Lesson 4: Pressure Control Valves

Basic Hydraulic Systems

- Hydraulic Tank
- Hydraulic Fluids
- Hydraulic Pumps and Motors
- **Pressure Control Valves**
- Directional Control Valves
- Flow Control Valves
- Cylinders

Introduction

Pressure Control Valves are used to control the pressure in a circuit or in a system. The valve function will remain the same although the design may change. Examples of pressure control valves include relief valves, sequence valves, pressure reducing valves, pressure differential valves and unloading valves.

Objectives

Upon completion of this lesson the student will:

1. List the four most common pressure control valves.
2. State the functions of the relief valve, sequence valve, pressure reducing valve and the pressure differential valve.
3. Identify the ISO symbol for the four most common pressure control valves.

Relief Valves

Hydraulic systems are designed to operate within a certain pressure range. Exceeding this range can damage the system components or become dangerous to personnel. The relief valve maintains the pressure within the designed limit by opening and allowing excessive oil to flow either to another circuit or back to the tank.

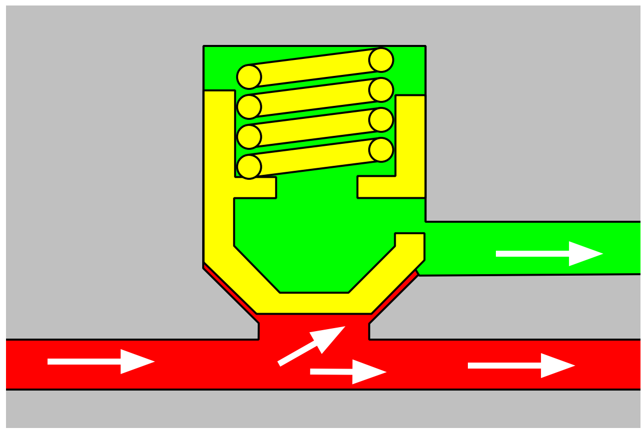

Fig. 3.4.1 Cracking Pressure

Simple Pressure Relief Valve, Cracking Pressure

Figure 3.4.1 shows a simple relief valve in the "cracking pressure" position.

The simple relief valve (also called direct acting relief valve) is kept closed by spring force. The spring tension is set to the "relief pressure" setting. However, the relief pressure setting is not the pressure at which the valve first begins to open.

When a condition develops that causes a resistance to the normal oil flow in the circuit, excessive oil flow causes the oil pressure to increase. The increasing oil pressure is sensed at the relief valve. When the force of the increasing oil pressure overcomes the force of the relief valve spring, the valve moves against the spring and begins to open. The pressure required to begin valve opening is called the "cracking pressure." The valve opens just enough to allow excess oil to flow through the valve.

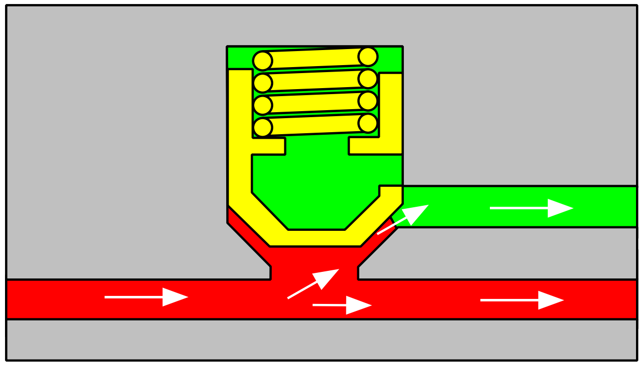

Fig. 3.4.2 Relief Pressure Setting

Simple Pressure Relief Valve, Relief Pressure Setting

An increase in the resistance to oil flow increases the volume of excess oil and increases the circuit pressure. The increase in circuit pressure overcomes the new spring tension and further opens the relief valve.

The process is repeated until the maximum volume of oil (full pump flow) is flowing through the relief valve. This is the "relief pressure setting" as shown in Figure 3.4.2.

The simple relief valve is commonly used where the volume of excess oil flow is low or where there is a need for a quick response. This makes the simple relief valve ideal for relieving shock pressures or as a safety valve.

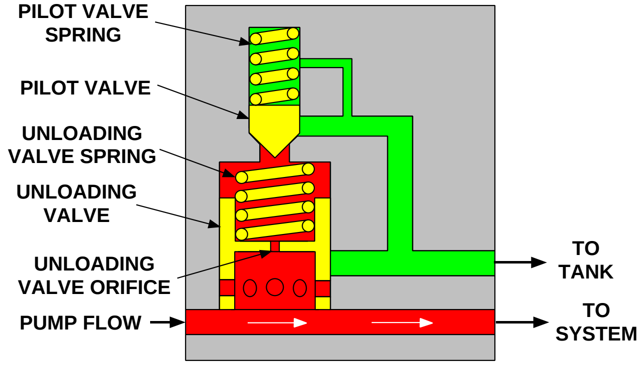

Fig. 3.4.3 System Oil Flow

Pilot Operated Relief Valve, CLOSE Position

The pilot operated relief valve (Figure 3.4.3) is often used in systems that require a large volume of oil and a small differential between the cracking pressure and the full flow pressure.

In the pilot operated relief valve, a pilot valve (simple relief valve) is used to control the unloading valve (main valve).

The pilot valve is much smaller and does not handle large volume oil flow. Therefore, the spring in the pilot valve is much smaller allowing more precise pressure control. The difference between the pilot valve cracking pressure and maximum pressure is held to a minimum.

The unloading valve is large enough to handle the complete pump flow at the designed maximum relief pressure. The unloading valve uses the system oil pressure to keep the valve closed. Therefore, the unloading valve spring does not need to be strong and heavy. This allows the unloading valve to have a more precise opening pressure.

The system oil flows into the relief valve housing, through the unloading valve orifice and fills the unloading valve spring chamber. The oil in the unloading valve spring chamber comes in contact with a small area of the pilot valve. This allows the pilot valve to use a small spring to control a high pressure. When the oil pressure increases in the system, the same pressure is in the unloading valve spring chamber. Therefore, the oil pressure is the same on both sides of the unloading valve. The combined force of the system oil pressure in the unloading valve spring chamber and the spring force on the top of the unloading valve is greater than the force of the system oil pressure against the bottom of the valve. The combined force in the spring chamber keeps the unloading valve closed.

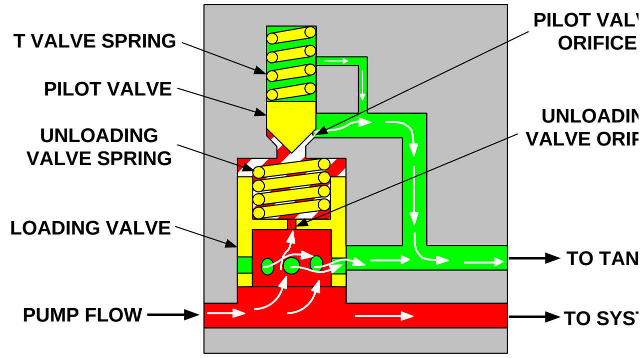

Fig. 3.4.4 Pilot Valve Open

Pilot Operated Relief Valve, OPEN Position

When the system oil pressure exceeds the pilot valve spring setting (Figure 3.4.4), the pilot valve opens. The open pilot valve allows the oil in the unloading valve spring chamber to flow to the tank. The pilot valve opening (orifice) is larger than the unloading valve orifice. Therefore, oil flows pass the pilot valve much faster than through the unloading valve orifice. This allows the pressure to decrease in the unloading valve spring chamber. The force of the higher system oil pressure moves the unloading valve against the spring. The excessive pump oil flows through the throttling holes in the unloading valve to the tank. The throttling holes allow the unloading valve to dump the volume of oil necessary to maintain the desired relief pressure.

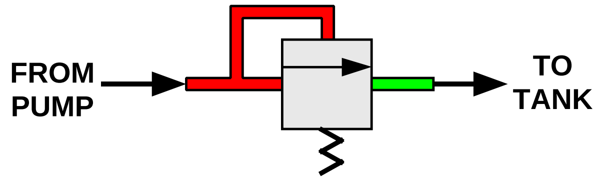

Fig. 3.4.5 Relief Valve ISO Symbol

Relief Valve ISO Symbol CLOSED

The relief valve ISO graphic symbol in Figure 3.4.5 can represent either a simple relief valve or a pilot operated relief valve. The ISO symbol is the same for all relief valves.

The above relief valve ISO symbol shows a single valve envelope in the CLOSED position. The system pressure is sensed through the pilot line at the top of the envelope and works to move the valve (arrow) against the spring. During normal operations, the pump flow is blocked at the closed valve.

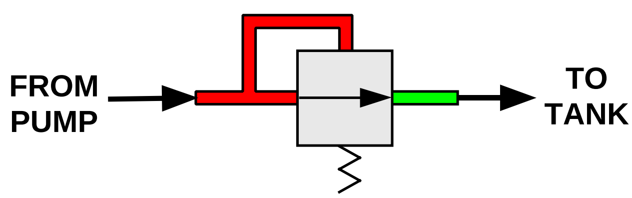

Fig. 3.4.6 Relief Valve ISO Symbol Open to Flow

Relief Valve ISO Symbol OPEN

The relief valve ISO symbol in Figure 3.4.6 shows a single valve envelope in the OPEN position.

When the force of the system oil pressure overcomes the spring force, the arrow moves down (valve opens) and connects the oil line from the pump with the oil line to the tank. The pump oil flows through the valve to the tank.

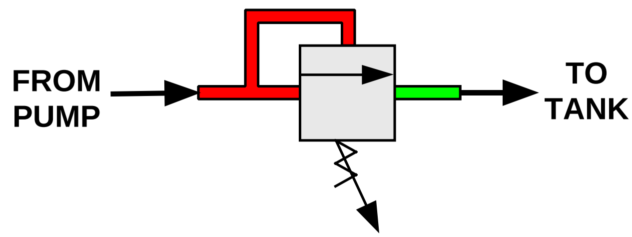

Fig. 3.4.7 Variable Relief Valve

Variable Relief Valve ISO Symbol

Figure 3.4.7 shows the ISO symbol for a variable relief valve.

The variable relief valve is a single envelope valve with an arrow through the spring. The arrow shows that the spring tension can be varied.

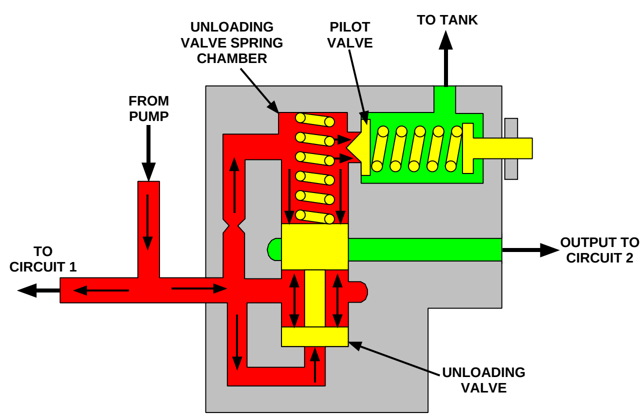

Fig. 3.4.8 Sequence Valve CLOSED

Sequence Valve, CLOSE Position

The sequence valve (Figure 3.4.8) is simply a pilot operated relief valve in series with the second circuit. The sequence valve is use when two circuits are supplied by one pump and one circuit has priority over the other.

The sequence valve blocks pump oil flow to circuit 2 until circuit 1 is satisfied. When pump oil fills circuit 1, the oil pressure begins to increase. The increase is sensed throughout the circuit as well as at the bottom of the unloading valve and in the unloading valve spring chamber of the sequence valve.

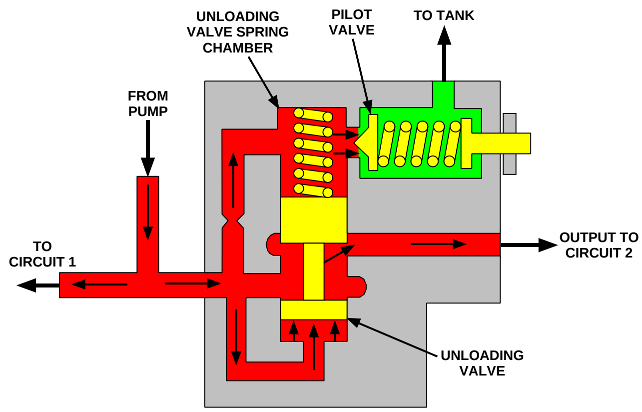

Fig. 3.4.9 Sequence Valve OPEN

Sequence Valve, OPEN Position

When the pressure in the unloading valve spring chamber exceeds the setting of the pilot valve spring, the pilot valve opens. The open pilot valve allows the oil in the unloading valve spring chamber to flow to the tank. This allows the pressure to decrease in the unloading valve spring chamber. The force of the higher system oil pressure moves the unloading valve against the unloading valve spring force and opens the passage to circuit 2. Pump oil flows through the sequence valve to circuit 2. The sequence valve remains open until the pressure in circuit 1 decreases to less than the pressure setting of the sequence valve.

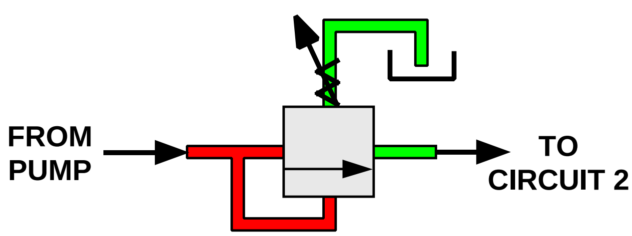

Fig. 3.4.10 Sequence Valve ISO SYMBOL

Sequence Valve ISO Symbol

The operation of the sequence valve is the same as the operation of the relief valve.

In the relief valve, the spring chamber is normally drained internally to outlet passage. In the sequence valve, the outlet passage connects to the second circuit. Because the second circuit is under pressure when the sequence valve opens, the pilot valve spring chamber must be externally drained to the tank.

Pressure Reducing Valve

The pressure reducing valve allows two circuits of different pressures to be supplied by the same pump. The maximum supply oil pressure is controlled by the system relief valve. The pressure reducing valve controls the maximum pressure in the controlled oil circuit.

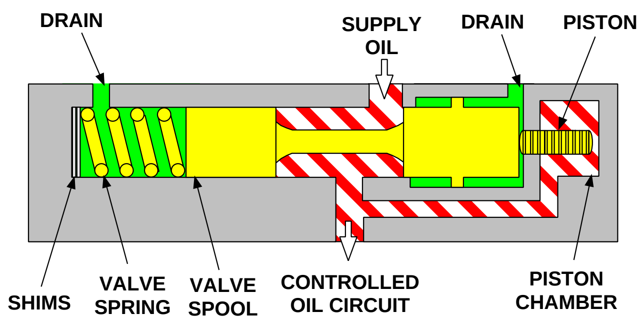

Fig. 3.4.11 Pressure Reducing Valve

Pump Start-up

Figure 3.4.11 shows the pressure reducing valve in the normally open position.

At pump start-up, the valve spring force holds the valve spool and the piston to the right. The supply oil flows around the pressure reducing valve spool to the controlled oil circuit (downstream side of the valve). The supply oil also flows through the oil passage to the piston chamber at the right of the valve spool. Any change in the controlled oil circuit pressure is sensed in the piston chamber. At pump start-up, the supply oil pressure and the controlled oil pressure are the same.

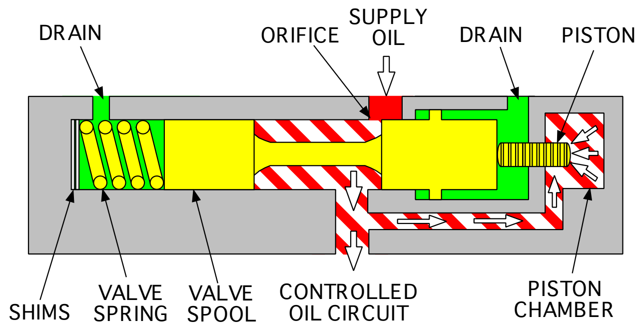

Fig. 3.4.12 Normal Operating Condition

Normal Operating Condition

Figure 3.4.12 shows the pressure reducing valve in the normal operating condition.

When the pressure increases in the controlled oil circuit, the increase is sensed in the piston chamber. The increasing pressure moves the piston to the left against the valve spool and the force of the spring. When the valve spool moves to the left, the valve spool restricts the supply oil flow through the valve and reduces the controlled oil circuit pressure.

The moving valve spool creates a variable orifice between the supply oil and the controlled oil circuit. The variable orifice allows the oil flow to increase and decrease as needed to control the pressure in the controlled oil circuit.

The oil in the spring chamber must be drained to the tank. Any increase in the spring chamber oil pressure will cause an increase in the valve setting.

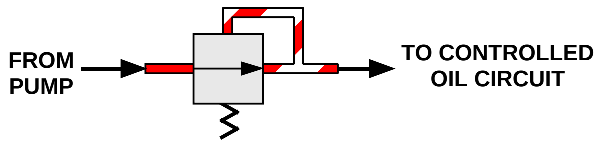

Fig. 3.4.13 Pressure Reducing Valve ISO Symbol

Pressure Reducing Valve ISO Symbol

Figure 3.4.13 shows the ISO symbol for the pressure reducing valve.

The ISO symbol uses a single envelope to represent the infinite positioning or metering capability of the pressure reducing valve.

The pump oil flows through the NORMALLY OPEN valve to the controlled oil circuit. The controlled oil circuit pressure is sensed through the pilot line and moves the valve (arrow) against the spring. When controlled oil circuit pressure overcomes the spring force, the valve shifts downward and restricts the oil flow to the controlled oil circuit. The upstream pressure may continue to increase. However, the downstream pressure will not increase beyond the pressure reducing valve setting.

When the controlled oil circuit pressure decreases, the spring force will shift the arrow upward to the open position. The valve constantly meters the oil flow to maintain the controlled oil circuit pressure.

Pressure Differential Valve

In figures 3.4.14 and 3.4.15, the spring exerts a 50 pound force on the 1 sq. inch valve spool. The supply oil pressure must exceed 345 kPa (50 psi) to overcome the spring force and move the valve spool.

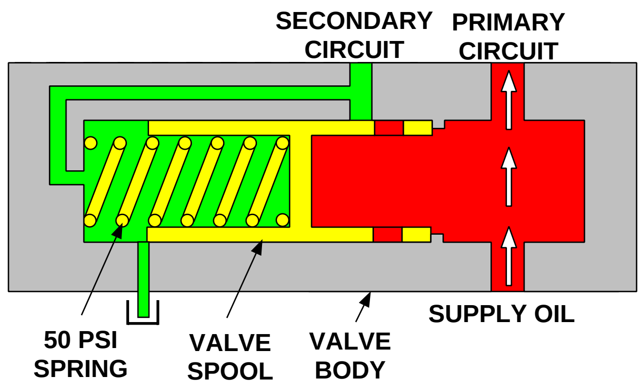

Fig. 3.4.14 Pump Start-up

Pump Start-up

Figure 3.4.14 shows a pressure differential valve. The pressure differential valve maintains a specified difference in pressure between two circuits.

At pump start-up and whenever the pressure in the primary circuit is less than 345 kPa (50 psi), the spring force holds the valve spool to the right. The oil flow is blocked to the secondary circuit. Any change in the primary circuit pressure is sensed at the valve spool.

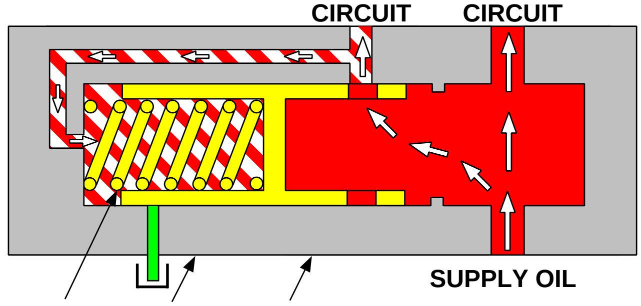

Fig. 3.4.15

Normal Operating Condition

When the primary circuit is filled, pressure begins to increase. When the primary circuit pressure increases to more than 345 kPa (50 psi), the primary pressure overcomes the 345 kPa (50 psi) differential valve spring force and moves the differential valve to the left. Supply oil flows to the secondary circuit. Supply oil also flows through the passage to the differential valve spring chamber.

When the secondary circuit is filled, the pressure begins to increase. The same pressure increase is sensed in the differential valve spring chamber. The combined oil pressure and spring force move the valve spool to the right and attempts to shut off the flow of oil to the secondary circuit. However, the increase in pressure in the primary circuit keeps the valve open. The pressure increases in both the primary and secondary circuits until the relief valve opens and sends the pump flow back to the tank.

The pressure differential valve establishes a position that constantly maintains a 345 kPa (50 psi) pressure difference between the primary and the secondary circuits at all pressures above 345 kPa (50) psi.

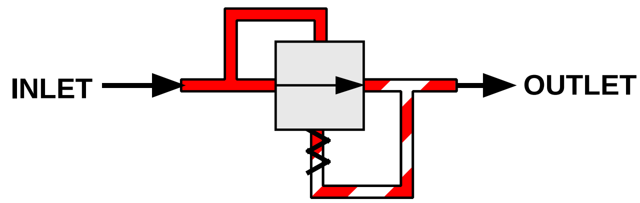

Fig. 3.4.16 Pressure Differential Valve ISO Symbol

Pressure Differential Valve ISO Symbol

The pressure differential valve ISO symbol (Figure 3.4.16) is a combination of the pressure relief valve symbol and the pressure reducing valve symbol.

The pressure from the inlet side is sensed by the valve and works against the spring force as in the pressure relief valve. The outlet pressure is sensed by the valve and works with the spring force. The difference between the inlet and outlet pressures is always equal to the valve spool spring force pressure regardless of changes in pressure at the inlet port. Example, a spring force pressure of 345 kPa (50 psi) will produce a pressure differential between the inlet and outlet pressure of 345 kPa (50 psi).

The spring is changed to meet any required change in the differential pressure. Normally, shims are not used to change the pressure requirements.

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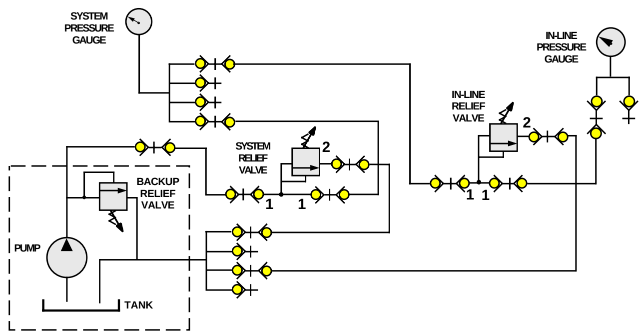

Lab.3.4.17 Relief Valve

LAB 3.4.1: RELIEF VALVE OPERATION

Purpose

To install and operate a relief valve in a simple circuit.

Materials needed

1. Basic Hydraulic Training Unit

Procedure

1. Construct the circuit in Figure 3.4.17.
2. Adjust the system relief valve to 5856 kPa (850 psi).
3. Turn the adjustment on the in- line relief valve counter-clockwise until it stops.
4. Turn ON the training unit.
5. Observe the pressure on the two gauges.
6. Turn the adjustment on the in-line relief valve clockwise until the in-line pressure gauge reads 2756 kPa (400 psi). Observe the readings on the system pressure gauges as you turn the adjustment knob.
   a. What happened on the pressure gauges while you were turning the knob? ________________

   ____

LAB 3.4.1: RELIEF VALVE OPERATION (continued)

7. Turn the adjustment on the in-line relief valve clockwise until the in-line pressure gauge reads 5684 kPa (825 psi). Observe the readings on the system pressure gauges as you turn the adjustment knob.

    a. What happened on the pressure gauges while you were turning the knob? ________________

    ____

8. Turn the adjustment on the in-line relief valve clockwise until the pressure readings on the two gauges no longer increase.

    a. What are the readings on the pressure gauges?

    System pressure _______ In-line pressure __________.

    b. Explain what happened in the system. ____

    ____

    ____

9. Turn Off the training unit and disconnect the hoses.

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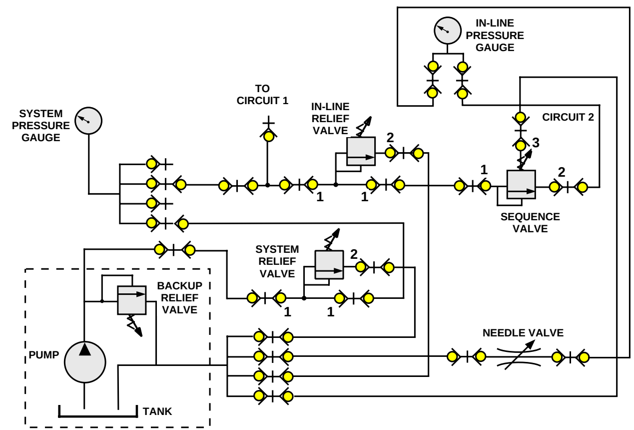

Fig. 3.4.18 Sequence Valve Schematic Field

LAB 3.4.2: SEQUENCE VALVE OPERATION

Purpose

To install and operate a sequence valve in a simple circuit.

Materials needed

1. Basic Hydraulic Training Unit

Procedure

1. Construct the circuit given in Figure 3.4.18.
2. Set the system relief valve to 5856 kPa (850 psi).
3. Turn the adjustment knob on the in-line relief valve fully counter-clockwise. Then turn the adjustment knob on the sequence valve fully clockwise. Turn the needle valve adjustment fully clockwise. (The needle valve is used to relieve the pressure in the in-line pressure gauge.)
4. Turn ON the training unit.
5. Monitor the readings on both pressure gauges and record readings in the space below. Notice that the system pressure gauge is reading in-line pressure and the in-line pressure gauge is reading the pressure in circuit 2.

   Gauge readings will depend on the hoses used and the oil temperature.

   System pressure gauge:____

   In-line pressure gauge:________________

6. Adjust the in-line relief valve to 2756 kPa (400 psi) at the system pressure gauge.

   a. What is the pressure in the secondary system?______________

LAB 3.4.2: SEQUENCE VALVE (continued)

b. Why is primary system pressure higher than pressure in the secondary system?

____

____

7. Slowly turn the adjustment screw on the sequence valve counter-clockwise until pressure is on the in-line pressure gauge. Stop turning the adjustment immediately. The sequence valve opening pressure should be approximately 2756 kPa (400 psi).

8. Turn the in-line relief valve adjustment fully counter-clockwise.

9. Turn the needle valve fully counter-clockwise for about 2 seconds then turn the needle valve fully clockwise. The needle valve serves as the load on circuit 2.

10. Monitor the gauges and record what happens.

    ____

    ____

    ____

11. Slowly turn the in-line relief valve adjustment screw clockwise while at the same time monitor both pressure gauges.

    At what pressure does the sequence valve open?

    ____

12. If you are still unclear about the operation of the sequence valve, repeat Steps 6 through 10 at a different pressure setting of the relief valve.
13. When you have completed your observations, turn OFF the training unit and disconnect the circuit.

Answer the Questions below.

1. A clamp and drill operation is a good example of a sequence valve application. Explain:

   ____

2.The sequence valve is normally _________.

3. How does activation of a sequence valve affect pressures in the entire system?

   ____

   ____

Name ______________________

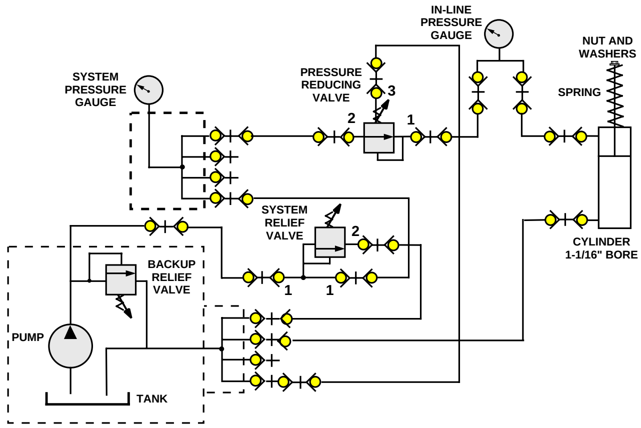

Fig. 3.4.19 Pressure Reducing Valve Circuit

LAB 3.4.3: PRESSURE REDUCING VALVE CIRCUIT

Purpose

To install and operate a pressure reducing valve in a hydraulic circuit.

Materials needed

1. Basic Hydraulic Training Unit

Procedure

1. Construct the circuit in Figure 3.4.19
2. Turn the adjustment knob on the pressure reducing valve fully counter-clockwise.
3. Set the system relief valve to 5856 kPa (850 psi).
4. Turn ON the training unit.
5. Adjust the pressure reducing valve so that the in-line pressure gauge reads 2756 kPa (400 psi).
   a. Compare the system and in-line pressures.

   ____

   ____

6. Adjust the pressure reducing valve so that the in-line pressure gauge reads 4134 kPa (600 psi).
   a. Compare the system and in-line pressures.

   ____

   ____

7. Turn OFF the training unit.
8. Disconnect the hoses.

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Name ____________________________

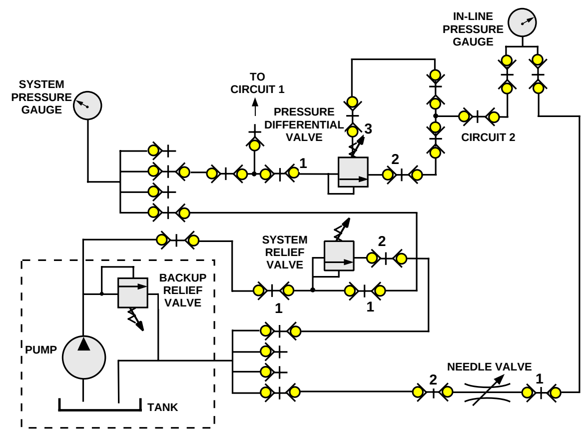

Fig. 3.4.20 Hydraulic Circuit

LAB 3.4.4 PRESSURE DIFFERENTIAL VALVE

Purpose

To install and operate a pressure differential valve in a hydraulic circuit.

Materials needed

1. Basic Hydraulic Training Unit

Procedure

In this exercise, the sequence valve is the same as the pressure differential valve.

1. Construct the circuit in Figure 3.4.20
2. Turn the adjustment knobs on the pressure differential valve and the needle valve fully counter-clockwise.
3. Set the system relief valve to 5856 kPa (850 psi).
4. Turn ON the training unit.
5. Turn the needle valve adjustment knob clockwise until the in-line pressure gauge reads 689 kPa (100 psi).

a. Compare the system and in-line pressures.

____

____

6. Turn the needle valve adjustment knob clockwise until the in-line pressure gauge reads 1378 kPa (200 psi).

   a. Compare the system and in-line pressures.

____

____

LAB 3.4.4 PRESSURE DIFFERENTIAL VALVE (continued)

7. Turn OFF the training unit.

8. Disconnect the hoses.

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