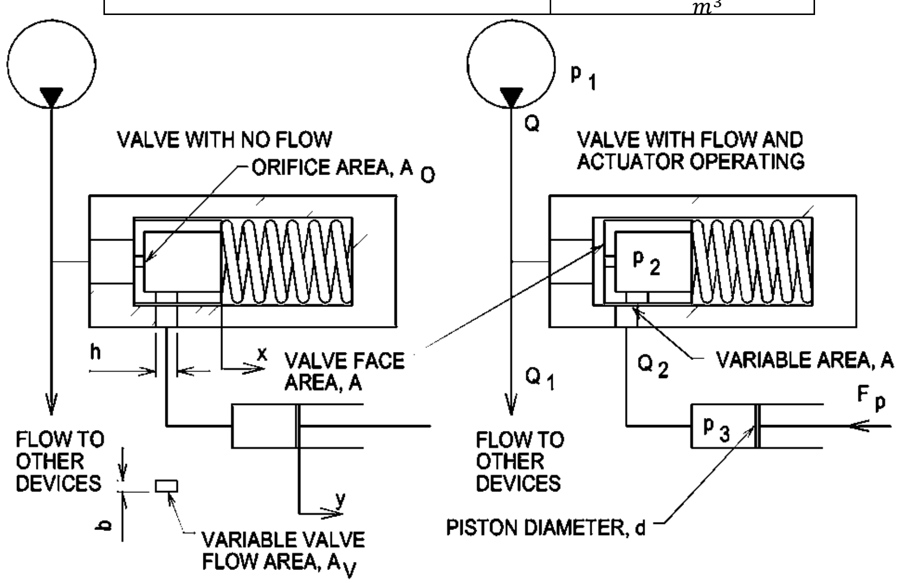
LECTURE 21 – FLOW AND FORCE ANALYSIS OF VALVES

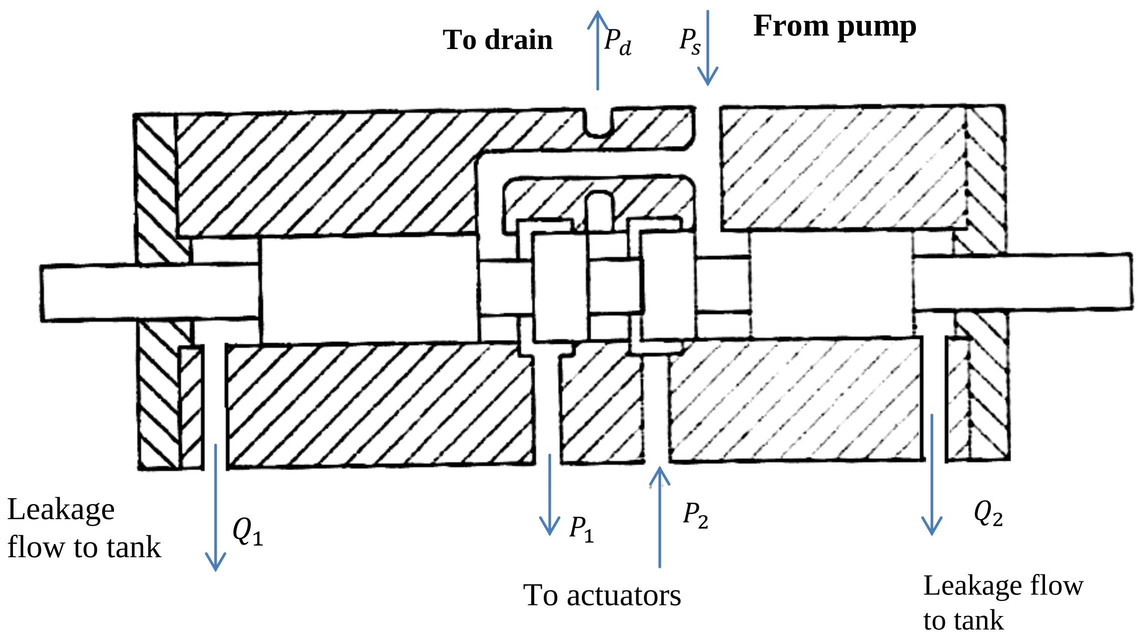
SELF EVALUATION QUESTIONS AND ANSWERS

1 A flow control valve is used to control the speed of the actuator as shown in the figure and the characteristics of the system are given in the following table. Determine the variable flow area Av, , the pressure downstream of the valve fixed orifice p_2, the valve displacement x, and the spring preload F for the given motor operating conditions.

Parameters	Value
Valve flow constant (C_d)	0.6
Length h	7.8 mm
Valve area gradient for flow area (A_v), b	1.25 mm^2/mm
Fixed orifice flow area (A_0)	4.9 mm^2
Valve face area	125 mm^2
Spring constant	57 kN/m
Motor displacement (D_m)	40 cm^3/rev
Motor torque	60 Nm
Motor speed	350 RPM
Motor Volumetric efficiency (η_v)	96 %
Motor mechanical efficiency (η_m)	97 5
System pressure (p_1)	14.5 MPa
Return pressure (p_4)	1 MPa
Fluid density	840 $\frac{kg}{m^3}$



2 **Leakage input flow ,$Q = Q_1 + Q_2$ passes through the spool valve as shown in the figure. The oil flows past the two spool lands in annular passages as Q_1 and Q_2. Write a set of equation, based on conventional fluid flow theory that can be solved for pressure p_s and the flow Q_1 and Q_2.**



Characteristics of flow division in a spool valve is given below

Spool diameter d_{sp}	20 mm
Land length l_1	93 mm
Land length l_2	73 mm
Spool radial clearance (centered)	0.025mm

3. Use the equations determined in the problem 2 to solve for numerical values of pressure p_s Leakage flow Q_1 and Q_2, when the leakage input flow ,$Q = Q_1 + Q_2$ equal to 0.01 L/s

Q1 solution

Flow from pump divides as Q_1 and Q_2. The pressure drop $P_1 - P_2$occurs acoss office A_o This make valve to move to right against the spring force F. the area of orifice A_v then adjusts to control the flow to the motor.

$$h = \frac{7.8}{1000} m, w = \frac{1.25}{1000} mm. \; k = 57000 N/m \;\; A_o = 4.9 \times 10^{-6} m^2 \;\; A = 125 \times 10^{-6} m^2$$

$$D_m = \frac{\frac{40}{100^3} m^3}{rev}, T = 60Nm \,.\; n = 350\, RPM \;\; \rho = 840 \frac{kg}{m^3} P_1 = 14.500 \times 1000 N/\, m^2$$

$$\eta_V = 96\,\%\, \eta_m = 97\,\% \;, P_4 = 1000x1000\, Pa\; \theta = \frac{2 \times \pi \times 350}{60} = 36.652\, rad/s$$

$$Q_2 = \frac{\frac{40}{100^3} m^3}{0.96} \times \frac{350}{60} = 2.431 \times 10^{-4} m^3/s$$

$$p_3 = \frac{T}{0.97} \times \frac{2\pi}{\frac{40}{100^3} m^3} + p_4 = 1.072 \times 10^7\, Pa$$

$$Q_2 = c_d A_o \sqrt{\frac{2}{840}} \times \sqrt{p_2} - p_1 = 2.431 \times \frac{10^{-4} m^3}{s}, solving\ we\ get$$

$$p_2 = 1.163 \times 10^7\, Pa$$

$$Q = c_d A_V \sqrt{\frac{2}{840}} \times \sqrt{p_2} - p_3 = c_d (h - x) w \sqrt{\frac{2}{840}} \times \sqrt{p_2} - p_3, solving\ we\ get$$

$$A_V = 8.688 \times 10^{-6} m^2\ or\ 8.688\, mm^2$$

$$x = \frac{h \times w - A_V}{w} = 8.499 \times 10^{-4}\, m$$

$$p_1 A = p_2 A + K\,X + F \;\; solving\ we\ get\ F = 310.4\, N$$

Q2 solution

$$Q = \frac{0.01}{1000}\ LPS, d_p = \frac{20}{1000}, l_1 = \frac{93}{1000}, l_2 = \frac{73}{1000}, \mu = 0.01\ \frac{Ns}{m^2}$$

$$Q = \frac{0.01}{1000}\ LPS, d_p = \frac{20}{1000}, l_1 = \frac{93}{1000}, l_2 = \frac{73}{1000}, \mu = 0.01\ \frac{Ns}{m^2}$$

$$Q_L = = \frac{\pi D\ c^3 \Delta P}{12\mu L}\left[1 + \frac{3}{2}\left(\frac{\in}{c}\right)^3\right]$$

$$\left(\frac{\in}{c}\right) = 1$$

Solving we get

$$Q_1 = = \frac{\pi D\ c^3 \Delta P}{12\mu l_1}[2.5]$$

$$Q_2 = = \frac{\pi D\ c^3 \Delta P}{12\mu l_2}[2.5]$$

$$Q = Q_1 + Q_2$$

Q3 solution

$$Q_1 = = \frac{\pi D\ c^3 \Delta P}{12\mu l_1}[2.5]$$

$$Q_2 = = \frac{\pi D\ c^3 \Delta P}{12\mu l_2}[2.5]$$

$$Q = Q_1 + Q_2$$

Use trial values of $Q_1 = 10^{-5}, Q_2 = 10^{-5} and\ p = 10^5$

Find $Q_1, Q_2\ p = \begin{Bmatrix} 4.398 \times 10^{-6} \\ 5.602 \times 10^{-6} \\ 2 \times 10^7 \end{Bmatrix}$

$$Q_1 = 4.398 \times 10^{-6}\frac{m^3}{s}, Q_2 = 5.602 \times 10^{-6}\frac{m^3}{s}, p = 2 \times 10^7\ Pa$$