MODULE 3: COMPONENTS AND HYDRAULIC CIRCUIT DESIGN

Components: Classification of control valves, Directional Control Valves-symbolic representation, constructional features of poppet, sliding spool, rotary type valves solenoid and pilot operated DCV, shuttle valve, and check valves.

Pressure control valves - types, direct operated types and pilot operated types.

Flow Control Valves - compensated and non-compensated FCV, needle valve, temperature compensated, pressure compensated, pressure and temperature compensated FCV, s mbolic representation.

Hydraulic Circuit Design: Control of single and Double - cting hyd ulic cylinder, regenerative circuit, pump unloading circuit, double pump hydr ulic system, counter balance valve application, hydraulic cylinder sequencing ci cuits, cylinder synchronizing circuit using different methods, hydraulic circuit for force multiplication; speed control of hydraulic cylinder metering in, metering out and leed off ci cuits. Pilot p essure operated circuits. Hydraulic circuit examples with accumulator.

COMPONENTS

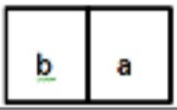
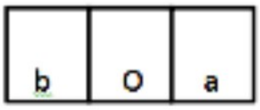
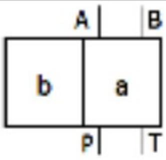
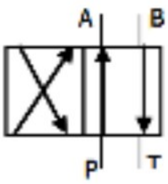
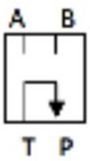
One of the most important considerat on n any fluid power systems is the control. If the control components are not properly selected, the entire system will not function as required. Fluid power is controlled primarily through the use of control devices called valves. There are three types of valves:

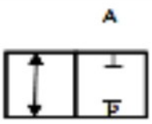
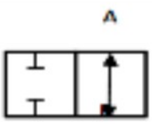
1. Direction control valves
2. Pressure control valves
3. Flow control valves

- he direction control valves determine the path through which fluid traverses in a given circuit.
- he pressure control valves protect the system against the excessive pressure, which may occur due to higher actuator loads or closing of valves.
- The flow control valves are used to control flow rate in various lines of a hydraulic circuit to control the actuator speeds.

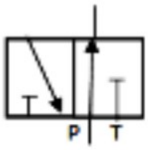
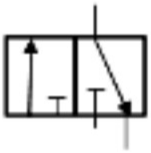
DIRECTION CONTROL VALVES:

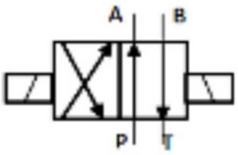
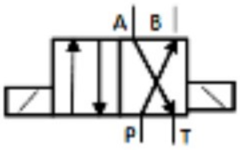
Symbolic Representation:

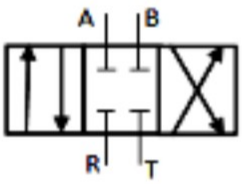
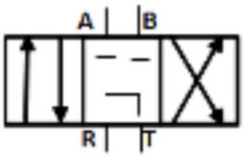
	Each individual switching portion is shown in a square
	Flow path is indicated by means of arrow within a square
	Closed position
	Two-position valve
	Three-position valve
	Ports added to the two-position valve
	Two flow paths
	Two ports are connected, two ports are closed

2/2-way valve: 2-ports and 2-position DCV	
	Normally closed position: P is not connected to A. When the valve is not actuated, the way is closed.
	Normally open position: P is connected to A. When the valve is not actuated, the way is open.

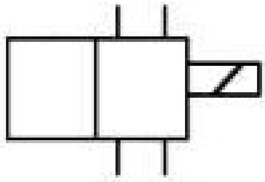
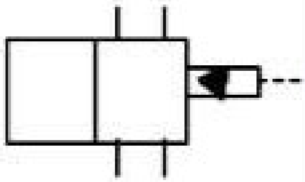
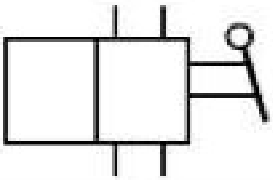
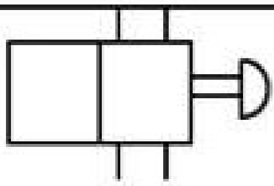
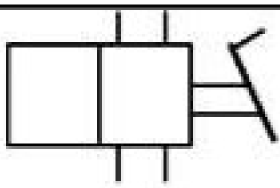
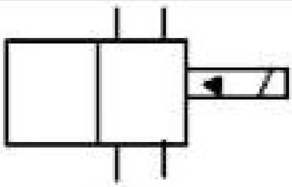
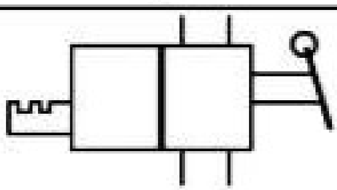
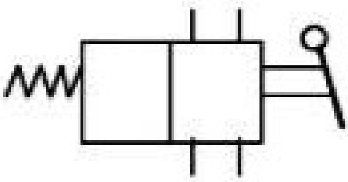
3/2-way valve: 3ports and 2 position DCV

	Normally open position: P is connected to A. When the valve is not actuated, the way is open.
	Normally open position: P is connected to A. When the valve is actuated, the way is closed

4/2-way valve – 4-port and 2-position DCV	
	P is connected to A B is connected to T
	Position 2: P is connected to B A is connected to T

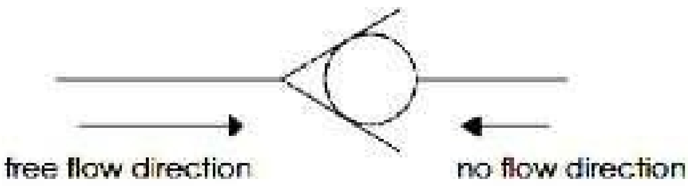
4/3-way valve – 4-port and 3-position DCV	
	P, T, A, B
	Mid-position pump reticulating: P to T, A and B closed

Actuating Devices:

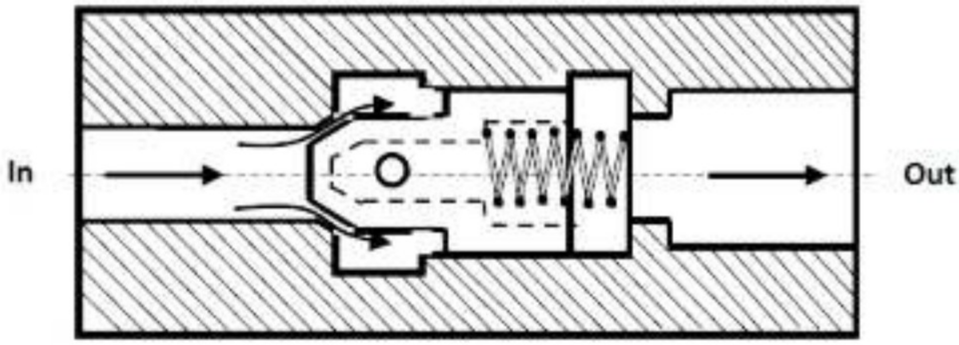
	Solenoid operated
	Pilot operated
	Manual operated
	Push button
	Foot operated
	Pilot-operated solenoid
	Two-position detent
	Spring return

Check Valve:

The simplest DCV is a check valve. A check valve allows flow in one direction, but blocks the flow in the opposite direction. Figure shows the graphical symbol of a check valve along with its no-flow and free-flow directions.



Poppet Check Valve:



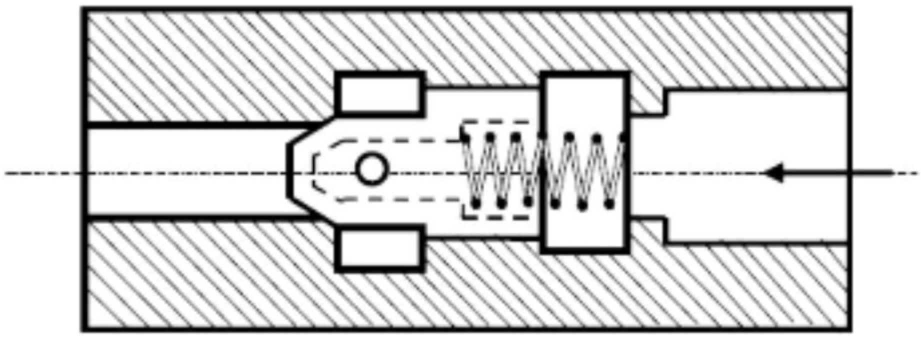
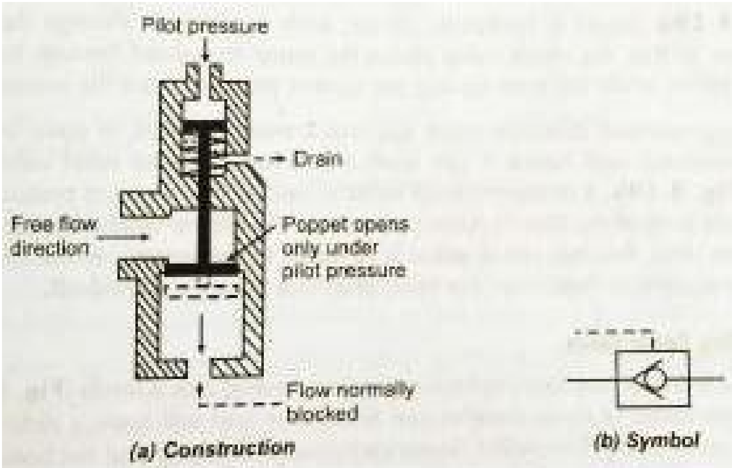


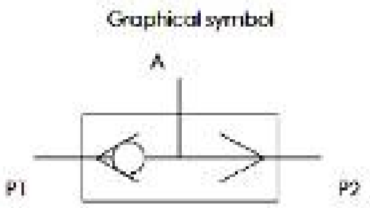
Figure shows the operation of a poppet check valve. A poppet is a specially shaped plug element held on a valve seat by a light spring. Fluid flows through the valve in the space between the seat and poppet. In the free flow direction, the fluid pressure overcomes the spring force. If the flow is attempted in the opposite direction, the fluid pressure pushes the poppet in the closed position. Therefore, no flow is permitted.

Pilot operated check valve (Pilot operated DCV):

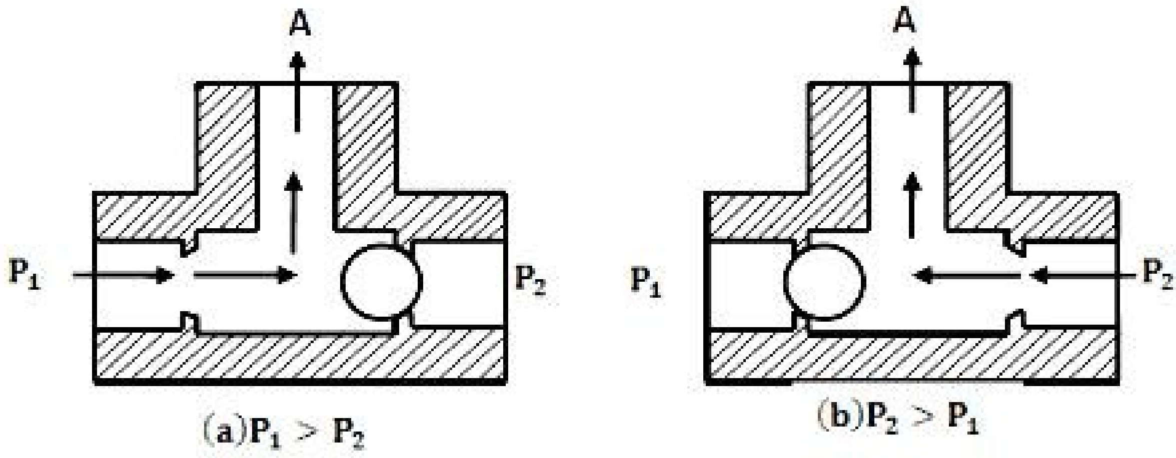
The pilot-operated check valve can permit flow in both the directions. In the normal operation, it functions like a check valve allowing free flow in one direction and blocking the flow in reverse direction. But when the pilot pressure is applied at the pilot port, it opens up the check valve and thus allows flow in the reverse direction. To achieve this function, the pilot piston is attached to the main poppet valve. The poppet is kept in normally closed condition with the help of a light spring.



Shuttle Valve:



A shuttle valve allows two alternate flow sources to be connected in a one-branch circuit. The valve has two inlets P1 and P2 and one outlet A. Outlet A receives flow from an inlet that is at a higher pressure. Figure shows the operation of a shuttle valve. If the pressure at P1 is greater than that at P2, the ball slides to the right and allows P1 to send flow to outlet A. If the pressure at P2 is greater than that at P1, the ball slides to the left and P2 supplies flow to outlet A.

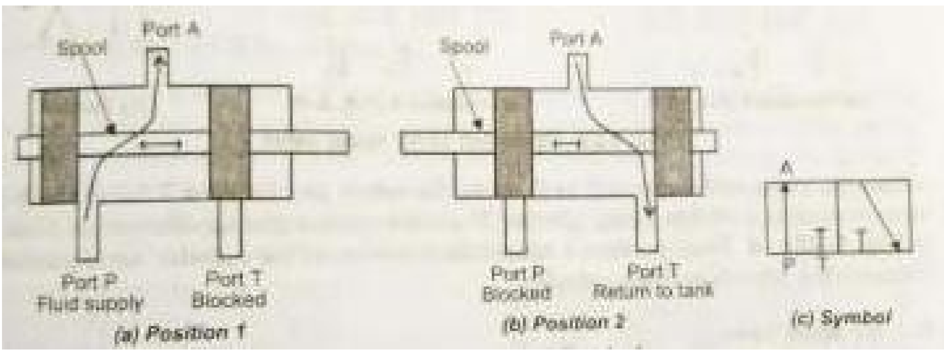


Sliding Spool Valve:

A spool is a step machined cylinder member, having 2 or 3 lands. The lands are machined to close dimensional tolerances and will have a sliding fit in the bo e of the valve body. The openings formed between the lands on the spool act as the flow passages between the connecting ports.

3/2 Spool valve:

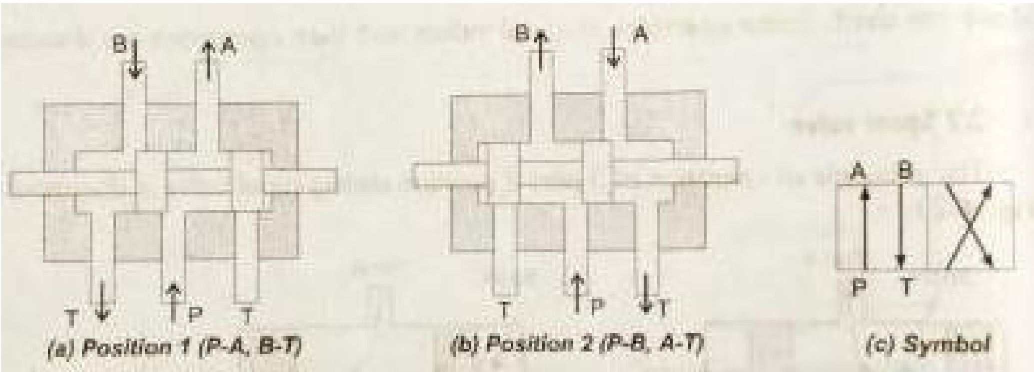
It has a cylindrical body with three ports P, T and A. Port P receives the fluid into the cylinder, Port A is connected to an actuation system and Port T is connected to the return line.



In operation, in the position 1, the fluid supply under pressure is connected to port P and port T is closed. That means pressure now flows through port A, and activates the device connected in that line. When the spool is moved to the position 2, the port P is closed, there by cutting the supply, while port is opened. Since there is pressure in the line (through port A), the pressure is relieved through the open port T and the fluid freely flows out the sump.

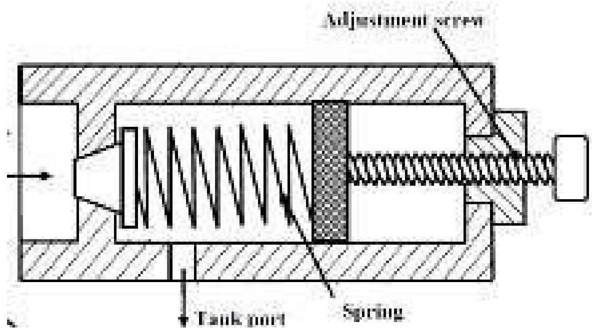
4/2 Spool Valve:

In position 1, the spool is connecting ports P to A, and ports B to T. This allows the pressure flow from P to A, while return from B to T. In position 2, the spool is connecting ports P to B and ports A to T. This allows the pressure flow from P to B, while return from A to T. Such a valve is used in double acting cylinder. Thus, position 1 causes the extension of the c linder, while position 2 causes the retraction of the cylinder.



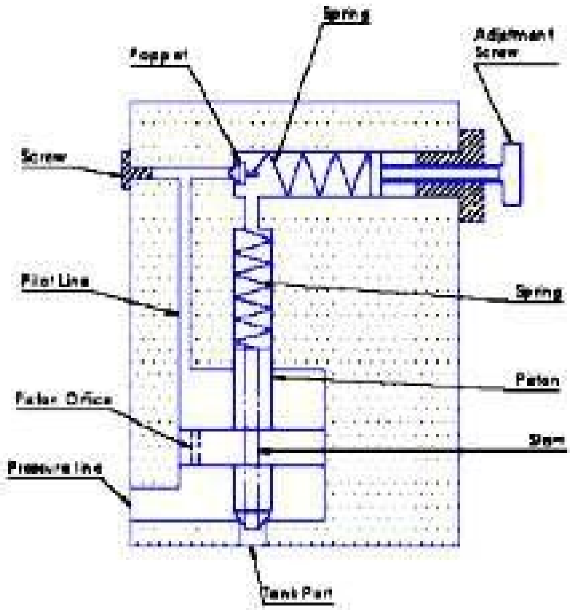
PRESSURE CONTROL VALVES:

Pressure Relief Valves:



he most widely used type of pressure control valve is the pressure-relief valve because it is found in practically every hydraulic system. It is normally a closed valve whose function is to limit the pressure to a specified maximum value by diverting pump flow back to the tank. A poppet is held seated inside the valve by a heavy spring. When the system pressure reaches a high enough value, the poppet is forced off its seat. This permits flow through the outlet to the tank as long as this high pressure level is maintained.

Compound Pressure Relief Valve (Pilot Operated Pressure Control Valve):

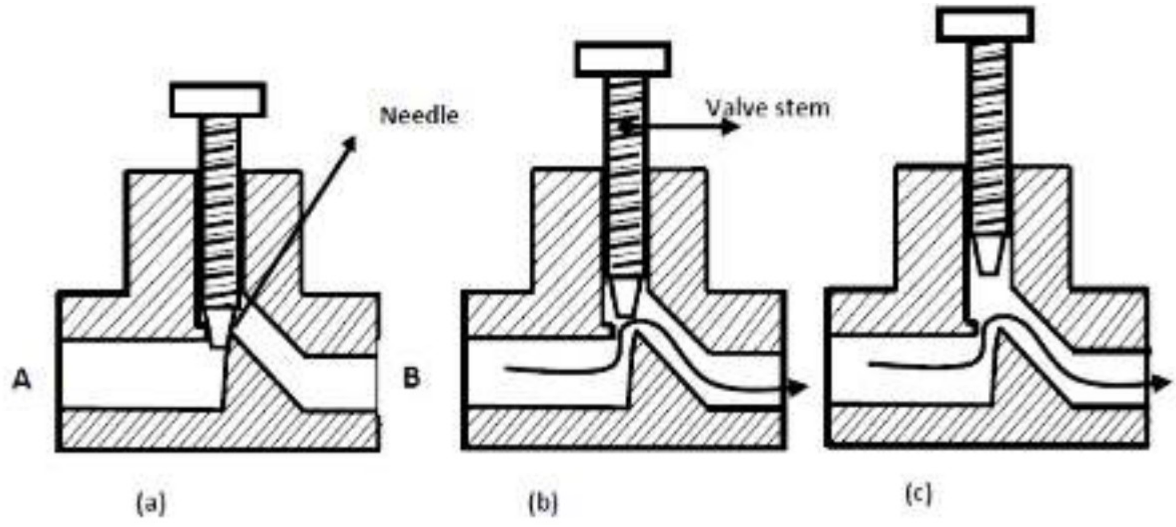


The pilot-operated pressure-relief valve has a pressure port that is connected to the pump line and the tank port is connected to the tank. The p lot relief valve is a poppet type. The main relief valve consists of a piston and a stem. The main relief piston has an orifice drilled through it. The piston has equal areas exposed to pressure on top and bottom and is in a balanced condition due to equal force acting on both the sides. It remains stationary in the closed position. The piston has a light bias spring to ensure that it stays closed. When the pressure is less than that of relief valve setting, the pump flow goes to the system. If the pressure in the system becomes high enough, it moves the pilot poppet off its seat. A small amount of flow begins to go through the pilot line back to the tank. Once flow begins through the piston orifice and pilot line, a pressure drop is induced across the piston due to the restriction of the piston orifice. This pressure drop then causes the piston and stem to lift off their seats and the flow goes directly from the pressure port to the tank.

Flow Control Valves:

Non-Pressure Compensated Flow Control Valves:

Non-pressure-compensated flow-control valves are used when the system pressure is relatively constant and motoring speeds are not too critical. The operating principle behind these valves is that the flow through an orifice remains constant if the pressure drop across it remains the same. In other words, the rate of flow through an orifice depends on the pressure drop across it.

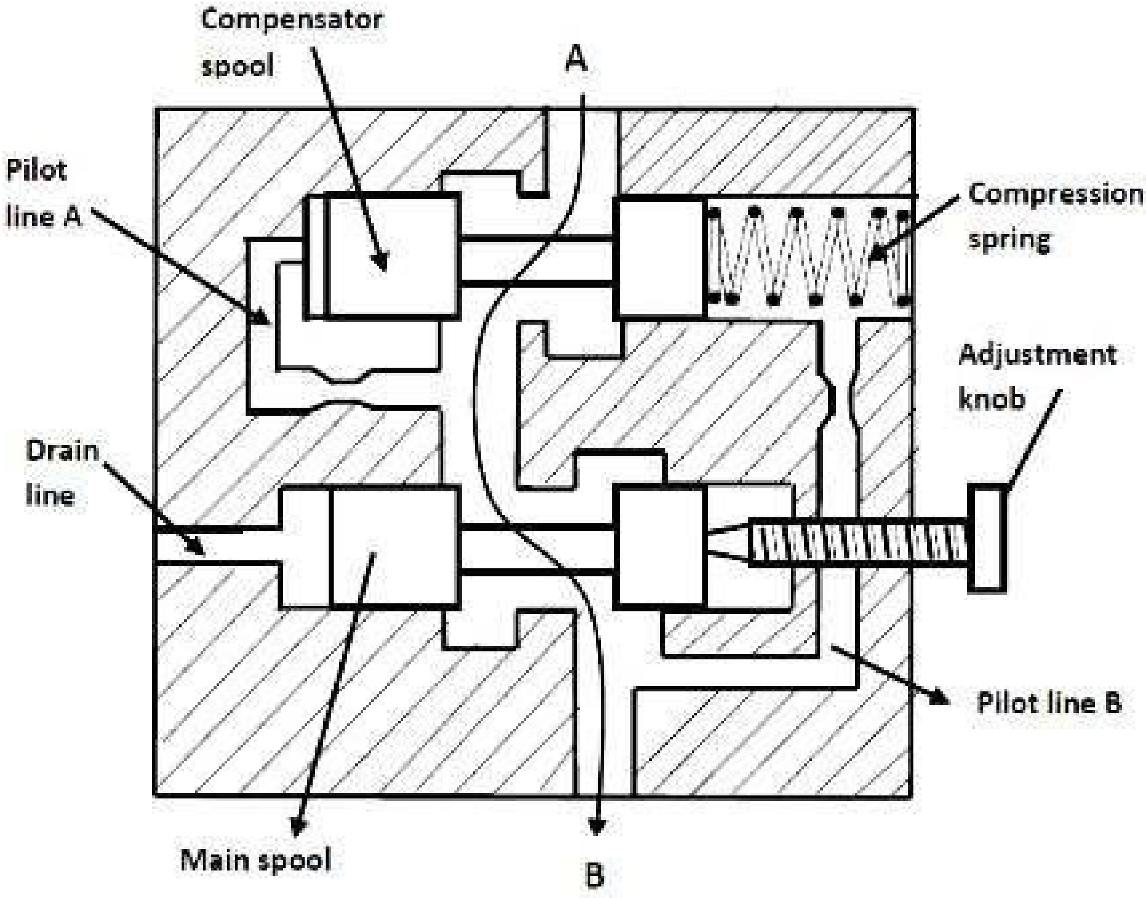


Non-pressure-compensated needle-type flow-control valve. (a) Fully closed: (b) partially opened: (c) fully opened.

It is the simplest type of flow-control valve. It cons sts of a screw (and needle) inside a tube-like structure. It has an adjustable or f ce that can be used to reduce the flow in a circuit. The size of the orifice is adjusted by turning the adjustment screw that raises or lowers the needle. For a given opening position, a needle valve behaves as an orifice.

Pressure Compensated Flow Control Valve:

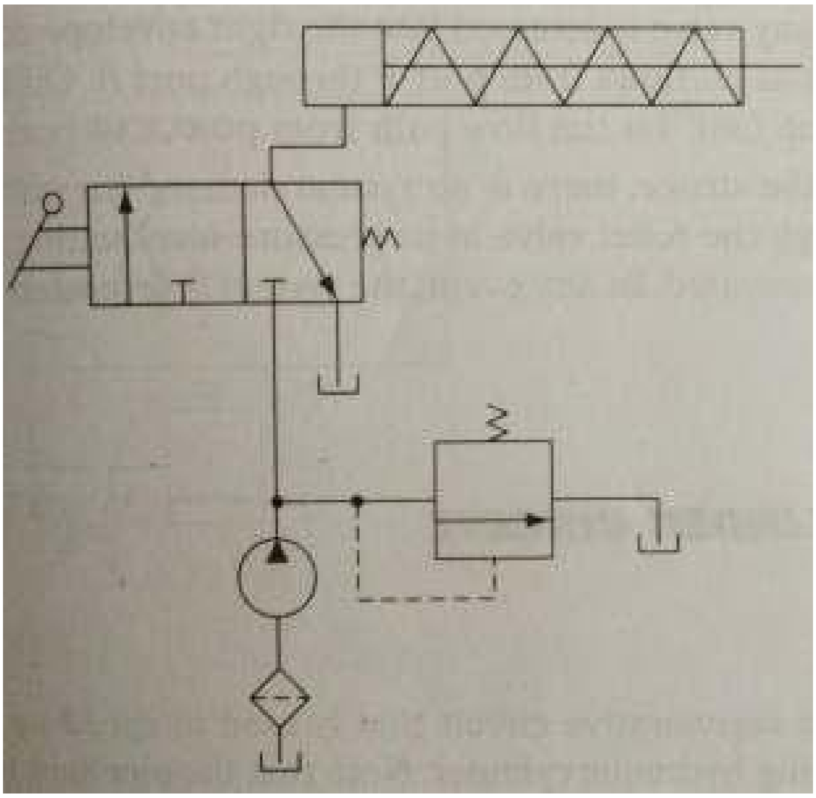
A pressure-compensated flow-control valve consists of a main spool and a compensator **spool. The adjustment knob controls the main spool's position, which controls the orifice size** at the outlet. he upstream pressure is delivered to the valve by the pilot line A. Similarly, the downstream pressure is ported to the right side of the compensator spool through the pilot line B. he compensator spring biases the spool so that it tends toward the fully open position. If the pressure drop across the valve increases, that is, the upstream pressure increases relative to the downstream pressure, the compensator spool moves to the right against the force of the spring. This reduces the flow that in turn reduces the pressure drop and tries to attain an equilibrium position as far as the flow is concerned.



In the static condition, the hydraulic forces hold the compensator spool in balance, but the bias spring forces it to the far right, thus holding the compensator orifice fully open. In the flow condition, any pressure drop less than the bias spring force does not affect the fully open compensator orifice, but any pressure drop greater than the bias spring force reduces the compensator orifice. Any change in pressure on either side of the control orifice, without a corresponding pressure change on the opposite side of the control orifice, moves the compensator spool. Thus, a fixed differential across the control orifice is maintained at all times. It blocks all flow in excess of the throttle setting. As a result, flow exceeding the pre-set amount can be used by other parts of the circuit or return to the tank via a pressure-relief valve.

HYDRAULIC CIRCUITS:

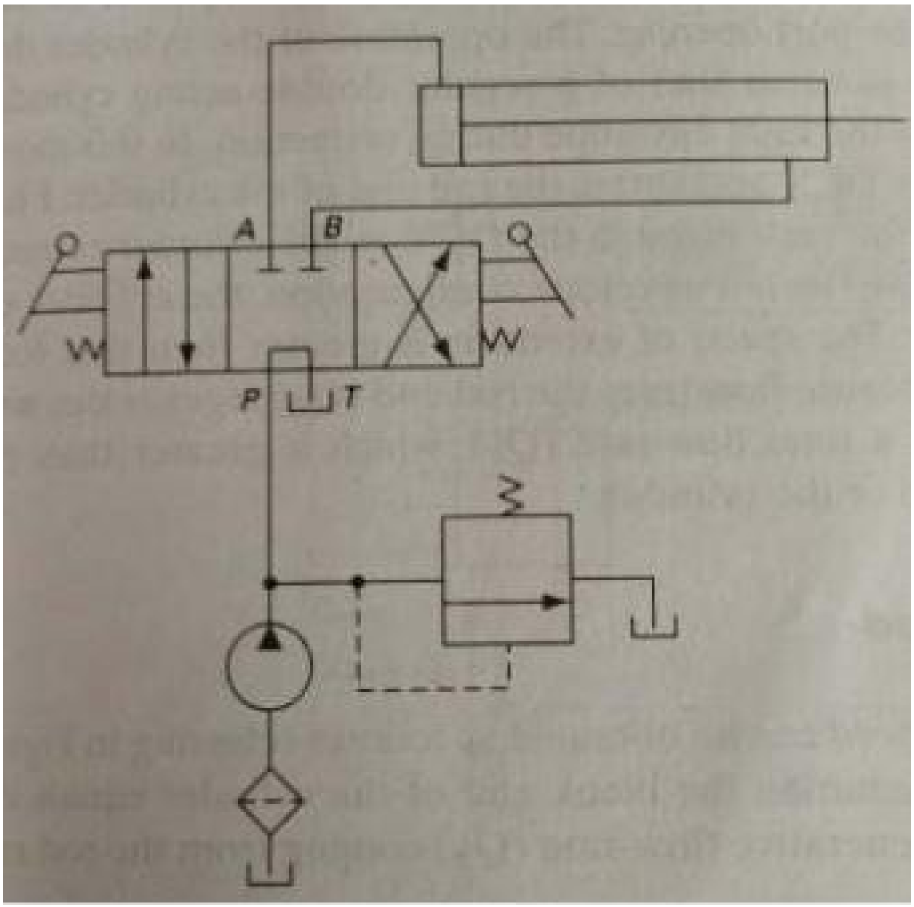
Control of a Single-Acting Hydraulic Cylinder:



The circuit has a filter, pump, pressure relief valve, a DCV and a spring return single acting cylinder. In operation, with the cylinder in normally retracted position (under spring pressure), when the valve is operated manually, the pressure port opens, the pump flow is directed to the piston end of the cylinder and causes extension of cylinder. Once, the extension is achieved, PRV opens-out and flow starts to pass through the PRV in the bypass line. When the DCV is deactuated, the pressure port is blocked, and the oil from the piston end of cylinder is routed to tank line. The cylinder starts retracting under spring pressure, and the oil flows back to the tank.

Control of a Double-Acting Hydraulic Cylinder:

Four-way DCVs are commonly used to control the operation of double acting cylinders. Here the valve shown in three positions: under extension (left envelope), neutral position (central envelope) and under retraction (right envelope).

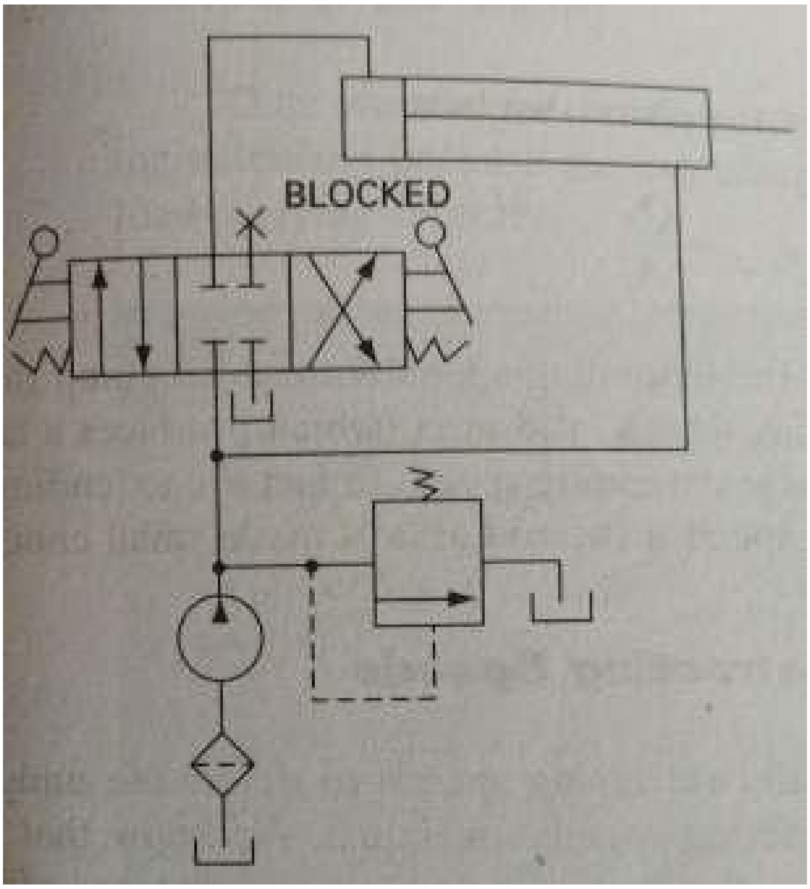


With the envelope in neutral position, the pump flow will continuously flow back to the tank through the DCV. Hence with this, the actuator and the pump are not pressurised. When the valve is actuated to the left envelope position, the pressure line is connected to the piston end cylinder port, while rod -end cylinder port is directed to the tank line. Under the pump pressure the cylinder extends and at the same time, the oil from the rod end freely flows back to the tank through the DCV. At the end of the stroke until the DCV is deactivated, the flow goes through the PRV. When the valve is actuated to the right envelope position, the pressure line is connected to the rod-end port, and the piston-end port is connected to the tank line.

his causes cylinder retraction, with the oil from piston-end flowing freely back into the tank. At the end of the stroke, the pressure builds up, the PRV opens out and the fluid flows through the relief line.

Regenerative Cylinder Circuit:

Figure shows a regenerative circuit that is used to speed up the extending speed of a double-acting hydraulic cylinder.

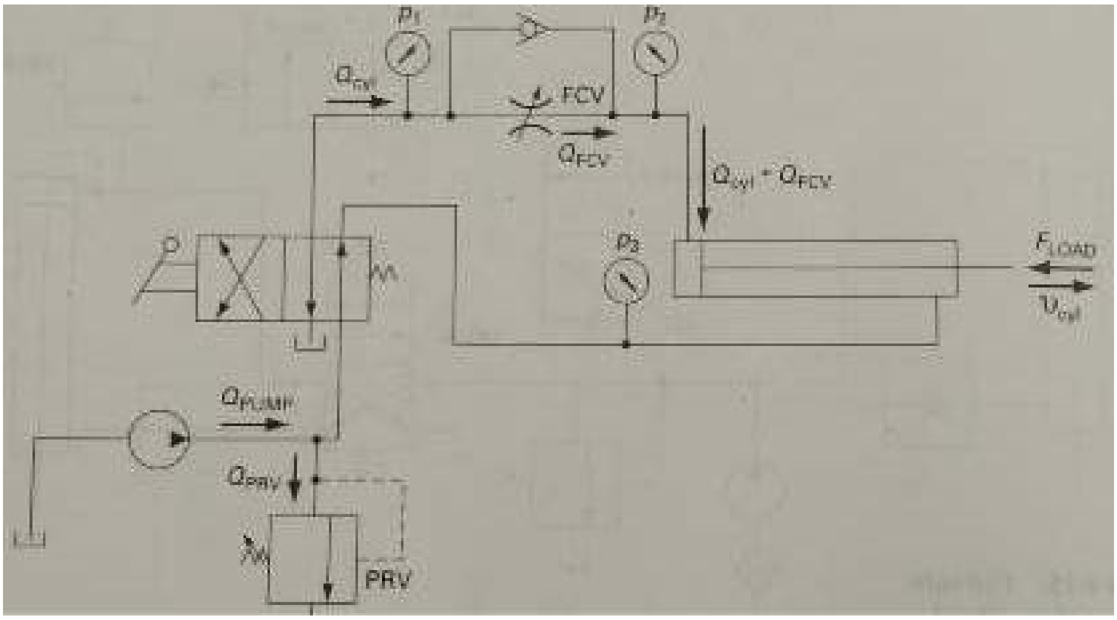


Note that the pipelines to both ends of the hydraulic cylinder are connected in parallel and that one of the ports of the four -way valve is blocked. Fluid flows through the DCV via the right envelope during retraction. In this mode, fluid from the pump bypasses the DCV and enters the rod end of the cylinder. Fluid in the blank end drains back to the tank through the DCV as the cylinder retracts.

When the DCV is shifted into its left envelope configuration, the cylinder extends. The speed of extension is greater than the that for a regular double-acting cylinder because flow from the rod end regenerates with pump flow to provide a total flow rate, which is greater than the pump flow rate to the blank end of the cylinder.

Meter-in Circuit:

Cylinder speeds can be controlled with the use of Flow Control Valves (FCV). The use of FCV to control the inlet flow to the cylinder hence the speed control is termed meter-in control.



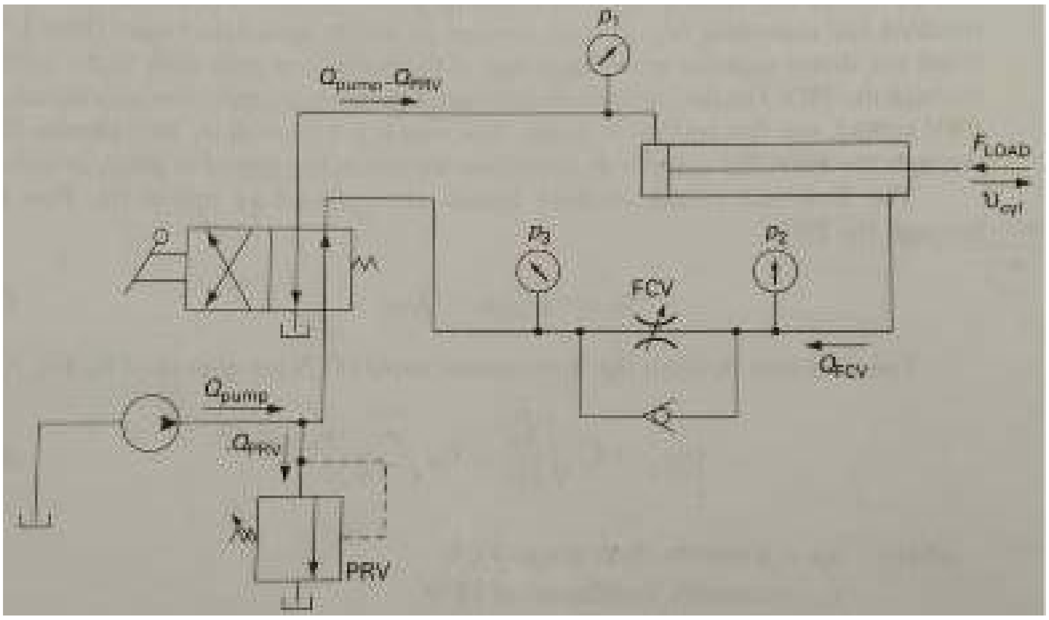
The operation of the cylinder to control its extension speed is explained with respect to two valve positions. When the DCV is actuated manually to its right envelope mode, the flow from the pressure line is directed to the p ston-end port of the cylinder through the FCV. Note that though there is a check valve, t s n closed position and the flow is forced to pass through the metering orifice. Thus depend ng upon the orifice opening the flow is metered to the inlet port. Hence the extending speed of the cylinder is controlled.

When the DCV is actuated manually to its left envelope mode, the flow lines are reversed. The pressure line is directed to the rod-end port in the cylinder while piston-end port is connected to the tank line. The cylinder starts retracting as the flow enters the rod-end port, and at the same time the flow from the piston-end passes through the FCV. Note that the check valve opens-out, thus the flow bypasses the orifice valve and passes through the least resistance path, that is through the check valve without any restriction. Thus in retraction, the cylinder moves back at its full design speed.

Meter-out Circuit:

The use of FCV to control the outlet flow from the cylinder hence its speed is termed as meter-out circuit. The operation of the cylinder to control its extension speed is explained with respect to two valve positions.

When the DCV is actuated manually to its right envelope mode, the flow from the pressure line is directed directly to piston-end port of the cylinder. As the cylinder extends, the fluid from the rod-end of the cylinder is forced out of the port. Since there is a FCV, the flow has to pass through it. As there is a restriction to the flow through the FCV, the flow rate is metered. Though the piston is pushing the fluid out with full force, it is resisted by the FCV hence the extension speed is controlled. Note that though there is a check valve along with the FCV, it is a one-way valve and remains closed when the fluid is being fo ced out of rod-end port to the tank line.

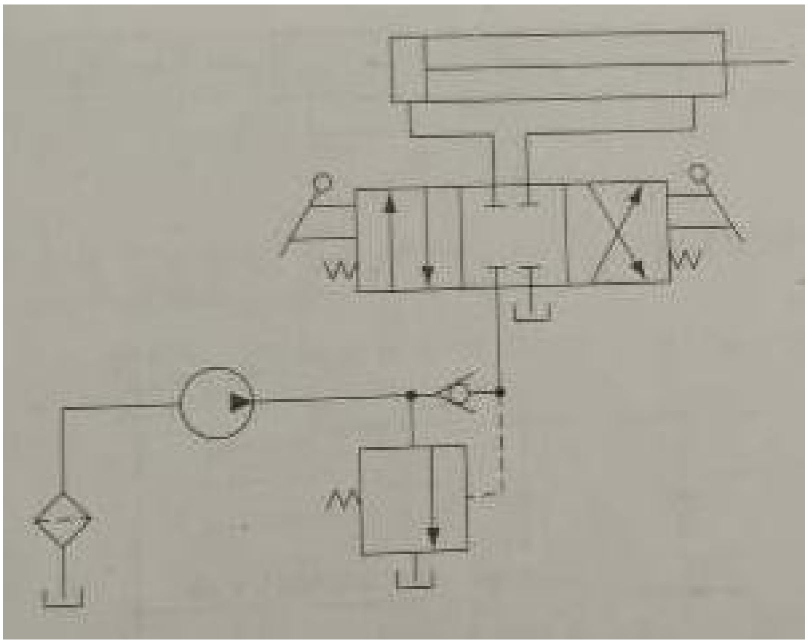


When the DCV is actuated to the left envelope mode, the flow lines are reversed. The pressure line is directed to rod-end port of the cylinder, while the piston-end port is connected to the tank line. he fluid under pressure enters rod-end port through the FCV, but bypassing the orifice. Instead it flows through the check valve, which now opens out due to favourable direction of flow. There is no restriction of flow through the check valve in this direction, hence full flow enters the cylinder, and it retracts with full design speed.

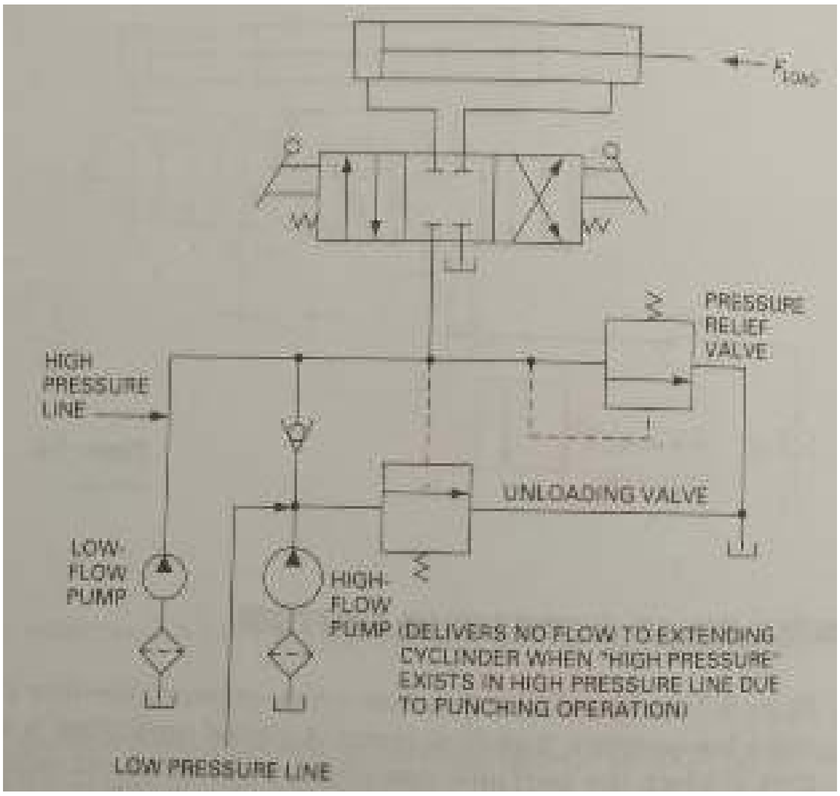
Pump Unloading Circuit:

An unloading valve is used to unload a pump in the circuit. The unloading valve opens when the cylinder reaches the end of its extension stroke because the check valve keeps high pressure oil in the pilot line of the unloading valve. When the DCV is shifted to retract the cylinder, the motion of the piston reduces the pressure in the pilot line of the unloading valve.

This resets the unloading valve until the cylinder is fully retracted, at which point the unloading valve unloads the pump.



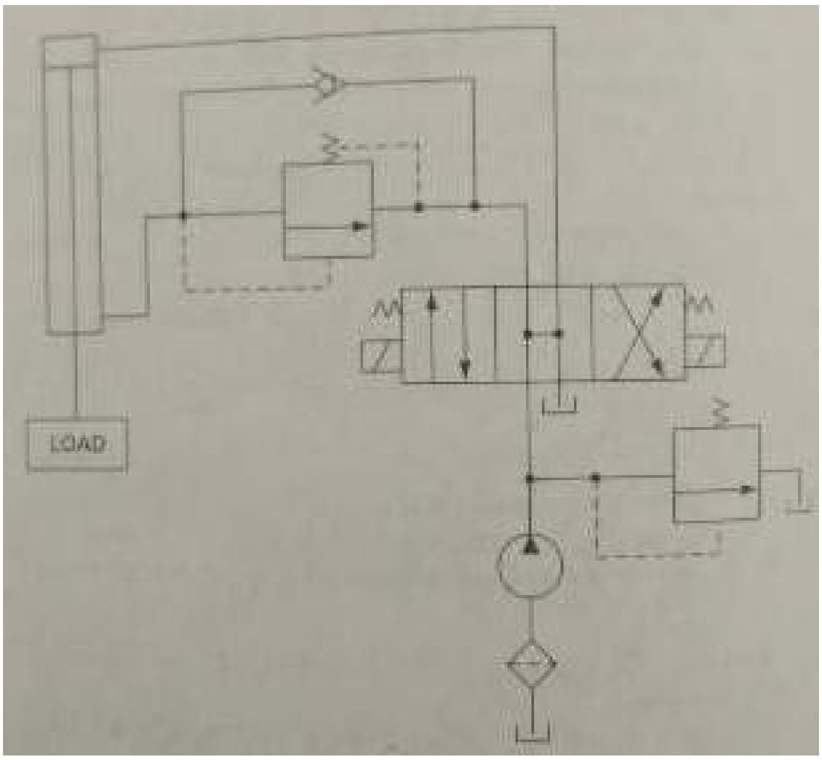
Double-Pump Hydraulic Circuit:



It uses a high pressure, low flow pump in conjunction with a low pressure, high flow pump. A typical application is a sheet metal punch press in which the hydraulic ram must extend rapidly over a great distance with very low pressure but high flowrate requirements. This rapid extension of the cylinder occurs under no load as the punching tool (connected to the end of the cylinder piston rod) approaches the sheet metal strip to be punched. However, during the short motion portion when the punching operation occurs, the pressure requirements are high due to the punching load. During the punching ope ation, the c linder travel is small and thus the flowrate requirements are low.

The circuit eliminates the necessity of having a very expensive high p essu e high flow pump. When the punching operation begins, the increased pressure opens the unloading valve to unload the low pressure pump. The purpose of the elief v lve is to protect the high pressure pump from overpressure at the end of the cylinder st oke and when the DCV is in spring centred mode. The check valve protects the low p essu e pump from hig pressure, which occurs during the punching operat on, at the end of cylinder stroke, and when the DCV is in its spring centred mode.

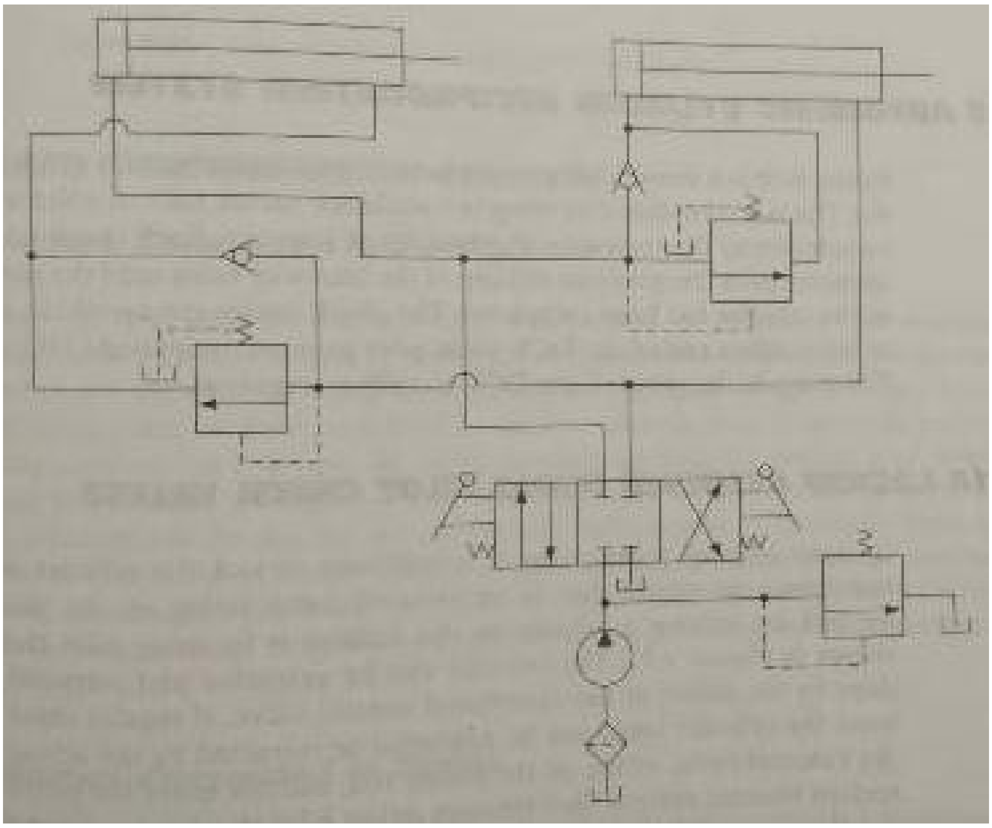
Counterbalance Valve Application C rcu t:



Here a counterbalance or backpressure valve is used to keep a vertically mounted hydraulic cylinder in the upward position while the pump is idling. The counterbalance valve is set to open at somewhat above the pressure required to prevent the vertical cylinder from descending due to the weight of its load. This permits the cylinder to be forced downward when pressure is applied on the top. The open centre directional control valve unloads the pump.

Hydraulic Cylinder Sequencing Circuits:

A sequence valve causes operations in a hydraulic circuit to behave sequentially. When the DCV is shifted into its left envelope mode, the left cylinder extends completely, and then the right cylinder extends. If the DCV is then shifted into its ight envelope mode, the right cylinder retracts fully, and then the left cylinder ret acts. This sequence of cylinder operation is controlled by the sequence valves. The spring cente ed position of the DCV locks both cylinders in place.



QUESTIONS FROM PREVIOUS YEAR QUESTION PAPERS:

DEC 2015/JAN 2016

1) Write the symbols representing various centre flow paths for two position four way valves.
2) Explain the operational features of the compound pressure relief valve.
3) Explain the construction and operation of a simple needle valve and also explain the expression for the flow rate through flow control valve.
4) Explain the concept of Meter in and Meter out circuit. List the advantages and limitations of each of the circuit
5) Explain regenerative circuit with a neat diag am and deuce egener tive speed of the cylinder.

JUNE/JULY 2016

1) Briefly classify valves based on the type of function performed.
2) Sketch and explain the construct onal features of poppet valve.
3) Sketch and explain pressure compensated flow control valve.
4) Sketch and explain the operation of a hydraulic circuit for the control of a spring return single acting cylinder.
5) What is regenerative circuit? Sketch schematically regenerative circuit to increase the extension speed of a double acting cylinder.

DEC 2016/JAN 2017

1) Explain the working principle of pilot operated check valve with a neat sketch. Illustrate the graphical symbol of the valve.
2) Explain with the aid of sketches:
   i) Non-compensated flow control valve
   ii) Compensated flow control valve
3) Explain the concept of Meter In and Meter Out circuit.
4) With a neat sketch, explain hydraulic circuit for sequencing of two cylinders.

JUNE/JULY 2017

1) Explain pressure reducing valve with graphical symbol.

2) Explain with a sketch non-compensated flow control needle valve.
3) With circuit diagram explain meter in circuit for controlling the speed of hydraulic cylinders.
4) Describe with a circuit diagram the construction and working of a counterbalance valve in hydraulic circuit.

DEC 2017/JAN 2018

1) Explain with neat sketch of 3/2 poppet valve with symbolic representation.
2) Explain with neat sketch of pilot operated pressure relief valve.
3) Explain with a neat sketch the working of shuttle valve with symbolic representation.
4) Explain with a neat circuit diagram, the working of double pump hydr ulic system.
5) Explain with a neat circuit diagram, the counter balance valve application.

JUNE/JULY 2018

1) How control valves are classified?
2) Explain with a neat sketch the work ng of a D rect Acting Pressure Relief valve.
3) Describe the working of 5/3 DC valve w th 4 ways with neat sketches. Also draw its graphical symbol.
4) What is the principle and purpose of regenerative circuit? Explain the working of a typical regenerative circuit with neat sketch.

CRASH COURSE – MAY 2017

1) With the aid of an appropriate hydraulic circuit explain the principle of unloading valve.
2) With the aid of neat sketch explain briefly the following:

i) Pressure reducing valve

ii) Pressure compensated flow controlled valve.

Give the graphic symbol for each.

3) Describe with the aid of an appropriate hydraulic circuit hydraulic cylinder sequencing.

ONE TIME EXIT SCHEME – APRIL 2018

1) Give the classification of hydraulic control valve. With a neat sketch, explain simple pressure relief valve and give its graphical symbol.
2) Explain compensated and non-compensated flow control valve. Also draw the symbol.

3) With a neat sketch, explain pump unloading circuit.
4) With neat sketch, explain hydraulic cylinder sequencing circuit used in hydraulic drill press.