Chapter 11. Some Pressure System Considerations

11.1 Pump Characteristics

Ideal pumps should deliver flow independent of the load as illustrated;

11.1.1   Fixed Displacement pump

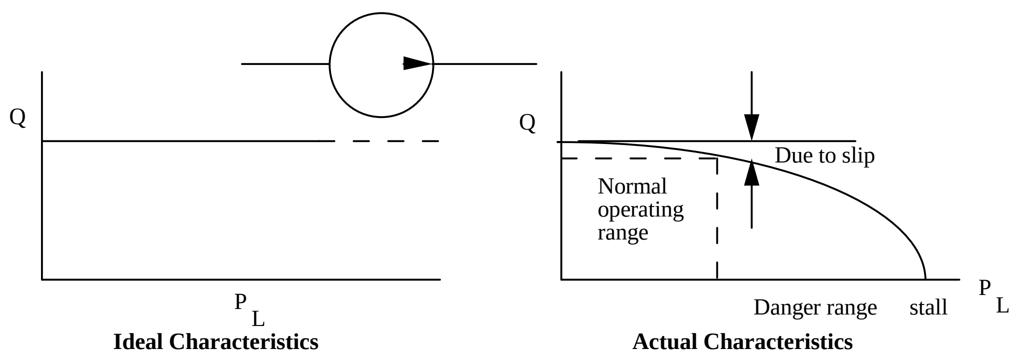


Figure 11.1 Pump characteristics

11.1.2 Variable displacement pump

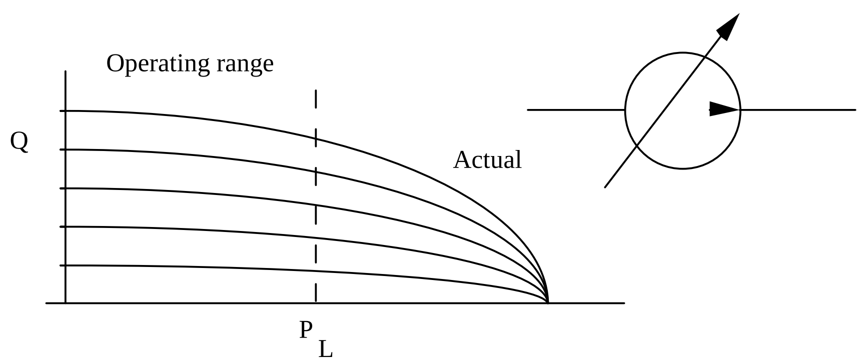


Figure 11.2 Pump characteristics (Var displ.)

11.1.3 Pressure compensated pump

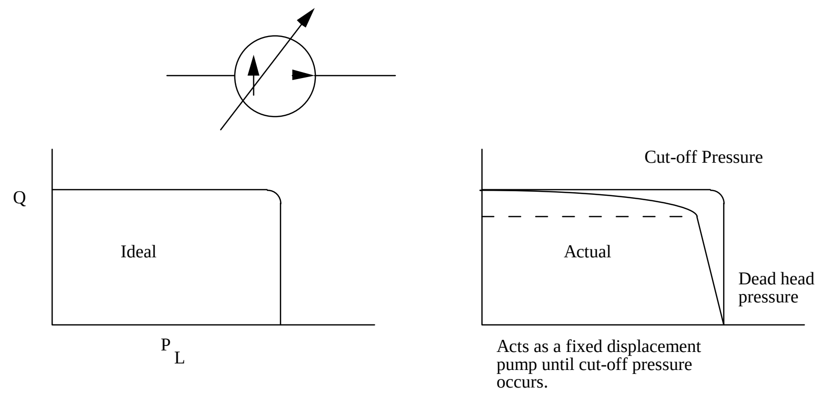


Figure 11.3 Pressure Compensated characteristics

11.1.4 Pressure compensated-load sensing pump

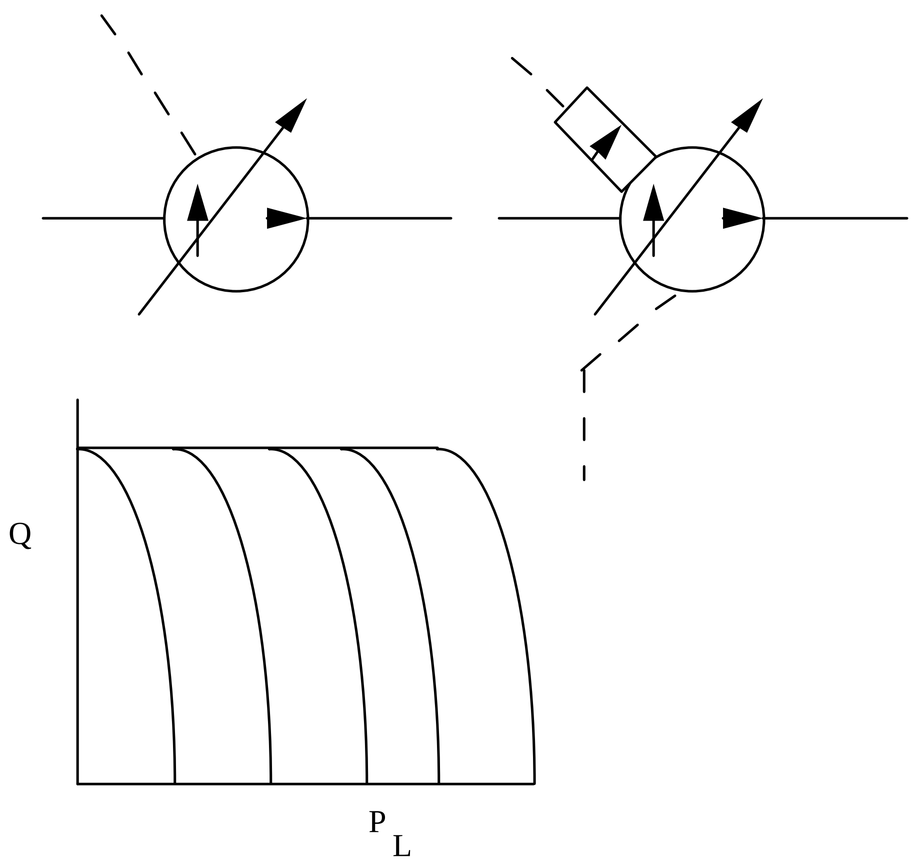


Figure 11.4 Load sensing characteristics

11.2 Pressure compensated pumps

A pressure compensated pump uses pressure feedback to act on a piston backed by a spring to de-stroke the pump when the system pressure is greater than the spring pretension value.

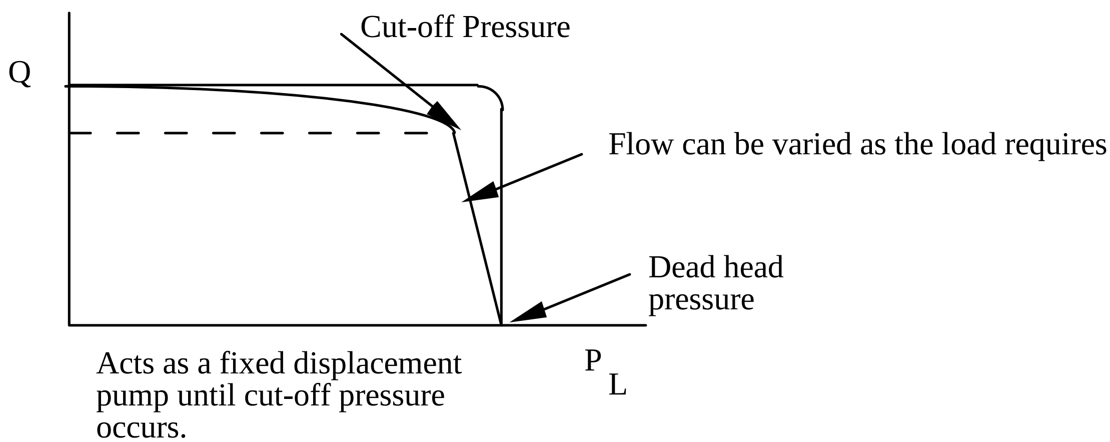


Figure 11.5 Pressure compensated pumps

11.2.1 Some pressure compensated pump circuits

11.2.1.1 No flow control valve

Consider:

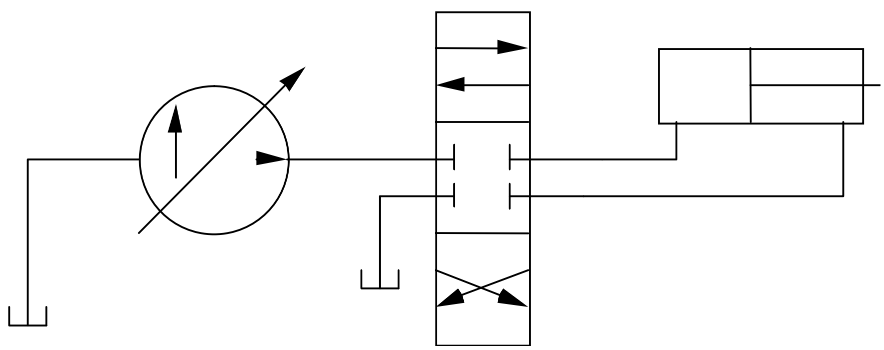


Figure 11.6 Circuit with no flow control valve

In this circuit, there is no attempt to control flow. Consider the center position. In this case, the ports are closed. The pump is at deadhead pressure and is fully de-stroked. Because of internal leakage, the power wasted is illustrated as follows.

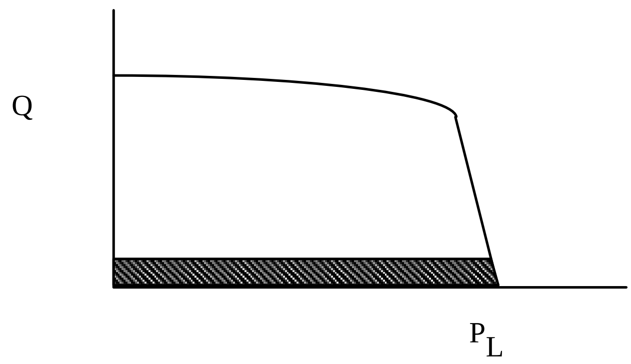


Figure 11.7 Closed Center Valve

If an open center valve is used, the pump is fully stroked and the load pressure is equal to the ΔP across the valve. Power wasted is illustrated below.

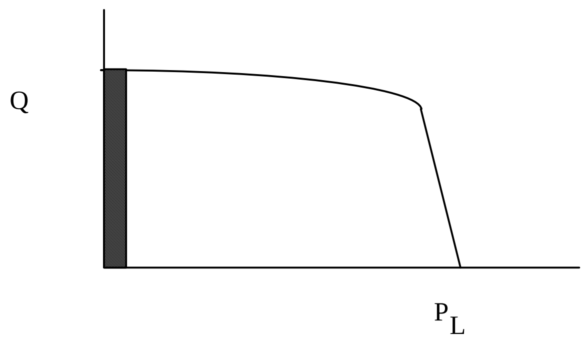


Figure 11.8 Open Center Valve

Let us consider the dynamics of this system (closed center). When the valve is opened, the force applied to the system to be moved must first over come stiction and then accelerate the mass (at a rate determined by the user) until an appropriate constant velocity is maintained. At this point, the force drops to that necessary to overcome friction and or external forces.

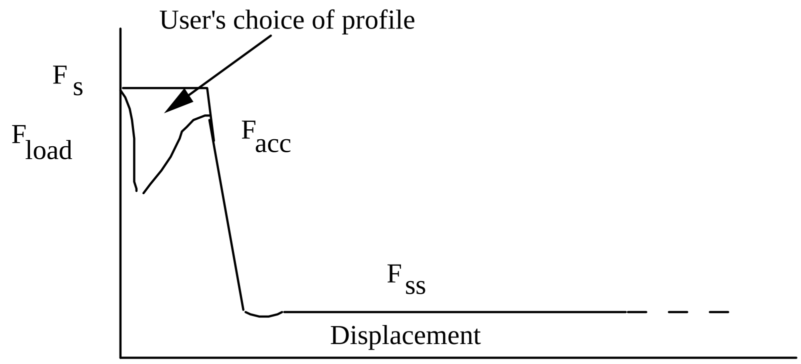


Figure 11.9 Force transient waveform

The pressure and flow at the pump after the valve is opened would appear as:

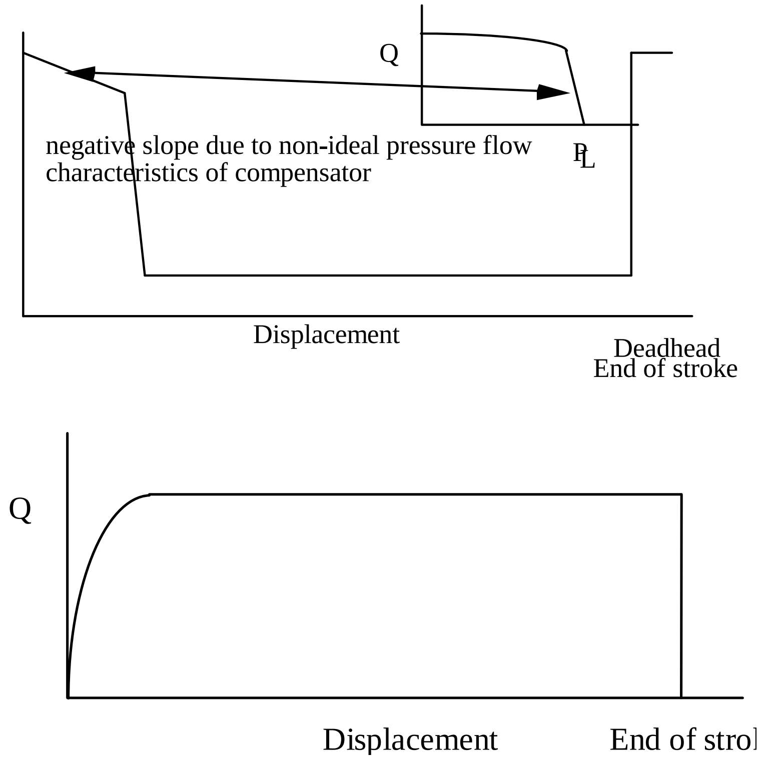


Figure 11.10 Pressure and flow waveforms

11.2.2.2 Bypass flow control**.**

Consider the circuit in which a bypass flow control valve is used to modulate the flow to the load. In the center valve position, the pump delivers full flow but is bypassed to tank at a lower pressure dictated by the pressure drop across the bypass valve (100-300psi typically).

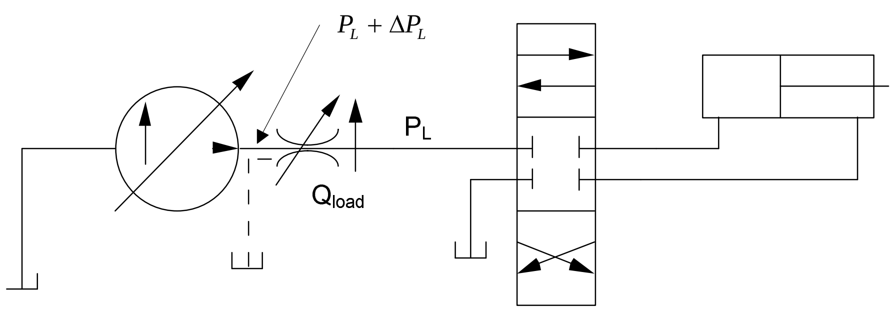


Figure 11.11 Bypass circuit

When the valve is actuated, the pump "sees" a load pressure P_L. The pump pressure is thus

$P_L + \Delta P$. where ΔP is the pressure drop across the valve in the direction of the flow to the actuator. The horsepower loss in this direction is thus $\Delta P^* Q_L$. Now, there is fluid which is being bypassed to tank via the flow control valve, Thus, the wasted HP is:
$(P_L + \Delta P)^*(Q_p - Q_L)$ This is shown graphically below:

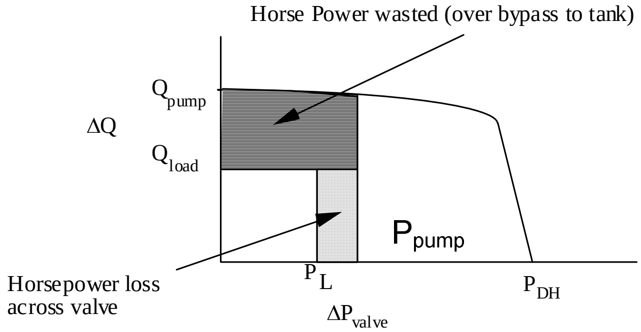


Figure 11.12 HP losses (low pressure)

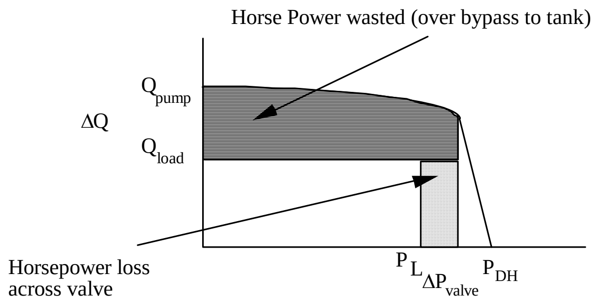


Figure 11.13 HP losses (High pressure)

It is apparent that at low load pressures and average flows, the HP loss is minimal. However, as the load pressure increases, the wasted HP increases substantially.

1.2.2.3 Restrictor flow control

Consider the circuit below. A restrictor, pressure compensated flow control is used to modulate the flow. Since flow to the actuator is always less than pump flow, the pump pressure is always at the deadhead pressure value. Thus, HP loss is restricted to that across the flow control valve and is equal to $Q_L * \Delta P$ where $= P_{deadhead} - P_L$

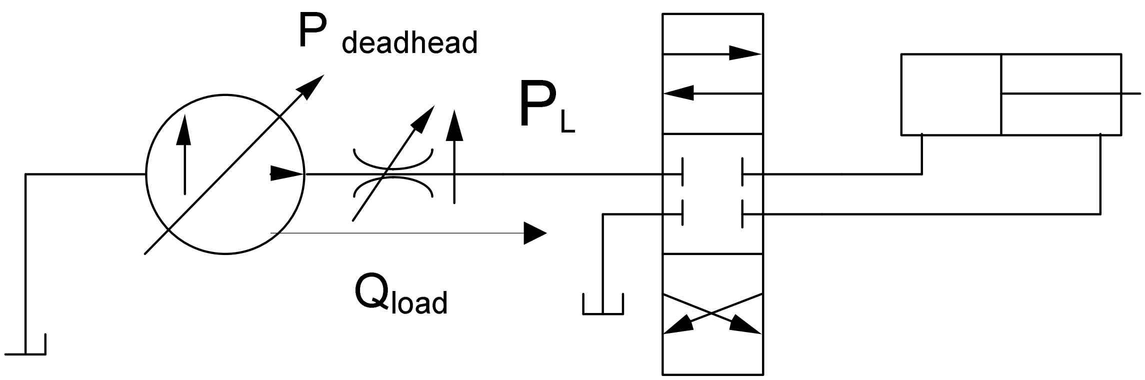


Figure 11.14 Restrictor flow control

The HP losses are illustrated below.

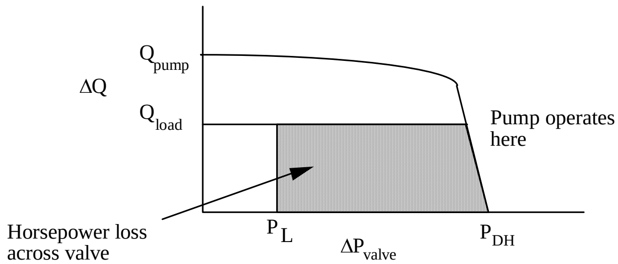


Figure 11.15 HP losses (small load pressures)

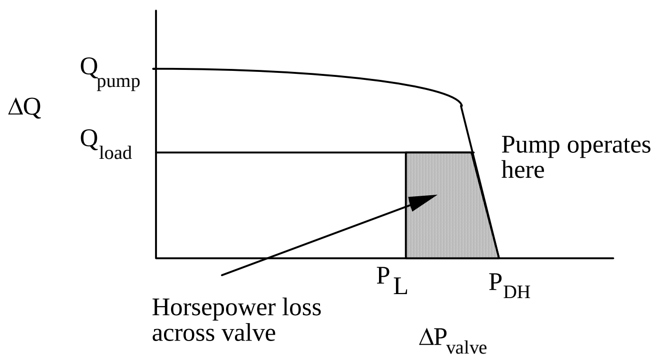


Figure 11.16 HP losses (larger load pressures)

At low pressure, and average flows, the HP loss is substantial. At large load pressures, the wasted HP decreases substantially.

11.2.2.4 Comparison

Lets us compare the losses of the restrictor vs bypass flow control valves.

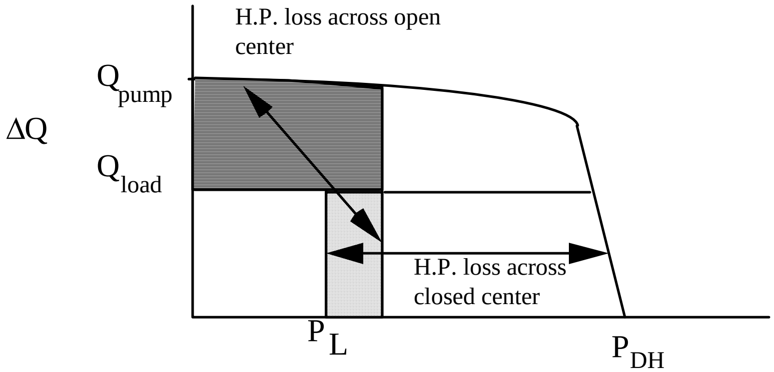


Figure 11.17 HP losses (low load pressures)

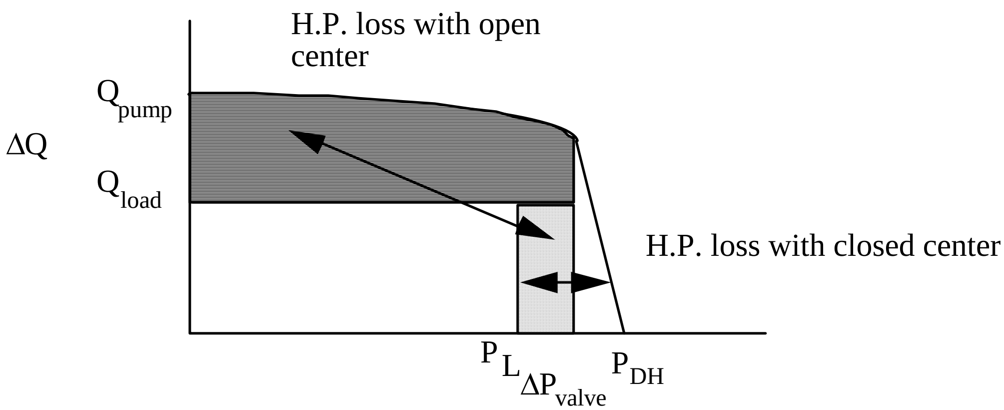


Figure 11.18 HP losses (higher load pressures)

If a large $P_{deadhead}$ is required for starting forces (torques) and the operating conditions are such that P_L is low, then an open center valve is desirable. If P_L is large, then a closed center flow control valve is preferred.

11.2.2.5 Load sensing

As discussed, HP losses still occur when using pressure compensated pumps in both open and closed circuits. Consequently, a load sensing device which in effect places the deadhead pressure just above load pressures and hence, can reduce the HP losses.

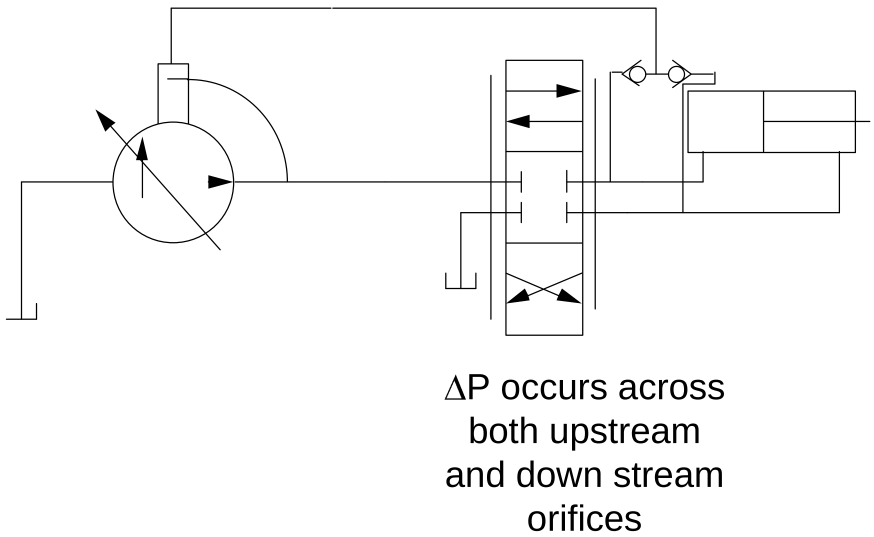


Figure 11.19 Load sensing (bi-directional)

The pump characteristics are illustrated below.

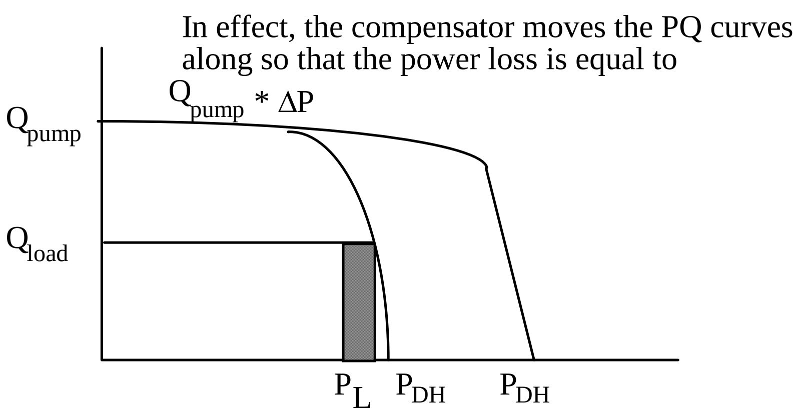
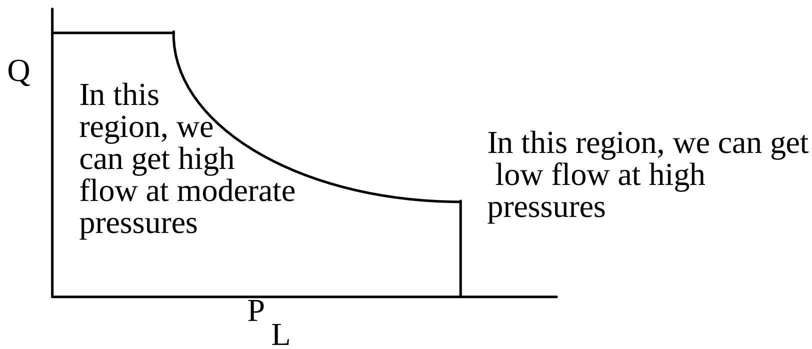


Figure 11.20 Load sensing HP losses

If we recall that $Q_L = K * A * (\Delta P)^{1/2}$, then if we can force ΔP to be constant at any load pressure, then Q_L is constant and is independent of variations in the load pressure. Thus the HP losses are always constant.

11.2.2.6 Torque limiting

Torque limiting systems use pressure and flow feedback to control pistons on the swash plate. When the system torque requirements (pressure) exceed a preset value, the swash plate (displacement) is changed to maintain a constant torque



H.P. requirements are moderate in both regions

Figure 11.21 PQ curves for HP limiting

In the region between high flows and low flows, we want the input driving torque (pump) to be constant. i.e.; we want to limit the necessary torque. This can be seen from the describing equations

torque = $D_m P_L$ and $Q_L = D_m \dot{\theta}$. Substituting for D_m, we get torque = $\frac{Q_L}{\dot{\theta}} * P_L$

Thus for a constant $\dot{\theta}$, then as P_L increases, Q_L must decrease.

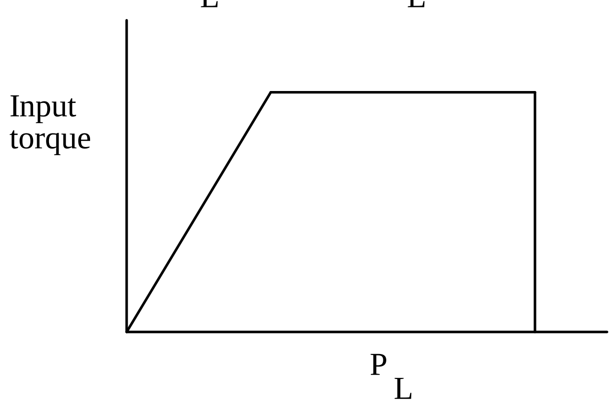


Figure 11.22 Input torque characteristic

11.2.2.7 Load sensing and torque limiting**.**

If we combine torque limiting with load sensing, we can get a HP loss reduction as illustrated below.

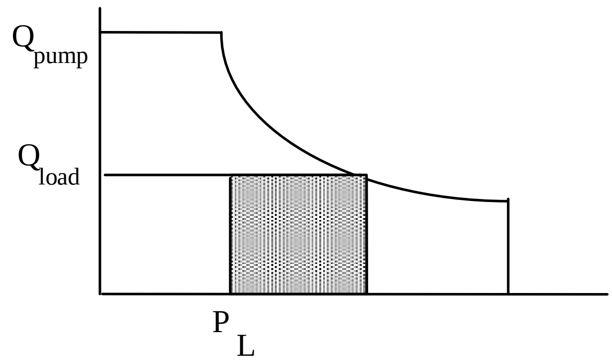


Figure 11.23 Torque limiting and load sensing.

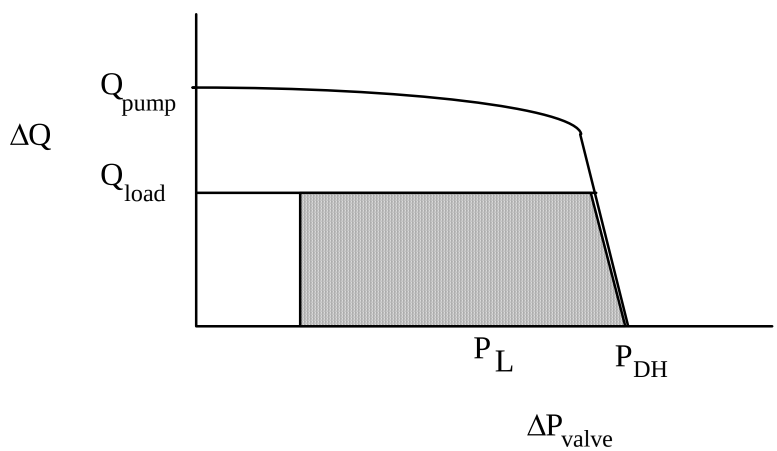


Figure 11.24 Same system without torque limiting.