Hydraulic Actuation System Components

- Hydraulic actuation systems convert **mechanical power** (provided by a motor or engine) into **fluid power**, transmit the fluid power to some location, and convert fluid power back into mechanical power to do **useful work**.

- The figures below depict **two typical systems**. The one on the left produces **translational** (or linear) motion, while the one on the right produces **rotational** motion. Even though power is lost each time it is converted to a different form or transmitted over some distance, these systems are still widely used, especially when it is required to control the motion of large loads.

- In each case shown, a **pump** is driven by an **electric motor** to produce **pressurized fluid**. In the system on the left, the fluid is used to extend or retract the piston in a **hydraulic cylinder**. In the system on the right, the fluid is used to rotate the **hydraulic motor** either clockwise or counter-clockwise.

- The **directional control valves** determine whether the cylinder extends or retracts, which way the hydraulic motor rotates, and in each case how quickly. For safety, both systems also use a **pressure relief valve**.

**Pumps**

- There are many different types of pumps used in industrial applications. The most common types are **vane** pumps, **gear** pumps, and **piston** pumps. Each of these can provide a **fixed** or **variable volume** of fluid to the system per revolution of the motor or engine. Fixed volume (or displacement) pumps are shown in the systems above.
Fixed volume pumps move a **fixed volume** of fluid into the system **irrespective of system pressure**. As system pressure rises beyond a specified limit, a **pressure relief valve** is used to divert unneeded flow back to the tank. Unfortunately, this tends to heat the hydraulic fluid.

Conversely, **pressure compensated variable volume pumps** will decrease the volume of flow into the system when system pressure goes beyond a specified limit. As the pressure continues to increase, the flow from the pump will eventually cease.

The figure shows a **performance curve** for a typical pressure compensated variable volume pump. The flow rate is zero at the compensator setting, but it will begin to significantly drop flow rate (by decreasing its volume) at pressures below this value. Hence, the pump lowers the hydraulic power to zero as the pressure approaches the compensator setting.

**Pressure Relief Valves**

Pressure relief valves are used to control the **maximum pressure** at some point within a system and should always be present for safety purposes.

In the system shown above **on the left**, the directional control valve has a **closed center position** meaning that when the valve spool is centered, no flow is allowed to pass through the valve. In this case, the use of a pressure relief valve is essential, because without it, the pressure in the line feeding the control valve would continue to rise when the valve is closed. This would result in one of two possibilities: 1) the pressure line would fail, or 2) the electric motor would be overloaded and stop.

**Directional Control Valves**

**Four-way directional control valves** are very commonly used in hydraulic actuation systems. The name implies there are **four ways (ports) for fluid to enter or leave the valve**. These ports are referred to as the pressure (P) port, the tank (T) port and the A and B ports. The supply line connects to the P port, and the return line to the T port.
- The figure above depicts some common four-way valve configurations. The two on the left and the one on the upper right are each four-way, three position, solenoid valves, each having a different center configuration. A solenoid is used to move the valve spool into either the left or right position, and a spring is used to center the spool when no voltage is applied to the solenoid.

- When the spool is in the left position, pressurized fluid is sent to the A port and the B port is connected to the tank. When the spool is in the right position, pressurized fluid is sent to the B port and the A port is connected to the tank.

- Open center valves allow fluid to flow freely from the P, A, and B ports to the tank when the valve spool is centered. If a cylinder is connected to an open center valve, it will be free to move when the valve spool is centered.

- Closed center valves stop all fluid flow when the valve spool is centered. A cylinder connected to this type of valve will be unable to move when the valve spool is centered.

- Tandem center valves block the flow to the A and B ports, holding a connected cylinder in place, but allow the pump flow to return to the tank when the spool is centered.

- The valve on the lower right is a proportional directional valve. The solenoid in this valve may be used to move the valve spool to a continuously variable position between the left and right extremes. This allows the circuit to not only control the direction of the flow, but also the flow rate. This type of valve combines the attributes of directional control and flow control valves.

Hydraulic Cylinders

- Hydraulic cylinders are used to convert fluid power into translational (or linear) mechanical power. Cylinders fall into three general categories – single-acting; double-acting, single-rod; and double-acting, double-rod.

- Each type of cylinder has a piston and a rod. In a single-acting cylinder, pressurized fluid is used to push on one side of the piston only (usually to extend), while in a double-acting cylinder, pressurized fluid is used to both extend and retract the cylinder.
In a single-rod cylinder, the area on the rod end of the piston is smaller than the area on the cap end. In a double-rod cylinder, the area on both ends of the piston are the same. Hence, for a given pressure, a single-rod cylinder will apply a larger force in extension than it does in retraction, where as a double-rod cylinder will apply the same force in both directions.

Assuming the hydraulic fluid is incompressible, the speed of the rod can be related to the flow rates in and out of the cylinder.

\[ Q_i = v A_i \quad \text{and} \quad Q_o = v A_o \]

Here, \( Q_i \) and \( Q_o \) are the volumetric flow rates in and out of the cylinder, \( A_i \) and \( A_o \) are the piston areas on the in-flow and out-flow sides of the piston, and \( v \) is the speed of the piston and rod.

Hydraulic Motors

Hydraulic motors are much like pumps except they are driven by pressurized fluid instead of an engine or electric motor. They convert hydraulic power into rotational mechanical power. The most common types are gear motors, vane motors and piston motors. (Gear motors are the most common.)

The speed and direction of rotation of the motor is determined by the rate and direction of flow through the motor.