Hydraulic Fluid

It wasn’t until the beginning of the industrial revolution when a British mechanic named Joseph Bramah applied the principle of Pascal’s law in the development of the first hydraulic press. In 1795, he patented his hydraulic press, known as the Bramah press. Bramah figured that if a small force on a small area would create a proportionally larger force on a larger area, the only limit to the force that a machine can exert is the area to which the pressure is applied.

What is a Hydraulic System?

Hydraulic systems can be found today in a wide variety of applications, from small assembly processes to integrated steel and paper mill applications. Hydraulics enable the operator to accomplish significant work (lifting heavy loads, turning a shaft, drilling precision holes, etc.) with a minimum investment in mechanical linkage through the application of Pascal’s law, which states:

“Pressure applied to a confined fluid at any point is transmitted undiminished throughout the fluid in all directions and acts upon every part of the confining vessel at right angles to its interior surfaces and equally upon equal areas (Figure 1).”

Figure 1 - Pascal's Law
By applying Pascal's law and Brahma's application of it, it is evident that an input force of 100 pounds on 10 square inches will develop a pressure of 10 pounds per square inch throughout the confined vessel. This pressure will support a 1000-pound weight if the area of the weight is 100 square inches.

The principle of Pascal's law is realized in a hydraulic system by the hydraulic fluid that is used to transmit the energy from one point to another. Because hydraulic fluid is nearly incompressible, it is able to transmit power instantaneously.

Hydraulic System Components

The major components that make up a hydraulic system are the reservoir, pump, valve(s) and actuator(s) (motor, cylinder, etc.).

Reservoir

The purpose of the hydraulic reservoir is to hold a volume of fluid, transfer heat from the system, allow solid contaminants to settle and facilitate the release of air and moisture from the fluid.

Pump

The hydraulic pump transmits mechanical energy into hydraulic energy. This is done by the movement of fluid which is the transmission medium. There are several types of hydraulic pumps including gear, vane and piston. All of these pumps have different subtypes intended for specific applications such as a bent-axis piston pump or a variable displacement vane pump. All hydraulic pumps work on the same principle, which is to displace fluid volume against a resistant load or pressure.

Valves

Hydraulic valves are used in a system to start, stop and direct fluid flow. Hydraulic valves are made up of poppets or spools and can be actuated by means of pneumatic, hydraulic, electrical, manual or mechanical means.

Actuators

Hydraulic actuators are the end result of Pascal's law. This is where the hydraulic energy is converted back to mechanical energy. This can be done through use of a hydraulic cylinder which converts hydraulic energy into linear motion and work, or a hydraulic motor which converts hydraulic energy into rotary motion and work. As with hydraulic pumps, hydraulic cylinders and hydraulic motors have several different subtypes, each intended for specific design applications.

Key Lubricated Hydraulic Components

There are several components in a hydraulic system, that due to cost of repair or criticality of mission, are considered vital components. Pumps and valves are considered key components. Several different configurations for pumps must be treated individually from a lubrication perspective, including:
Vane Pumps

There are many variations of vane pumps available between manufacturers. They all work on similar design principles. A slotted rotor is coupled to the drive shaft and turns inside of a cam ring that is offset or eccentric to the drive shaft. Vanes are inserted into the rotor slots and follow the inner surface of the cam ring as the rotor turns.

The vanes and the inner surface of the cam rings are always in contact and are subject to high amounts of wear. As the two surfaces wear, the vanes come further out of their slot. Vane pumps deliver a steady flow at a high cost. Vane pumps operate at a normal viscosity range between 14 and 160 cSt at operating temperature. Vane pumps may not be suitable in critical high-pressure hydraulic systems where contamination and fluid quality are difficult to control. The performance of the fluid’s antiwear additive is generally very important with vane pumps.

Piston Pumps

As with all hydraulic pumps, piston pumps are available in fixed and variable displacement designs. Piston pumps are generally the most versatile and rugged pump type and offer a range of options for any type of system. Piston pumps can operate at pressures beyond 6000 psi, are highly efficient and produce comparatively little noise. Many designs of piston pumps also tend to resist wear better than other pump types. Piston pumps operate at a normal fluid viscosity range of 10 to 160 cSt.

Gear Pumps

There are two common types of gear pumps, internal and external. Each type has a variety of subtypes, but all of them develop flow by carrying fluid between the teeth of a meshing gear set. While generally less efficient than vane and piston pumps, gear pumps are often more tolerant of fluid contamination.

1. Internal gear pumps produce pressures up to 3000 to 3500 psi. These types of pumps offer a wide viscosity range up to 2200 cSt, depending on flow rate and are generally quiet. Internal gear pumps also have a high efficiency even at low fluid viscosity.

2. External gear pumps are common and can handle pressures up to 3000 to 3500 psi. These gear pumps offer an inexpensive, mid-pressure, mid-volume, fixed displacement delivery to a system. Viscosity ranges for these types of pumps are limited to less than 300 cSt.

Hydraulic Fluids

Today’s hydraulic fluids serve multiple purposes. The major function of a hydraulic fluid is to provide energy transmission through the system which enables work and motion to be accomplished. Hydraulic fluids are also responsible for lubrication, heat transfer and contamination control.

The properties of a hydraulic fluid depend on the additives used and the base oil. Additives in Hydraulic fluid offer a range of specific performance characteristics. Common hydraulic fluid additives include rust and oxidation inhibitors (R&O), anticorrosion agents, demulsifiers, antiwear (AW) and
extreme pressure (EP) agents, VI improvers and defoamants. Mineral-based fluids offer a low-cost, high quality, readily

**Fluid Properties**

When choosing a hydraulic fluid, consider the following characteristics: viscosity, viscosity index, oxidation stability and wear resistance. These characteristics will determine how your fluid operates within your system.

1. **Viscosity (ASTM D445-97)** is the measure of a fluid’s resistance to flow and shear. A fluid of higher viscosity will flow with higher resistance compared to a fluid with a low viscosity. Excessively high viscosity can contribute to high fluid temperature and greater energy consumption. Viscosity that is too high or too low can damage a system, and consequently, is the key factor when considering a hydraulic fluid.

2. **Viscosity Index** is how the viscosity of a fluid changes with a change in temperature. A high VI fluid will maintain its viscosity over a broader temperature range than a low VI fluid of the same weight. High VI fluids are used where temperature extremes are expected. This is particularly important for hydraulic systems that operate outdoors.

3. **Oxidation Stability** is the fluid’s resistance to heat-induced degradation caused by a chemical reaction with oxygen. Oxidation greatly reduces the life of a fluid, leaving by-products such as sludge and varnish. Varnish interferes with valve functioning and can restrict flow passageways.

4. **Wear Resistance** is the lubricant’s ability to reduce the wear rate in frictional boundary contacts. This is achieved when the fluid forms a protective film on metal surfaces to prevent abrasion, scuffing and contact fatigue on component surfaces.