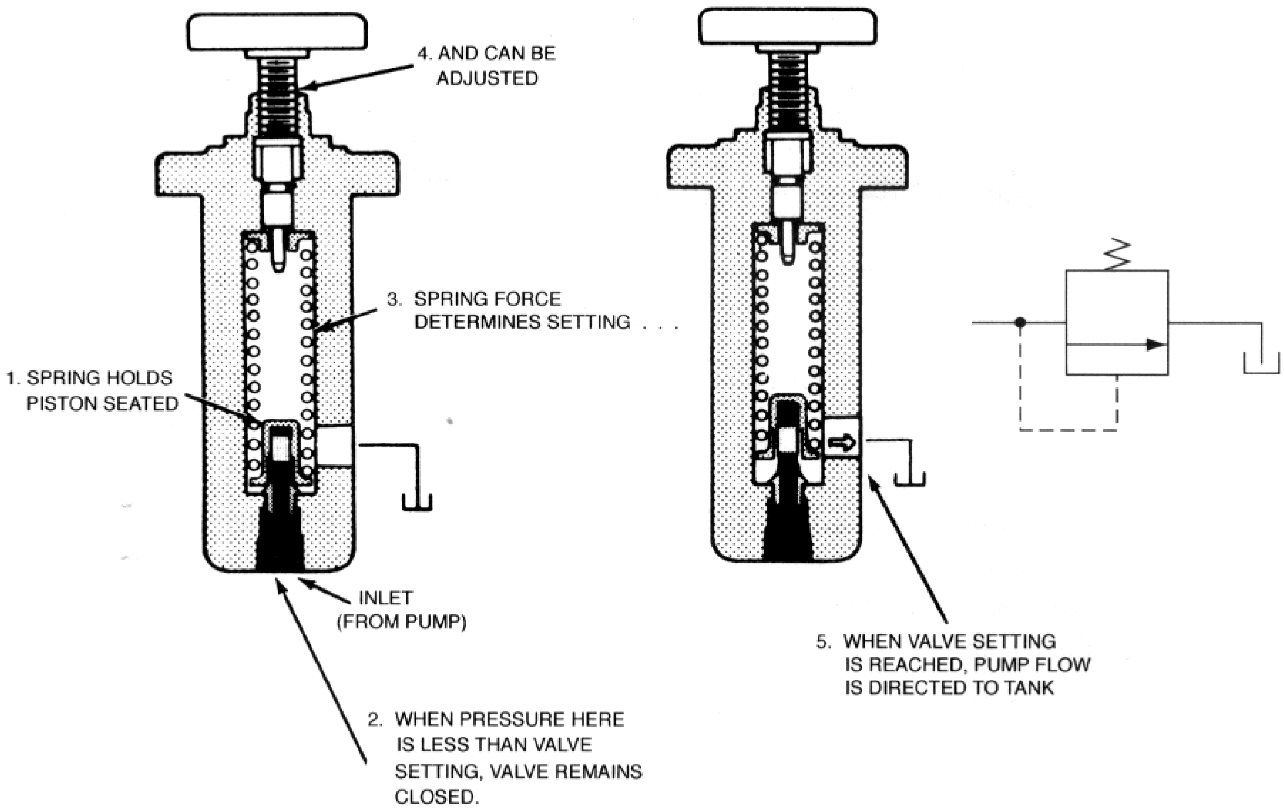
Simple Pressure Relief Valve:



EXAMPLE 8-1

A pressure relief valve contains a poppet with a 0.75 in^2 area on which system pressure acts. During assembly a spring with a spring constant of 2500 lb/in is installed to hold the poppet against its seat. The adjustment mechanism is then set so that the spring is initially compressed 0.20 in from its free-length condition. In order to pass full pump flow through the valve at the PRV pressure setting, the poppet must move 0.10 in from its fully closed position. Determine the

a. Cracking pressure

b. Full pump flow pressure (PRV pressure setting)

Solution

a. The force (F) a spring exerts equals the product of the spring constant (k) and the spring deflection (S) from its free-length condition. Thus the spring force exerted on the poppet when it is fully closed is

$$F = kS = 2500 \text{ lb/in} \times 0.20 \text{ in} = 500 \text{ lb}$$

In order to put the poppet on the verge of opening (cracking), the hydraulic force must equal the 500-lb spring force.

$$\text{hydraulic force} = \text{spring force}$$

$$p_{\text{cracking}}A = 500 \text{ lb}$$

$$p_{\text{cracking}}(0.75 \text{ in}^2) = 500 \text{ lb} \quad \text{or} \quad p_{\text{cracking}} = 667 \text{ psi}$$

Thus, when the system pressure becomes slightly greater than 667 psi, the poppet lifts off its seat a small amount to allow fluid to begin flowing through the valve.

b. When the poppet moves 0.10 in from its fully closed position, the spring has compressed a total of 0.30 in from its free-length condition. Thus the spring force exerted on the poppet when it is opened 0.10 in to allow full pump flow is

$$F = kS = 2500 \text{ lb/in} \times 0.30 \text{ in} = 750 \text{ lb}$$

In order to move the poppet 0.10 in from its fully closed position, the hydraulic force must equal the 750-lb spring force.

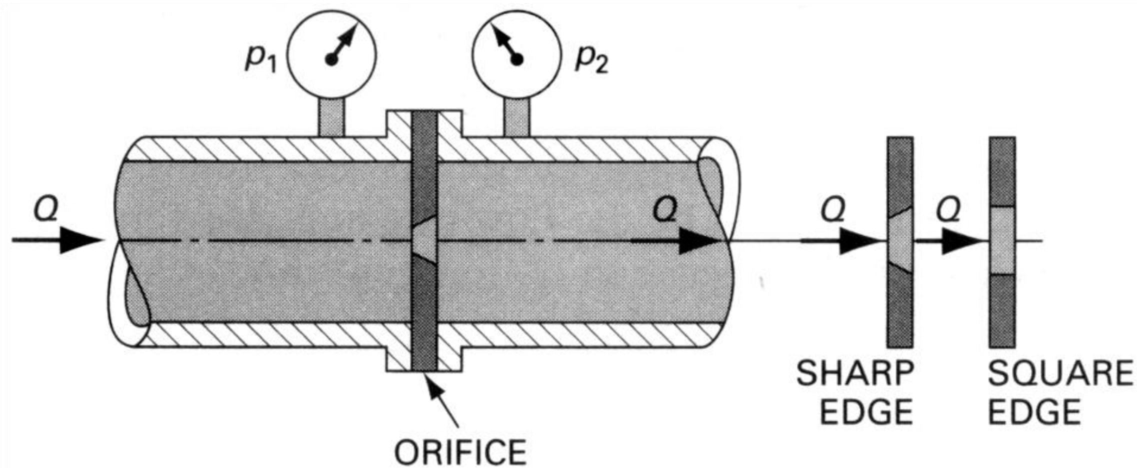
$$\text{hydraulic force} = \text{spring force}$$

$$p_{\text{full pump flow}}A = 750 \text{ lb}$$

$$p_{\text{full pump flow}}(0.75 \text{ in}^2) = 750 \text{ lb} \quad \text{or} \quad p_{\text{full pump flow}} = 1000 \text{ psi}$$

Thus, when system pressure reaches a value of 1000 psi, the poppet is lifted 0.10 in off its seat and the flow-rate through the valve equals the pump flow-rate. This means that the PRV pressure setting is 1000 psi and is 333 psi higher (or 50% higher) than the cracking pressure.

Orifice Flow Meter:



$$Q = 0.0851\ CA\sqrt{\frac{\Delta p}{SG}}$$

C = Flow Coefficient:

(**C = 0.8** for **Sharp-Edged, Orifice**)
(**C = 0.6** for **Square-Edged Orifice**).

Example 8-4

The pressure drop across the sharp-edged orifice of Figure 8-31 is 100 psi. The orifice has a 1-in diameter, and the fluid has a specific gravity of 0.9. Find the flow-rate in units of gpm.

Solution Substitute directly into Eq. (8-1):

$$Q = (38.1)(0.80)\left(\frac{\pi}{4} \times 1^2\right) \times \sqrt{\frac{100}{0.9}} = 252 \text{ gpm}$$

Needle Valves

$$Q = C_v \sqrt{\frac{\Delta p}{SG}}$$

where **Q** = **Volume Flow-rate** (gpm, Lpm),
C_v= **Capacity Coefficient** (gpm/√psi, Lpm/√kPa),
Δp = **Pressure Drop** across the **Valve** (psi, kPa),
SG = **Specific Gravity** of the **Liquid**.

EXAMPLE 8-5

A flow control valve experiences a pressure drop of 100 psi (687 kPa) for a flow-rate of 25 gpm (94.8 Lpm). The fluid is hydraulic oil with a specific gravity of 0.90. Determine the capacity coefficient.

Solution Solving Eq. (8-2) for the capacity coefficient, we have

$$C_v = \frac{Q}{\sqrt{\Delta p/SG}}$$

Using English units yields

$$C_v = \frac{25}{\sqrt{100/0.9}} = 2.37 \text{ gpm}/\sqrt{\text{psi}}$$

For metric units the result is

$$C_v = \frac{94.8}{\sqrt{687/0.9}} = 3.43 \text{ Lpm}/\sqrt{\text{kPa}}$$

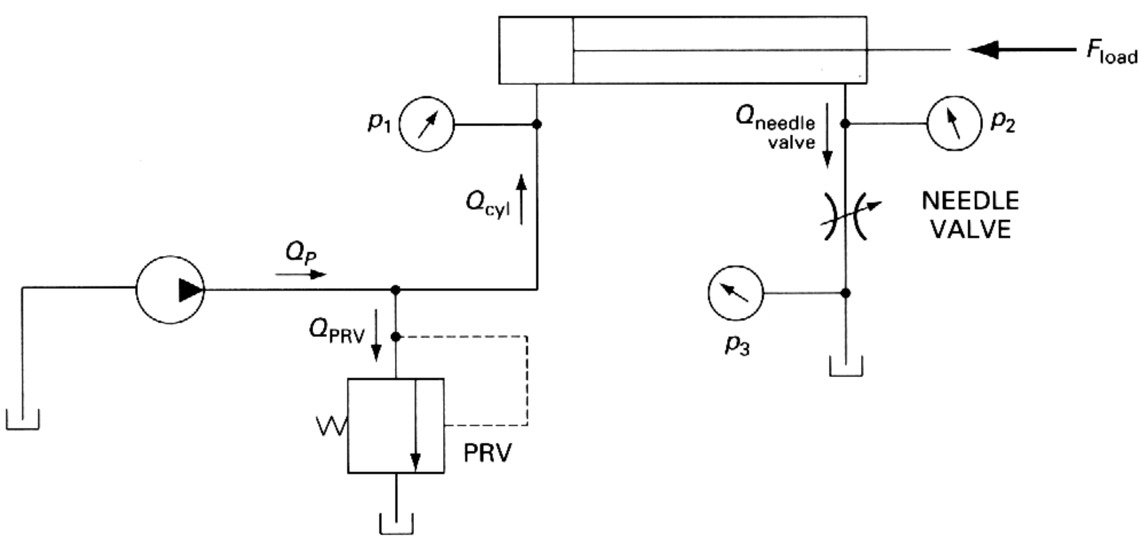
Example 8-6

A needle valve is used to control the extending speed of a hydraulic cylinder. The needle valve is placed in the outlet line of the hydraulic cylinder as shown in Figure 8-34. The following data are given:

1. Desired cylinder speed = 10 in/s
2. Cylinder piston diameter = 2 in (area = 3.14 in^2)
3. Cylinder rod diameter = 1 in (area = 0.79 in^2)
4. Cylinder load = 1000 lb
5. Specific gravity of oil = 0.90
6. Pressure relief valve setting (PRV setting) = 500 psi

Determine the required capacity coefficient of the needle valve.

Solution When the needle valve is fully open, all the flow from the pump goes to the hydraulic cylinder to produce maximum hydraulic cylinder speed. As the needle valve is partially closed, its pressure drop increases. This causes the back pressure p_2 to increase, which results in a greater resistance force at the rod end of the cylinder. Since this back pressure force opposes the extending motion of the cylinder, the result is an increase in cylinder blank end pressure p_1. Further closing of the needle valve ultimately results in pressure p_1 reaching and then exceeding the cracking pressure of the pressure relief valve. The result is a slower cylinder speed since part of the pump flow goes back to the oil tank through the pressure relief valve. When the cylinder speed reaches the desired value, p_1 approximately equals the PRV setting and the amount of pump flow not desired by the cylinder goes through the pressure relief valve. When this occurs, the cylinder receives the desired amount of flow-rate, which equals the pump flow-rate minus the flow-rate through the pressure relief valve.



First we solve for the rod end pressure p_2 that causes the blank end pressure p_1 to equal the PRV setting. This is done by summing forces on the hydraulic cylinder.

$$p_1A_1 - F_{\text{load}} = p_2A_2$$

where

A_1 = piston area,

A_2 = piston area minus rod area.

Substituting values yields

$$500 \text{ lb/in}^2 \times 3.14 \text{ in}^2 - 1000 \text{ lb} = p_2(3.14 - 0.79) \text{ in}^2 = p_2(2.35 \text{ in}^2)$$

$$p_2 = 243 \text{ psi}$$

Next we calculate the flow-rate through the needle valve based on the desired hydraulic cylinder speed.

$$Q = A_2v_{\text{cylinder}} = 2.35 \text{ in}^2 \times 10 \text{ in/s} = 23.5 \text{ in}^3\text{/s}$$

$$= 23.5 \text{ in}^3\text{/s} \times \frac{1 \text{ gal}}{231 \text{ in}^3} \times \frac{60 \text{ s}}{1 \text{ min}} = 6.10 \text{ gpm}$$

Since the discharge from the needle valve flows directly to the oil tank, pressure $p_3 = 0$. Thus, p_2 equals the pressure drop across the needle valve and we can solve for C_v.

$$C_v = \frac{Q}{\sqrt{\Delta p/SG}} = \frac{6.10}{\sqrt{243/0.90}} = 0.37 \text{ gpm}/\sqrt{\text{psi}}$$