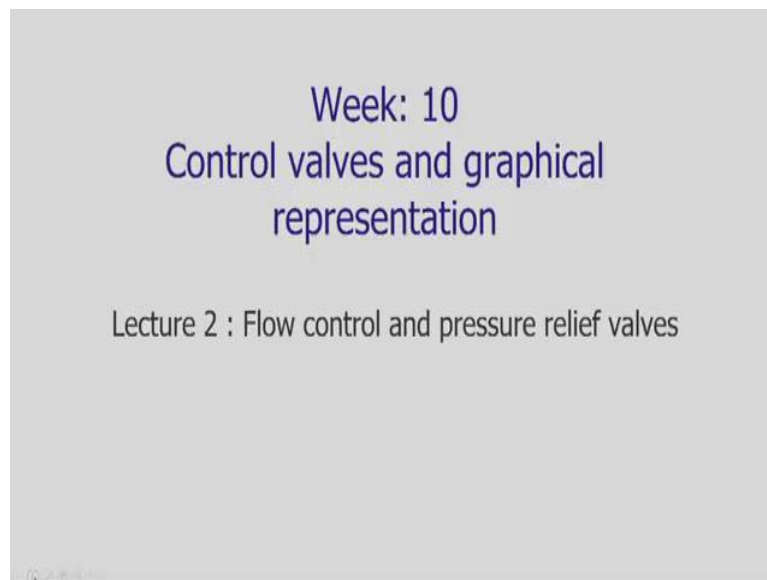


Automation in Manufacturing
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Week – 10
Control valves and graphical representation
Lecture – 31
Flow control and pressure relief valves

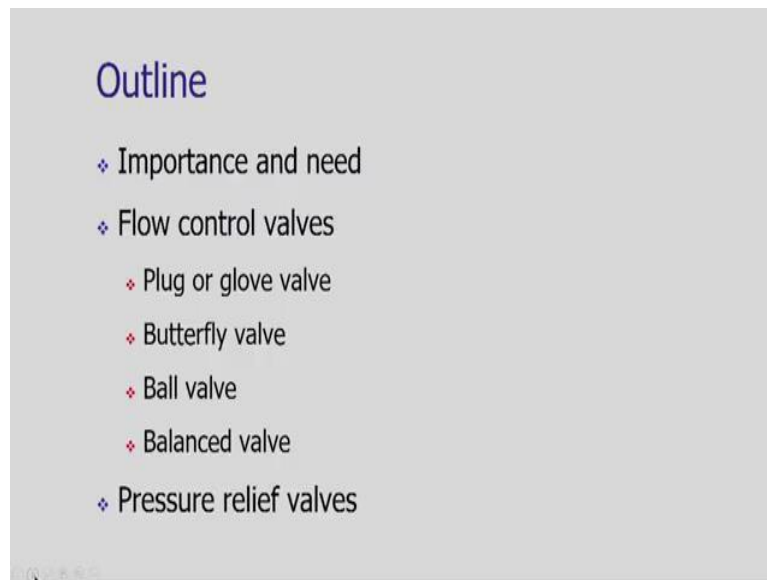
Hello and welcome to the lecture 2 of week 10, in week 10 we are studying the Control valves and the graphical representation.

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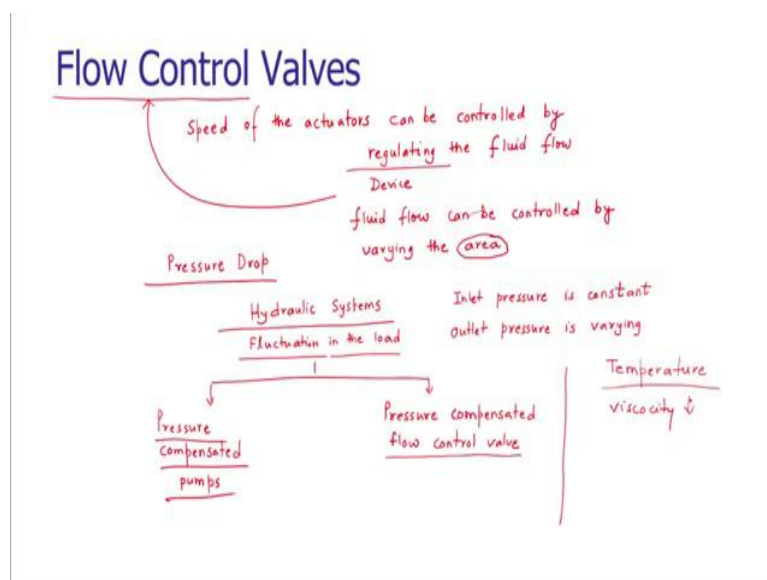
In this lecture we will be studying the Flow control valves and the pressure relief valves, the construction, working details and the applications of these valves.

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The outline of this lecture is there in front of you, at start we will look at the importance and need of the pressure relief valve and flow control valve. There are various types of control valves are used in industry; these are plug valves, butterfly type of valve, ball valve and the balanced valve. We will have a discussion on all these valves. At the end of the lecture we will see the pressure relief valves, principle of operation and its applications.

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Let us begin the lecture 2. After studying how to control the direction of fluid flow inside a hydraulic circuit, now let us study how can we have the flow control of the hydraulic fluid

inside a hydraulic circuit. Basically, the speed of the actuators which we are using in the hydraulic circuits can be controlled by regulating the fluid flow. The speed of the actuators can be controlled by regulating the fluid flow.

To carry out this regulation operation, we need the devices and the device which is providing that regulation operation is nothing, but the flow control valves. We can achieve the fluid flow by varying the area of the passage, the fluid flow can be varied or can be controlled by varying the area through which the fluid is passing.

For this purpose there are variety of mechanisms that are available. When we are using such devices there is a inherent problem or there is a inherent characteristics of this system is that they are generating the pressure drop. When we are carrying out the change in the direction of fluid flow or when we are controlling the flow of the fluid, there is a pressure drop.

And, this pressure drop is to be considered during the selection of a proper flow control valve. In typical hydraulic circuits, there is a pressure fluctuation at the load; at the application we are having the fluctuation in the load. The load is varying, sometimes the loads are higher, sometimes the load is less. However, the inlet pressure is constant. The pump is giving the fluid at a constant pressure, but the outlet pressure may be different.

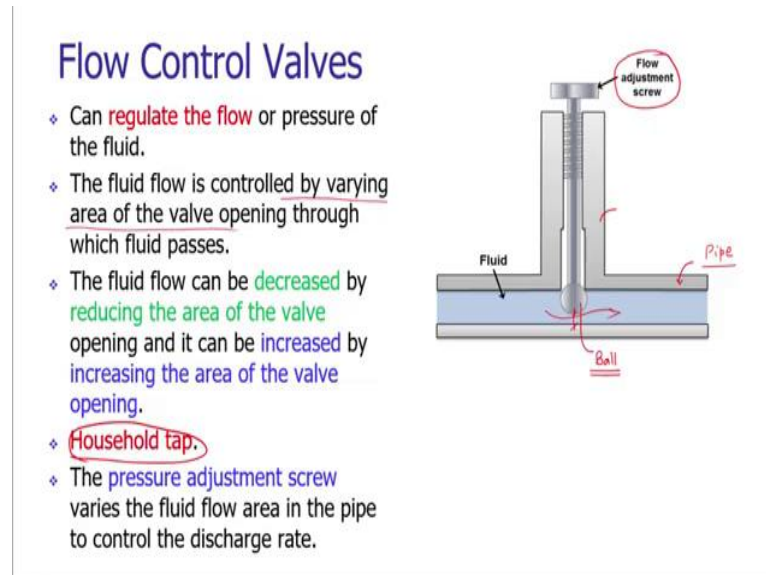
The inlet pressure is constant whereas, the outlet pressure is varying. To take care of this fluctuation in the load either we can have the pressure compensated pumps. We can compensate the pressure at the pump level itself. We can have the pressure compensated pumps or we can have pressure compensated flow control valve; pressure compensated flow control valve.

These control valves may have the spool and by changing the position of the spool; we can change the area of the passage. We can change the area of the passage and accordingly the required flow can be maintained during the flow of fluid through the device, that is a control valve. Well, in addition to the pressure compensation the hydraulic systems are having the temperature problem as well.

As we have seen that lot of moving components are there, the friction of the moving components is generating the heat energy; the rise in temperature is affecting the viscosity of the hydraulic fluid. Thus, viscosity will be reduced. As the fluids viscosity is reduced, we

have to change the flow rate. We cannot apply the same pressure; we cannot have the same flow rate of the hydraulic fluid.

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A very basic and simple example of the flow control valve is our household tap. A schematic of a household tap is shown. It is having the pipe through which the fluid is passing and this pipe is fitted with a flow control valve. The flow control valve is having a flow adjustment screw and that flow adjustment screw is having a ball. By rotating the flow adjustment screw we can change, we can vary the orifice area.

If the area is reduced then the flow would be restricted, the control will be there on the flow, the flow will be minimized; as we are increasing the area of the orifice by rotating the fluid adjustment screw more amount of fluid will be passed through the passage. By varying the area of the valve we can certainly have the passage of the fluid as per our requirement.

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Types of Flow Control Valves

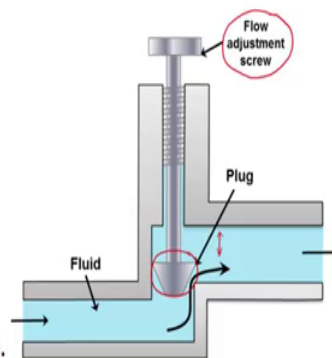
- ❖ Plug or glove valve
- ❖ Butterfly valve
- ❖ Ball Valve
- ❖ Balanced valve

There are various types of flow control valves are used in the industry. And some of the valves are the plug or the glove valve, butterfly valve, ball valve and the balanced valve. Let us look at the construction and working of these valves.

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Plug or glove valve

- ❖ Also termed as glove valve.
- ❖ This valve has a plug which can be adjusted in vertical direction by setting flow adjustment screw.
- ❖ The typical example of plug valve is stopcock that is used in laboratory glassware.
- ❖ The valve body is made of glass or Teflon.
- ❖ The plug can be made of plastic or glass.

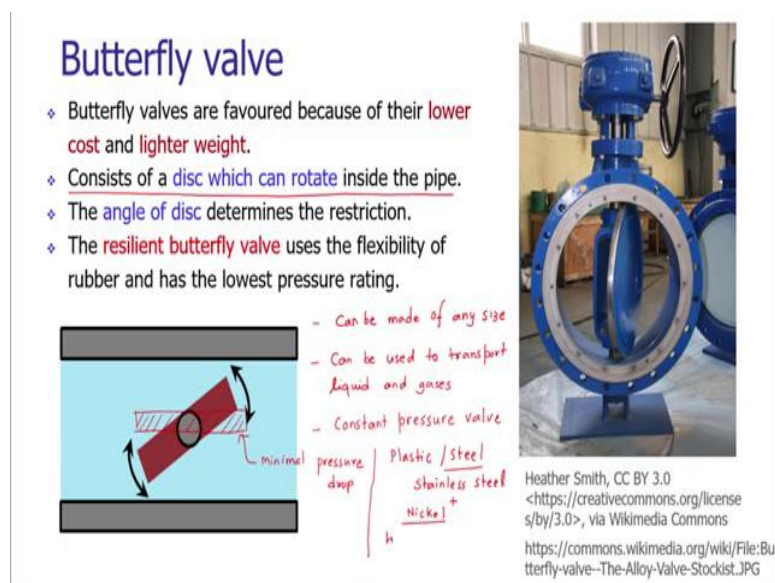


The plug or the glove valve, the plug valve is also called as the glove valve. It is having a plug which is nothing, but a tapered cylindrical component. This tapered component or part is placed in between the passage of the fluid flow. The position of the plug inside the fluid flow

is controlled by a flow adjustment screw. As we rotate the flow adjustments screw there is movement of the plug inside the passage.

The accuracy of fluid flow is dependent upon the accurate machining of the taper angle of the plug, the adjustment of the plug is altering the orifice size between the plug and the valve sink. The typical example of the plug valve is the stopcock which we used in our glassware that is laboratory glassware. In general the body of these plug valves is made up of glass or Teflon. And, the plug is made up of plastic or the glass.

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The next type of valve is the butterfly valve. In the construction of the butterfly valve we are using a disc which can rotate inside the pipe, you can see the construction of a butterfly valve. This is the body of the butterfly valve and inside that we are having the disc. As we change the orientation of the disc, we can easily control the orifice, we can easily control the area of passage of fluid flow inside the pipe.

If we rotate this, either by using an electric motor or by using the manual operation; we can rotate this disc. As the disc is rotated, the passage can be easily changed. This is the top view of the butterfly valve. The disc can be now rotated about its vertical axis. The angle of the disc determines the restriction.

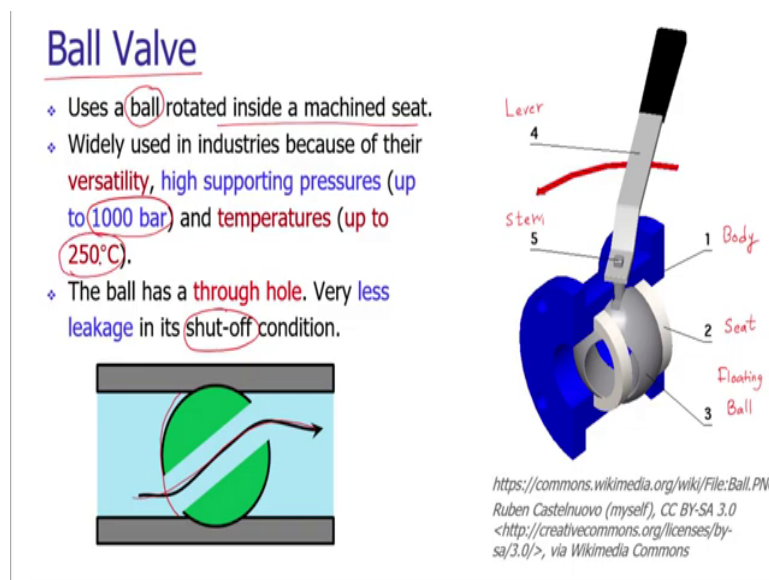
In general the resilient type butterfly valve uses the flexibility of rubber and has the lowest pressure rating. The butterfly valves can be made of any size and they are widely used to,

they are widely used to flow the fluids as well as the gases; can be used to transport or to control the liquid as well as gases.

One important characteristic of butterfly valve is that there is a constant pressure drop; although we will be holding the disk in a parallel direction to the valves of the pipe. There is a constant pressure drop in case of the butterfly valve.

But, in this case the pressure drop would be minimal, the disc of the butterfly valve are generally made up of plastic or steel. In general stainless steel is used and if nickel is added then it offers the high corrosion resistance.

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The next type of valve is the ball valve; it is very widely used in the industry. Here we are using a ball which is rotated inside a machined seat. The typical construction of the ball valve can be seen on the screen. It is having the body of the ball valve. There is a seat and that seat is housing the ball, the ball is the floating ball, ball is floating and the ball is having the passage as well.

It is having a through hole through which the fluid is passing, the ball valve is operated by a lever and the lever is having a stain. As the lever is rotated the ball is also getting rotated. And, then we can easily have the passage of fluid through the perforated ball. If the passage is in line with the passage of the body then the fluid will be passed in this way. Otherwise, if

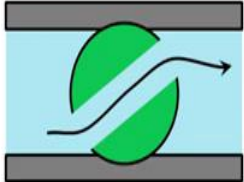
this portion comes here in this way it is shutting off the fluid flow, it is stopping the fluid flow.

The ball valves are widely used for the shut off conditions, shut off applications as well. These kind of valves are used for high pressure applications around 1000 bar pressure can be sustained by these ball valves. And, they can work at a very high temperature as well say around 250 degrees Celsius.

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Ball Valve

- ❖ Uses a ball rotated inside a machined seat.
- ❖ Widely used in industries because of their versatility, high supporting pressures (up to 1000 bar) and temperatures (up to 250°C).
- ❖ The ball has a through hole. Very less leakage in its shut-off condition.

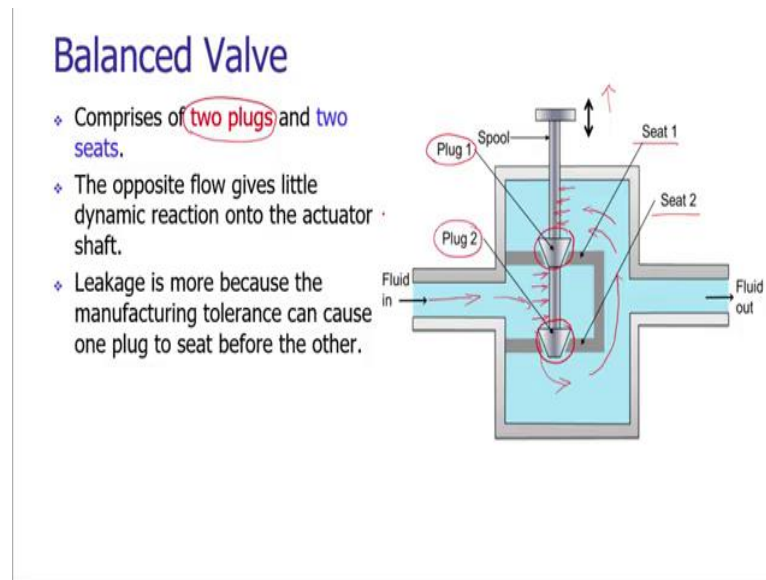




<https://commons.wikimedia.org/wiki/File:Valve-balls-The-Alloy-Valve-Stockist.jpg>
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Some steel balls which are machined are shown. This is the circular passage which is machined inside the spherical balls. And, these spherical balls are having the protrusion at the top and at the bottom which is used to get hold inside the lever and the stem arrangement.

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The next type of valve is the balanced valve; the balanced valve is having two plugs. If there is only one plug and one stem arrangement, there may be chances of having the excessive thrust on the stem body.

And, due to that excessive thrust there may be more wear and tear, more damage to the stem of the valve; to avoid that we are using two plugs. Here we are having plug number 1 and the plug number 2; both these plugs are precisely machined.

And a spool is housing plug 1 and plug 2, the spool with plug 1 and plug 2 is rested on seat 1 and seat 2 to the corresponding seats are provided for plug 1 and plug 2. The entire arrangement is kept inside the passage of the fluid, the pressurized fluid is coming and then it is passing through the passage provided by the plug 1 and plug 2. If we provide the upward movement to the spool there would be a gap between this plug 2 and plug 1 and the pressurized fluid will pass through.

As the pressurized fluid is passing, there is application of the pressure on the stem on this side. But, the pressurized fluid which is coming in this area, this will also apply pressure on the stem in the opposite direction. This little dynamic reaction on the actuator shaft in the opposite direction is balancing the pressure applied by the fluid in the forward direction. Due to this we can balance the application of pressure on the stem and we can reduce the damage to the valve.

However, these type of balanced valves are having the problem of leakage because the tolerances which are provided on the plug 1 and plug 2. If there are inaccuracies, if there are imperfections in the machining of plug 1 and plug 2 then we may have the leakages from plug 1 or plug 2. Therefore, the machining of the taper of plug 1 and plug 2 and the tolerances are to be tightly maintained during the machining process.

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Pressure relief valves

- ❖ The pressure relief valves are used to protect the hydraulic components from excessive pressure.
- ❖ Essentially required for safe operation of the hydraulic system.
- ❖ Its primary function is to limit the system pressure within a specified range.
- ❖ Various types of pressure control valves are:
 - ✓ Direct type of relief valve ✓
 - ✓ Unloading Valve ✓
 - ✓ Pressure Reducing Valve ✓
 - ✓ Sequence valve
 - ✓ Counterbalance Valve

During the hydraulic circuit operations, we need to control the direction of the movement of the fluid as well as we need to control the flow rate of the fluid. In addition to these two important factors we have to control the pressure inside the system. If the pressure of the system is excessively high then that will damage the entire system. There may be catastrophic failure of the hydraulic system, there may be bursting of the system.

And, that and to avoid such failures of the system we should employ the pressure relief valves. Pressure relief valves are basically used to protect the hydraulic components from the excessive pressure. These are very essential for the safe operation of the hydraulic system. The primary function of this relief valve is to limit the system pressure within a specified range.

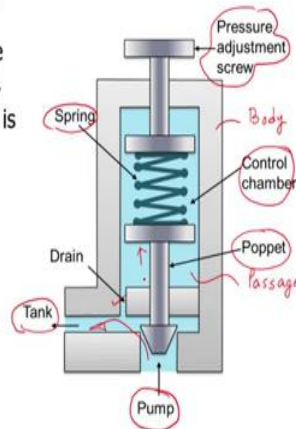
The pressure relief valve is also used during our cooking operation as well. In a similar fashion, there are lot of pressure control valves are used, pressure relief valves are used in the industry, in hydraulic industry. And, these are the direct type of the relief valve, unloading type of the valve and the pressure reducing valve.

There are also two types of valves being used, these are the sequence valves and the counterbalance valve. At the preliminary discussion we will be studying about the direct type of relief valve, unloading valve and the pressure reducing valve.

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Direct type of relief valve

- ❖ **Two ports**, one of which is connected to the pump and another is connected to the tank.
- ❖ Consists of a **spring chamber** where poppet is placed with a spring force.
- ❖ The **poppet** is held in position by combined effect of spring force and dead weight of spool.
- ❖ A **drain** is also provided in the control chamber. It sends the fluid collected due to small leakage to the tank and thereby prevents the failure of the valve.



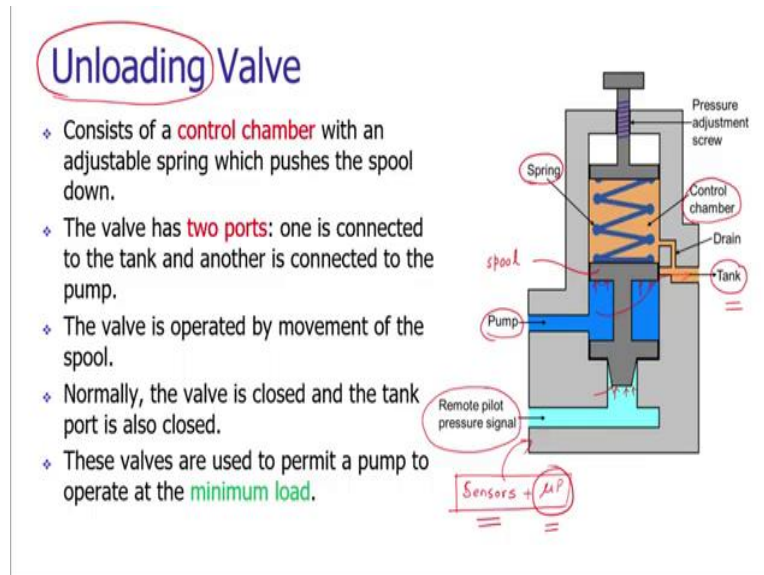
The direct type of relief valve is having two ports. The first port is the pump port at which we are applying the pressurized fluid and the second port is the tank port. These type of relief valves are put inside the hydraulic circuit. When the pressurized fluid which is coming inside the valve if that, pressurized fluid is having pressure more than the specified pressure or the pre-determined pressure then the valve will get actuated.

The valve will get operated and it will drain, it will bypass the excessive pressurized fluid to the tank. To have this arrangement we are having the body of the valve, the body of the valve is having a passage or it is also called as the control chamber. Inside the control chamber, a poppet is used. The poppet is the spring loaded poppet and we can even adjust the spring loading or the spring constant by using a screw.

When the applied pressure is more than the set pressure by the spring, the poppet will be moved in upward direction and the excessive pressurized fluid will pass through the passage provided here and it will bypass to the tank. During the operation there may be leakage of the fluid inside the upper portion of the body of the pressure relief valve.

To drain that leaked hydraulic fluid inside the body that also can be drained by using a small passage provided here. This will save the failure of the valve due to the leakage problem.

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The second type of pressure control valve is the unloading valve. The unloading valve operation is very much similar to the DCV, that we have seen in our previous lecture. In one of the direct control valve we have seen that a pilot pressure can be utilized to use or to convert the direction controlled valve as the unloading valve.

The unloading valve is having a control chamber. This is the control chamber of the unloading valve, it is having an adjustable spring. This is the adjustable spring which is pushing the spool down. This is the spool, the spring is pushing it in a downward direction. The unloading valve is having two ports that is a pump port and the tank port and we are also having a remote pilot pressure signal port.

In normal condition this valve is the closed valve. This is allowing the system to run at a constant pressure at minimum load application. But when the pressure is increased; when the pressure is above the critical value then the valve will get operated. The if you consider if the pressure is more than the valve will get pushed in upward direction and the excessive pressure of the hydraulic fluid will be released by bypassing the fluid to the tank itself.

In certain cases, if we are having the signal arrangements, we if we are having the sensors and the microprocessor arrangement. And, this sensor and the microprocessor arrangement is

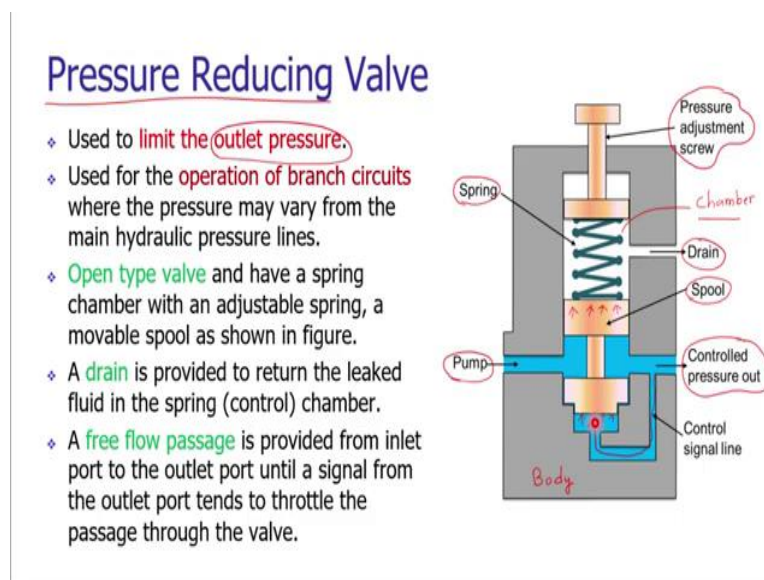
continuously monitoring the fluid pressure inside the system. Based upon the signals received by the sensors and the decision taken by the microprocessor, we can actuate a pressure signal to the pilot arrangement.

The pilot arrangement is nothing, but an externally applied hydraulic fluid. The separate system is there and that separate system is applying fluid, pressurized fluid at this location. But, through this passage by using the solenoid valves which are operated by the microprocessor; we are pushing the spool in upward direction.

As we push the spool in the upward direction, the tank port will get open to the pump port. And the pressure which is built up at the pump, the excessive pressure which is built up at the pump that will be released by bypassing the excessive pressurized fluid through the tank. In this way we can have the continuous monitoring of the fluid flow inside the system.

And, we can have an automated fluid flow monitoring system, automated fluid flow control system by using the sensors and the microprocessor arrangement.

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The next pressure relief valve is the pressure reducing valve and the purpose of this valve is to limit the outlet pressure inside the system. By controlling the outlet pressure, we can safeguard the hydraulic system. The typical pressure reducing valve is on your screen; it has the body, the body is having a chamber. The chamber is housing the spool; the spool is being maintained by the spring.

The spool is operated by the spring and the spring is being controlled by a pressure adjustment screw. The stiffness or the pressure on the spring is controlled by the pressure adjustment screw. The valve is having two ports that is a pump port and the outlet port. When the outlet pressure is more due to certain reason for example, these kind of valves are used for the holding purpose, the pressurized fluid is applied to hold or to clamp a device.

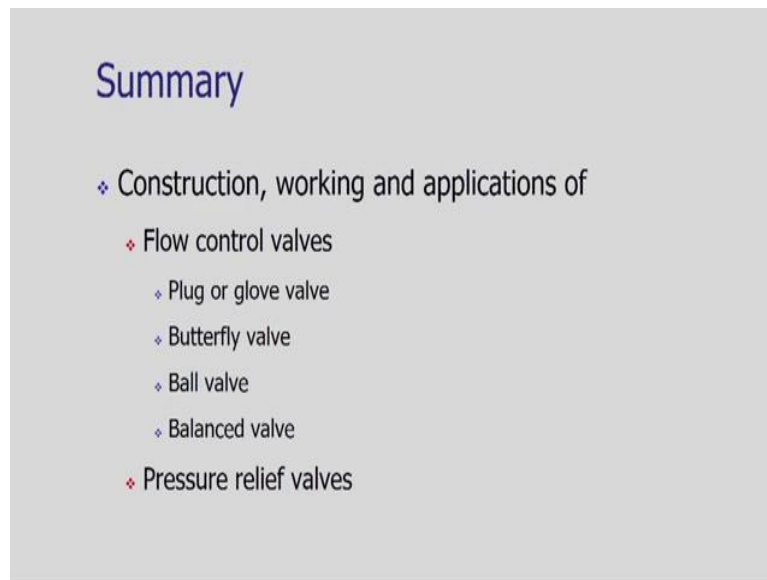
The excessive pressure which is being applied in inside the system may lead to the failure of the work part or it may lead to failure of the system itself. When the pressure at the outlet is more than the back pressure which is created is applied at the bottom side of this spool. And, that back pressure will push the spool in upward direction against the spring.

And as the spool is moved in a upward direction, the pressure at the outlet port will get relieved; pressure at the output port will get reduced. And, in this way we can save the damage, we can protect the valve by getting damaged. Whatever the fluid is leaked in the gap between the spool and the valve body or the bore of the valve that will be drained through a small port, is called the drain port.

Thus, we can summarize that pressure reducing valve is allowing free flow of the pressurized fluid from the pump to the controlled pressure outlet; until a signal from the outlet port which is asking to throttle the passage through the valve. The meaning is that there is continuous flow is allowed, but in case there is increase in the pressure at the outlet, we need a control signal.

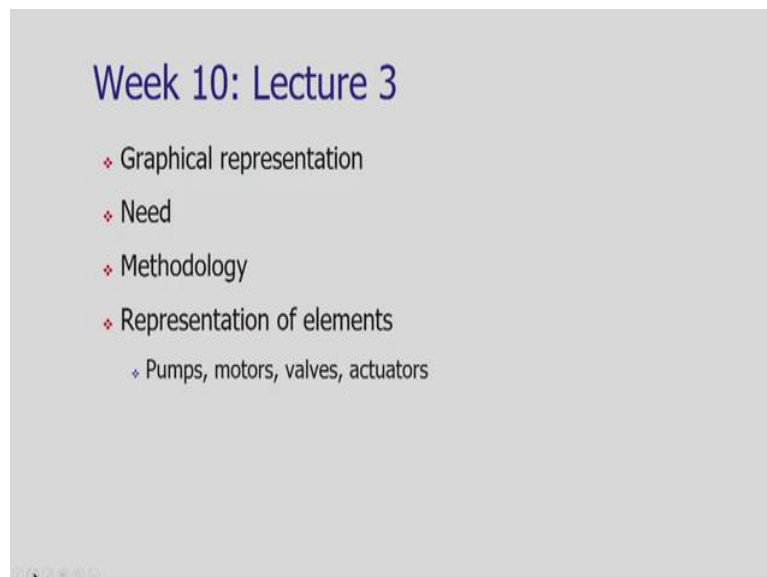
We need a signal which is making the throttling of the fluid; that is reducing the pressure of the fluid inside the system. This is possible by using a simple control signal line which is provided as you can see on your screen. In this way these all variety of valves are helping us to maintain the direction of the fluid inside the system, the flow rate as per the desired value and they are safeguarding the entire system.

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Well, let me summarize the lecture 2 of week 10. In this week we have seen two important control valves and these are flow control valves and pressure relief valves. We have seen the constructional details, principle of operation and application of variety of valves. These were plug or glove valve, butterfly valve, ball valve and balanced valve.

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Well, in the next lecture that is lecture 3 of week 10, we will see how to graphically represent various elements of a typical hydraulic system. Hydraulic system elements are very complex as we have seen and when we club them together, when we integrate them together; the

design becomes very complex. To synthesize it in a proper way, to understand the meaning of the circuit or the arrangement easily we have to represent them graphically.

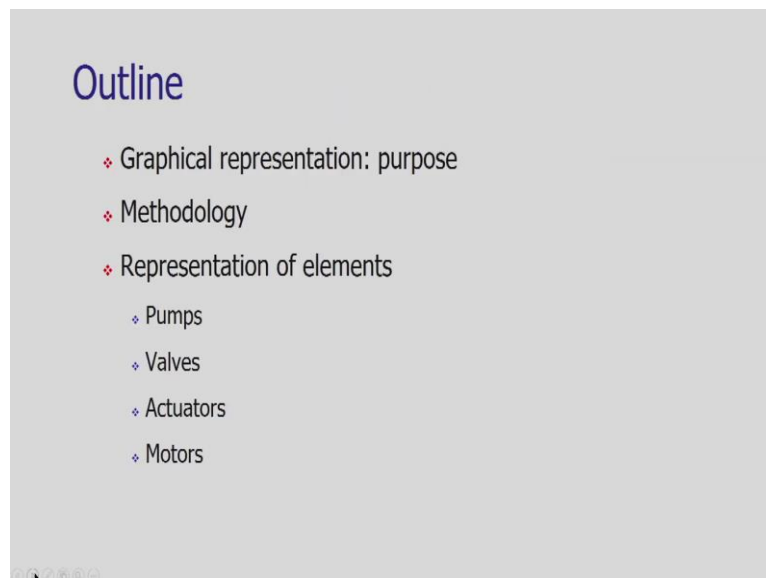
Thank you.

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Week – 10
Control valves and graphical representation
Lecture – 32
Graphical representation of hydraulic system elements

I welcome you all to the lecture 3 of week 10. In week 10 we are studying various control valves and the Graphical representation. In this lecture, we will have a elaborate discussion on the graphical representation of various elements, which are used in a typical hydraulic system.

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Let us look at the outline of the lecture. At start of the lecture we will have a discussion on the purpose, why it is needed to have the graphical representation? What is the methodology of representing a hydraulic system by using variety of elements? There are lot of elements we have seen till now and we will see how to represent them in a proper way in a standard way. These elements are pumps, valves, actuators and motors. Let us begin the lecture 3 of week 10.

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Graphical representation of hydraulic elements

- ❖ **Graphical symbols** are used to indicate elements of a hydraulic circuit.
- ❖ Specify the function of the element without indicating the design of the element.
- ❖ Indicate the actuation method, direction of flow of fluid and designation of the ports.
- ❖ Symbols are described in various documents like DIN24300, BS2917, ISO1219 and the new ISO5599, CETOP RP3 and the original American JIC and ANSI symbols.

Till now we have seen various elements of hydraulic system. We have seen pumps, we have seen various valves, we have seen the variety of actuators, such as the hydraulic cylinders, piston cylinder arrangements. The valves, the actuators, pumps, and electric motors, they do combine and give us a hydraulic power pack. Such hydraulic power packs are used in the industry for variety of applications.

In a typical automation industry, there may be many applications of hydraulic system and they are integrated to each other. Some of the applications are interdependent. When we design a hydraulic system, we have to first select the appropriate elements for the hydraulic system then we have to assemble them together.

During the process of selection and assembly, we have to communicate the hydraulic circuits, which are designed by the designer to the process planner or the purchase engineer. And it is also to be communicated to the shop floor engineers those who are doing the actual assembly operation.

In this process, there is lot of communication that to be carried out. And as we have seen the construction of the hydraulic elements is very complex. The valves are complicated and some of the valves they do have the similar construction. There may be chances of having the ambiguity, there may be chances of having the confusion during the communication based on the actual figure, the real picture of the drawing. It is very tedious; it is very cumbersome for communication with this.

Therefore, the graphical representation of these elements have been developed for the simplification, for the ease in communication of the complicated hydraulic circuits. The graphical representation is also very much helpful for the comprehension of the hydraulic circuit, for the better understanding of the hydraulic circuit.

Based upon the graphical representation various drawings can be created various circuits can be created, which are very similar to the electrical circuits or the mechanical circuits, or mechanical systems.

The graphical symbols are thus used to indicate the various elements that are used in a hydraulic circuit. The primary function of the graphical symbol is to specify the function of that element. The primary purpose of representing the elements graphically is to specify the function of the element without indicating the design of the element, without indicating the physical appearance or the internal construction of that hydraulic system element.

However, these graphical symbols or graphical representation should indicate the actuation method. What kind of actuation method is being applied? Is it the mechanical actuation, or pneumatic actuation, or pilot actuation, hydraulic actuation, or electromechanical actuation? The graphical symbols should represent the direction of flow of fluid which is very essential. Otherwise, it is meaningless to just put the symbols in the circuitry without giving the direction of the flow of fluid.

The designation of the ports: we have seen various types of external openings are there to the valves and these ports are to be designated. This may be the pressure port or the application port or they may be the tank port or the sub port. To standardize this communication, to standardize the convention of providing the graphical symbols, various guidelines are available.

And, these guidelines can be seen on your screen. These are DIN24300, BS2917, ISO1219, the newer guideline or newer standard is the ISO5599 and many such standards are available. These standards are being employed by these standards are being practiced by the practicing engineers in the industry.

Therefore, it is very much essential for the budding engineers for the students of the automation engineering or the manufacturing engineering should know how to represent properly a typical hydraulic element.

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Characteristics of graphical symbols

- ❖ Function
- ❖ Actuation and return actuation methods
- ❖ Number of connections
- ❖ Number of switching positions
- ❖ General operating principle
- ❖ Simplified representation of the flow path

What characteristics of the graphical symbols? The characteristics are as follows. The graphical symbols are designating they are defining the function of the element; they are defining the actuation and the written method. The symbols are providing the information about the number of connections to that to a particular element or to a particular hydraulic system. The symbols are also providing the information about the switching positions. How many positions are there?

It may be a two position valve, or it may be three position or the four position valve, based upon this we can you know communicate in a better way about the operation of the hydraulic system. The graphical symbols are also providing information about the operating principle of that element.

Overall we can say that the graphical symbols are providing the simplified representation of flow of path of the fluid. It may be hydraulic fluid or it may be the compressed air in pneumatic systems.

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The symbol **does not represent** the following characteristics:

- ❖ Size or dimensions of the component
- ❖ Particular manufacturer, methods of construction or costs
- ❖ Operation of the ports
- ❖ Any physical details of the elements

But, what it is not indicating? What the symbols are not representing? These characteristics are the size and dimensions of the component. The sizes may be very large or very small, huge sizes of the components such as the motors, tanks or piston, cylinder, arrangement to draw them on the paper it is very difficult.

The size and the dimensions are not being represented on the paper or in the digital drawings, which we are using commonly nowadays. The graphical representation does not provide the information about the manufacturer or the method of construction of the element.

It also does not indicate the cost of that particular element, it also not representing the operation of the port. The internal construction of the port or the internal operation of the port is also not been communicated by the symbols. Any physical details about the element is not specified in the symbol.

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Port designations

❖ As per ISO5599, ports on valves are marked based on a letter or number system. A list of common ports and their designed markers is as follows.

Port	Letter system	Number system
Pressure port	P	1
Working port	A	4
Working port	B	2
Tank / Sump	T	3, 5
Pilot port	Z	14
Pilot port	Y	12

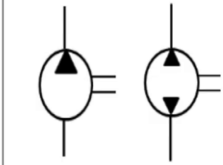
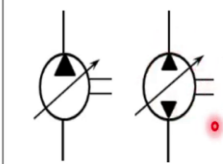
Now, let us look at what are the port designations as per the ISO5599. On our screen we can see the various ports that are used in a typical hydraulic system. As per ISO5599 or as per the various designation systems, we can use a letter or we can use the numbers as well.

Particularly the ISO5599 is providing the facility to designate the ports by using the numbers, or in general we are using the letters such as the letter P for the pressure port or the power port or you can call that as the pump port as well. However, in number system number 1 has been designated to the pressure port, there are various working ports which we have seen.

Working ports are the actuation ports. The port A is connected to the extension requirement of the piston cylinder arrangement and B may be connected for the retraction or the contraction of the piston cylinder arrangement. The number 4 is assigned to port A, number 2 is assigned to port B.

We have seen in our previous slides that the tank or the sump is the integral part of a hydraulic power pack. To designate the tank or the sump the letter T is used and in number system it may be 3 or 5. We are using the external fluid; we are using external air, compressed air, to actuate the valves, to operate the valves. These are called as the pilot ports. Pilot ports are designated by using the letters Z or Y or X and the numbers can be seen on our screen.

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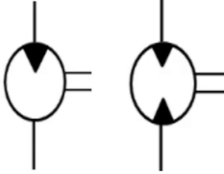
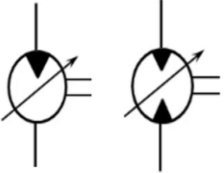
SYMBOL	DESIGNATION	EXPLANATION
	Hydraulic pump	One direction and two direction of rotation with constant displacement volume
		One direction and two direction of rotation with variable displacement

The hydraulic pump is basically designated by using a circle and that circle is having a filled in triangle. The triangle in this format which is filled in that is designating the hydraulic pump.

When only one triangle is provided the meaning is that, this is the one direction pump, when 2 triangles are provided in opposite direction that is the meaning is that it is a 2 direction of the pump. With two parallel lines is designating that the displacement volume is constant, with constant displacement volume the pump is working.

But, many pumps are having the variable displacement. The displacement is changing as per the requirement. To represent that variable displacement, we are using an arrow, the arrow is placed in this format as the arrow is there we can easily say that the pump which is represented is having the variable displacement.

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Rotary actuators		
SYMBOL	DESIGNATION	EXPLANATION
	Hydraulic motor	One direction and two direction of rotation with constant displacement volume
		One direction and two direction of rotation with variable displacement

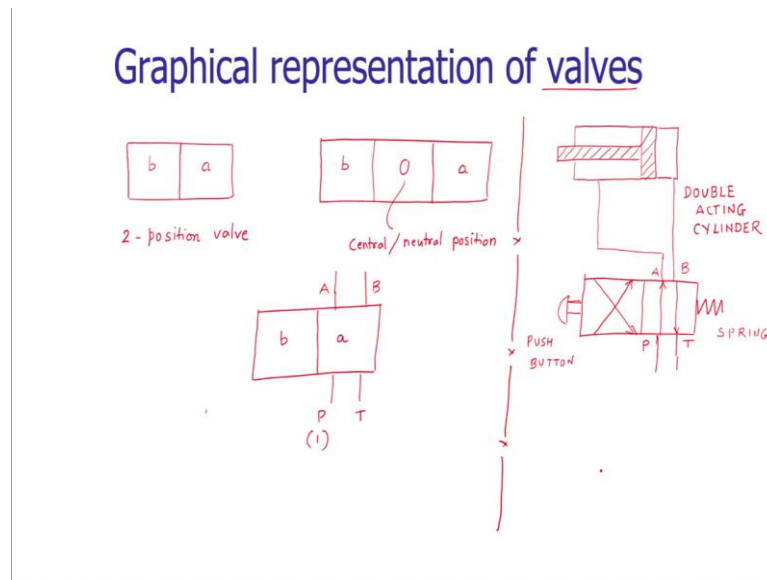
We can use the representation for the actuators as well and the hydraulic motor is a rotary actuator. The hydraulic motor is working on the principle that we are using the hydraulic energy and that hydraulic energy will be converted into the rotational energy. And that rotational energy or rotational moment will be utilized for our intended application.

The hydraulic motor is also represented by circle, it is also having a triangle, but the, but the orientation of the triangle is exactly opposite to the orientation of triangle that we have seen for the hydraulic pump, the triangle is filled in triangle. When only one triangle is represented the meaning is that the motor is allowing to have only one direction of the rotation.

The two parallel lines are designating the constant displacement volume. If we are using two filled in triangles for the hydraulic motor; that means, it is providing us the two way direction or the rotation. And, the two parallel lines for the second schematic representation is giving us the information that, it is also the constant displacement volume hydraulic motor.

Similar to hydraulic pump, if we want to have the variable displacement that to be accommodated a variable displacement that to be provided, then we are, then we are putting an arrow as you can see on your screen. The meaning of the arrow is that the motor is working with the variable displacement.

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Now, let us study how to represent a typical valve. A valve is represented by a square for each of its switching positions. A typical two position valve can be represented by using 2 squares, now let us draw the 2 squares. This is position b and position a. This is 2-position valve. We can have a 3-position valve as well for that purpose we may need to utilize 3 squares.

So, this is position b, position a, and the O position. O is basically used to designate the central or the neutral position. O is the central or we can call this as the neutral position. Now to these positions, we are adding the ports, we are adding the actuation information.

Let us see, if we are having a typical now here we are designating the ports. Consider these two position valve is having the 4 ports. The port P is designated the pressure port, the port T is designated the tank port and it is having two application ports A and B.

The vertical lines outside the square are representing the ports and the letters or the numbers, which are designated here are representing the ports. The P is 1. Now, if these positions are also to be added the information about the actuation. Now, let us understand how to represent, how to designate the valves.

Now to understand the graphical representation of valves, let us take an example how to control the moments of a double acting cylinder. Let us consider a double acting cylinder and we have to control its operation by using a valve. To communicate this information to the shop floor how we will carry out the representation.

The double acting cylinder is represented by using a simple T that is the piston, which is located inside a cylinder. Now to actuate this, we are applying the fluid energy at the top center, the there would be extension of the cylinder the piston will come out. And, the pressurized fluid which is at the rod side that to be moved to the tank.

Now, in the next position we need to have an arrangement, which is making us possible for the retraction of the cylinder. For that purpose, we have to have the pressurized fluid flow at the rod side and so that the cylinder will get retracted, but the pressurized fluid which is there at the top side that to be taken to the tank side. For that purpose, we need a valve, so we need the 2-position that is the extension position and the retraction position.

Let us draw a 2-position valve, we need to have a 2-position valve. Now, the normal position we are considering here is the contraction or the retraction of the cylinder. The retraction of the cylinder as mentioned, that we have to have the pressurized fluid a at the rod side.

Let us connect this to the rod side. The valve should have a application port A, which is connected to the rod side. Let us draw this as port A which is connected to the rod side and we are having, another purpose that is the discharge of the pressurized fluid at the top of the piston, that to be taken out to the tank.

For that purpose, we need to have another port, this is another port, that is needed and this is the port B. Port A for application of the pressurized fluid at the rod side and port B is to take the fluid back to the tank. To provide the pressurized fluid we need a pressure port that is P and to take the pressurized fluid from the piston cylinder arrangement back to the tank we need a port T.

Now, for this position we have to designate the direction of fluid flow as well. Here we are representing as per the convention, the number of positions are shown, the number of ports are shown the connections are drawn, but we have to show the direction of fluid flow.

For this position the direction of fluid flow is from P to A. Let us draw P to A, and the fluid is getting to the tank from B to T, but the valve is operating on what actuation? This particular position has been maintained by a spring. Spring is designated by using a zigzag line.

These zigzag lines are representing the spring. The spring is controlling this particular position. This is the normal position of this particular valve. Now, as mentioned I have to now extend

the piston cylinder arrangement, I have to extend the cylinder. For that purpose, we need to provide the pressurized fluid from P to B and I have to get back pressurized fluid from the rod side to the tank.

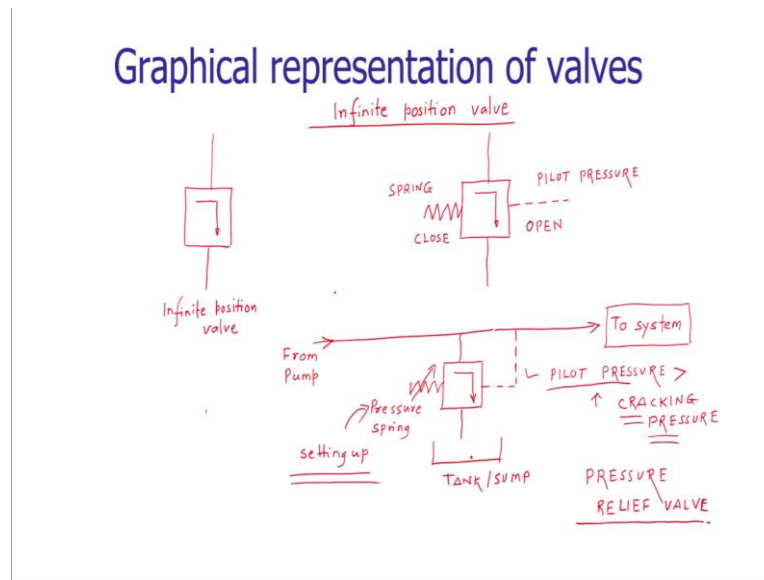
The connection are now to be from P to B and A to T. Thus the initial position will now be changed to the next position. In the next position P is to be connected to B and the A is to be connected to P. In this case we are not rewriting the A B, P T for the next position, it is understood that this point is P, this point is T, this port is A, this port is B. Only, we are providing the direction of movement of the fluid for the next position.

But, we need to provide how this position is getting achieved? How this position is getting actuated? For that purpose, consider if we are using a push button. When we apply the energy, when we apply the force at the push button, the position from the spring operated port connection to the opposite connections will be achieved.

When somebody will look at and will try to comprehend this particular circuitry simple circuitry, then it is very easy to understand that the valve is having 2-positions, it is having 4 number of ports. The default position is P to A and B to T that is the contraction of the double acting cylinder and that is controlled by using a spring.

To change the position or to change the connections of the ports we are using a push button arrangement as we actuate, as we push the button here the connections are getting in a opposite direction. The P is getting connected to B and A will get connected to T. In this way by drawing simple graphical representation we can communicate very complex phenomena, very complex operations of the hydraulic systems.

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Now, let us see how can we represent the infinite position valve. Infinite position valve is nothing but a valve which is providing a number of position. In general as we have seen that the valves are providing only 2 or 3 the finite number of position, in this case it is providing the infinite number of position so we have to just operate the valve, we have to operate the stem of the valve and we can have a variety of positions.

That infinite number of position valve can be designated by using a simple square and in that square we are using an arrow. This is the arrow which is placed in the square and it is showing the line of application of the fluid. This is the simple designation of the infinite position valve.

Now, if we want to put the actuation symbols with actuating symbols or with actuation symbols, it can be designated as the square with the arrow the line of fluid flow and now we have to put the actuation. Normally, the infinite position valve is closed and that the closed position is being controlled by a spring.

To open this particular valve, we are using a pilot pressure. To designate the actuation by pilot pressure we are using the dotted lines, a pilot pressure is applied and when the pilot pressure or the external pressure is applied, the valve is getting open; opening of the valve due to the pilot pressure. Now, let us see how it is working in the practice to understand that, let us draw a flow line.

Here we are getting the pressurized fluid from pump and it is going to the system to the load or to the application. Inside this line we are using this infinite position valve. We have taken a branch of the fluid and that branch of the fluid is passed through this valve.

As we know that the normal position of the valve is closed due to the spring. The pressure is applied by the spring, but when the system pressure is increased, the load is very high is it is blocked, there is no need of the pressurized fluid from the pump continuously to the system it is not essential.

Already the load, already the pressure at the system is very high. Due to the increase in pressure at the application at the load at the system, we need to now relieve the pressure, we have to reduce the pressure of this particular flow line. To carry out this we are using a pilot pressure which is part of the system pressure itself. We are getting a branch of flow line from the system and that is connected to the valve itself. This dotted line is the pilot pressure and that pilot pressure is part of the system itself.

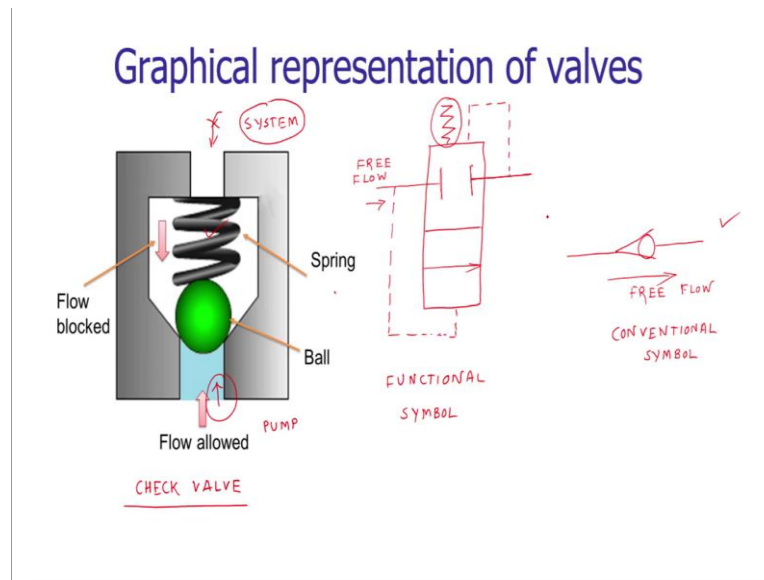
Now, when this pilot pressure is more than the cracking pressure of the valve? When the pilot pressure is more than the cracking pressure the valve will get open and after opening up that valve, it will pass that excessive pressurized fluid to the tank or the sump.

How to decide the cracking pressure? Now, how to provide the cracking pressures for that purpose we have to use the screw. The screw based arrangement is utilized and that has been shown by using an arrow which is put over the spring.

Meaning of that arrow over the spring is that we are setting the pressure. We can set the pressure here, setting up of the pressure by using the screw arrangement. In this way, a simple in finite position valve is converted into a pressure relief valve. By default it is closed the pressure of the spring has been set up by a screw, when the system pressure is more, when the load pressure is more.

And we have to safeguard the entire system from the damage we are using the pilot pressure, branch of the pressure, branch of the flow line from the system itself, which is operating the valve and as the pilot pressure is more than the cracking pressure of the valve the valve will get open and it will send that fluid to the tank.

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Let us draw the graphical representation of the check valve. Very useful element of hydraulic power pack that is check valve. We have seen the working of the check valve in our previous lecture itself. The check valve is having a ball and a spring arrangement and it is not allowing the fluid in one of the directions, but when the applied pressure is more than the cracking pressure of the spring, then the fluid will be allowed to pass from the other direction.

In this case the fluid is passed or it is allowed to pass from the pump to the application line, but it is not allowed to pass from the application line to the pump. This is the pump port and this is the system now to show the operation of this valve, let us draw 2 squares. At normal position the flow is blocked. Let us consider the flow is there inside the valve, but it is blocked. There is no pressurized fluid passing through the valve at its default position.

The free flow is from left to right; however, it is blocked. And, then blocking is due to the spring. Due to the spring we are blocking the flow of fluid, it is not only the spring, it is due to the system pressure itself. The system is applying the pressure on this side due to that as well there is blocking. To designate that system pressure we are showing the dotted lines.

This is the default position of the check valve, but when the inlet pressure is more than the cracking pressure. Let us consider a branch of the free flow is used as an actuation element itself. When the inlet pressure which is designated by using a dotted line.

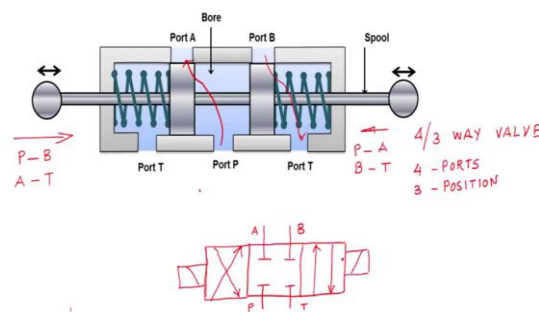
If this inlet pressure is more than the cracking pressure, is more than the spring pressure here, then there is flow of fluid is possible from the direction shown over here. From left to right, the flow of fluid is possible when the inlet pressure is more than the cracking pressure.

In this way the check valve has been represented. Though the construction of the check valve is very simple its operation is also very simple, but the representation is very complex. In conventional way, we are representing this flow valve by using an arrow and a circle and there is the flow line. In this way, conventionally we are representing the check valve. This is the functional symbol, this is functional symbol and this is the conventional symbol.

It is very tedious every now and then to you use such a complex representation in the hydraulic circuit, it will consume lot of space and it will it may lead to the confusion as well. Therefore, we are using a simplified representation in this way. This arrowed designates that there is a blockage and on left to right side the flow is allowed. This is the free flow is from left to right is allowed. However, from right to left the flow is blocked.

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Graphical representation of valves



One more example, we will study for the representation of the valves. On our screen, we can see a 4/3 way valve. We have seen the meaning of the 4/3 way valve in our previous class. It is having 4-ports, there are 4-ports and 3-positions.

The default position is seen on our screen that is the blocking i.e. the holding position. The port A is blocked the port B is also blocked and they are at hold position. Port T there is no fluid is

coming to the port T the port through port P through pressure port as well no fluid is going to the port T and port A and B.

By default or the center position is the hold position or the neutral position is the hold position. Here we are having the 2 ports. These are the 2 ports which are blocked port A and port B both of them are blocked from port P there is no fluid is going. We can consider this also a block in block position port P and the tank is also in a block position. But let us consider that when we you know give the movement from right towards the left. What will happen?

Say, if we move the spool from right to left, we are changing the position of the spool. Let us add the square. If we change the position of the spool from right to the left, what will happen? When the spool is moving from right to left port P will be connected to port A and port B will connect to tank port T. P is giving the pressurized fluid to port A and the pressurized fluid from B is coming back to T.

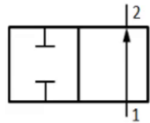
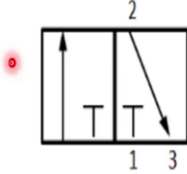
Here what is happening? P is connected to A and B will be connected to the T. For the first position, I can draw here the P will be connected to the A. Simply I will just draw an arrow indicating that P is connected to A and B is connected to T. This is consider we are giving spool movement from left to right.

When we are giving the movement from left to right we are having one more position here. To draw that we are using one more square. Now, when we are pushing the spool from left to right power port will be connected to B and application port A will connected to port tank T.

Here P will be connected to application port B and A will be connected to the tank port T P to B. P to B just draw right and from A to T, A to T. This is the representation of 4/3 way valve. Now, here we can add the actuation. Now, let us consider that the valve movements are actuated by the solenoid. By using the solenoid, we are actuating the valves.

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Direction control valves (DCVs)

SYMBOL	DESIGNATION	EXPLANATION
	2/2 way valve	Two closed ports in the closed neutral position and flow during actuated position
	3/2 way valve	In the first position flow takes place to the cylinder In the second position flow takes out of the cylinder to the tank (Single acting cylinder)

In a similar way we can now represent various DCVs that is the directional control valve, on your screen you can see a 2/2 way valve. It is having 2 positions and there are 2 ports. By default it is blocked. When we are actuating the port 1 is getting connected to the port 2. It is a 2 closed ports in the neutral position and the flow will occur when we are actuating the valve.

Similarly, we can have the representation of 3/2 way valve. Here the 3 means number of ports are 3 so 1 2 3 number of ports and there are 2 positions position number 1 and position number 2. In the first position the flow is taking place to the cylinder now flow is taking place to the cylinder.

From port 1 i.e. pressure port it is giving to the piston cylinder arrangement and the tank port is blocked. In the second position the flow is taking place from the cylinder back to the tank. This is in general the working of a single acting cylinder by using the 3/2 way valve, 3 ports 2 position way valve.

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Direction control valves (DCVs)

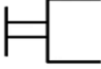
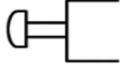
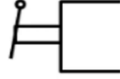
SYMBOL	DESIGNATION	EXPLANATION
	4/2 way valve	For double acting cylinder all the ports are open
	4/3 way valve	Two open positions and one closed neutral position

We can have the understanding of the 4/2 way valve, we just observe the 4/ 2 way valve, so the 4 is the number of ports and 2 is number of positions. Port 1, port 2, port 3 and port 4. Port 1 is the pressure port, port 3 is the tank port, 2 and 4 are the application ports. 4/2 way valve is generally used to actuate the double acting cylinder, by default or the neutral position is allowing the ports that are open. 1 is connected to 4 and 2 is connected to 3.

We are allowing the pressurized fluid that to flow inside the double acting cylinder from the rod side end, the fluid is coming back to the tank. When we actuate this valve, the connections are getting reverse. 1 is getting connected to 2 and 4 is connected to 3. In similar way we can also have a 4/3 way valve which we have already seen, in our previous slide so the designation can be seen on your screen. There are two open positions, one closed neutral position.

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Direction control valve actuation methods

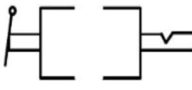
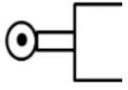
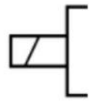
SYMBOL	DESIGNATION	EXPLANATION
	General manual actuation	Manual operation of DCV
	Push button actuation	Manual operation
	Lever actuation	Manual operation

There are various ways to represent the actuation methods. Now consider a manual actuation method. If we want to control the valve by using the manual actuation, we are using a simple symbol. The symbol is having 2 parallel lines and a vertical line. That is designating is a manually operated.

If we are using these kind of arrangement, it is called as the push button actuation. When we want to give the push button. We are using a semi-circular representation with 2 parallel lines a bar and a push button, a button which is attached to the bar. When we are trying to represent the lever? Now, we are using a little inclined line with a circle to represent the lever based actuation.

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Direction control valve actuation methods


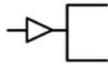
SYMBOL	DESIGNATION	EXPLANATION
	Detent lever actuation	Mechanical actuation of DCV
	Roller lever actuation	Mechanical actuation
	Solenoid actuation	Electro-mechanical actuation

The mechanical actuations can be represented as like the detent lever actuation. Detent is the locking mechanism. By the detent we can have the facility to hold the position of the valve, for that purpose a detent is the mechanical element which is having the various the slots. And, that slots are utilized to lock the valve in its intended position.

We can have the roller lever actuation. The roller lever can be represented by a circle with concentric field in circle, this is representing the solenoid actuation. This solenoid actuation, we are using a rectangle and an inclined line the solenoid actuation as we know that it is the electromechanical actuation.

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Direction control valve actuation methods

SYMBOL	DESIGNATION	EXPLANATION
	Spring actuation	Energy stored in the spring
	Direct pneumatic actuation	Pneumatic actuation of DCV

The springs are represented by using a zigzag line and we can also utilize the pneumatic based actuation. When we are using now compressed air to operate the valves we are using an arrow which is not filled in arrow. Empty arrow and that is designating the direct pneumatic actuation.

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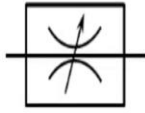
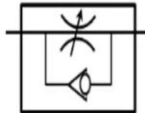
Non return valves

SYMBOL	DESIGNATION	EXPLANATION
	Check valve	Allows flow in one direction and blocks flow in other direction
	Spring loaded check valve	

The check valve is represented by using this symbol, already we have seen the meaning of this symbol and how it has been derived? The check valve is allowing the flow in only one direction and it is blocking the flow in the other direction. We can have the spring loaded check valve as well. When the check valve is spring loaded we are using a zigzag line, as shown on the slide.

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Flow control valves

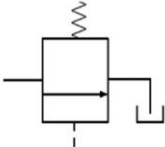
SYMBOL	DESIGNATION	EXPLANATION
	Flow control valve	To allow controlled flow
	Flow control valve with one way adjustment	To allow controlled flow in one direction and free flow in other

The flow control valve can be represented by using a rectangle and there are two curves, you know these two curves are represented in this way and it is having an arrow. Arrow is representing the variable displacement, the variable flow of the fluid through the flow control valve. The flow control valve with one-way adjustment can be shown by using the diagram on your screen. Here we are having two arcs which are represented in this way and an arrow and there is a check valve.

What is the meaning of with one-way adjustment? It is allowing the controlled flow in one direction and the free flow in other direction. It is allowing the flow of the fluid in a free way from left to right through the check valve, against the spring pressure in this direction and in the reverse way the flow control valve is taking care.

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Pressure control valves



SYMBOL	DESIGNATION	EXPLANATION
	Unloading valve	Allows pump to build pressure to an adjustable pressure setting and then allow it to be discharged to tank

The unloading valve which we have seen in our previous lecture can be represented by using a square and a fluid flow line by default the unloading valve is closed. Now the closed valve due to the spring action is represented by a spring a zigzag line over here.

When the external pressure we are applying, external fluid pressure or the pilot pressure is applied to safeguard the system, then the valve will open and it will allow the pressurized fluid the excess pressurized fluid to pass through the valve and that will send to the tank. In this way, the unloading valve is controlling the pressure and that has been designated by using a simple representation.

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Actuators

SYMBOL	DESIGNATION	EXPLANATION
	Single acting cylinder	Spring loaded cylinder with retraction taking place by spring force
	Double acting cylinder	Both extension and retraction by pneumatic/hydraulic force

The hydraulic actuators such as the single acting cylinder and the double acting cylinder can be seen on your screen. The single acting cylinder can be seen it is having the piston and the rod and the piston are having a spring. When we are applied the hydraulic pressure at the top side of the piston it will be extended, the cylinder will be extended.

However, restoring of the cylinder will be done by the spring force itself. In double acting cylinder we are using 2 ports, in single acting cylinder there is only 1 port. In double acting cylinder as you can notice there is a pressure port at the top side of the piston and there is a 1 more port at the other side of the piston movement.

The double acting cylinder is based upon the extension and retraction both by using the pneumatic or the hydraulic force. However, in the single acting cylinder the retraction by taking place the spring force, but the extension would be carried out by the hydraulic fluid only, the pressurized hydraulic fluid.

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Hydraulic fluids

- ❖ The medium thru which power is transferred in hydraulic machinery.
- ❖ General hydraulic fluids are mineral oil or water.
- ❖ The primary function of a hydraulic fluid is to transmit the power.

In the industry lot of hydraulic fluids are being utilized. And, as we know that the hydraulic fluid is the medium through which we are transferring the power to the hydraulic machinery. In general water is the best hydraulic fluid, but the flash point of the water is very less. It will get evaporated at a low temperature comparatively low temperature.

Due to the friction inside the system, the system pressure may increase. The temperature will also increase and that may lead to the boiling of the water, which is leading to the cavitation problem and the failure of the device itself. The viscosity of the water is also a concern the viscosity of the water is low so we need a little high viscous fluid.

For that purpose, the mineral oils are the best choice to be used as the hydraulic fluid. The primary function of the hydraulic fluid is to transmit the power; we have to transmit the power from the pump to the designated load or the desired application.

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Required properties of an ideal hydraulic fluid

- ❖ Non compressible (high bulk modulus)
- ❖ Low foaming tendency
- ❖ Low volatility
- ❖ Good thermal capacity and conductivity
- ❖ Thermal and oxidative stability
- ❖ Hydrolytic stability
- ❖ Cleanliness and filterability
- ❖ Anti-wear characteristics
- ❖ Corrosion control

There are certain properties that an ideal hydraulic fluid should have the fundamental properties that, it should be non-compressible it should not compress. That it will intact it will transmit the power efficiently. It should not form any foam during the operation it must be less volatile; the ideal hydraulic fluid should have very good thermal capacity.

The heat capacity should high and it should have good thermal conductivity. If the conductivity is low, it will get heated up and that hot hydraulic fluid will lead to the failure of the system, it will damage the system. The hydraulic fluid should have sufficient thermal and oxidative stability; the fluid should be stable enough. It should have the hydrolytic stability as well the fluid must be clean and it can be easily filtered.

The hydraulic fluid should provide the anti-wear characteristic, it should provide good lubricating characteristic, it should be non-corrosive. Generally, the hydraulic fluids are corroding the mechanical elements the ferrous elements of the system and we need to continuously monitor the condition of the hydraulic elements.

Due to the corrosion the system strength will get reduced and that may lead to the failure of the system. The corrosion is concerned in the hydraulic fluid based stems the hydraulic fluid should provide minimum possible the corrosion inside the system.

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Required properties of an ideal hydraulic fluid

- ❖ Low toxicity when new or decomposed
- ❖ Biodegradability
- ❖ Fire resistance
- ❖ Radiation resistance

The hydraulic fluid should be low toxic. We are using the hydraulic systems in presence of the human beings, the fluid will be handled by the human beings. It should not harm the health of the human beings it should be less toxic, it can be easily decomposed, if it is a biodegradable that would be the best the hydraulic fluid. It should have the resistance capability to the fire and it should have even the radiation resistance as well.

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Material

- ❖ Base stock
- ❖ Water
- ❖ Mineral oil -> inherent lubrication properties and ability to be used at temperatures above the boiling point of water.
- ❖ Now, most hydraulic fluids are based on mineral oil base stocks.
- ❖ Natural oils such as canola oil are used as base stocks -> biodegradability and renewable sources

The fluid material, as mentioned, is the water earlier when the hydraulic system started people started using the water, but later they changed the water or they replace the water as base stock to the mineral oil.

The mineral oil is having inherent lubrication properties and we can use the mineral oil at the temperatures above the boiling point of the water. Most of the hydraulic fluids are based on the mineral oil as a base stocks. Natural oils such as the canola oil can also be used as the base stock.

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Additional elements

- ❖ Hydraulic fluids can contain a wide range of chemical compounds
- ❖ oils, butanol, esters, poly alkylene glycols (PAG), organophosphate
- ❖ silicones, alkylated aromatic hydrocarbons, corrosion inhibitors, anti-erosion additives, etc.

The canola oil or the vegetable oils are having the best characteristics as they are bio degradable to improve the performance of the hydraulic fluids. Certain elements are being added in the hydraulic systems and these contains various chemical compounds.

These are the butanol, esters, poly alkylene glycols and various chemicals are added to get the required properties as I mentioned in the previous slides. Even we are adding the silicones, corrosion inhibitors, anti-erosion additives and many such elements are added to improve the performance of the hydraulic fluid.

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Summary

- ❖ Importance of graphical representation
- ❖ Aim and methodology
- ❖ Representation of elements
 - ❖ Pumps
 - ❖ Valves
 - ❖ Actuators
 - ❖ Motors

Well let me summarize the lecture 3 of week 10. In this lecture we have seen the graphical representation of variety of elements which are required to build a hydraulic circuitry. We discussed the importance of graphical representation; we have seen what are the aims and methodologies to represent these elements? We have seen typical elements representations such as pumps valves actuators and motors.