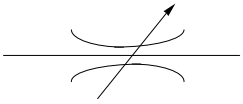
Chapter 9 Flow control valves

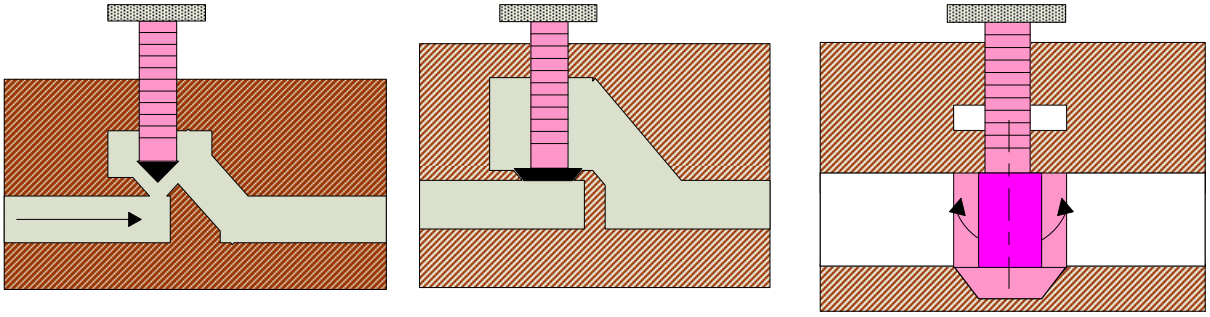
- Used to regulate flow in a hydraulic circuit

9.1 Two-Way Valves

Examples are check valves, two-way valves.



Needle, Globe, and Gate Valves



Needle valve Disk valve Gate valve

Figure 9.1 Two way valves.

Needle - Can throttle flow
Globe - Note suitable for throttling
Gate - Used as on-off valves

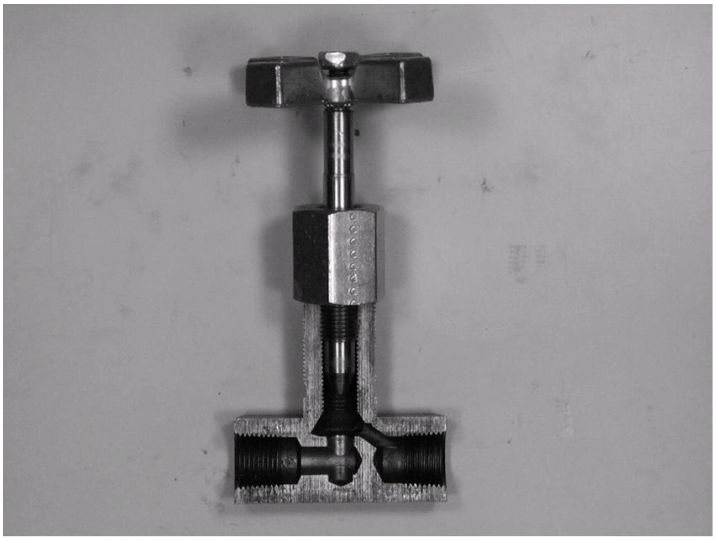


Figure 9.2 Needle valve

9.2 Non-Compensated Flow Control

- Valve which has no feedback to compensate for pressure or temperature variations.

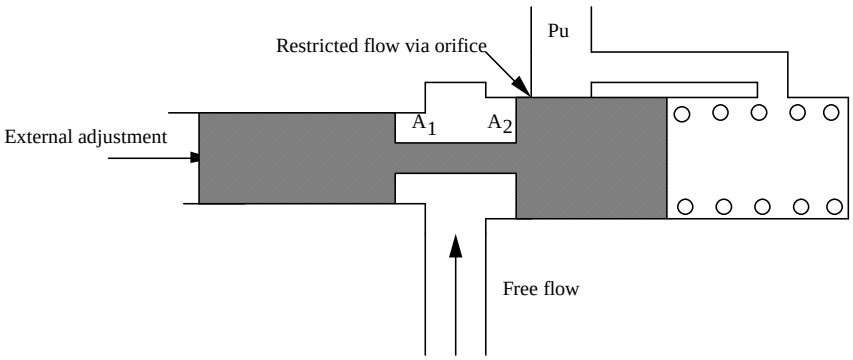
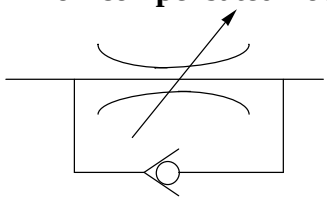


Figure 9.2 Non-compensated flow control



In the free flow direction $A_2 > A_1$, therefore, piston will open fully.
In restricted direction adjusting screw is set to create a small orifice.
Since P_u acts on A_3, the spool is fixed in place against the adjusting screw.

9.3 Compensated Flow Control

Recall that flow through an orifice is given by

$$Q = K \cdot A_o \sqrt{\Delta P}$$

In order to maintain a constant Q, if ΔP increases then A_o must decrease to compensate.
Hence, some sort of feedback must be used.

9.3.1 Restrictor Flow Control

Usually an orifice setting is fixed and to maintain flow control, a constant ΔP across the orifice is attempted.

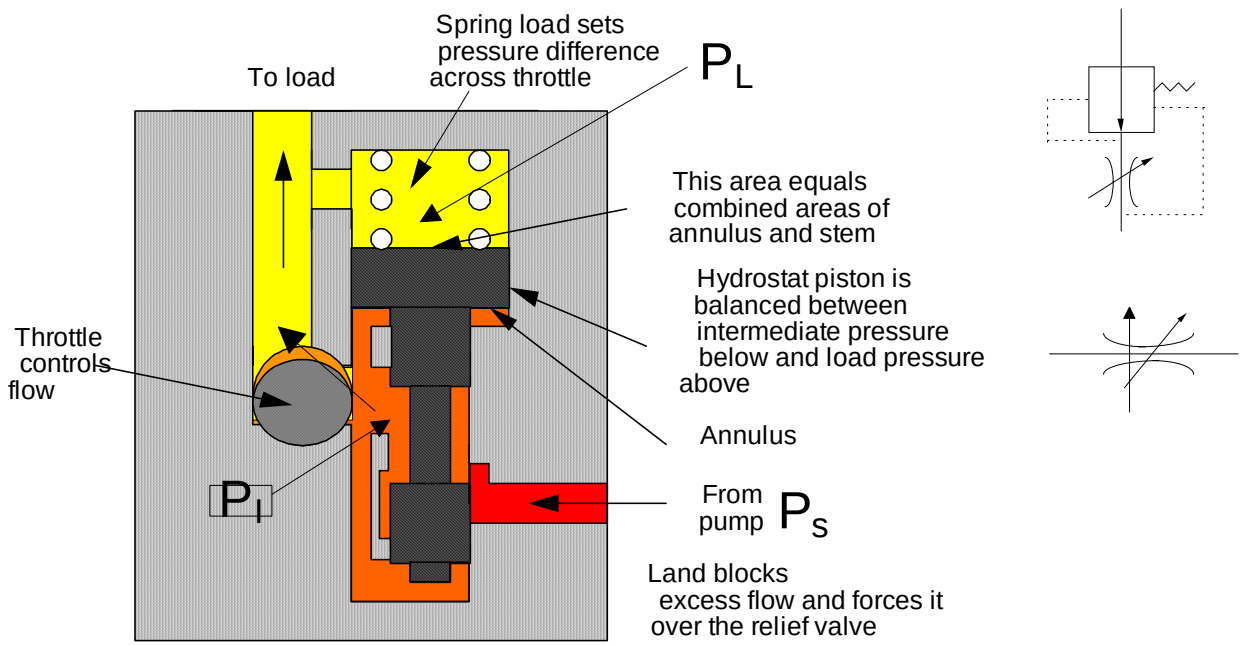


Figure 9.3 Restrictor pressure compensated flow control valve

Assume P_L increases, therefore Q decreases temporarily at throttle. Therefore Q_{in} at variable orifice is > $Q_{Throttle}$. Therefore, P_I increases. As well ΔP across piston forces the variable orifice open causing P_I to increase until original balance on ΔP is achieved.

- Used in const. flow dump systems, where P_{pump} is not fixed.

Assume initially load is zero ... and pump is off. The piston is pushed down by the spring creating an orifice for the pump. As fluid is pumped through because of the restrictor (throttle) pin, the chamber pressure increases. When this $P_I \cdot A$ is equal to the spring force, the desired ΔP across the throttle has been reached - hence Q_D. But if the pump attempts to put more Q than Q_D, P_I rises above the desired value and forces piston upward restricting the inlet flow. Since flow is restricted at the inlet P_{inlet} will rise. A balance occurs when $Q_P = Q_R + Q_V$ where Q_R flows through a relief valve.
Now if P_L increases, ΔP_{piston} decreases, the spool moves down creating a larger orifice and, hence, less restriction; P_I thus rises unit ΔP balance is achieved.

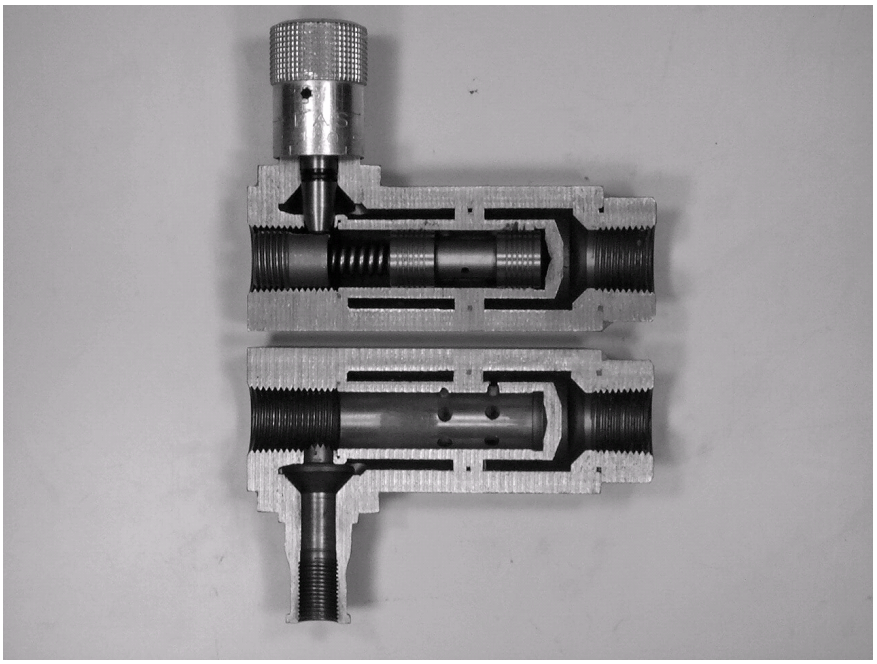


Figure 9.3 (a) Pressure compensated restrictor flow control valve

9.3.2 By-Pass Type

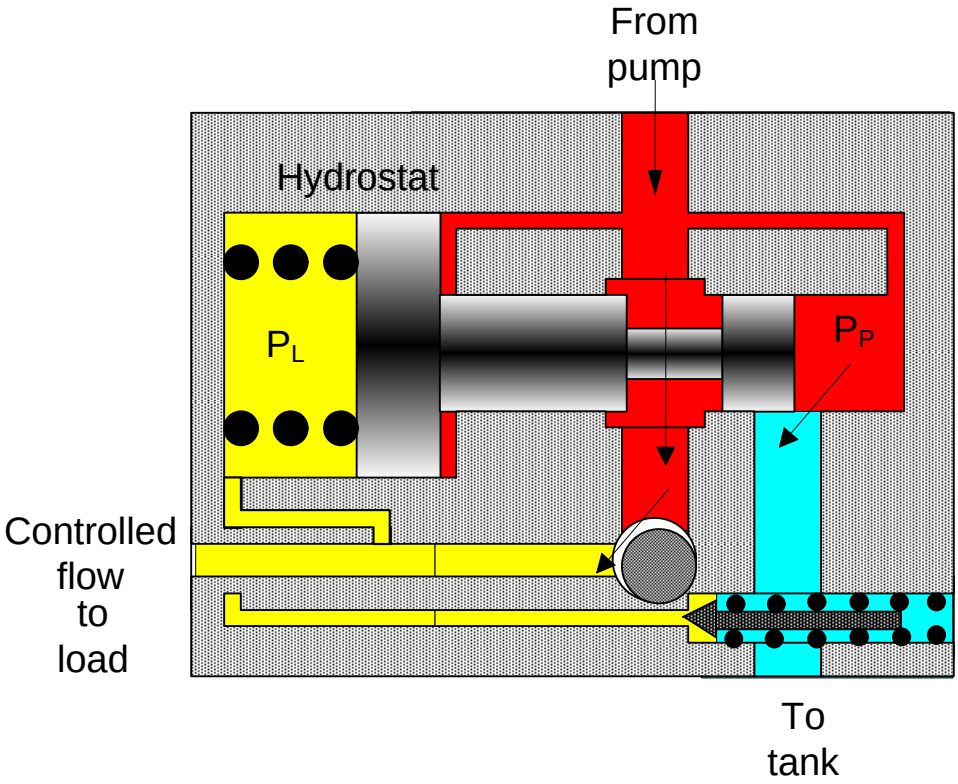


Figure 9.4 Bypass pressure compensated flow control valve

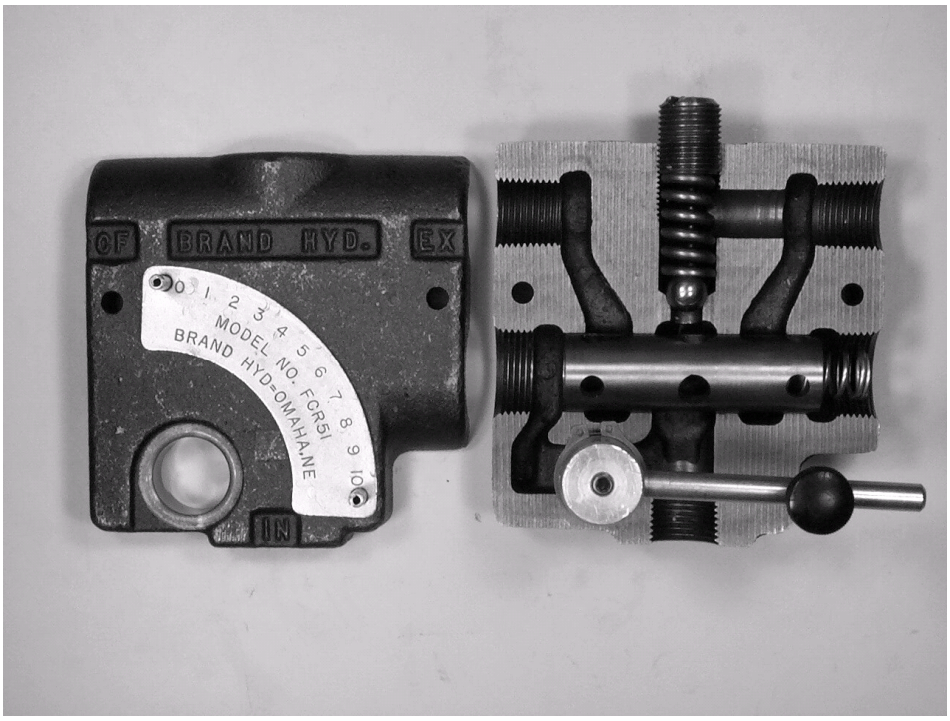
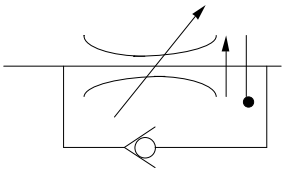


Figure 9.4 (a) By pass pressure compensated flow control valve.

Operation similar except excess flow is diverted to tank within the valve. It is noticeable that in this design, P at pump is only ΔP higher than the working pressure, hence an energy saving device.

10.3.3 Temperature Compensated

Compensator varies the "fixed orifice" with changes in temp.



9.4 Control Valve Circuits

- Meter in, meter out - bleed off

9.4.1 Meter Out

Used when a load may run away when a restricting force on the ram suddenly is removed. Free or rapid reverse flow through check valve.

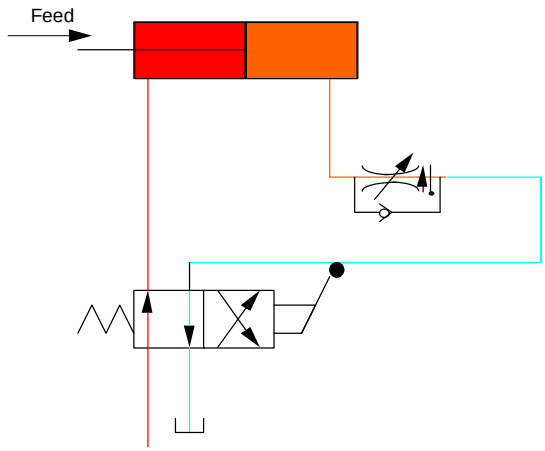


Figure 9.5 Meter-out circuit

9.4.2 Meter In

- Controls amount of fluid to actuator
- excess flow is diverted over relief valve.
- Load continuously resists actuator in one direction.

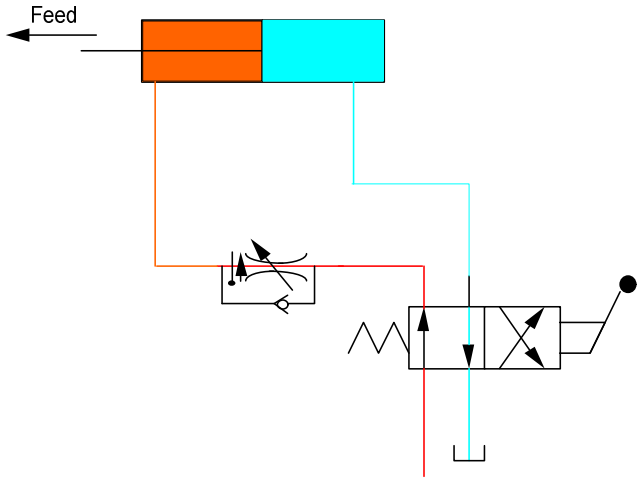


Figure 9.6 Meter in circuit

NOTE: If meter-in or meter-out is required in both directions, the valve is placed before the directional control valve.

9.4.3 Bleed-Off Circuit

- Divert some of a system flow to a lower pressure area.

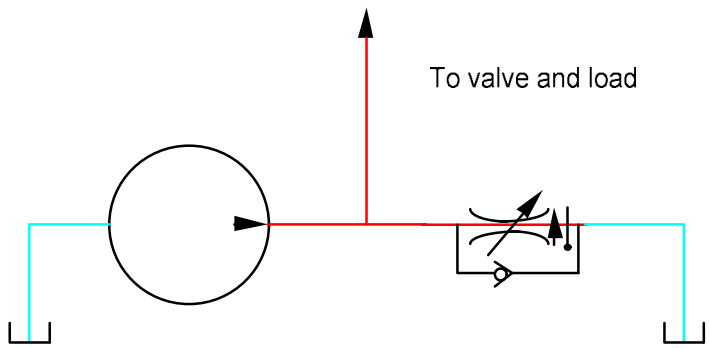


Figure 9.7 Bleed-off circuit

9.5 Flow Divider Valves

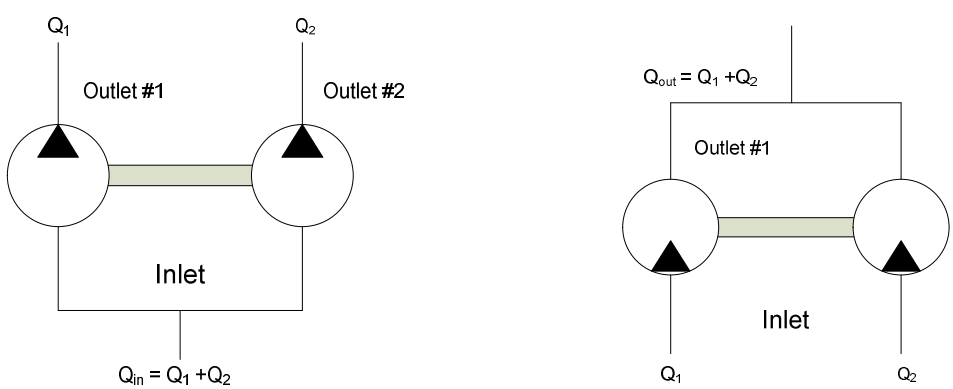
Definition: A valve which divides a single flow into two or more prescribed flows regardless of the load pressures at the outlet ports.

Application:
(1) Control the movements of hydraulic motors or hydraulic cylinders under adverse conditions.
(2) Supply lubricating oil from a single source to different areas at some prescribed flowrates.

There are two common types of flow-divider valves, rotary and sliding-spool.

Rotary Type

Make use of linked gear pumps/motors.



Flow divider Flow combiner

Figure 9.8 Rotary flow divider – combiner valves

Operation:
- Two gear pumps are installed in a common valve housing.
- Pumps 1 and 2 control the fluid flowrate to outlet ports 1 and 2 respectively.
- Gears A and B are fastened to a common shaft and, therefore, they are running at the same speed.

Flowrate to outlet port 1, $Q_1 = D_{P1}\,\dot{\theta}$

Flowrate to outlet port 2, $Q_2 = D_{P2}\,\dot{\theta}$

$$\therefore \quad \frac{Q_1}{Q_2} = \frac{D_{P1}}{D_{P2}} \qquad \text{(fixed ratio)}$$

Advantage: Contaminants or dirt in the fluid have little effect on the performance of the valve due to its large clearance gap between the gears and the housing.

Disadvantage: Low accuracy due to the internal leakages which are not the same at pump 1 and pump 2 because they are under different load pressures. This type of valve is noisy.

Sliding-Spool Type

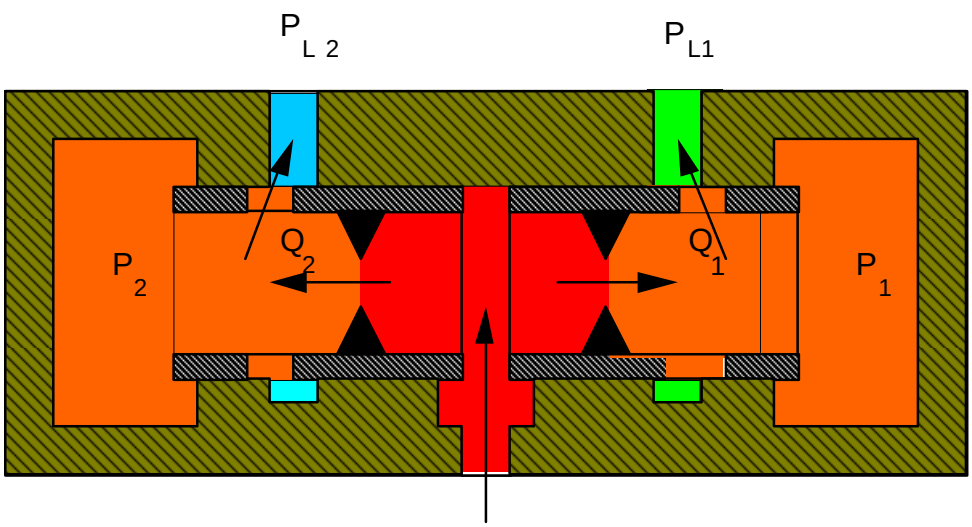


Figure 9.9 Sliding spool flow divider valve

Operation:
- If P_{L2} is greater than P_{L1}, P_2 greater than P_1 will result
- A net force $F = (P_2 - P_1)A$ will act on the spool to move it to the right.

- Area of variable orifice 2 is increased and, therefore, the flow resistance is reduced. Area of variable orifice 1 is decreased and, therefore, the flow resistance is increased.
- P_2 is decreasing and P_1 is increasing.
- The spool will oscillate and eventually stop at the position where $P_1 = P_2$ and equal flow to the ports will be achieved.

Basic equations for analysis

$$Q = C_d A \sqrt{\frac{2\Delta P}{\rho}} \qquad \text{(from steady-state Bernoulii equation)}$$

$$(P_2 - P_1)A = (\dot{m}_2 V_2 - \dot{m}_1 V_1) \cos\theta \qquad \text{(from momentum equation)}$$

<u>Advantage:</u>
- Quiet operation
- More accurate than the rotary type

<u>Disadvantage:</u>
- Very sensitive to contaminants or dirt in the fluid.
- Flow force is a problem associated with accuracy of the valve.

9.6 Priority Flow Divider

- Delivers all fluid to one circuit until pump delivery exceeds the needs of that circuit; then extra delivery is made available to other circuits.
- Similar in operation to a bypass flow regulator

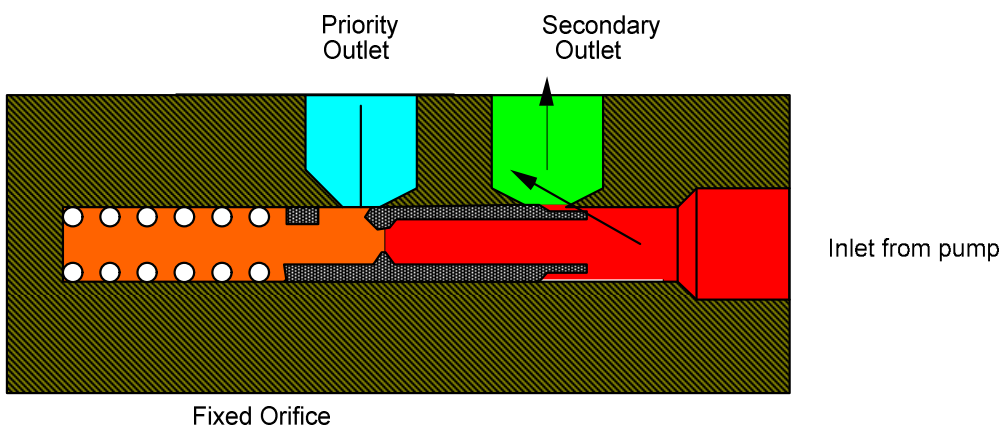


Figure 9.10 Priority flow divider

9.7 Proportional Flow Divider

- Maintains flow divided at a specific ratio independent of the load.

Advantage: - Quiet operation
- More accurate than the rotary type

Disadvantage: - Very sensitive to contaminants or dirt in the fluid.
- Flow force is a problem associated with accuracy of the valve

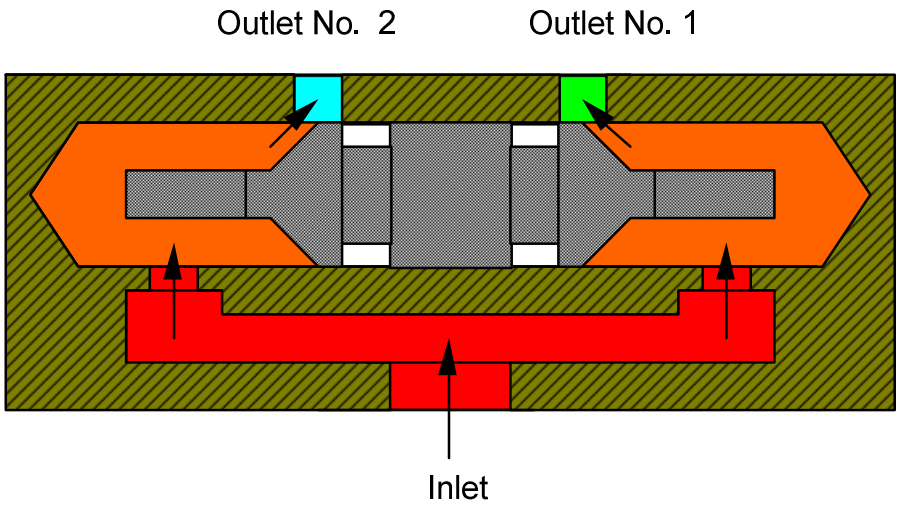


Figure 9.11 Proportional flow divider valve