is available at the at other side of the cushioning plunger, the impact energy will be absorbed by this cushioning plunger. In this way, we are decelerating the piston when it is in contact with the cushion a plunger. A check valve is provided to achieve the fast break away from the end position during the retraction motion.

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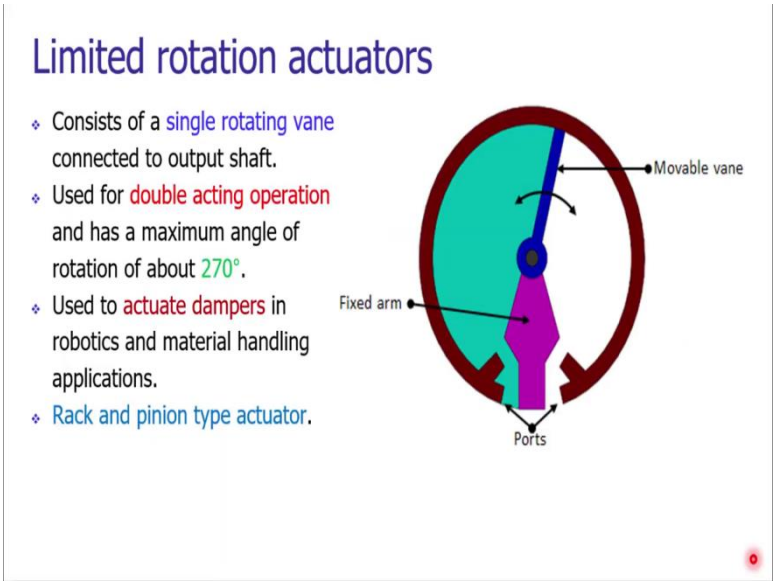

The compressed airs are also providing us the rotary motion and the devices which are converting the pneumatic energy into the rotational motion are called as the rotary actuators or rotation actuators. A typical arrangement of a rotation actuator canbe seen on your screen.

It is having a circular casing, inside the circular casing, we are having a fixed arm and there is a movable vane. The movement of the vane is controlled by using the compressed air. To control the movement, we are having two ports and through these ports, we apply the compressed air energy for the displacement of the movable vane.

This is the double acting kind of arrangement; when a pressurized fluid is applied on the left side, there would be movement from the left to right side in clockwise direction. When we reverse the direction of application of the pressurized fluid, we may have the anticlockwise movement.

Based upon the direction of application or based upon the ports, we are using the application of the pneumatic energy, we can have the required movement of movable vane.This particular rotation is restricted up to 270 degrees for a typical limited rotation actuator.

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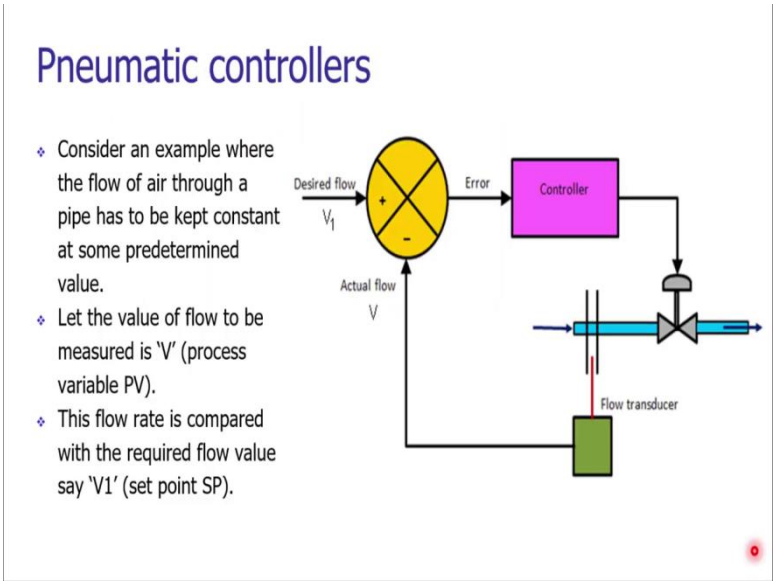

Now, to control the flow of the pneumatic energy or the compressed air inside a mechanical system, we are using the controllers. Let us consider an example where we need to control the flow of air through a pipe. We need to have a constant supply of the compressed air at the application. To have the controlling of the constant air or to apply the constant air, we are using a controller, but this controller is working upon the input which is the error.

Error is difference between the desired flow and the actual flow. To measure the actual flow, we need to have a flow transducer, which is continuously measuring the flow inside the pipe and that is giving results to the comparator. Comparator is comparing and giving the error value to the controller and controller is taking the decision based upon the error value.

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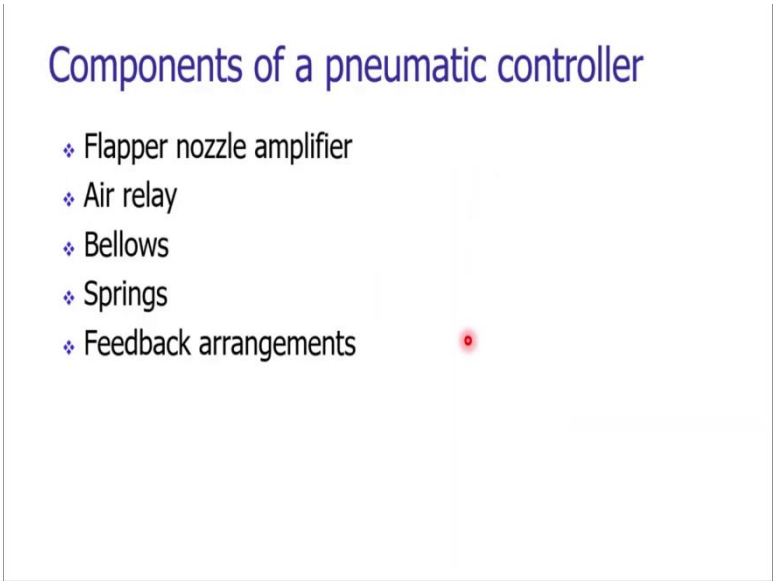

The typical components of a pneumatic controller are flapper nozzle amplifier, air relay, various types of bellows, springs and the feedback arrangement.

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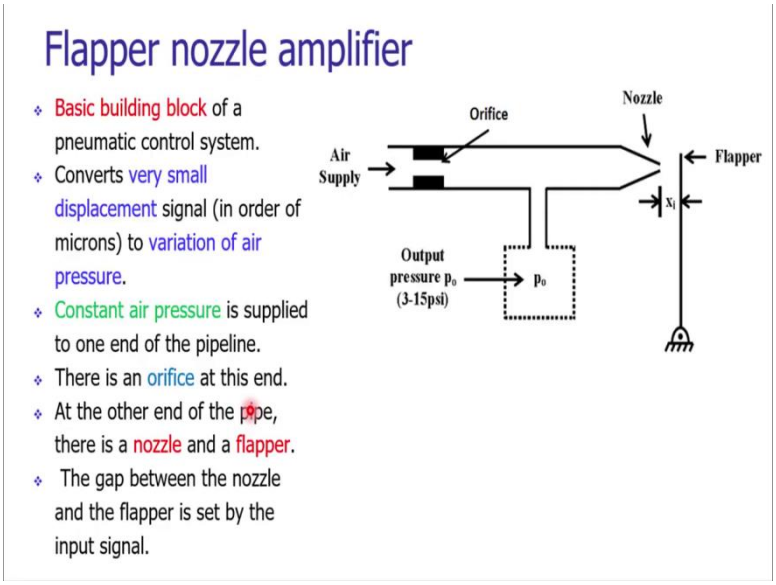

The flapper nozzle arrangement is the basic building block of the pneumatic controller system. It is basically converting a very small displacement signal into the variation of air pressure. The arrangement of flapper nozzle amplifier can be seen on your screen. We are having a tube and this tube is getting a supply of the pressurized fluid compressed air.

The compressed air may be at a very high pressure. We are using an orifice which will reduce the pressure of that compressed air. The orifice is providing the manageable pressure for the amplification operation. During the process of reduction in the pressure, the velocity of the compressed air is get is getting increased.

The flapper nozzle arrangement is having a flapper, it is a mechanical element which is hinged at one of its ends. The other end of the flapper is in a proximity to the nozzle tip. We can change the distance between the nozzle and the flapper by moving the flapper near to the nozzle or away from the nozzle.

The displacement of the flapper can be sensed by the change in back pressure in the tube. For a small movement of the flapper, if it is coming near to the nozzle, when there is a creation of back pressure and that back pressure is giving the signal based on which, we can take the decision then what is the displacement of the flapper. This the basic principle of the flapper nozzle amplifier, a small displacement is amplified in terms of the change in pressure.

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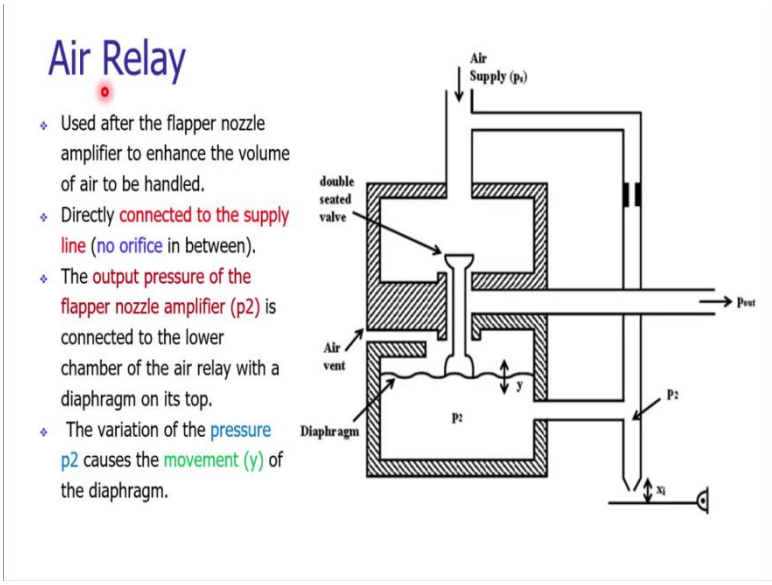

Air relay is one of the building blocks of the pneumatic based controller and it is using the flapper nozzle amplifier to enhance the volume air handling methodology to enhance the volume of air to be handled during the relaying operation.

The construction of the air relay can be seen on the screen, it is having a chamber at the top side and there is another chamber at the bottom side. The top side chamber is connected to

the air supply, the pressurized air is coming at the top center and to that top center air supply, we have attached the flapper nozzle arrangement which we have seen in our the previous slide.

The air relay is having a double seated valve and this double seated valve is in a balanced condition due to a diaphragm. The diaphragm is a mechanical plate or mechanical element here it is shown in the curve heated. The curve heated diaphragms are having more sensitivity than the flat diaphragms. At the other side of the diaphragm, we are having a port and that port is connected to the pipe of the flapper nozzle arrangement itself.

Now, by using the air relay, we want to control the volume of air that to be handled; so, p out to be controlled by using this air relay arrangement. Let us consider an air supply at a pressure of ps. So, this continuous air supply of ps is passed through the p out. Now, for the steady state condition or for the default condition, the double seated valve is in this position itself.

The port is open so, whatever the ps pressurized air supply is open to the p out. The p out is equal to ps in this situation and the same ps supply is connected to the flapper nozzle arrangement itself so, as we have seen that the flapper nozzle arrangement is having a constriction and orifice through which the air pressure is reduced so that it can be easily managed. The same port is connected to the bottom side of the diaphragm as well.

Now, let us check the flapper near to the nozzle. If we take the flapper near to the nozzle or consider we are just touching the flapper to the nozzle so, there is a blockage of the fluid which is coming out of the nozzle. As the blockage is there, the back pressure is created, the p 2 will be increased. As the p 2 is getting increased, now we are pushing it upward, then p 2 is getting increased and due to increase in the p 2, there is a displacement of the diaphragm in upward direction.

As the diaphragm is moving in a upward direction, the valve stem will also move in upward direction which is widening the opening of the valve from air supply. This portion will get widened up. If we open it up further, more and more amount of pressurized air will come inside and that will be sent to the required port that is the output port. In this way by displacing the flapper, we can control the flow of pressurized air at the application.

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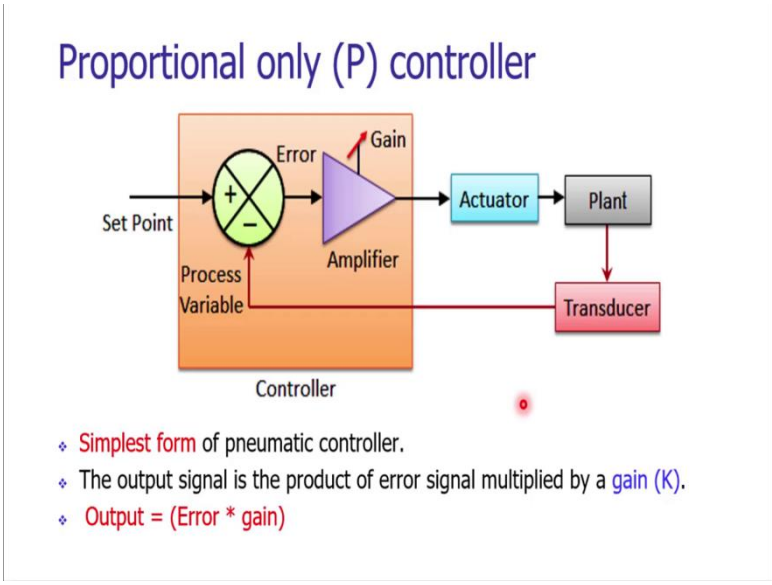

A typical proportional only controller schematic is there on the screen. Basically, we are trying to learn how to control, how to have the controlled application of compressed air at the desired level.

For that purpose, let us consider a load, a plant and that plant load is continuously monitored by a transducer and there is a comparator which is giving the error that is magnified, it is amplified by using an op-amp, that is a operational amplifier and based upon that the actuator is taking the decision.

The increase or the decrease of the compressed air volume or pressure is in proportional to the signal given to the controller and that is nothing, but the proportional only controller. The output is nothing, but the error into the gain that is the gain we have seen in our the previous modules or previous weeks.

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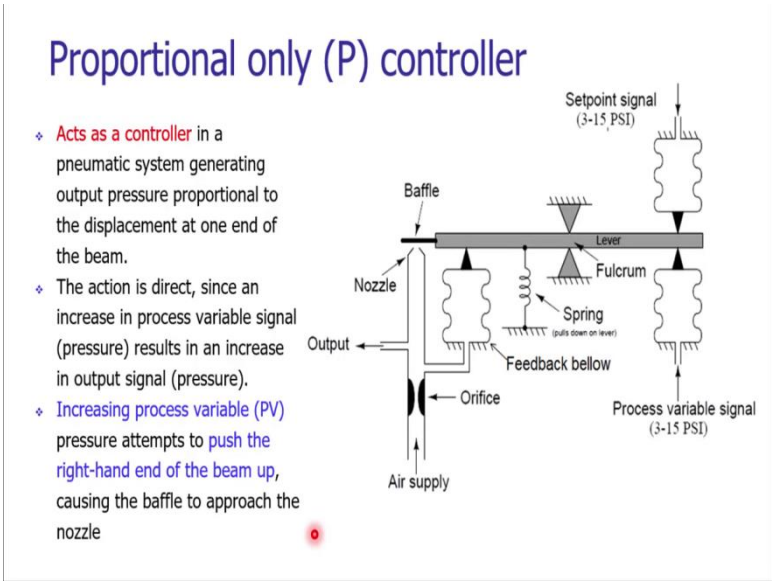

The typical proportional only controller based upon the pneumatic applications can be seen on your screen. Basically these type of controllers are used to generate the output pressure in proportional to the displacement of one of the end of the beam. Now, here we can see there is a lever, or a beam and that beam is fulcrumed.

At one end of the lever, we are having a baffle or a flapper and the nozzle arrangement. At the other end of the lever, there is a bellow and that bellow is given the process variable signal. We are applying the pressure which we are getting from the compressed air.

At the other side of the lever, we are having bellows. The first bellow is getting the input from the process variable and that may be around 3 to 15 PSI and there is another bellow and that is the setpoint bellow here also, we are getting a pressure and that is the setpoint of the system that is the desired level, expected level. Certain expected pressure is continuously applied and we want to achieve that pressure only during our signal.

But, let us consider that the input pressure or the pressure which is generated inside the system that is the process variable signal is very high, it is more. When the process variable signal or the input pressure is exceeding the setpoint signal, if the pressure in this bellow is more than the pressure in the setpoint bellow, then what will happen?

This bellow will expand in upward direction and due to the expansion in upward direction, the lever will be in unbalanced condition, this portion will go in upward movement and the baffle will reach or it will come near to the nozzle or it may in contact with the nozzle itself.

As the flapper or the baffle is touching the nozzle, there is a creation of back pressure and that back pressure is in proportional to the increase in process variable here. The back pressure is getting increased that will be sensed by the system and accordingly, there would be now reduction in the flow of that pressurized air inside the system.

But to get the required equilibrium, we are having another bellow that we call the feedback bellow. When the flapper is touching the nozzle, the back pressure is getting increased and that back pressure is energizing the bellow. As the bellow is getting the back pressure here, it will push this point in upward direction, and it will restore its horizontal position.

In this way, the increase in the process variable signal will be sensed and accordingly, the decisions will be taken in proportional to the process variable's increased or the decreased levels.

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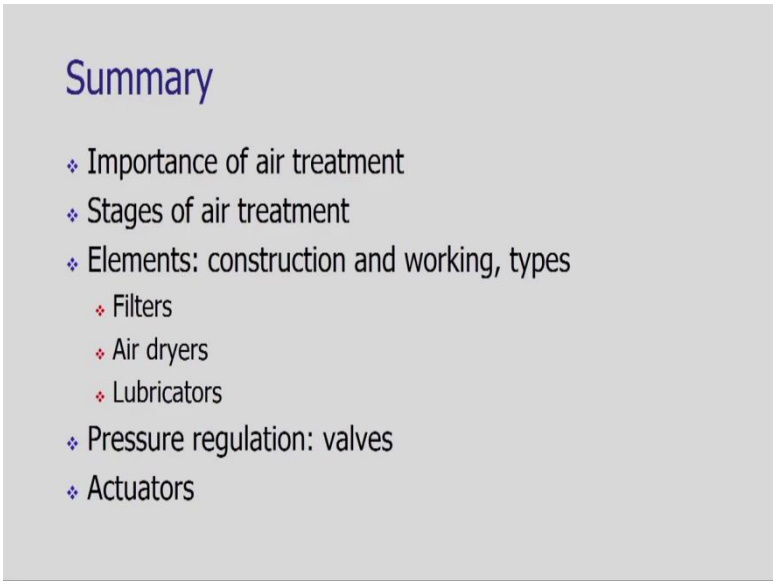

In this lecture, we saw the importance of air treatment. We learnt the importance of air treatment and various stages of the air treatment. During this air treatment, various elements are needed, and these are filters, air dryers and lubricators. We have seen their construction, working and types. Various control valves are used in pressure regulation of the pneumatic

systems. We have seen their construction, working and utilization. At the end of the lecture, we have also seen what are the various actuators being utilized in pneumatic systems.

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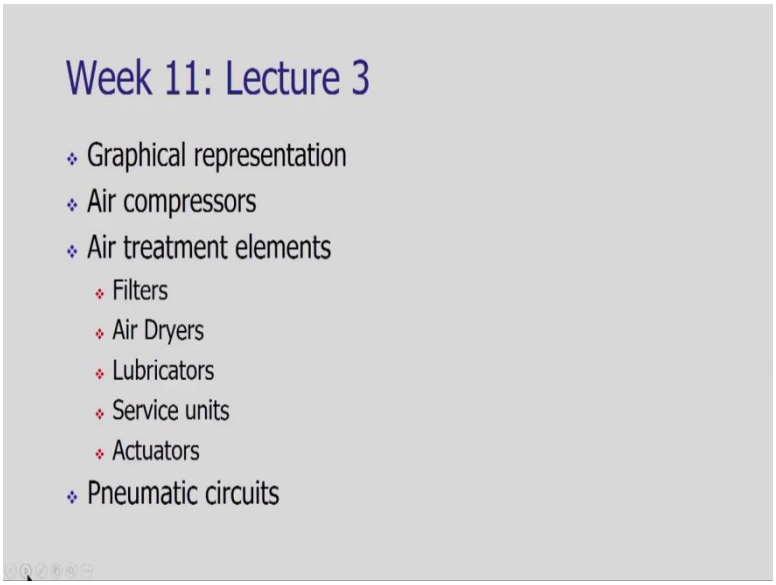

Well, in the next lecture that is the lecture 3 of week 11, we will see how to graphically represent various pneumatic system elements. In previous week, as well we have seen how to represent graphically various hydraulic elements.

In this week, we will study how to represent graphically the pneumatic elements, how to represent the air compressors, filters, air dryers, lubricators, service units and actuators. Then, we will have certain case studies on the pneumatic systems.