UNIT II CONTROL AND REGULATION ELEMENTS

Pressure - direction and flow control valves - relief valves, non-return and safety valves – actuation systems.

Chapter 2

Hydraulic Control Valves

3- Pressure Control Valves

A pressure control valve can be used :

1-To limit the maximum pressure

2-To set a back pressure

3-To pass a signal when a certain pressure is reached

4- To protect the pump from over pressure

Types of Pressure Control Valves

Six pressure-control valves will be discussed. These valves are:

1. Relief valves
2. Unloading valves
3. Sequence valves
4. Pressure-reducing valves
5. Counterbalance valves
6. Safety Valve

Each of these valves works on the same principle;

a spring force balances a hydraulic force.

The hydraulic force is produced by pressure acting on a given area. When the hydraulic force becomes greater than the spring force, the valve spool moves.

1- Pressure Relief Valve (PRV)

Its function is to set the maximum pressure in the hydraulic system.

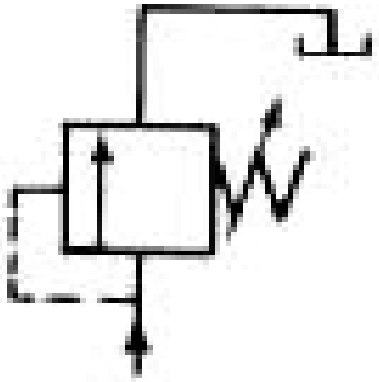
The pressure can rise in a hydraulic system if:

1- The flow rate from the pump is larger than the flow rate through the actuator

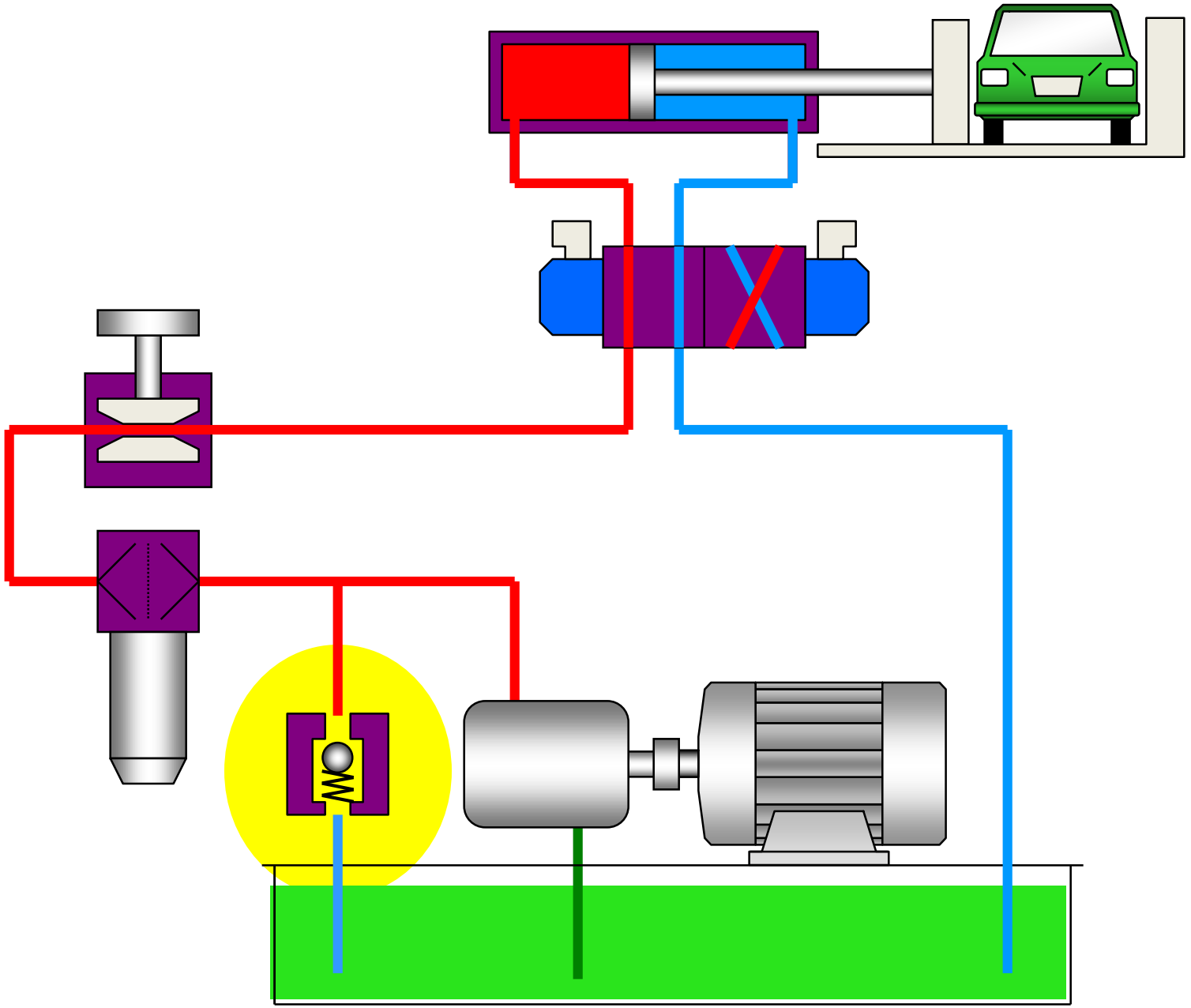
2- The volume of a closed system is reduced

3- The load of the actuator rises

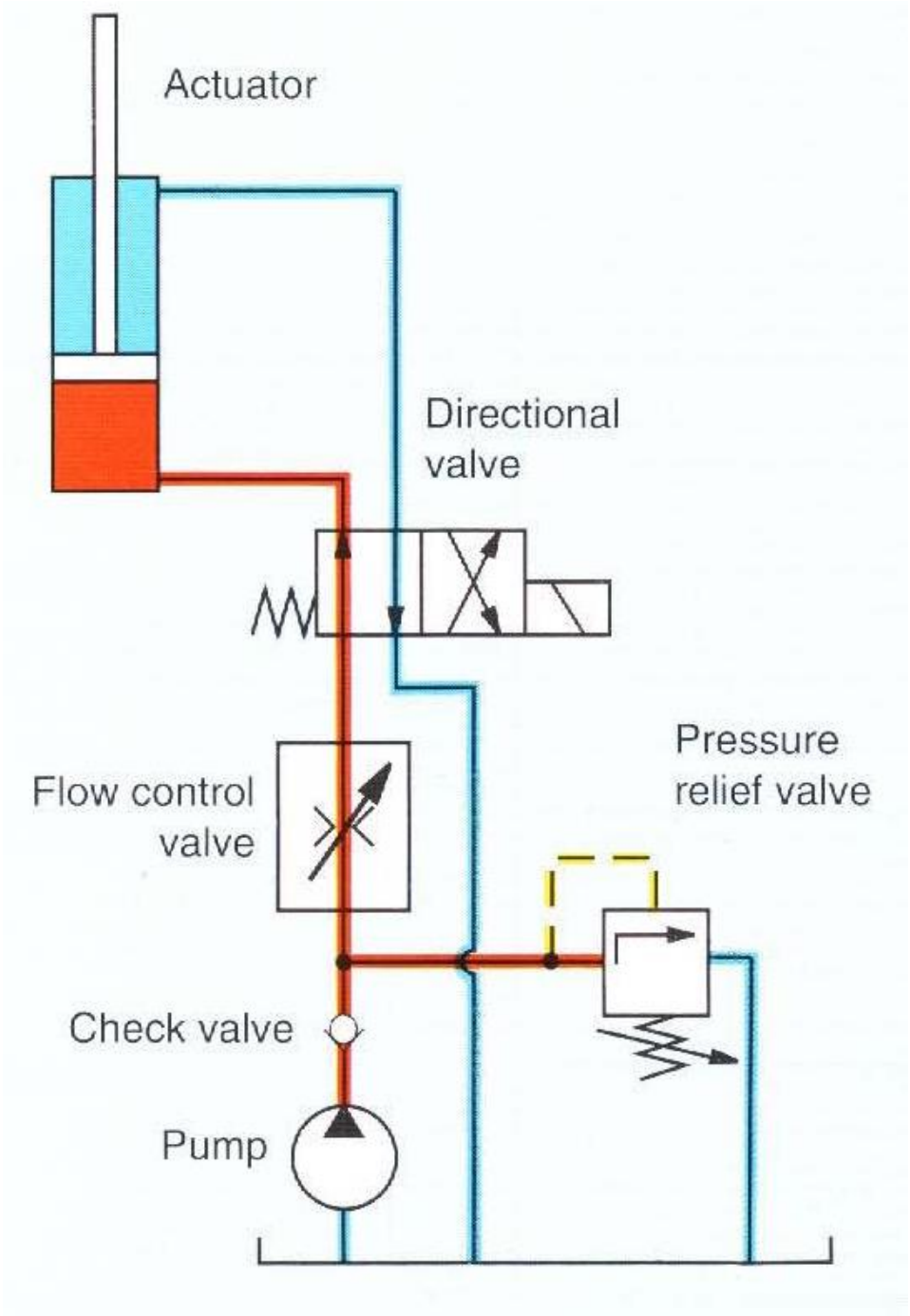
4- The hydraulic resistance of the system rises



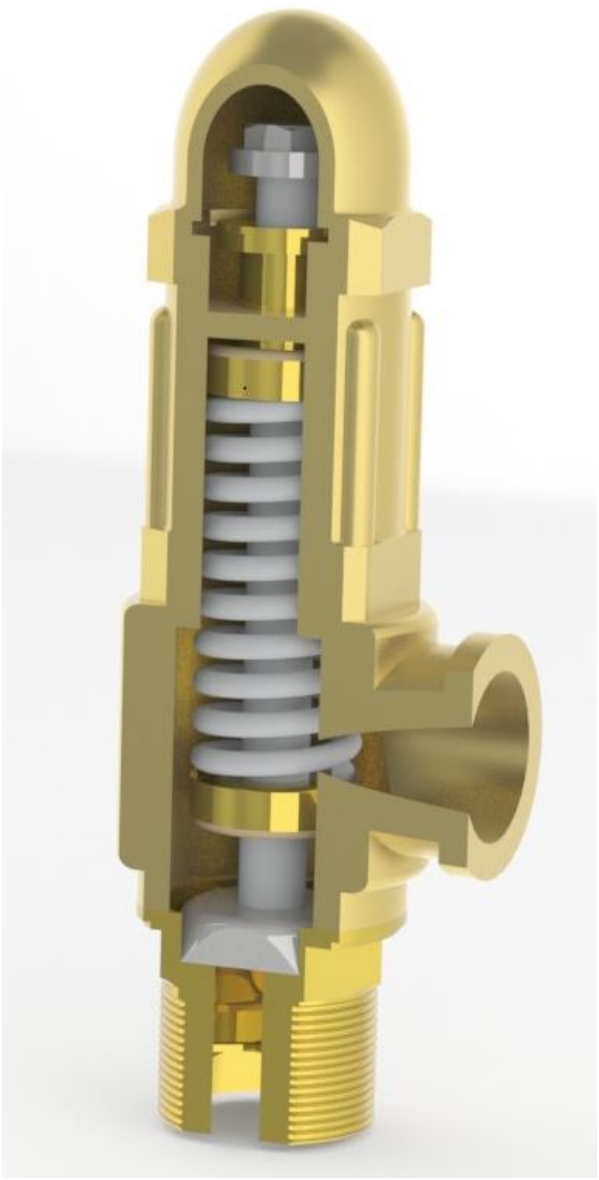
Pressure relief valve is the first component downstream from the pump.

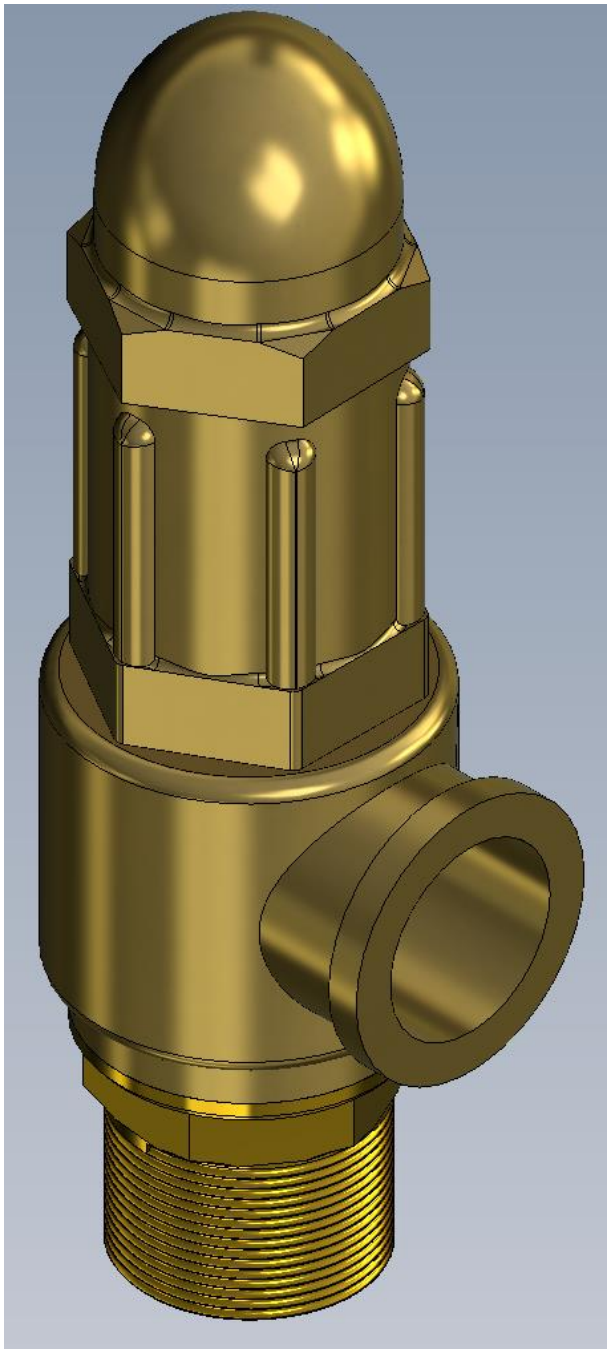


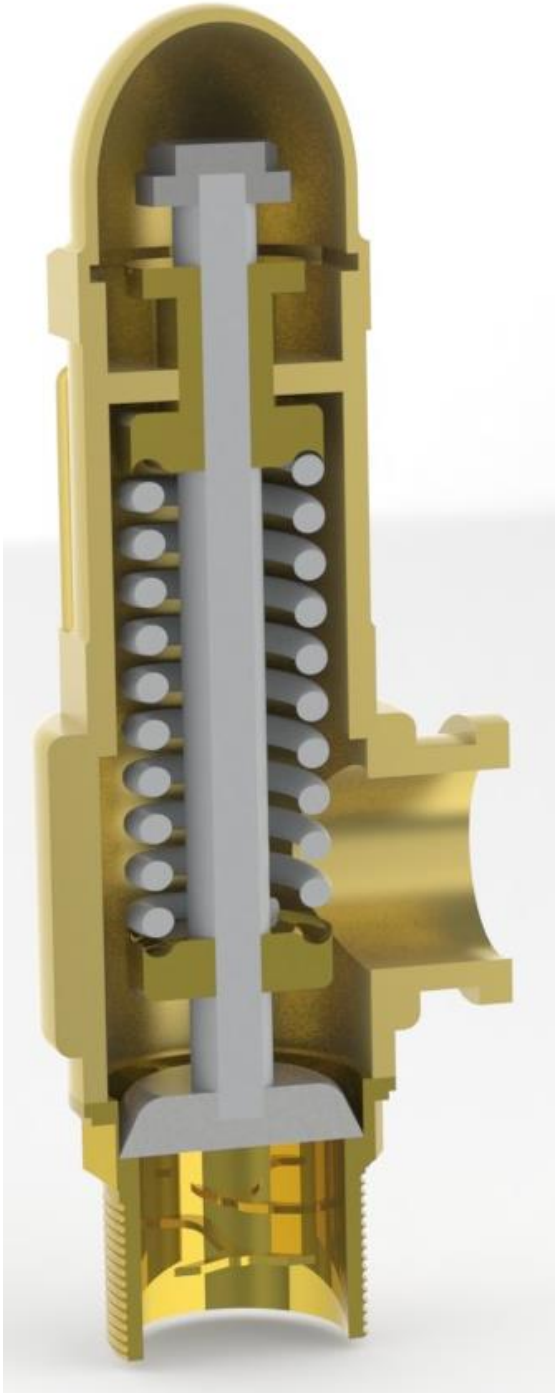
Complete Circuit



1- Direct Acting Relief Valve

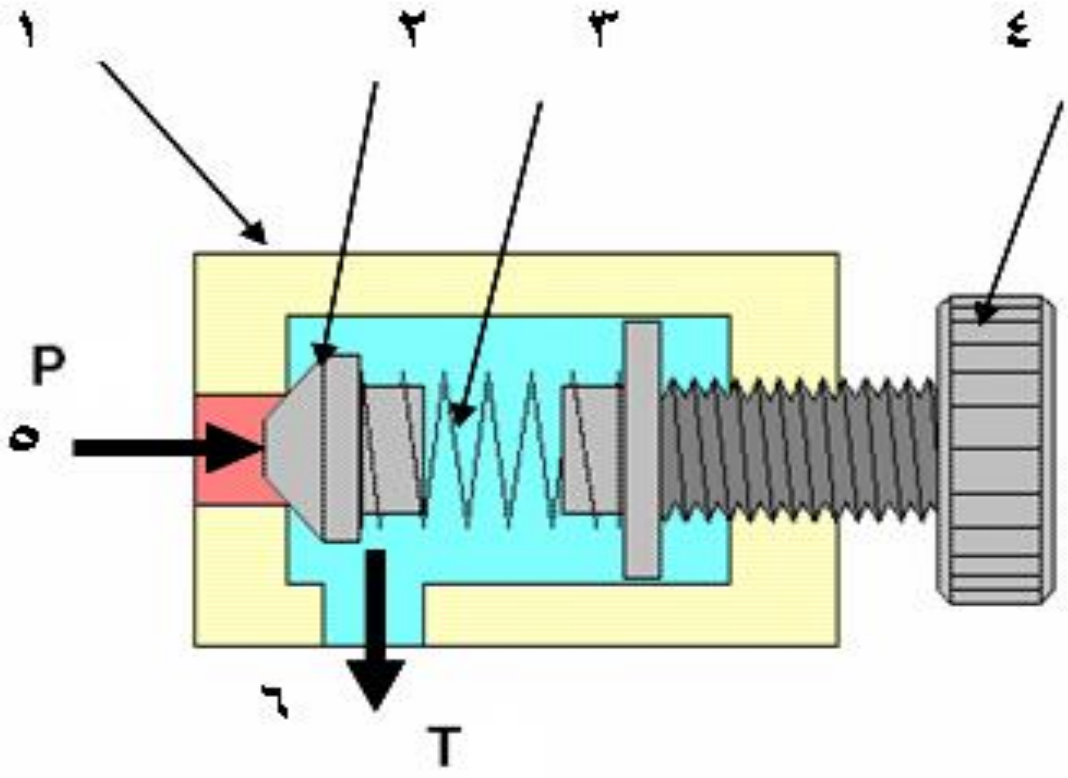






1- Direct Acting Relief Valve

(A) The composition of the LED(PRV)

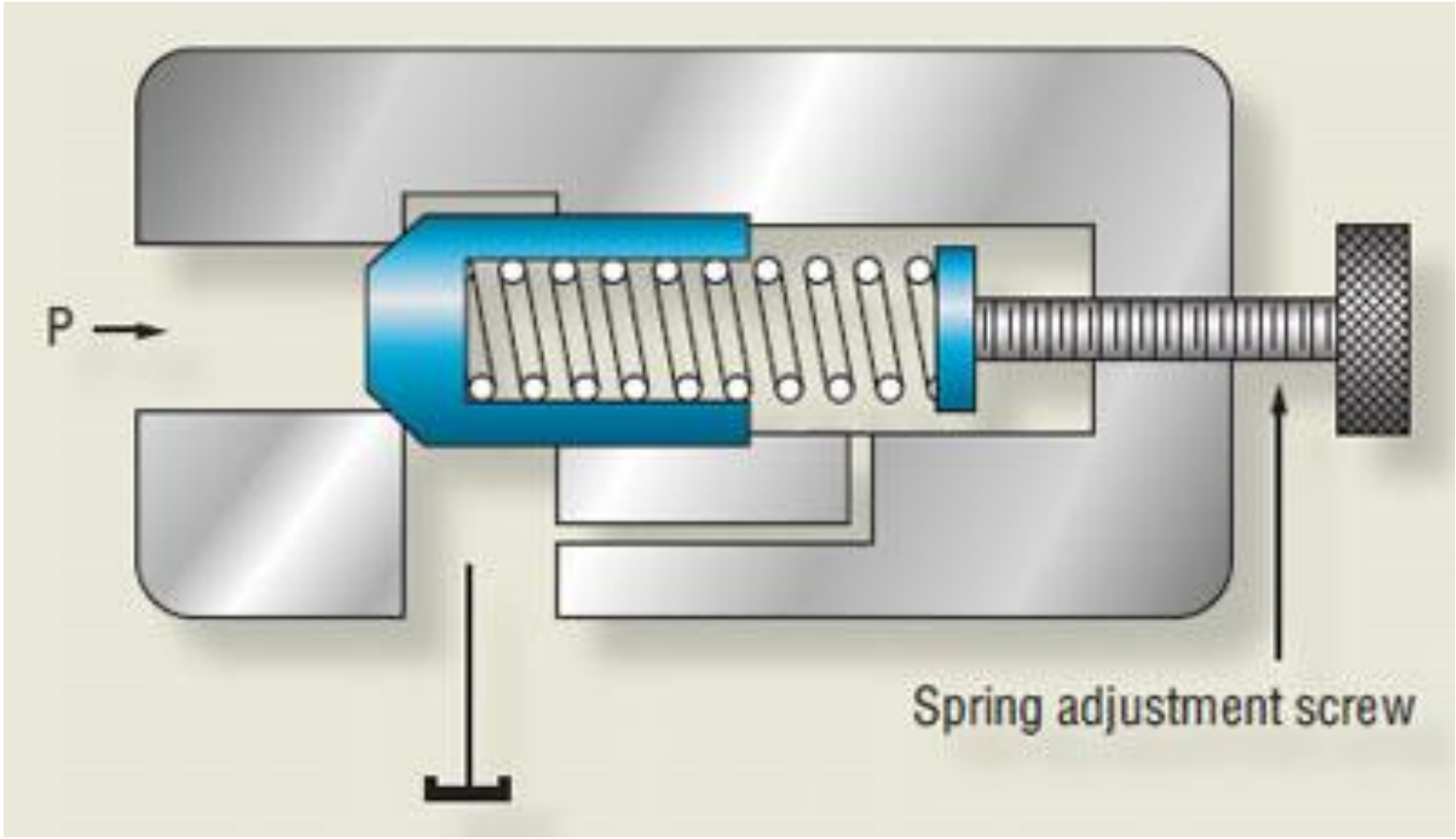


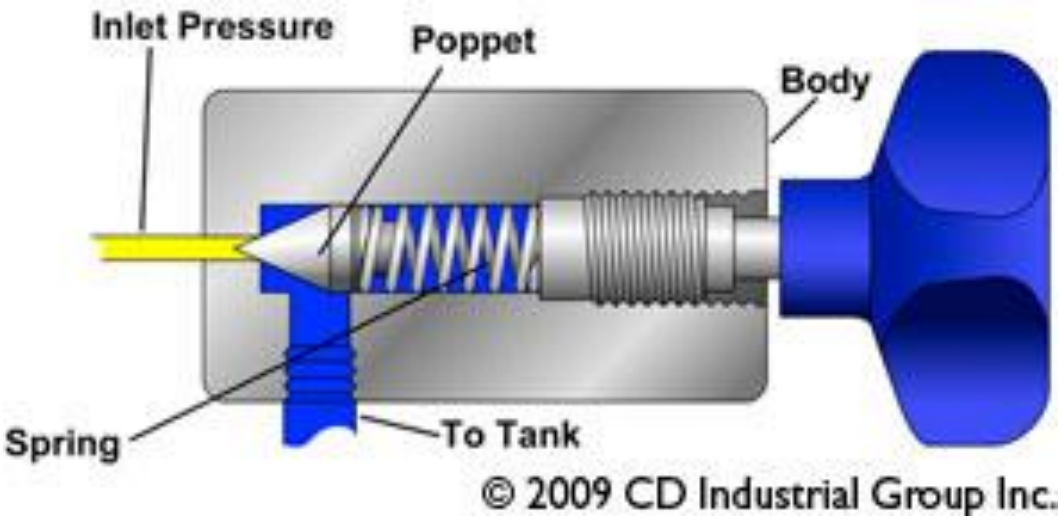
Pressure relief valve

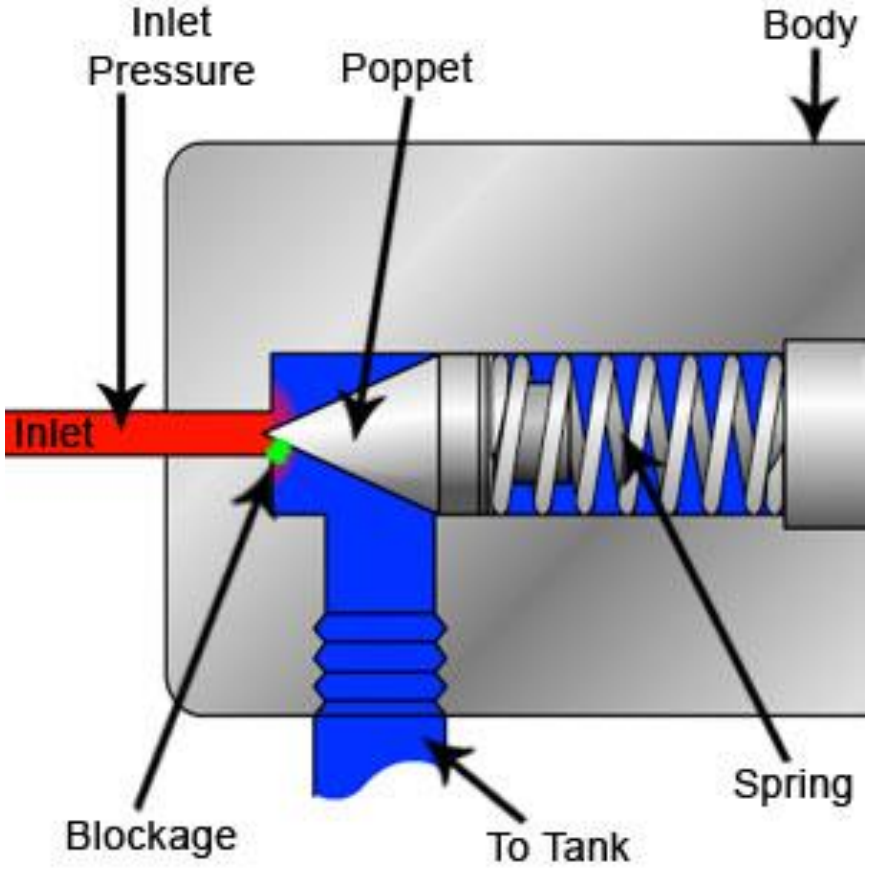
Pressure discharge valves are designed in the form of LED glove or slider,

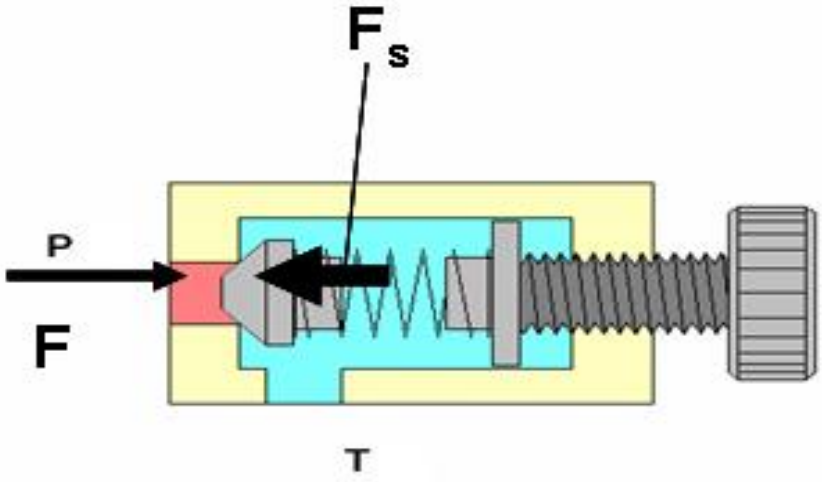
always be Alaay to lock piece presses

Slot to enter the liquid valve

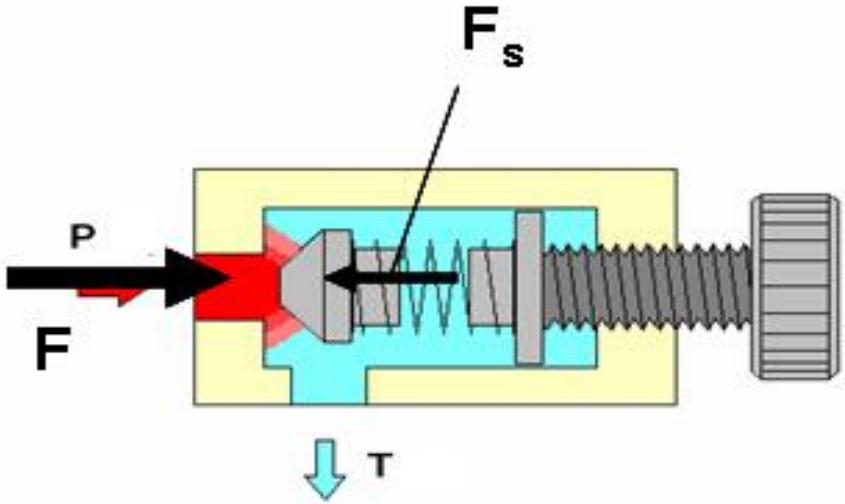

P
Spring adjustment screw



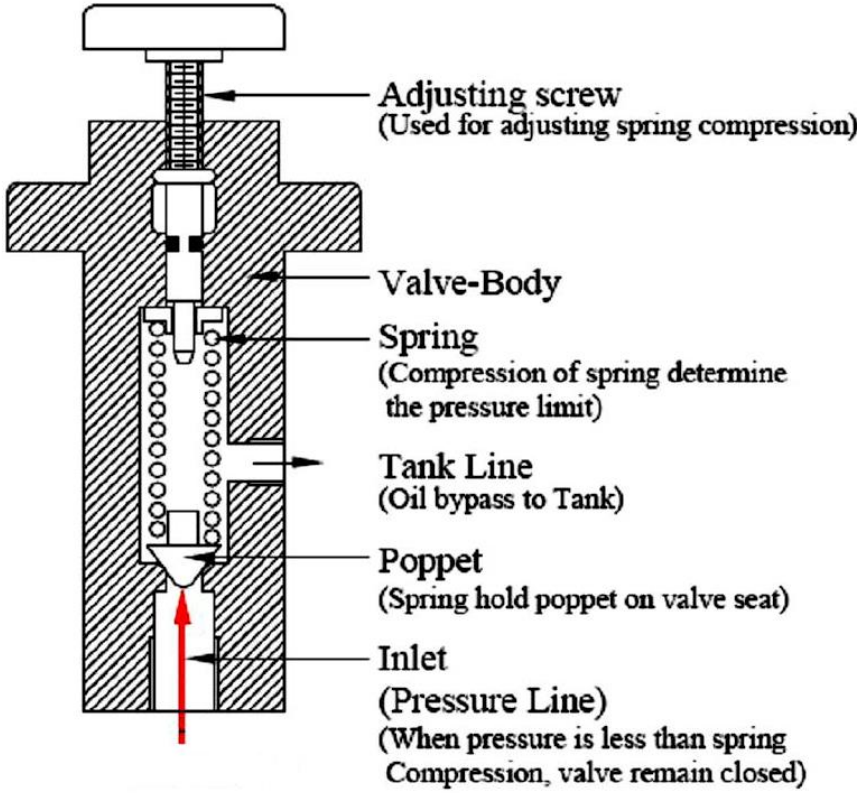




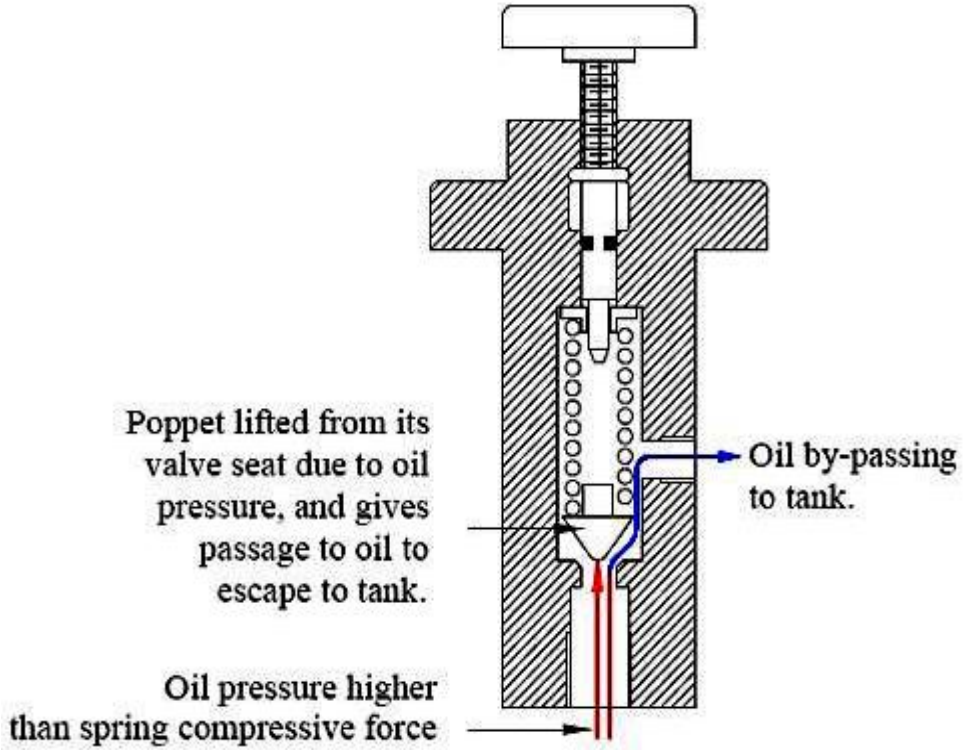
Pressure relief valve



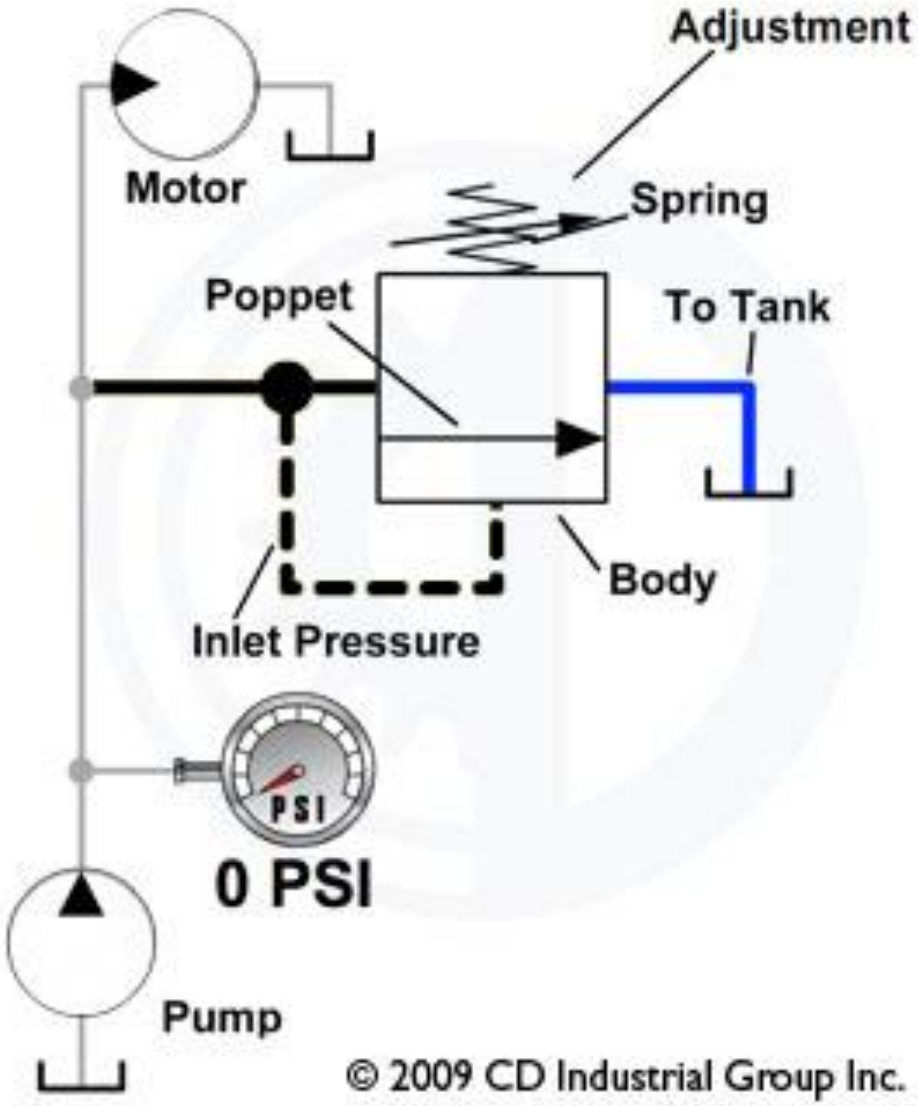
Pressure relief valve

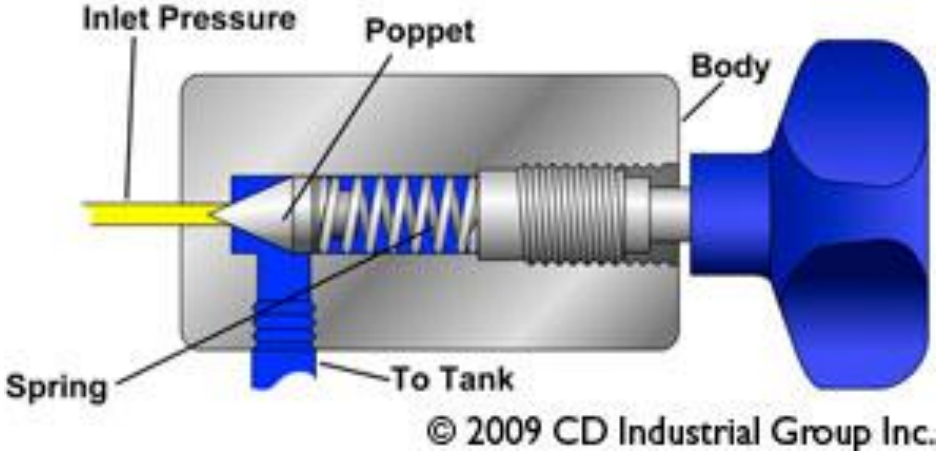


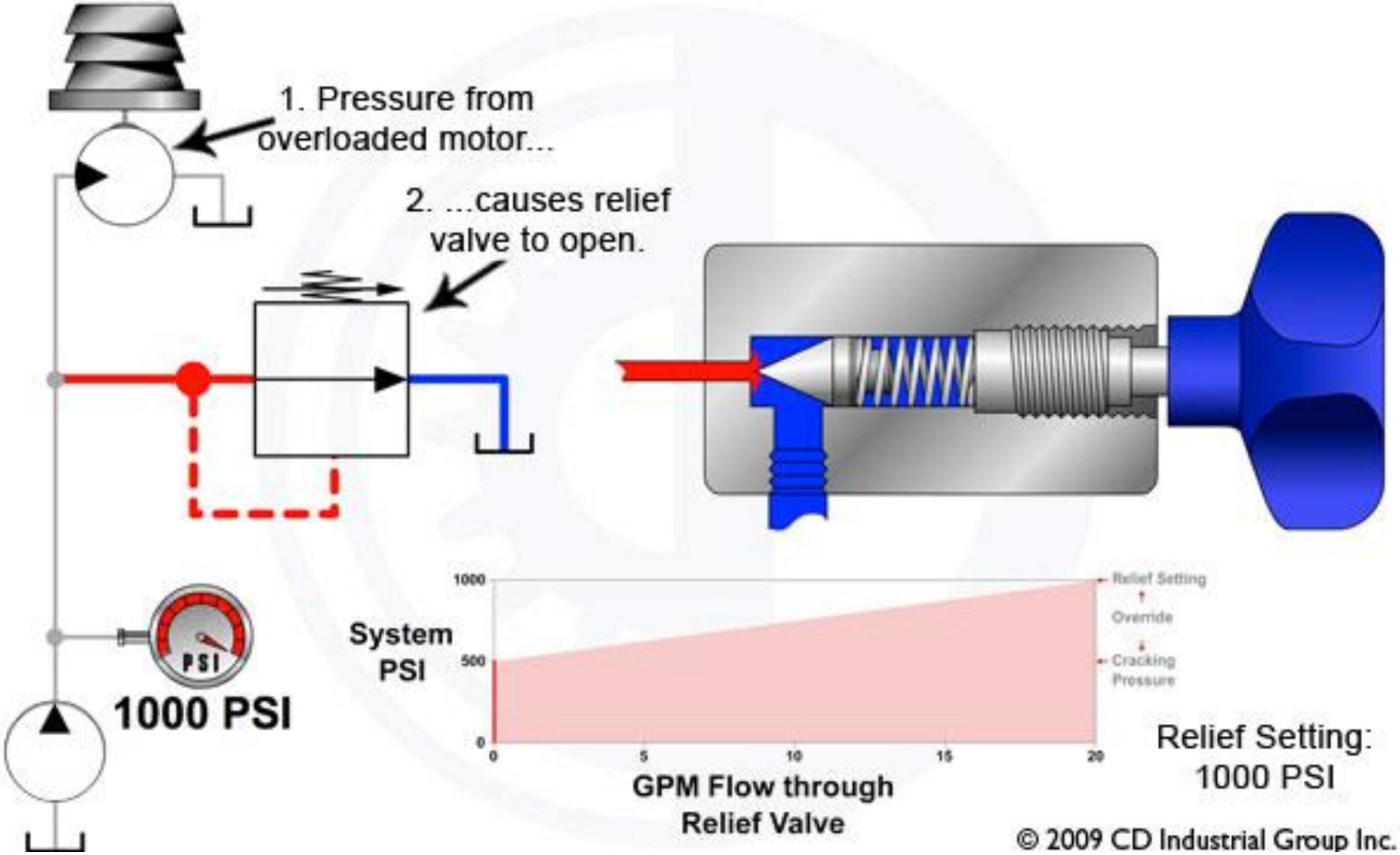
(a) Closed Relief Valve

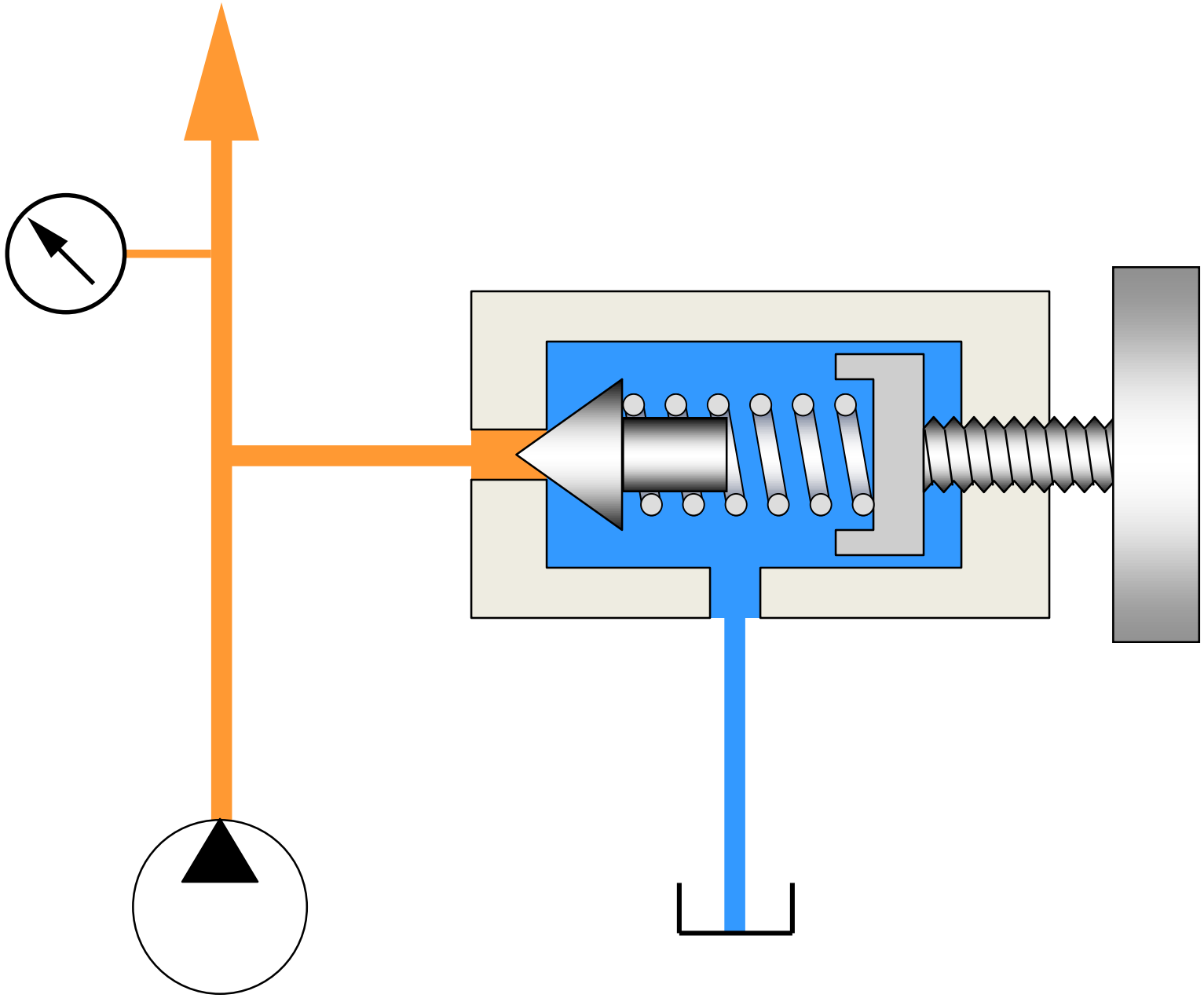


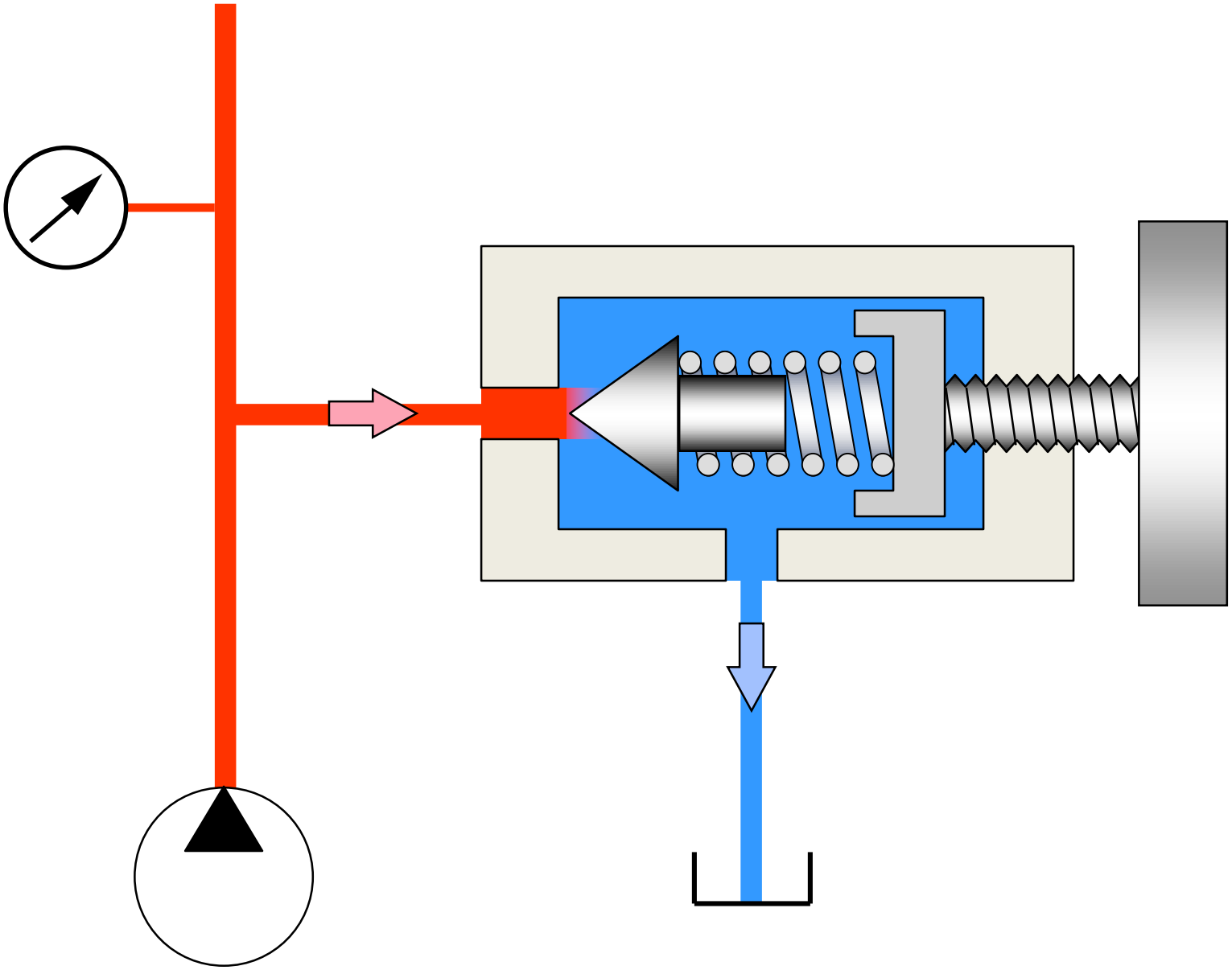
(b) Opened Relief Valve

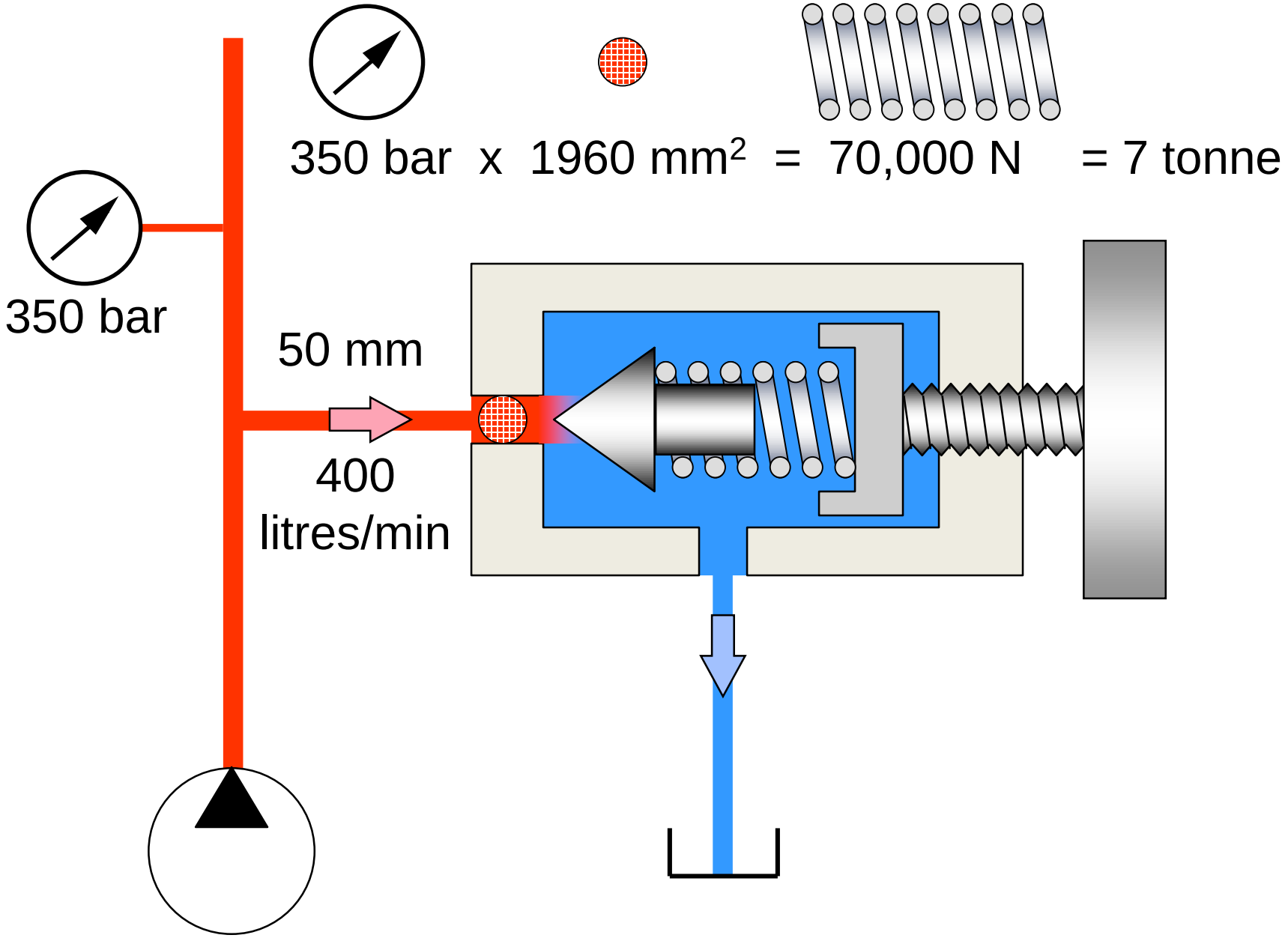

Adjustment
Motor
Spring
Poppet
To Tank
Body
Inlet Pressure
PSI
0 PSI
Pump
© 2009 CD Industrial Group Inc.


Inlet Pressure
Poppet
Body
Spring
To Tank
© 2009 CD Industrial Group Inc.








350 bar x 1960 mm² = 70,000 N = 7 tonne
350 bar
50 mm
400
litres/min

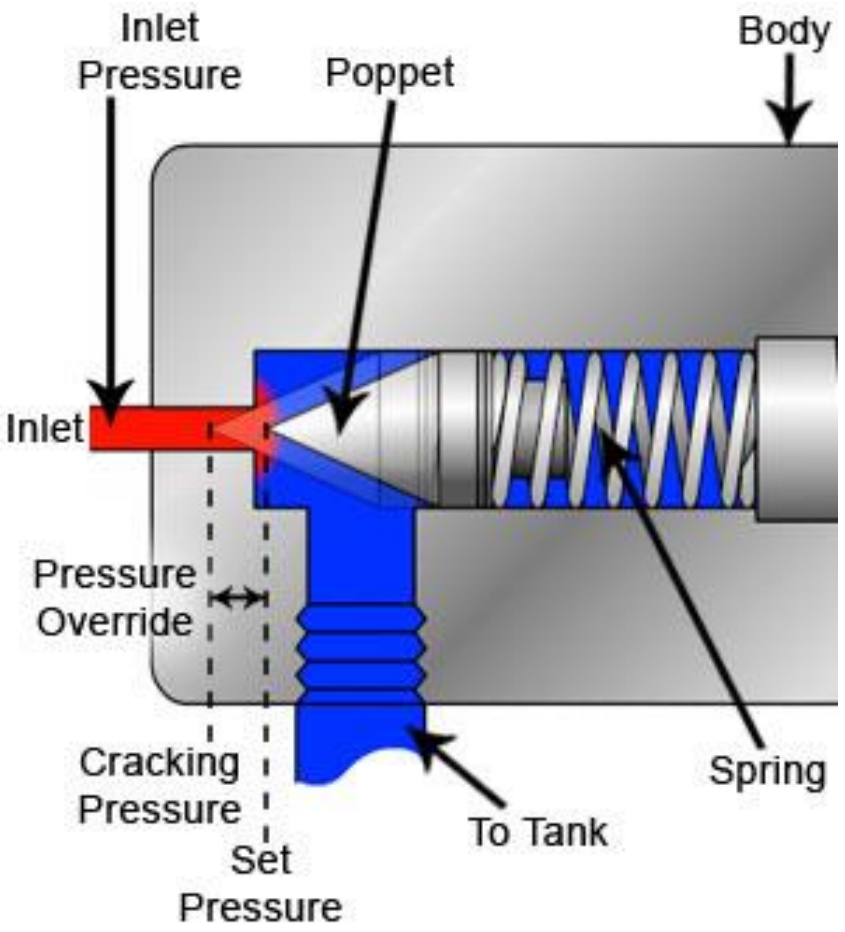
$$F_s = K.x_0$$

$$F_h = P.A_p$$

The two forces are equal when the pressure reaching the cracking pressure

$$P_{cr}.A_p = K.x_0$$

$$P_{cr} = \frac{K}{A_p}.x_0$$

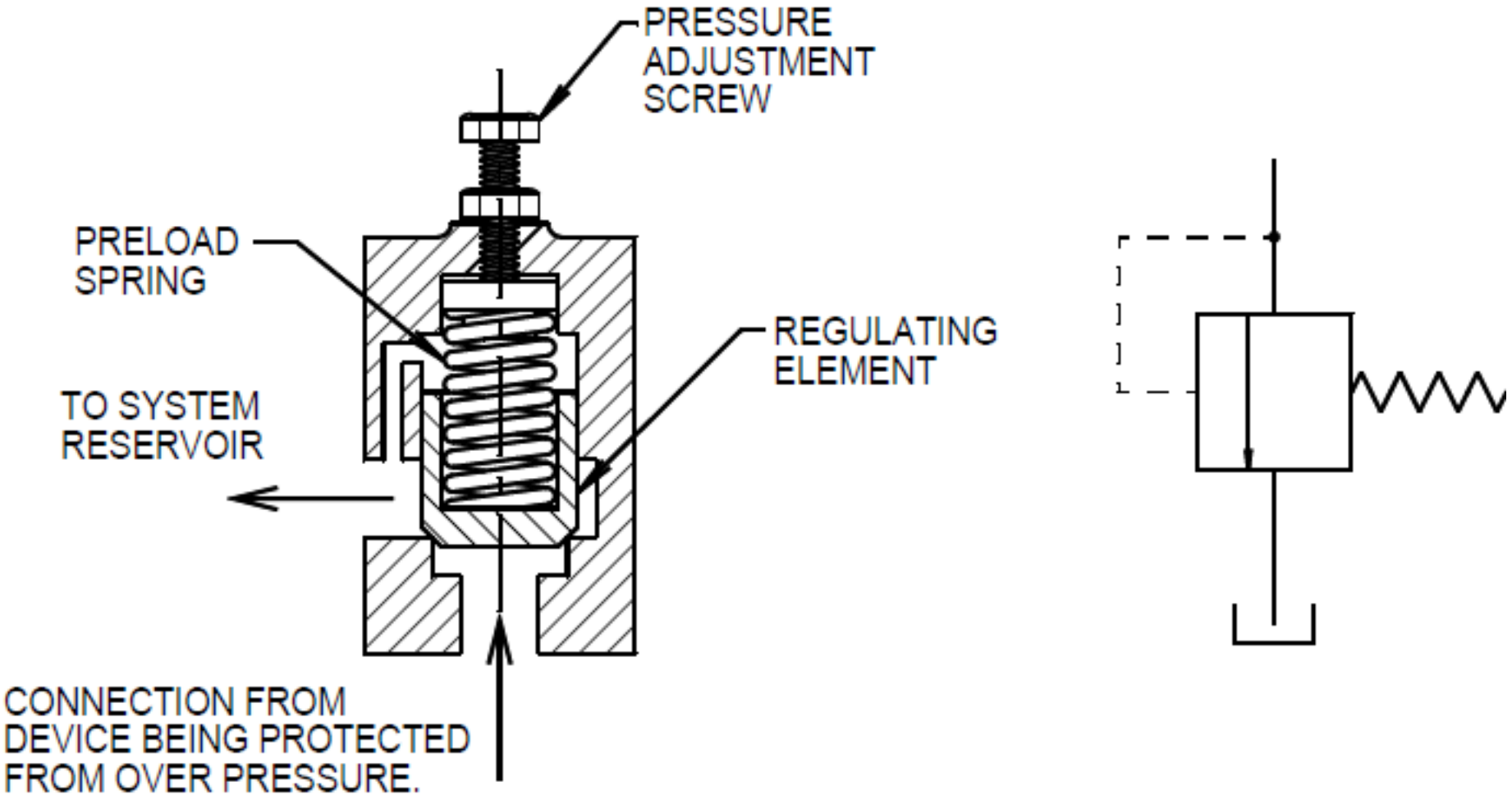


$K = \text{Spring stiffness}, N/m$

$x_0 = \text{Spring pre-compression distance, m}$

$P_{cr} = \text{Cracking Pressure}, Pa$

$A_p = \text{Poppet Area subjected to pressure}$



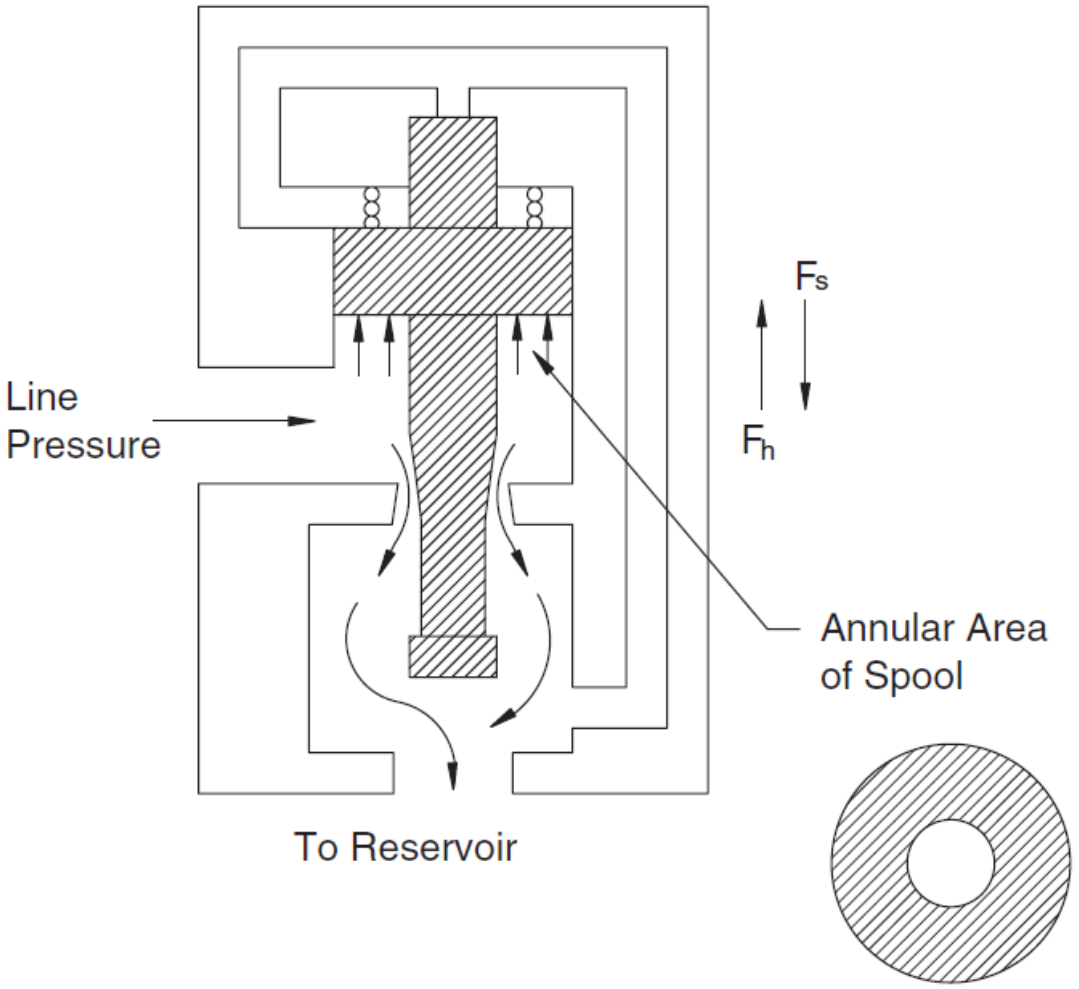
POSSIBLE PHYSICAL
GEOMETRY

CONVENTIONAL
SYMBOL

Pressure acts on the annular area of the valve spool. The hydraulic force is given by

$$F_h = P.A_a$$

A_a = Annulus Area

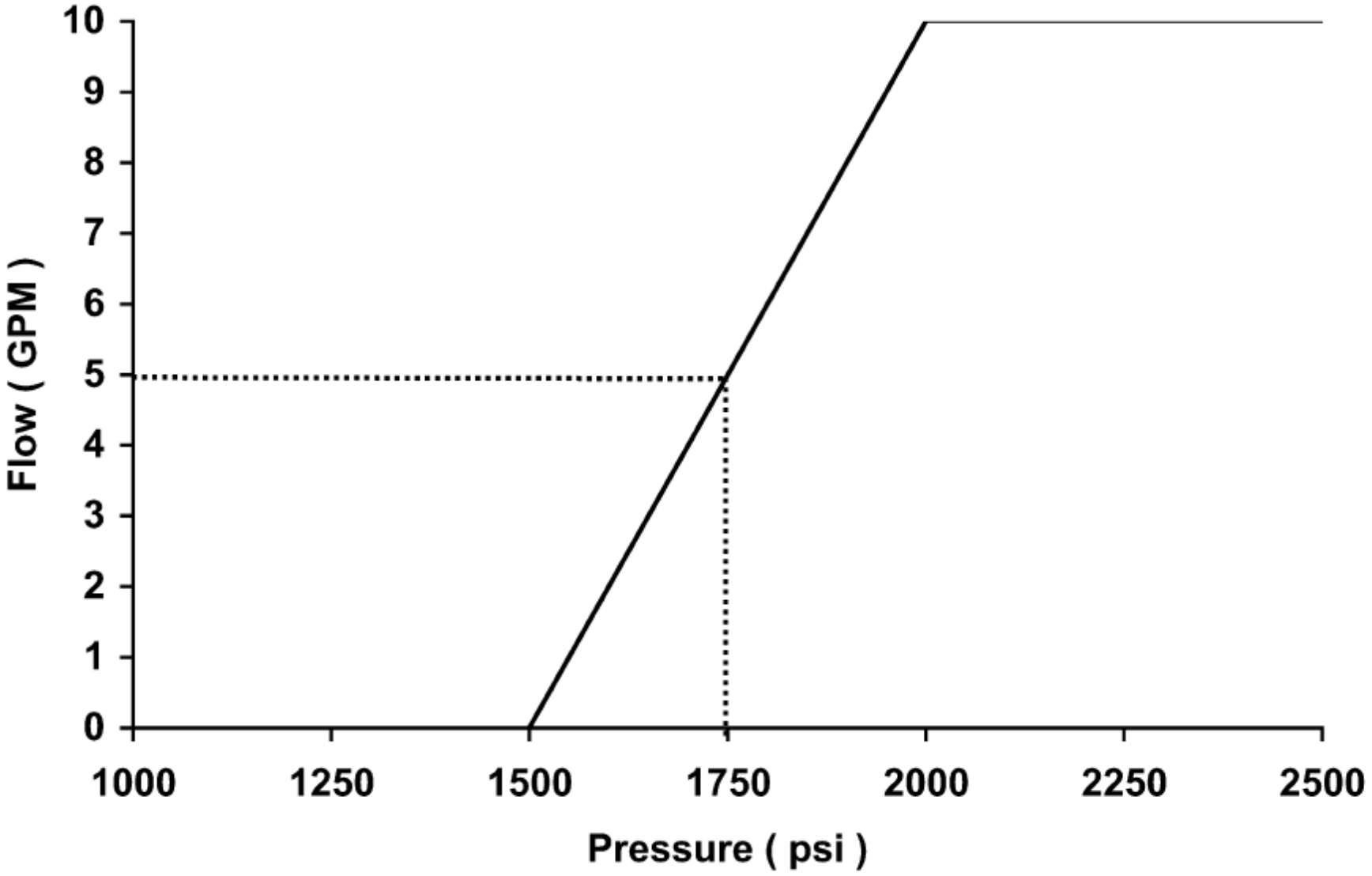


1- When F_h equals F_s, the valve remain closed.

2- When pressure increases, the spool lifts higher, allowing more flow to bypass to the reservoir.

3- At some pressure level, the total flow bypasses to the reservoir.

Direct Relief Valve Performance



Typical flow vs. pressure curve for a direct-acting relief valve.

1- The valve is set to open at 1500 psi. This pressure is known as the

cracking pressure.

2-When pressure reaches 2000 psi, the valve is fully open, and all flow is bypassed to the reservoir; no flow goes to the remainder of the circuit.

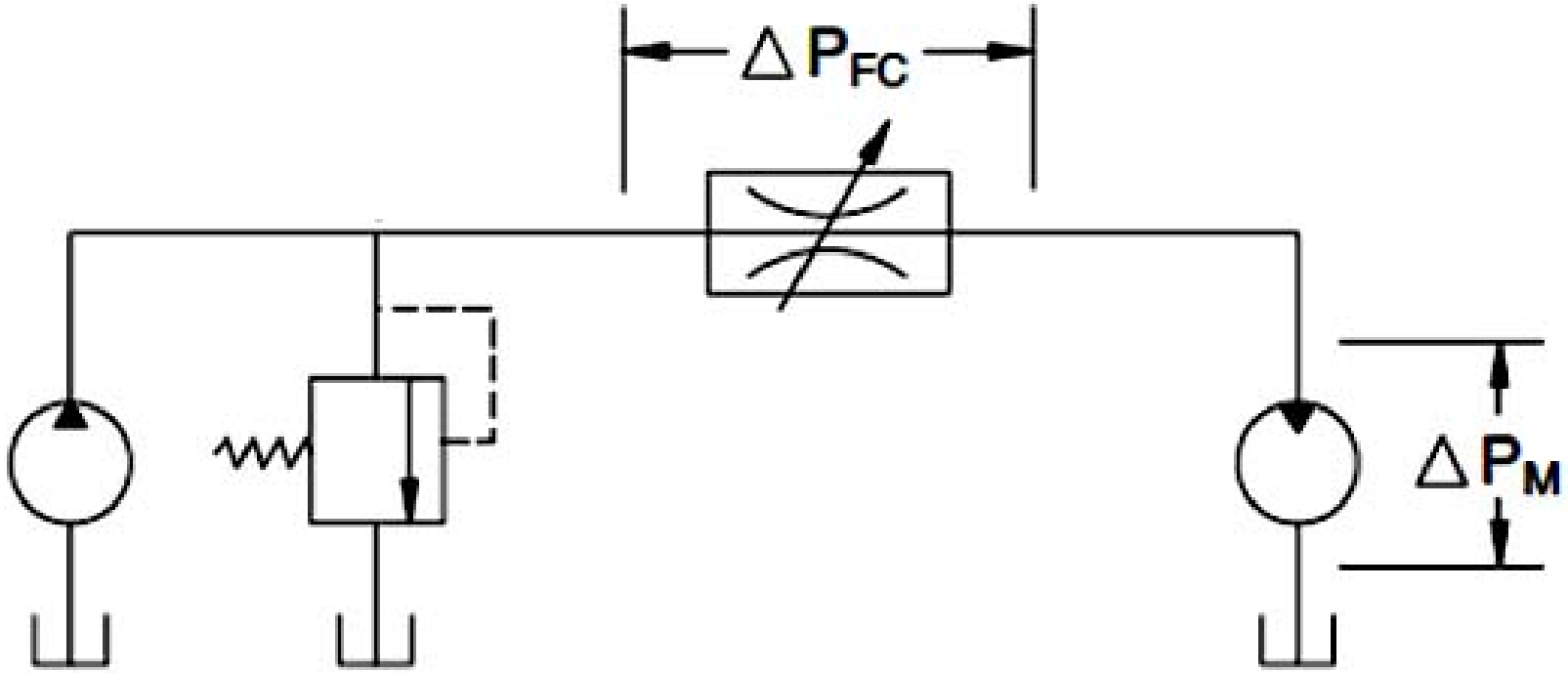
3- The 500 psi differential between cracking and full bypass is needed for a direct-acting valve when it has a functional role in flow control in addition to its pressure limiting function.

4- This differential between cracking and full bypass is called

override pressure.

Override Pressure = 2000 – 1500 = 500 Psi

Circuit in which motor speed is controlled with a flow control valve

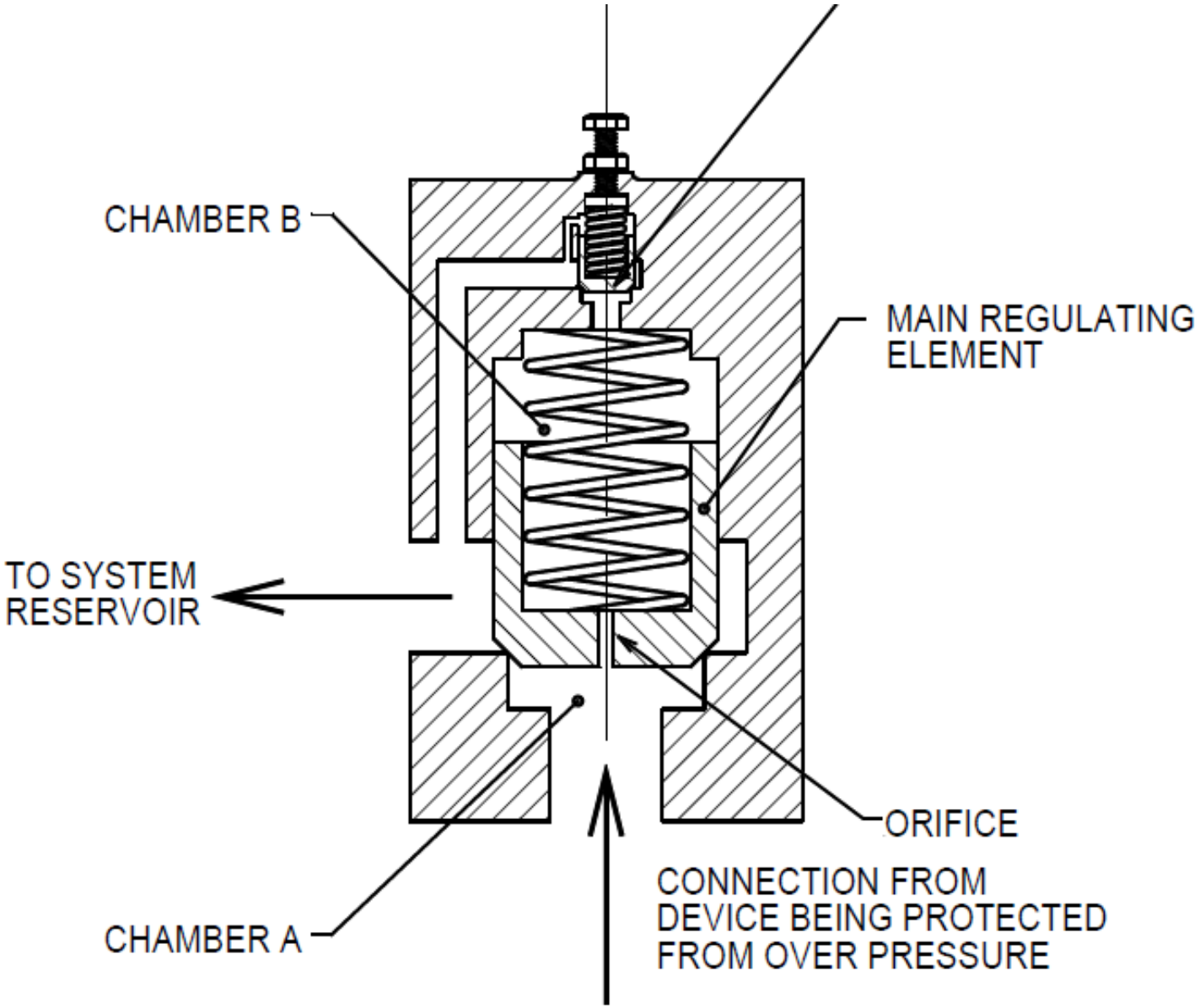


1- Pressure at the relief valve is the sum of the pressure drop across the flow control valve plus the pressure drop across the motor.

2- To slow the motor, the flow control valve is closed to create enough pressure at the relief valve to cause it to crack open.

3- Part of the pump output now bypasses to the reservoir; thus, flow to the motor is reduced, and the speed decreases.

2- Pilot-Operated Relief Valve



• The pilot element can be quite small because this pilot is only required to pass a small flow.

• During the normal closed condition of the valve, there is no flow through the orifice in the main regulating element, so there is no pressure difference across the main element. Thus the main element can be held in a closed position by a light spring.

• As the pressure in chamber A increases, the pressure downstream of the orifice matches this pressure until the pilot valve opens and there is flow to the system reservoir.

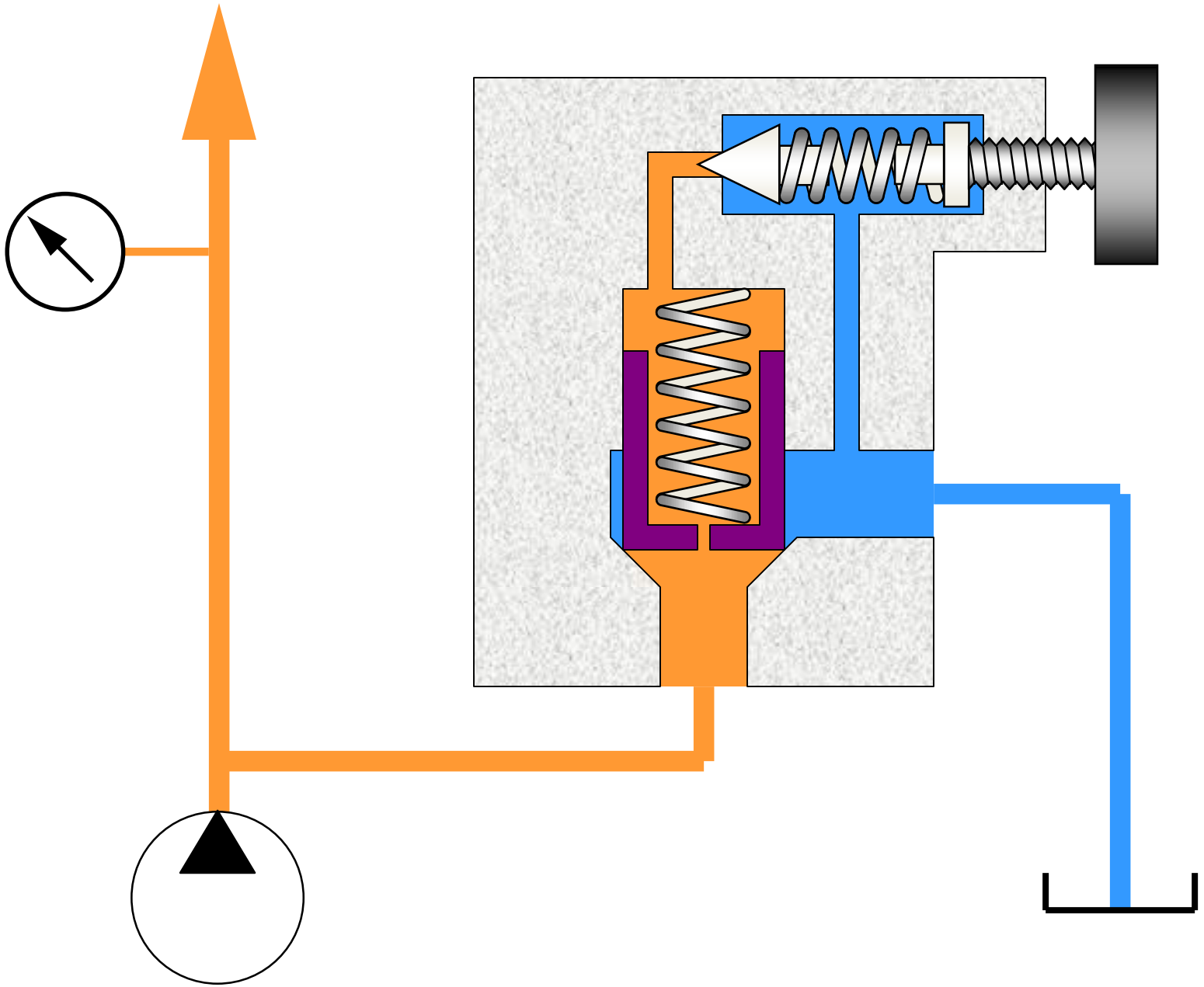
• Now that there is flow through the orifice in the main regulating element, a pressure difference will be developed across the orifice. As indicated earlier, the spring controlling the main regulating element is light, so only a small pressure difference is required to move the main regulating element into its open position.

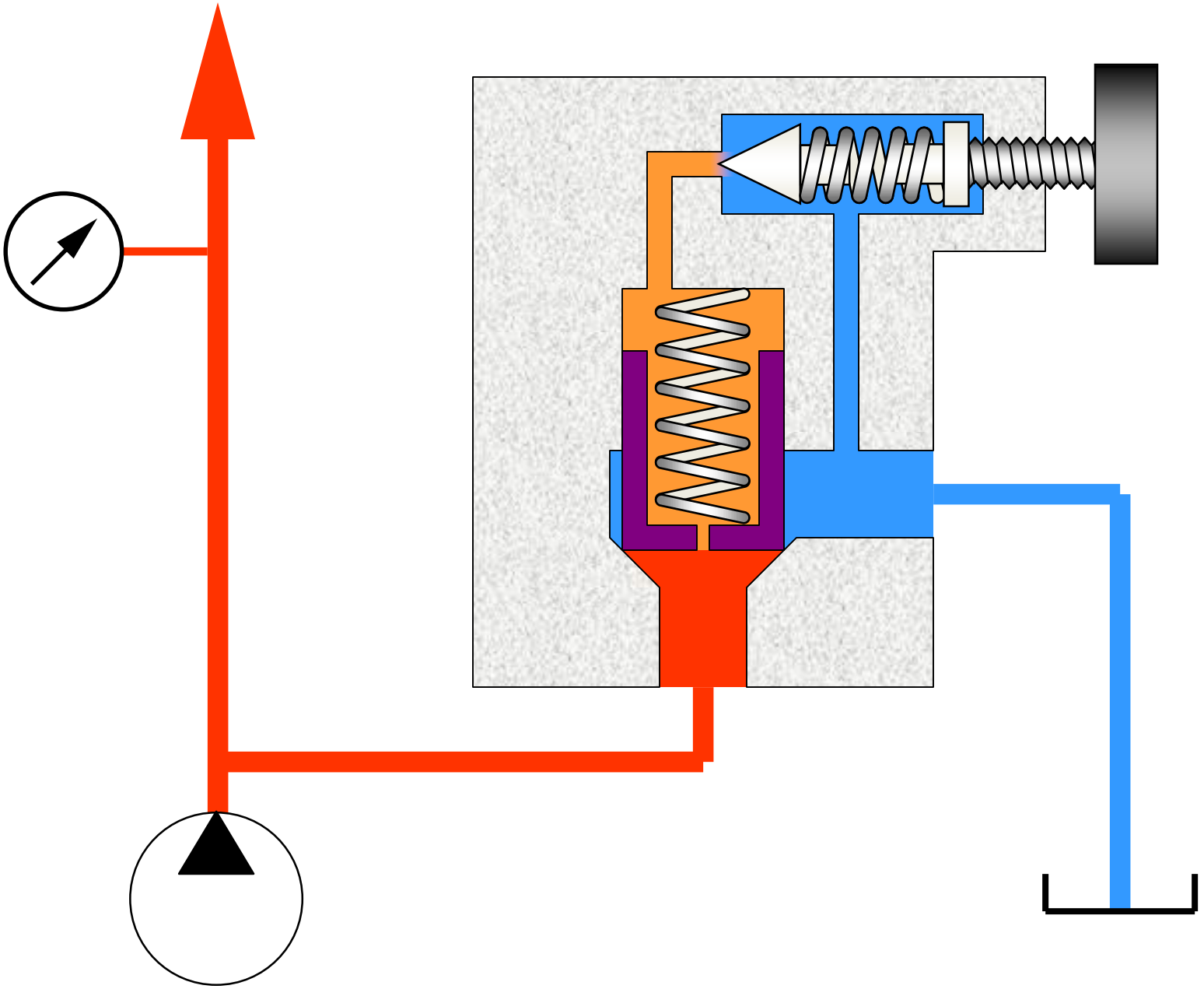
• With flow through the valve, there must be sufficient pressure in chamber B to keep the pilot valve open.

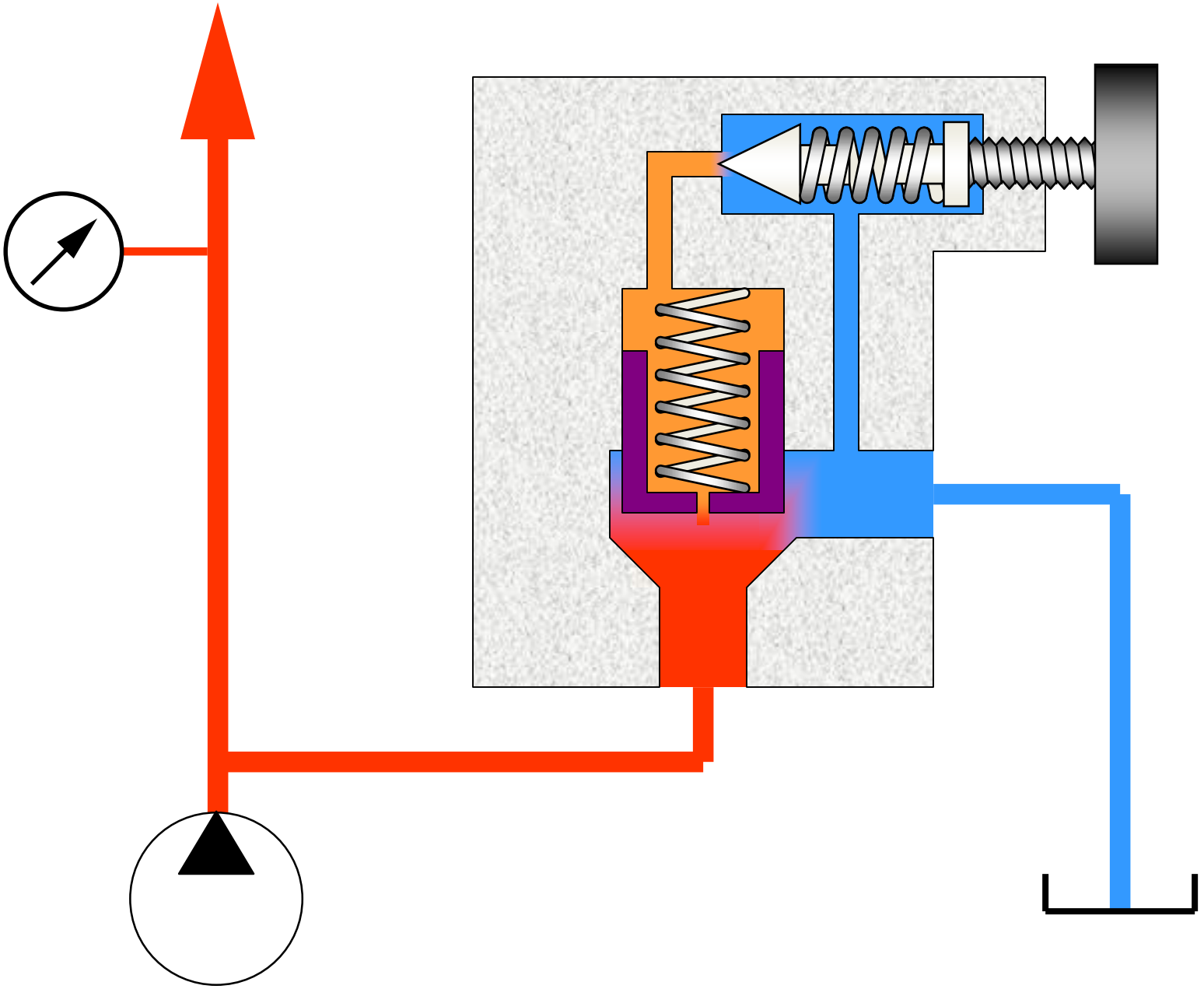
• Thus the pressure in chamber A must exceed the pressure in chamber B by a small amount. The amount being the pressure drop across the orifice in the main regulating element.

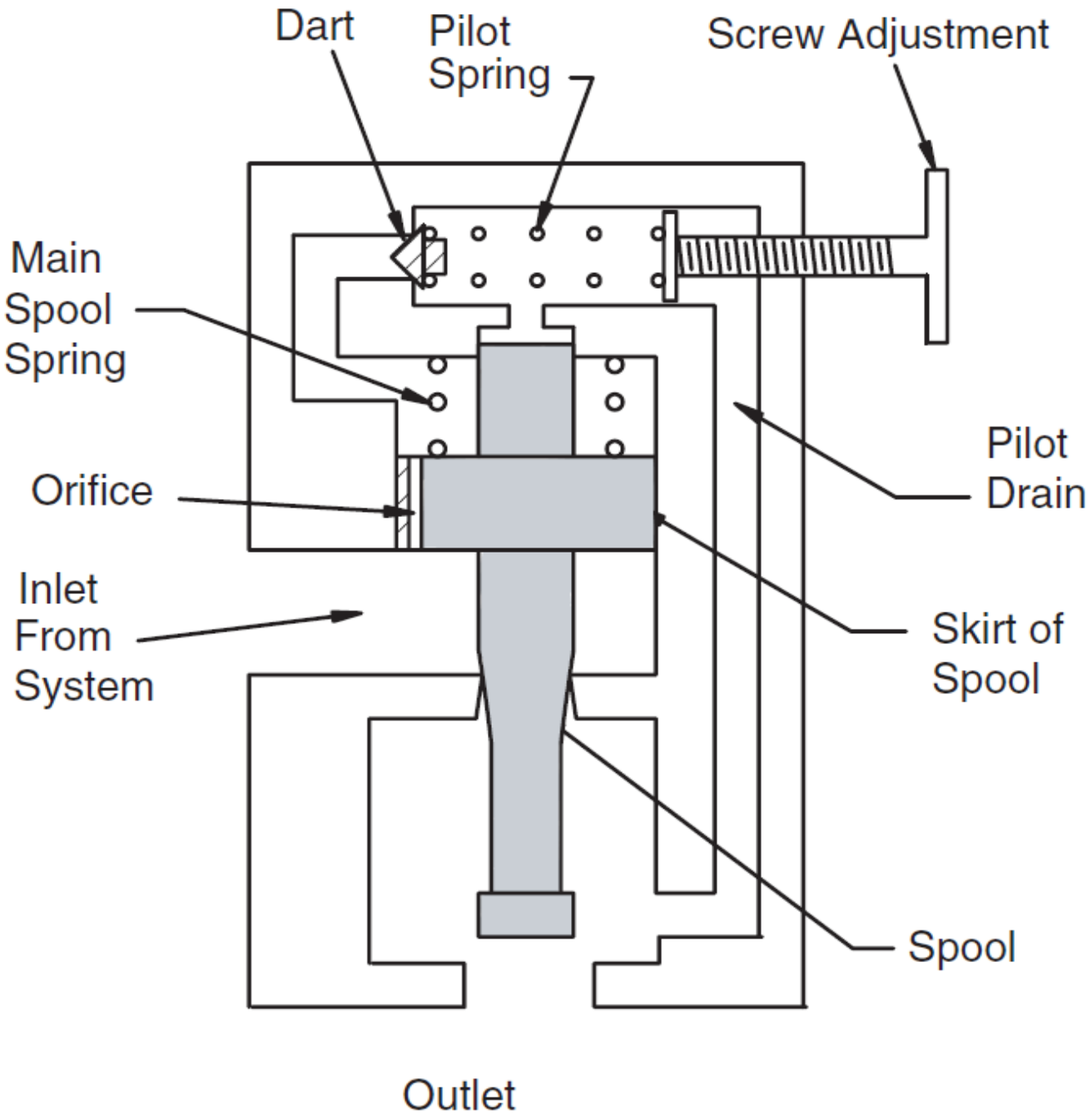
• Because the main element is controlled by a light spring, the operating pressure is only a small amount above the pressure at which the pilot valve cracked.

• Consequently the pressure required to open a pilot operated valve is much less dependent on the flow through the valve than is the situation with a direct acting valve.

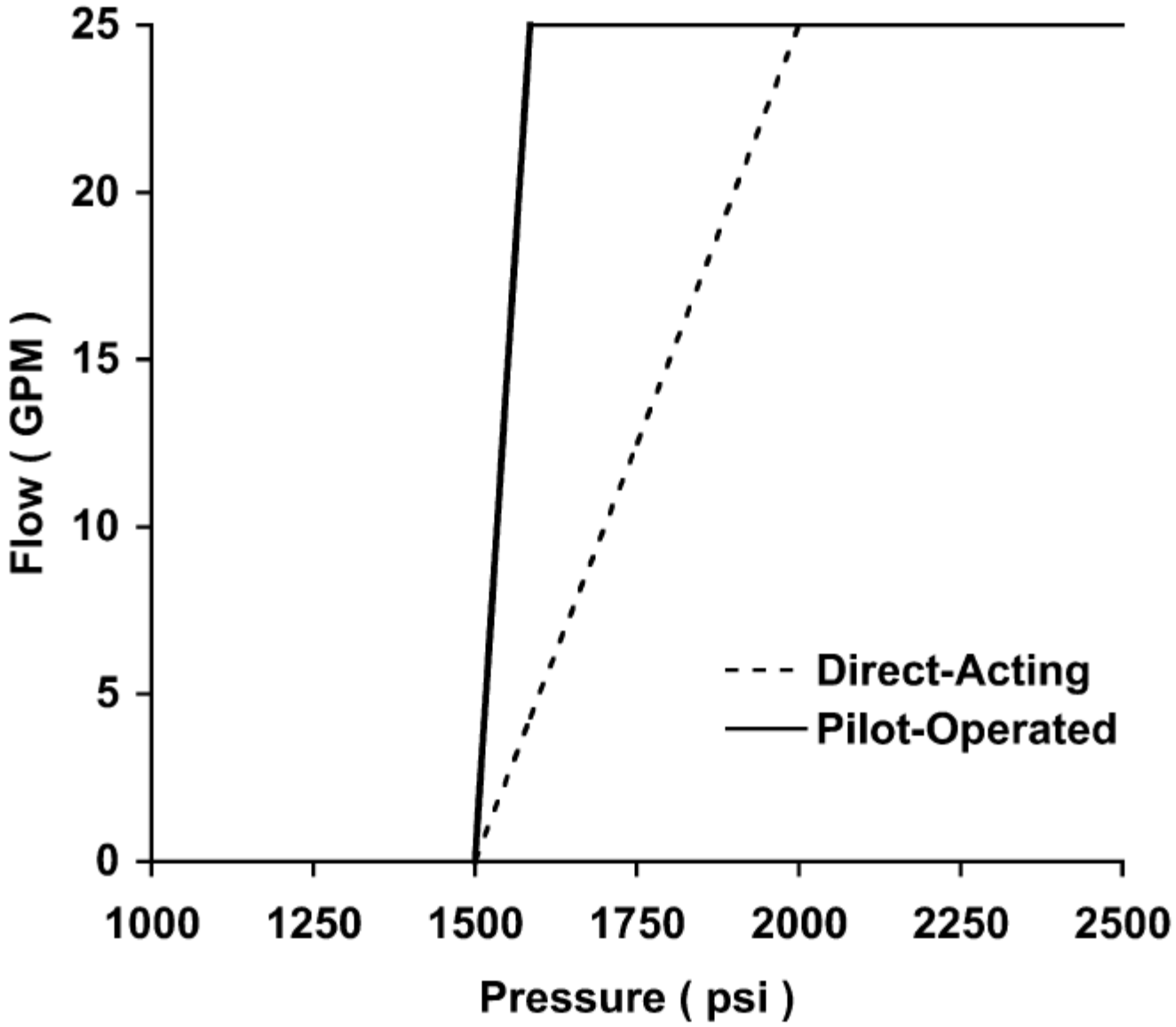







Dart
Pilot Spring
Screw Adjustment
Main Spool Spring
Orifice
Pilot Drain
Inlet From System
Skirt of Spool
Spool
Outlet

Comparison of performance curves for direct-acting and pilot-operated relief valves.



1- A pilot-operated relief valve has the same function as a direct-acting relief valve; however, it has a different pressure vs. flow curve.

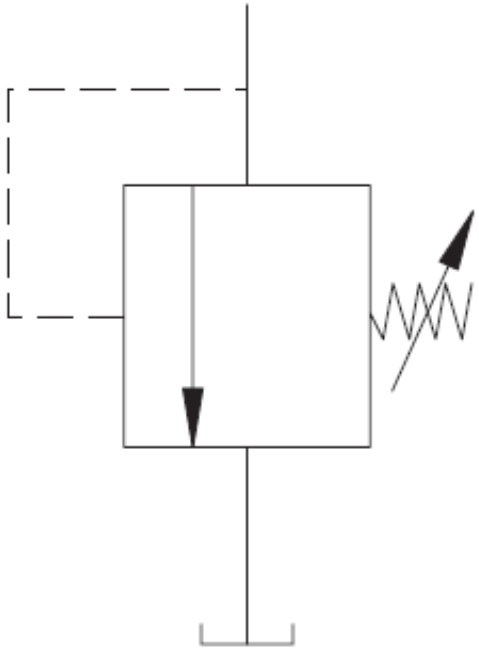
2- The pilot-operated valve opens completely over a narrow pressure range.

3- This allows the circuit to operate over a wider pressure range without loss of fluid over the relief valve.

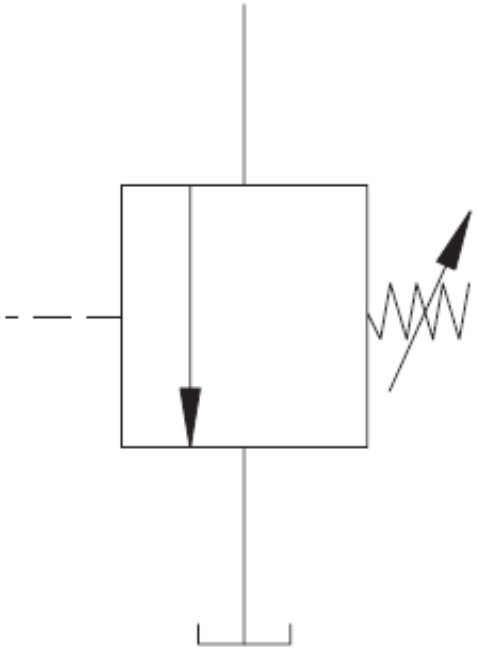
The key advantage of a pilot-operated valve is that it allows the designer to use pressure to within 100 psi of the valve setting to meet the functional objective of the circuit. In comparison, the direct-acting valve cracks open at 1500 psi, and pressure must increase to 2000 psi before it is fully open.

2- Unloading Valve

The symbol for an unloading valve is similar to the symbol for a relief valve except that the pilot line is not connected to sense pressure at the valve inlet.



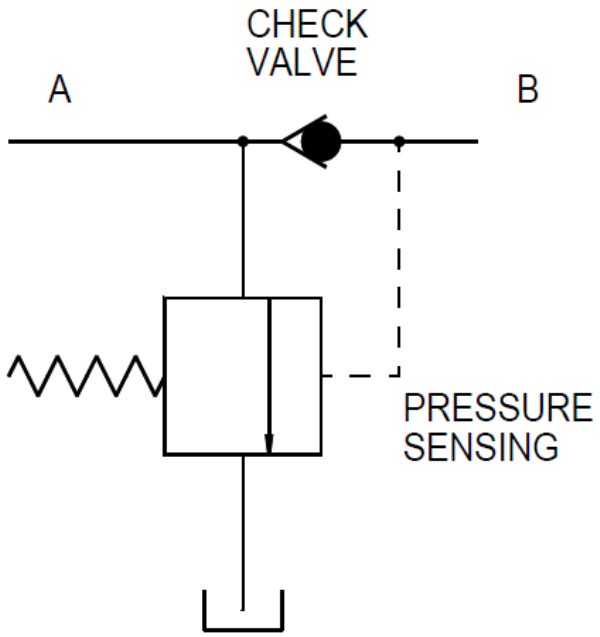
Relief Valve

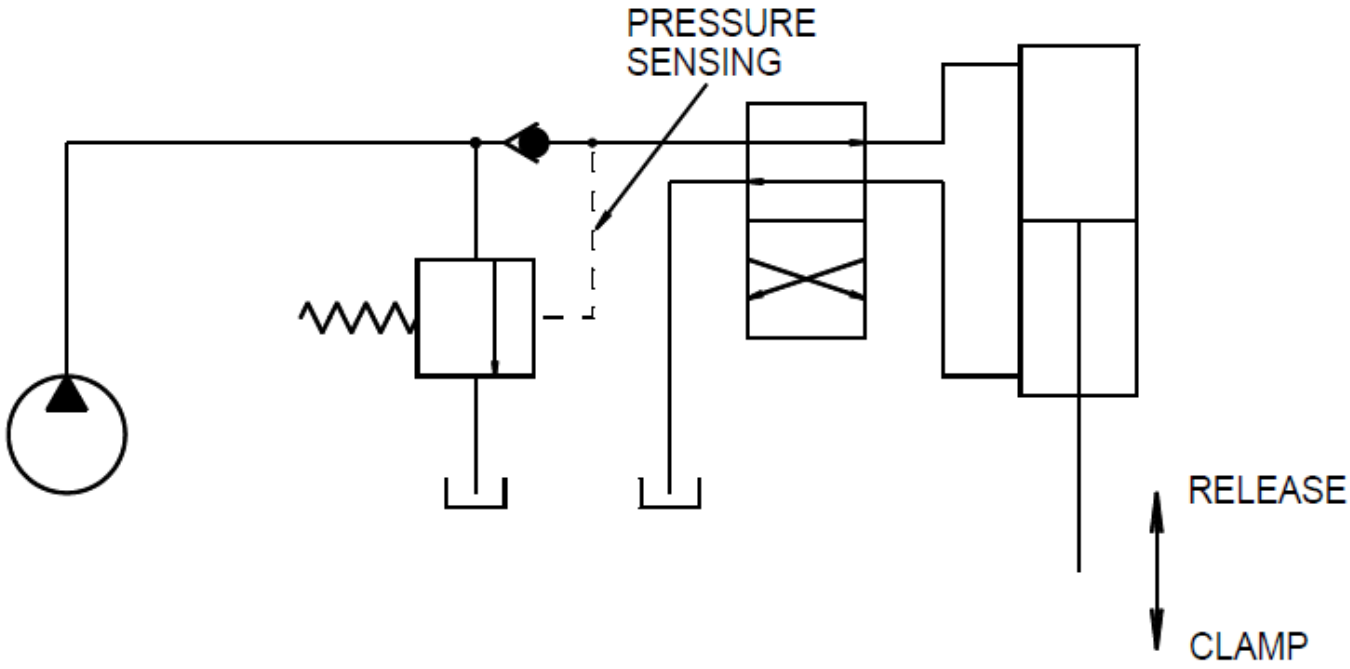


Unloading Valve

Function of Unloading Valve

The flow from the pump enters at port A and passes through the check valve to the actuator connected at port B.

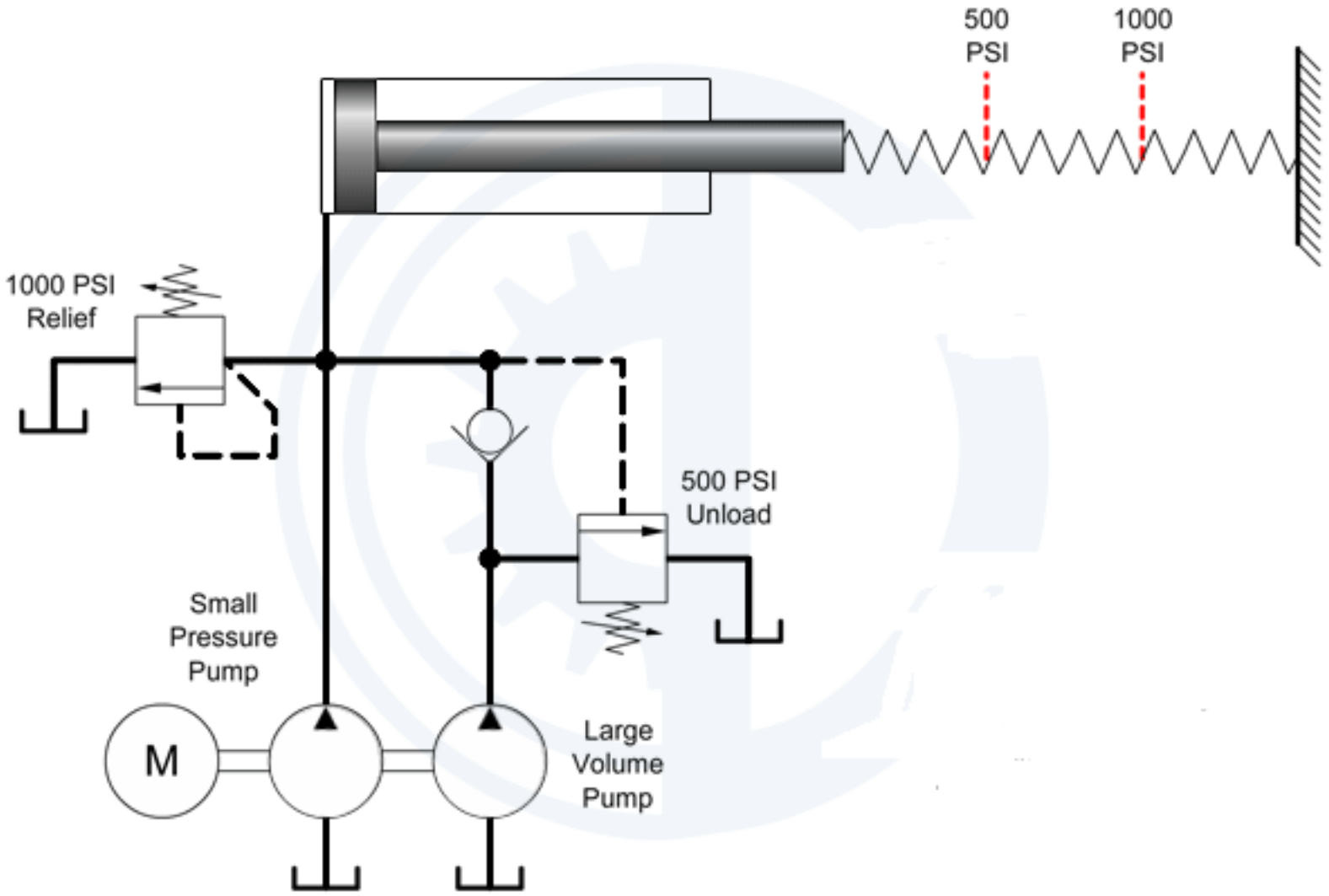




The desired function of such a circuit would be to actuate the cylinder until the item is held and the pressure in the system rises to some value considered adequate for the clamping force. At this juncture, no work is being done by the cylinder, so ideally no power should be delivered to the pump supplying the cylinder. The desired pressure is sensed by the feedback line downstream of the check valve (port B).

The unloading valve now opens and flow from the pump can pass through the valve to the reservoir across a low pressure.

Circuit Using Unloading Valve



The circuit is sometimes referred to as a fast approach, slow-feed circuit.

1- The valve is put to good use in a system where a large flow volume is needed at a lower pressure, and then later, a very low flow volume is required with a higher pressure.

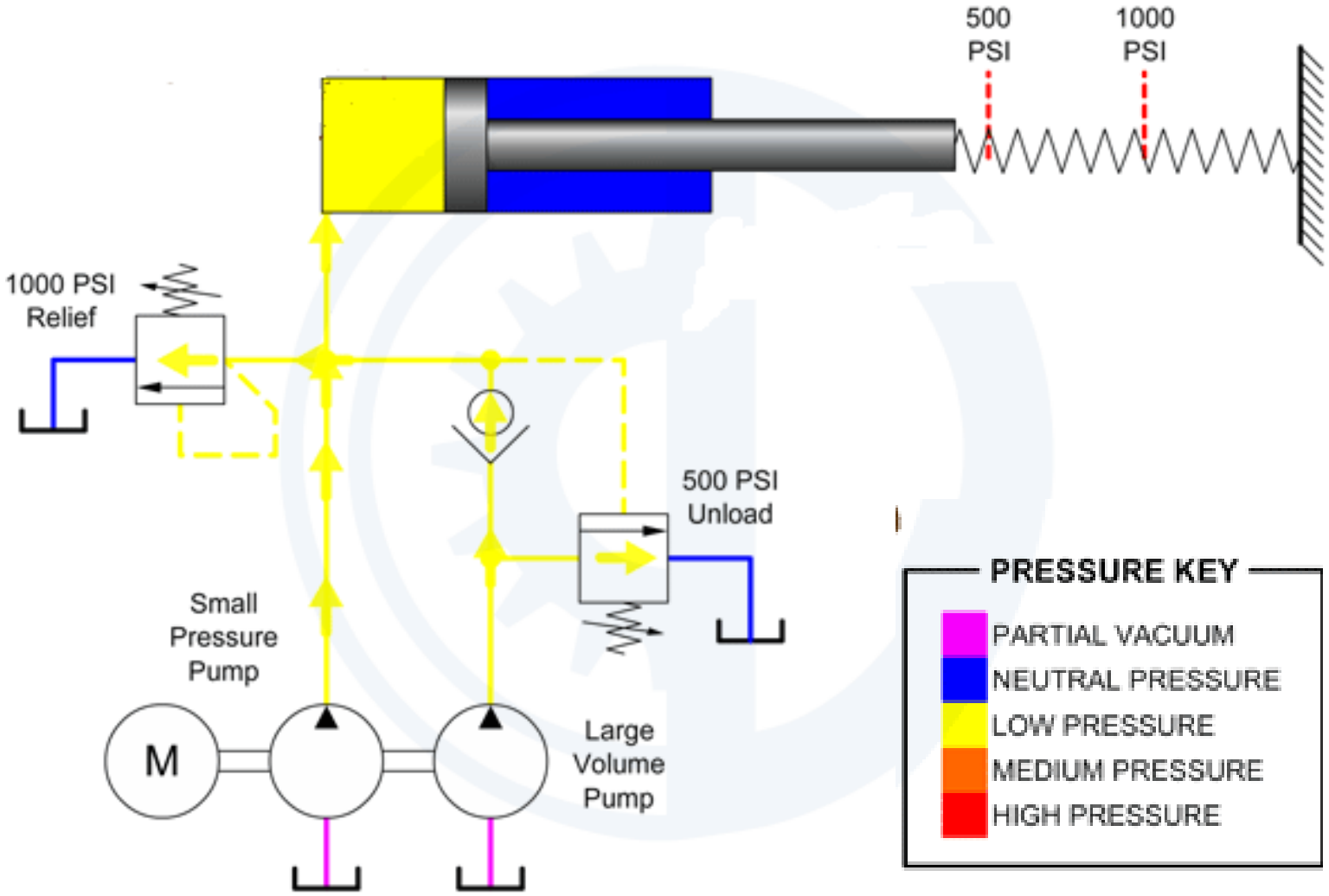
2- Two pumps, plumbed in parallel, are used in such a circuit.

One fixed displacement pump provides volume for the lower pressure, high flow mode, while a small pump provides the low flow at the higher pressure.

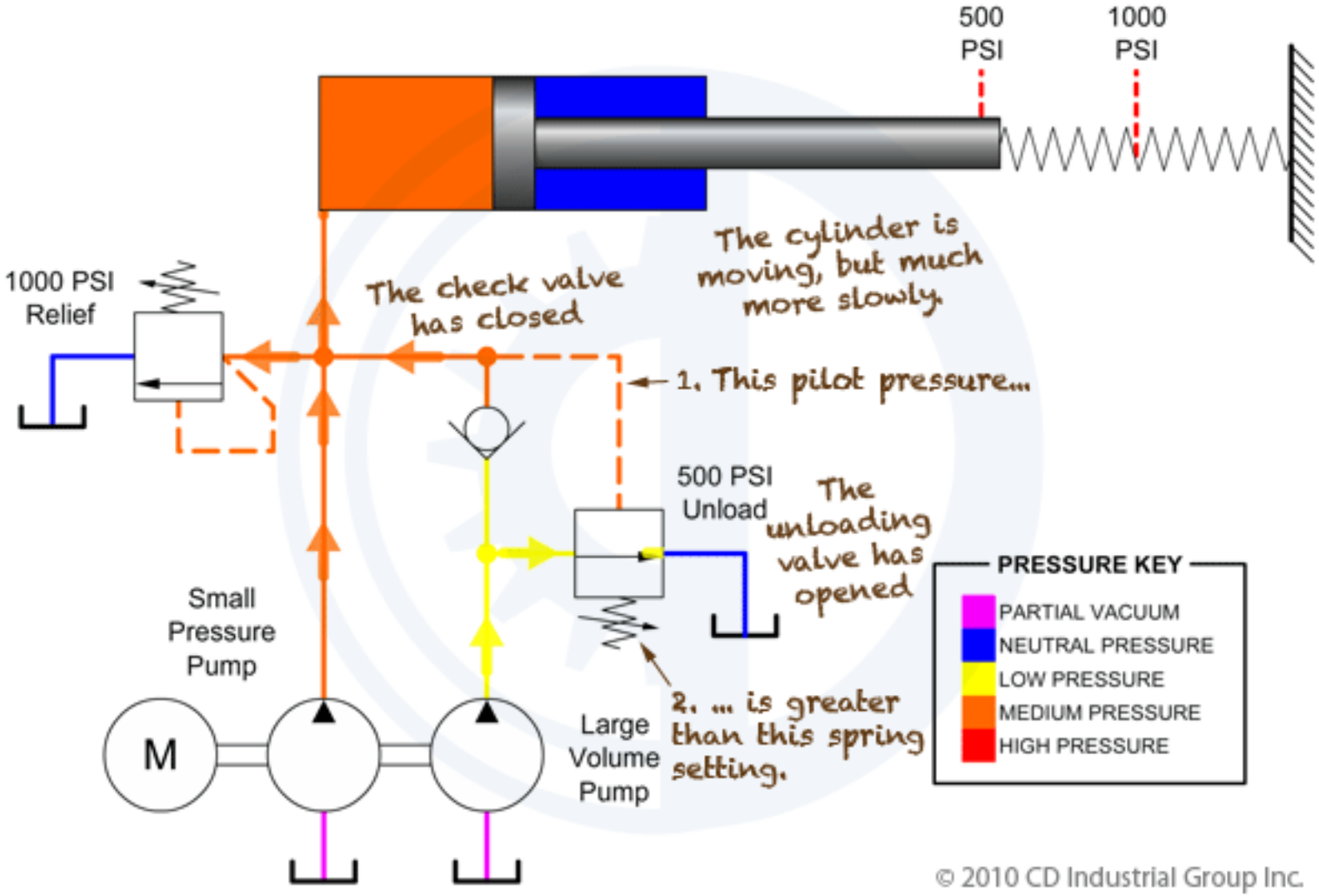
3- The purpose of using the two pumps is to save energy draw at the prime movers during the long periods when the only function of the hydraulic system is to maintain an even maximum pressure with very little or no flow.

4- When the system cylinders are extending quickly at low pressure (any pressure below the setting of the unloading valve), both pumps send their full volume into the cylinder.

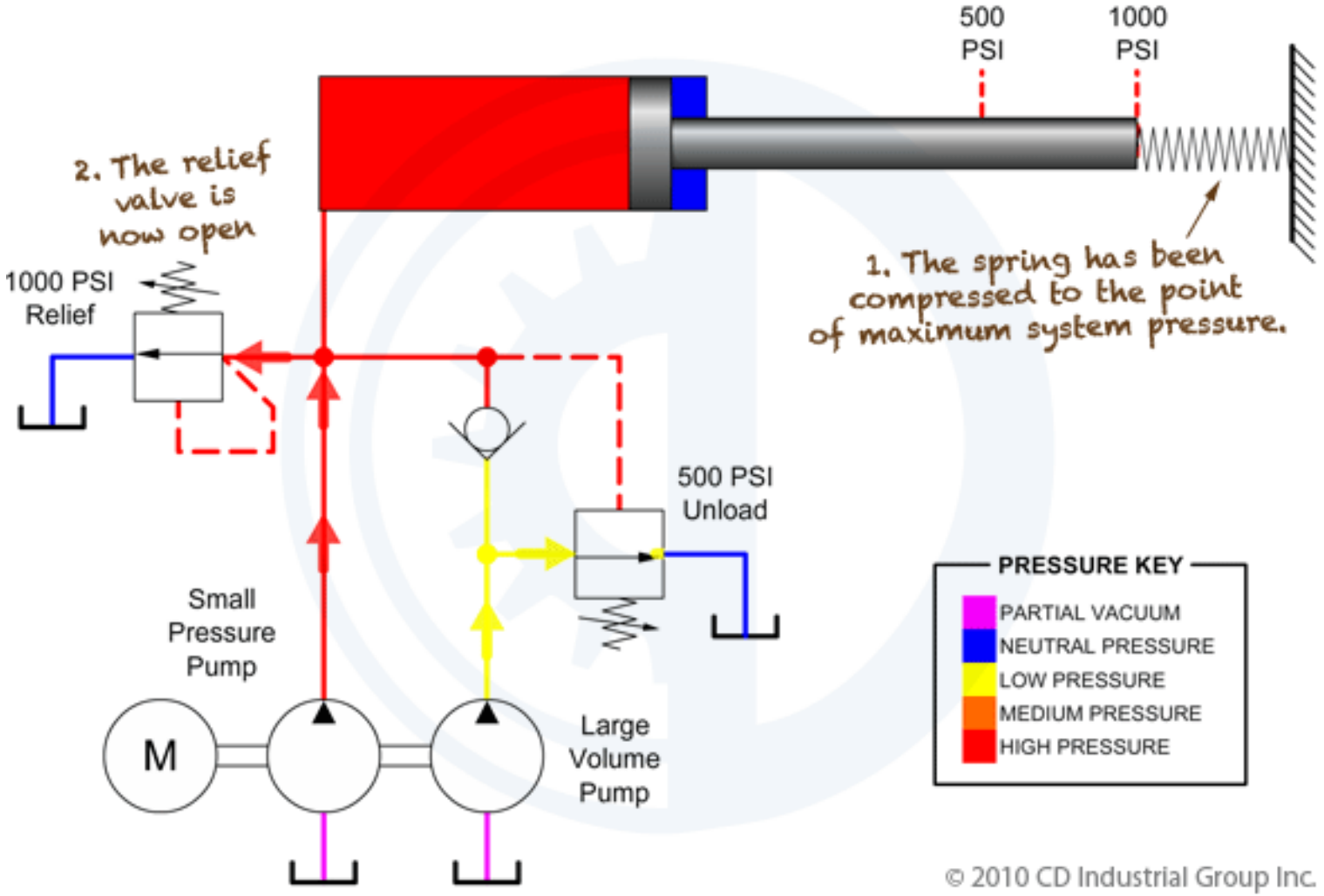
When the cylinders encounter enough mechanical resistance to bring the system pressure up to the setting of the unloading valve, the high flow volume pump is directed to tank through the piloted unloading valve.



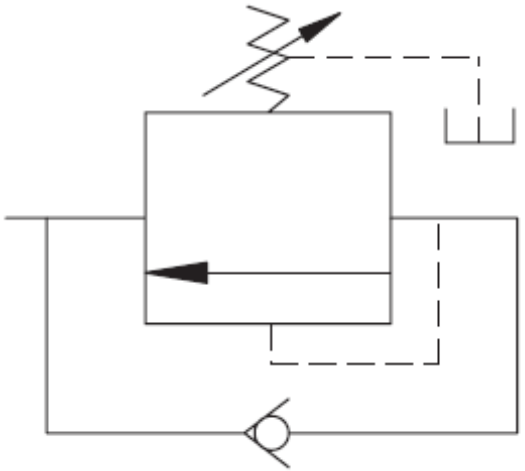
The volume of the smaller pump cannot escape to tank through the unloading valve due the check valve in the system. The presence of the check valve makes the schematic symbol for the unloading valve distinct from a typical relief valve.



As the cylinder continues to move against resistance (system pressure) that is higher than the unloading valve setting, the motion is slower as only the volume from the small pump is available.



3- Sequence Valve



Sequence Valve

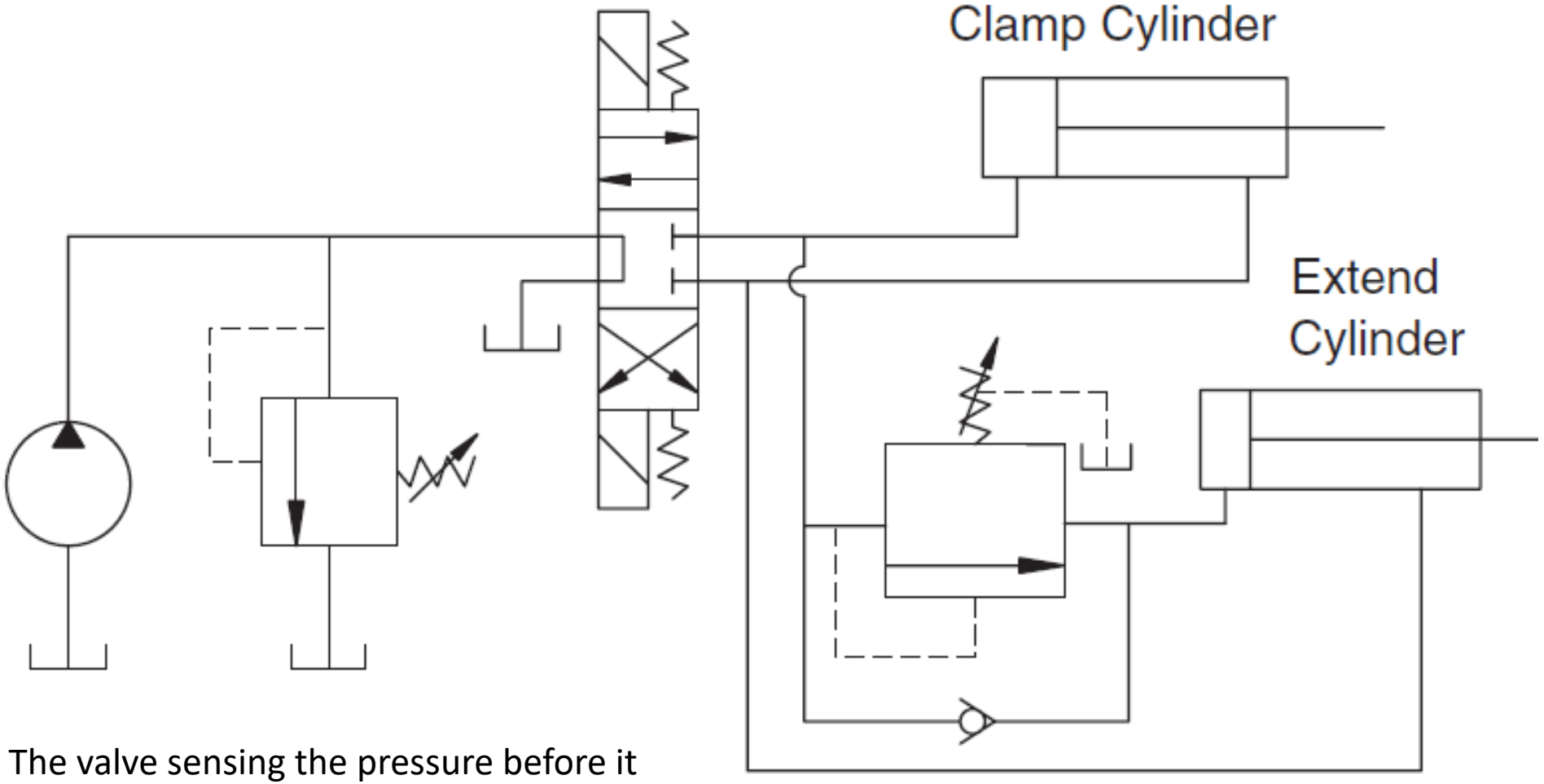
sequence valve is a normally closed valve with pilot line to sense inlet pressure

The sequence valve is used to ensure that a certain pressure level is achieved in one branch of the circuit before a second branch is activated.

This valve is externally drained, meaning that there is a separate line from the valve back to the reservoir

Circuit Using Sequence Valve

Consider a machining operation where the workpiece must be clamped with a certain force before it is extended to make contact with the cutting tool.



The valve sensing the pressure before it

1- The sequence valve is set on 600 psi, meaning that pressure must build to 600 psi before the valve opens.

2- This setting ensures that the clamp cylinder exerts a 600-psi clamp force before the extend cylinder moves.

3- Proper sizing of the cylinders will minimize energy loss in a sequence valve circuit.

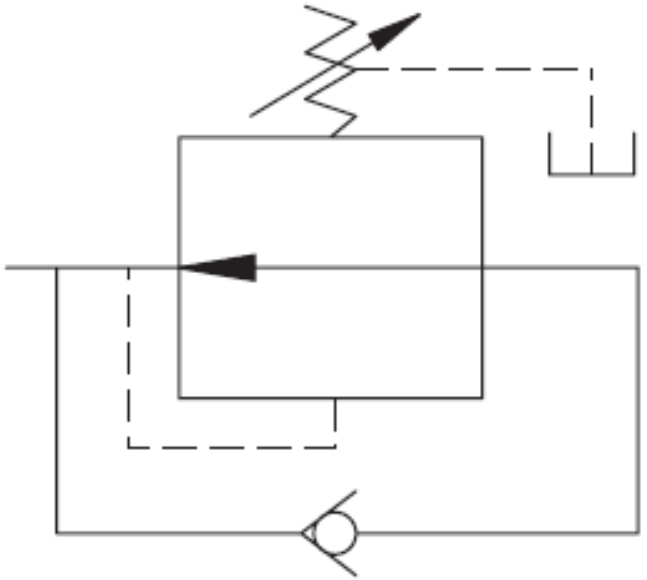
4- Suppose the maximum pressure to extend the workpiece is 400 psi. Pressure drop across the sequence valve is 600 − 400 = 200 psi.

4- Pressure-Reducing Valve

In some situations, two or more pressures are required in different parts of a circuit, but only one pump is specified to keep costs down.

Pressure-reducing valve is a normally open valve with pilot line to sense outlet pressure

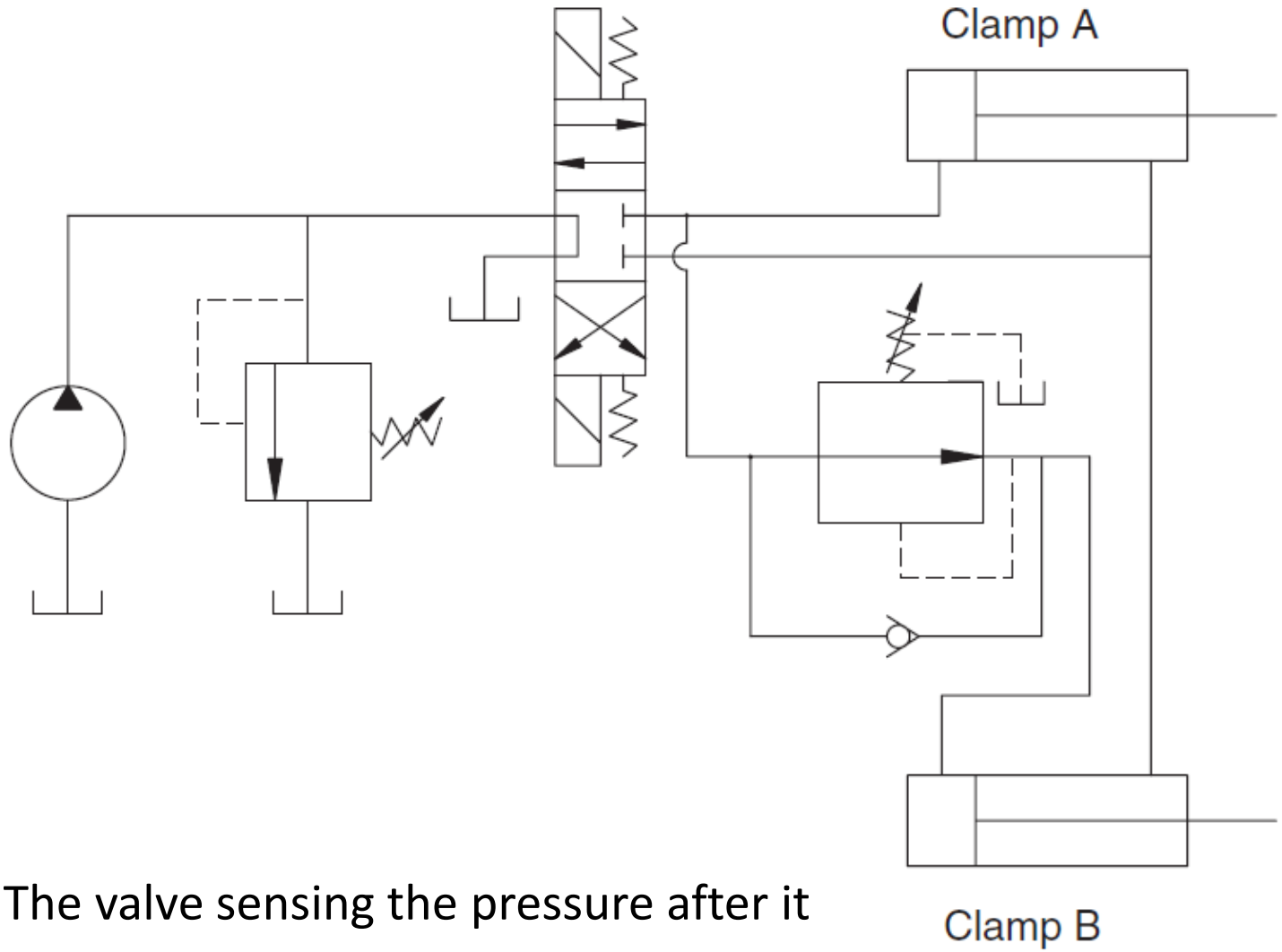
This valve is externally drained, meaning that there is a separate line from the valve back to the reservoir



Pressure-Reducing Valve

Circuit Using Pressure Reducing Valve

A pressure-reducing valve does not allow pressure downstream of the valve to exceed the set point.



The valve sensing the pressure after it

Suppose the workpiece must be clamped with two clamps.

The second clamp is placed at a point where too much clamping force will damage the workpiece.

Suppose the valve is set on 500 psi. If pressure at the outlet of the valve increases above 500 psi, the pressure-reducing valve partially closes to create an orifice.

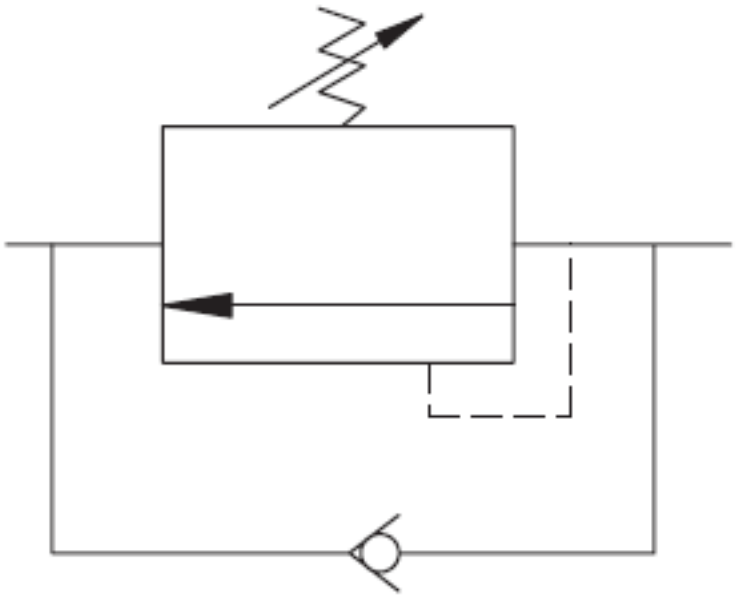
Pressure drop across this orifice reduces the downstream pressure to 500 psi.

5- Counterbalance Valve

Resistive load: A load that acts in the opposite direction to actuator motion.

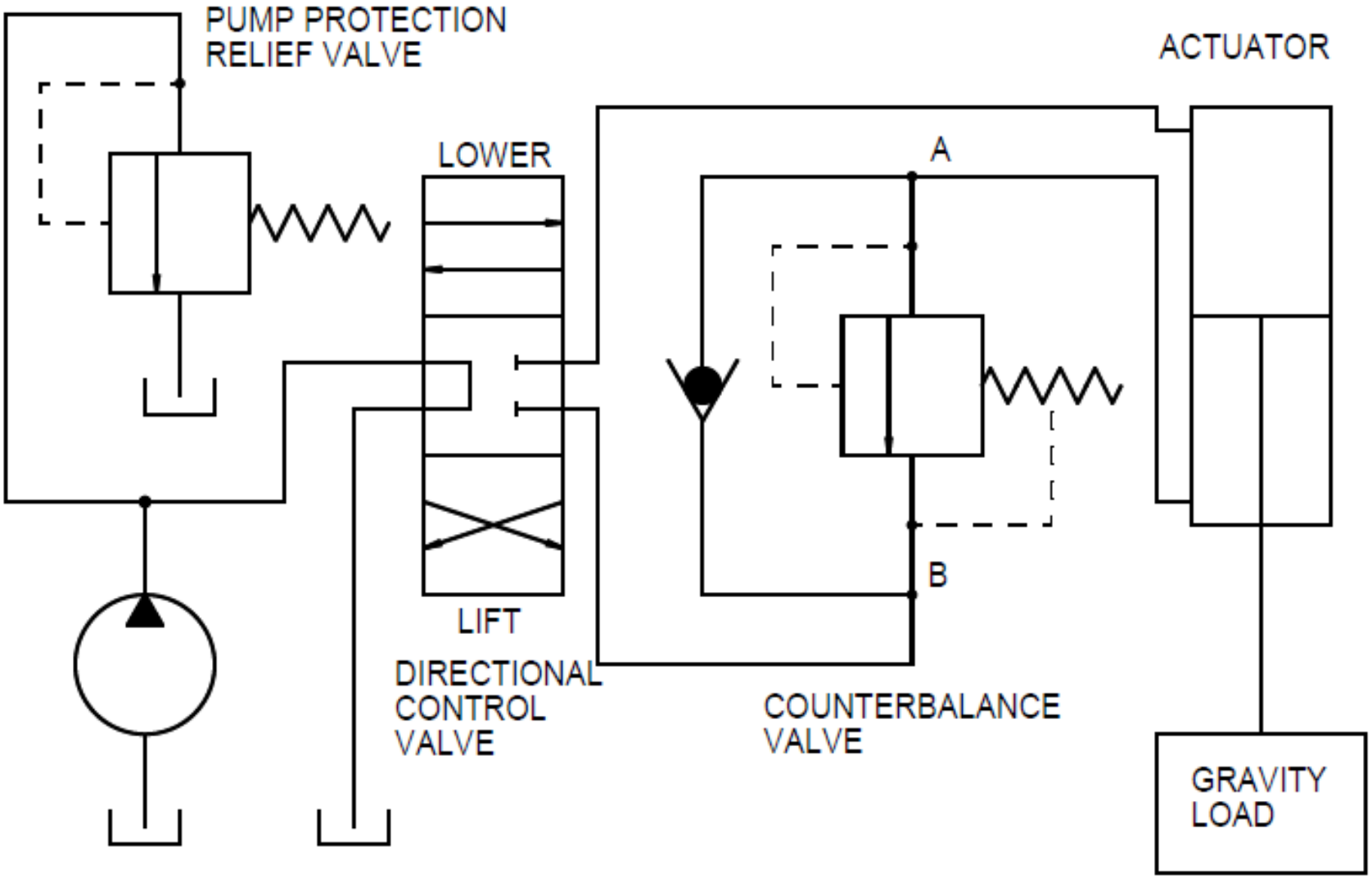
Overrunning load: A load that acts in the same direction as actuator motion.

The counterbalance valve, is used to prevent a weight from falling uncontrollably.



Counterbalance Valve

Circuit Using Counterbalance Valve



1- If the direction control valve is moved to lower the load, fluid under pressure flows from the pump into the cap end of the actuator.

2- Fluid expelled from the rod end passes into port A of the counterbalance valve.

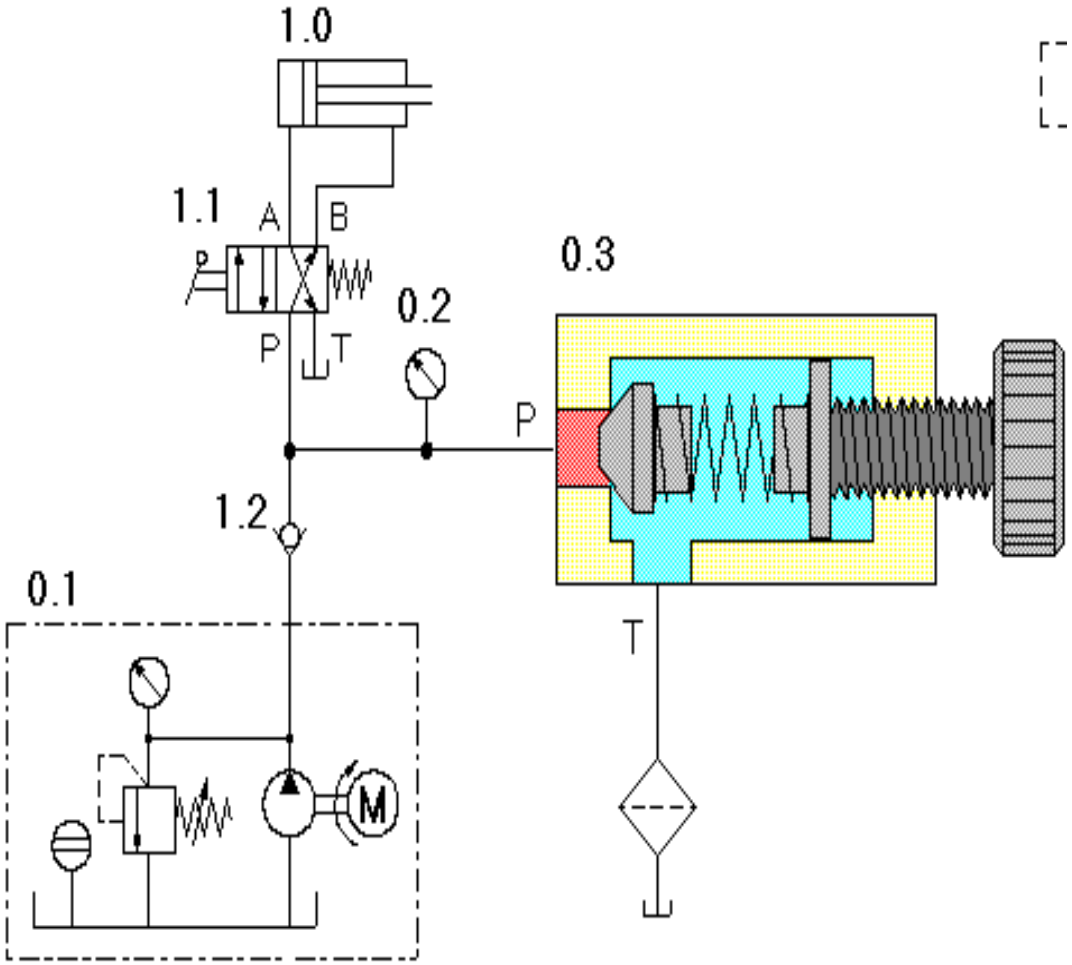
3- In this position of the directional control valve, the pressure on port B is reservoir pressure, so the pressure differential across the main fluid control element is large.

4- The force from the spring operating on the main flow control element is set some amount higher than the force generated by this pressure differential caused by the static load.

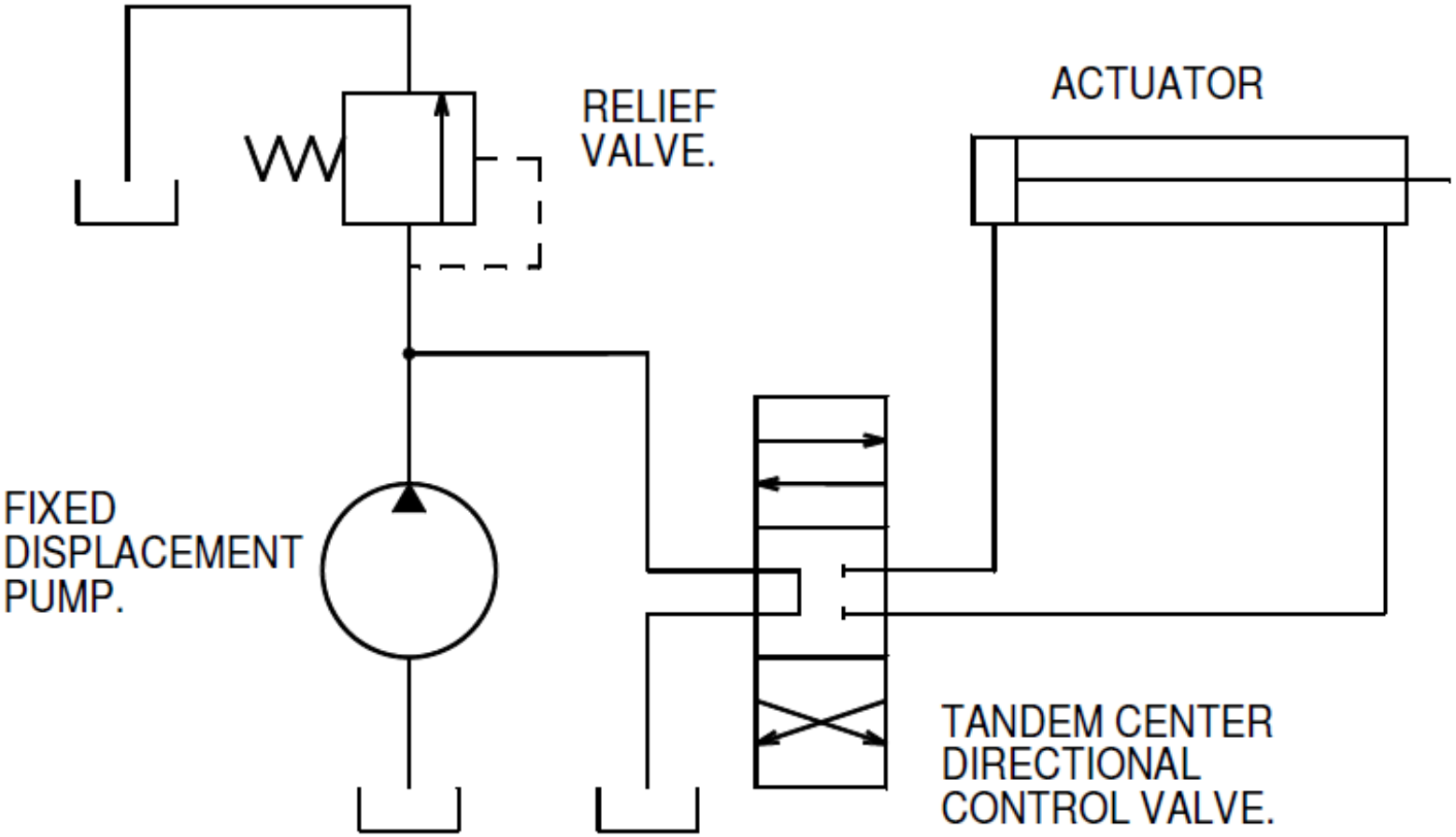
5- The valve remains closed until more fluid enters the cap side of the actuator and tries to expel fluid from the rod side. Because the valve is closed, the pressure at port A rises until the spring load is overcome.

6- Oil can now pass through the valve to the reservoir.

6- Safety Valve



PRV used to limit system pressure



Pump protection with a relief valve