METC 279

Basics of Fluid Powers

Elijah Hon

Introduction

What is Fluid Power? According to the National Fluid Power Association (NFPA) it is the use of pressurized fluids, such as pneumatics and hydraulics, to transmit power from one place to another. Fluid Power is used in many different ways from hydraulic presses to pneumatic truck brakes. Fluid Power is versatile and allows for many of the technological advances in the Modern era.

Advantages of Fluid Power

As stated in the introduction fluid power is a crucial tool to the modern advances of today's technology. There are three basic methods to transmit power. These are electrical, mechanical, and fluid power. Fluid Power is so widely used for several reasons. Two of them being its versatility and its manageability. For example, mechanical power is dependent upon the geometry of a machine whereas fluid power is not. There are four primary advantages to fluid power over the other two types.

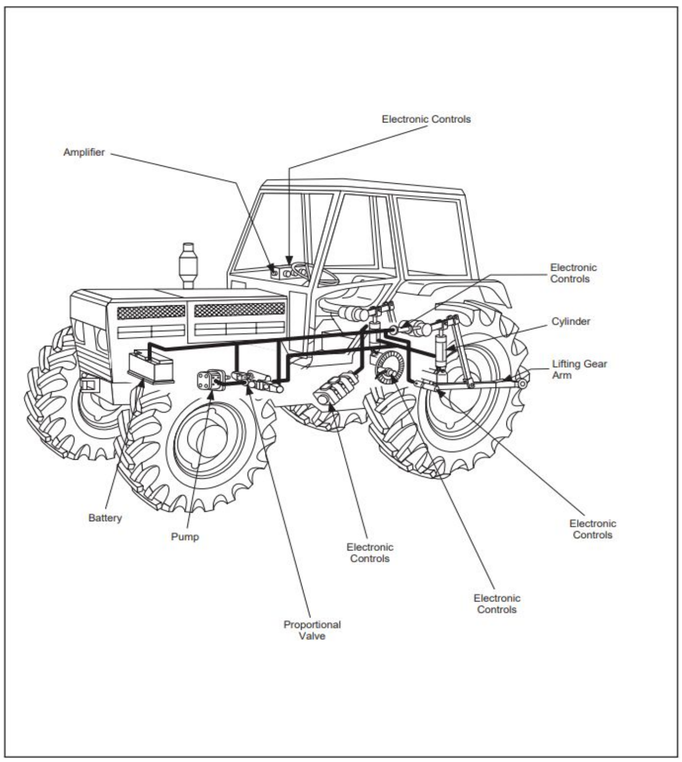

Figure 1-1. Hitch control for a tractor. (Courtesy of National Fluid Power Association, Milwaukee, Wisconsin.)

1. Ease of control and accuracy: Fluid power can be easily managed by the use of simple mechanisms such as push buttons and levers. This allows the operator to easily control fine movements of the fluid power system without the need for complex setups. This also allows the operator to be highly accurate in the movements of the fluid power system.

2. Force multiplication: Fluid power can easily multiply forces through Pascal's Law.
3. Constant force: Fluid power systems are the only systems that can provide a constant force/torque despite any speed changes.
4. Simplicity and size: Fluid Power systems rely on less moving parts than its two counterparts. Generally this makes them simpler to maintain. Also, with less parts, fluid power systems take up less space than electrical or mechanical systems. This allows them to fit in confined spaces while maintaining power transmission capabilities.

Figure 1-1 is an example of how fluid power systems are used in modern technology.

Disadvantages of Fluid Power

Although there are many benefits to fluid power systems there are also a few drawbacks to them as well. For example, fluid power systems require a sealed system setup. This means that in order to have proper power transmission the entire system must be sealed. Any fluid leakage could drastically reduce any power transmission. Some other disadvantages to fluid power include;

- Can be Messy
- Can be Loud
- Can be Flammable

- Can be Corrosive
- Risk of injury due to over-pressurised system

Applications of Fluid Power

There are many applications for fluid power in today's world including those previously mentioned. The following are two more examples of how fluid power is used today.

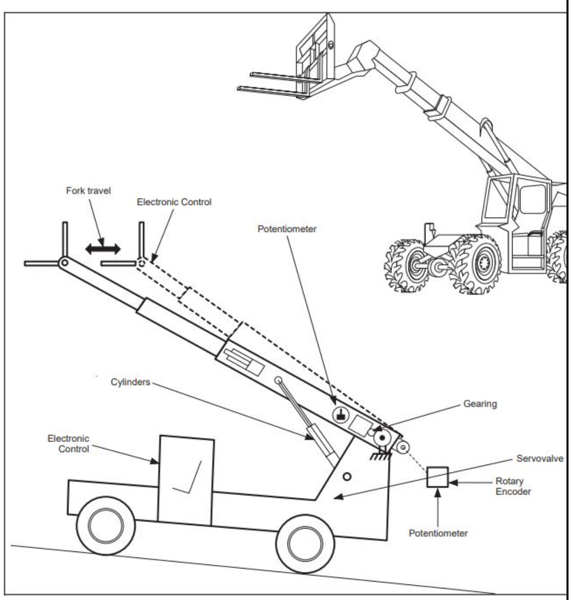

Figure 1-2. Rough terrain forklift driven by hydraulic cylinders. (*Courtesy of National Fluid Power Association, Milwaukee, Wisconsin.*)

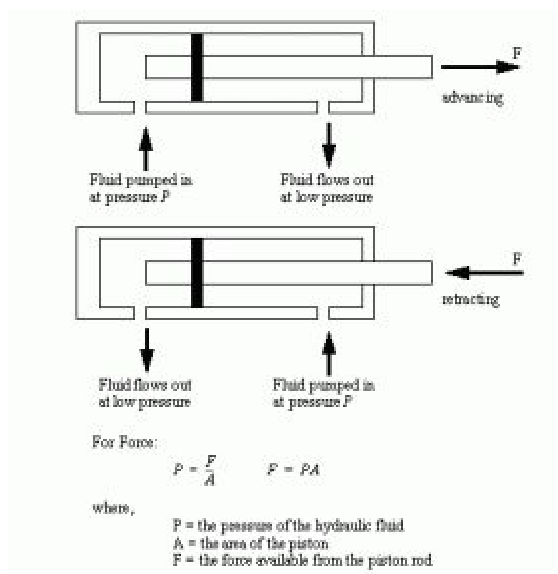

Figure 1-3. Bidirectional hydraulic cylinder. (*Courtesy of hydrualiconline.com)*

Figure 1-2 shows a rough terrain forklift using hydraulic cylinders to drive the arm of the forklift. Forklifts require steady movement and fine control to operate correctly. The hydraulic cylinder allows the operator to control the speed at which the arm is lifted and extended giving them full control over the forklift.

Figure 1-3 is a basic example of a hydraulic cylinder and the equation to determine the force exerted by the piston. As fluid is pumped into the cylinder (on the right) fluid flows out of the cylinder at the same time (on the left). In order for the rod to retract, the volume of fluid pumped into the right side of the cylinder must equal the volume of fluid flowing out of the cylinder. The force can be determined by multiplying the force of the fluid times the area or annular area of the piston.

Hydraulics

Hydraulics is a branch of fluid power that deals with practical applications (such as the transmission of energy or the effects of flow) of liquid (such as oil) in motion. Hydraulics deals specifically with liquid-based power systems. Hydraulic systems require six basic components (see **Figure 1-4**):

1. A tank or reservoir - Holds the hydraulic oil
2. A pump - Forces oil through the system
3. Motor - Drives the pump
4. Valves - Controls liquid direction, flow rate, and pressure
    a. Directional Control Valve
    b. Check valve

c. Needle valve

5. Actuator - Converts fluid pressure into mechanical force or torque

    a. Cylinder - Converts flow to linear mechanical force

    b. Motor - Converts flow to radial mechanical force

6. Piping - Carries oil from one location to another.

Hydraulics use pumps that **create flow** and allow the hydraulic circuit operate. Without flow the hydraulic power system is rendered useless as it is vital in the conversion to mechanical force.

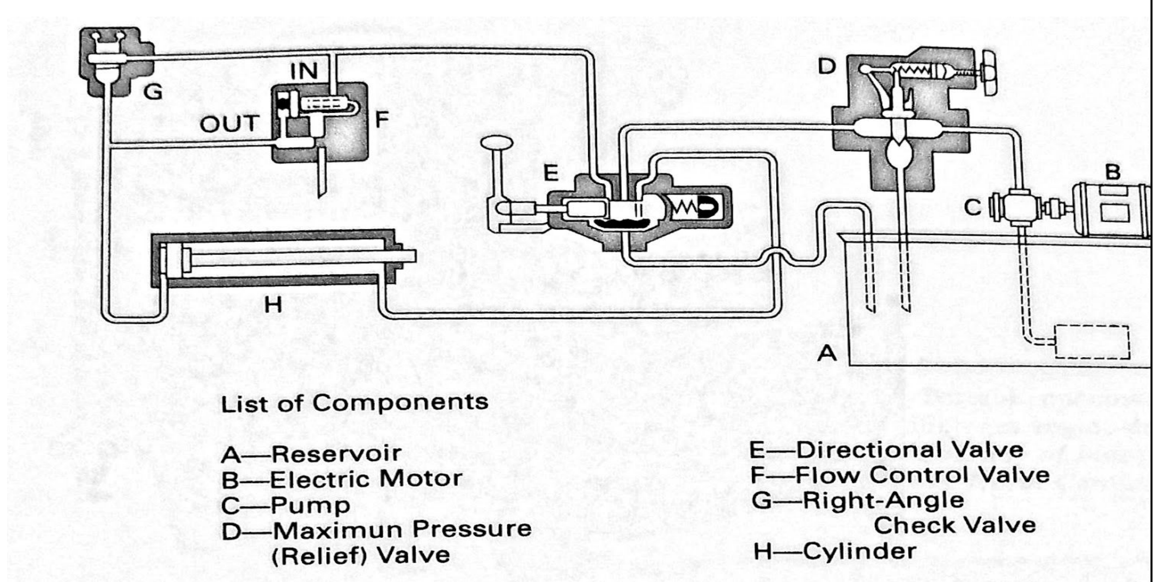

Figure 1-4. Basic components of a hydraulic system. (*Courtesy of Sperry Vickers, Sperry Rand Corp., Troy Michigan.)*

Pneumatics

Pneumatics is a branch of fluid power that deals with practical applications (such as the transmission of energy or the effects of flow) of gases (such as air) in motion. Pneumatics deals specifically with gas-based power systems and require six basic components similar to a hydraulic based system:

1. Air tank - Stores compressed air
2. Compressor - Compresses atmospheric air
3. Motor - Drives the compressor
4. Valves - Controls gas direction, flow rate, and pressure
    a. Directional Control Valve
    b. Check valve
    c. Needle valve
5. Actuators - Converts fluid pressure into mechanical force or torque
    a. Cylinder - Converts pressure to linear mechanical force
    b. Motor - Converts pressure to radial mechanical force
6. Piping - Carries pressurized air from one location to another

Pneumatics use compressors to **create pressure** in a pneumatic circuit. Pneumatics rely heavily on pressure build up in order to complete work. Without pressure it is impossible to create mechanical force.

Pascal's Principle

Hydraulic and pneumatic power systems are possible because of a few basic principles in fluid mechanics. One of these basic principles is Pascal's Principle. Pascal's Principle can be stated as the following: *Pressure applied to a confined fluid is transmitted equally in every direction throughout the fluid and acts perpendicular to the surfaces contacting the fluid.* This principle reveals how it is possible for fluid power systems to perform useful work.

Pascal's principle is useful when analyzing force multiplication. The equation for force multiplication is a combination of Pascal's Principle and the equation for pressure. When analyzing force multiplication the input pressure must be equal to the output pressure (Pascal's Principle). This can be represented by the following equations:

$$\frac{F1}{A1} = \frac{F2}{A2}$$

Or

$$\frac{F1}{F2} = \frac{A1}{A2}$$

Figure 1-6 shows an example of how to apply Pascal's Principle to Force Multiplication. On the left there is a 10lb weight that is placed in a 1 in^2 cylinder. On the right there is a 100 lb weight that is placed in a 10 in^2 cylinder. Because of

Pascal's Principle the 10 lb weight must move 10in downward to move the 100 lb weight upward. This principle is commonly used in vehicle brakes. Using a small force (driver's foot against brake) and large distance (driver pressing brake) can create a large force (brake pad against rotor) over a small distance (distance between brake pad and rotor).

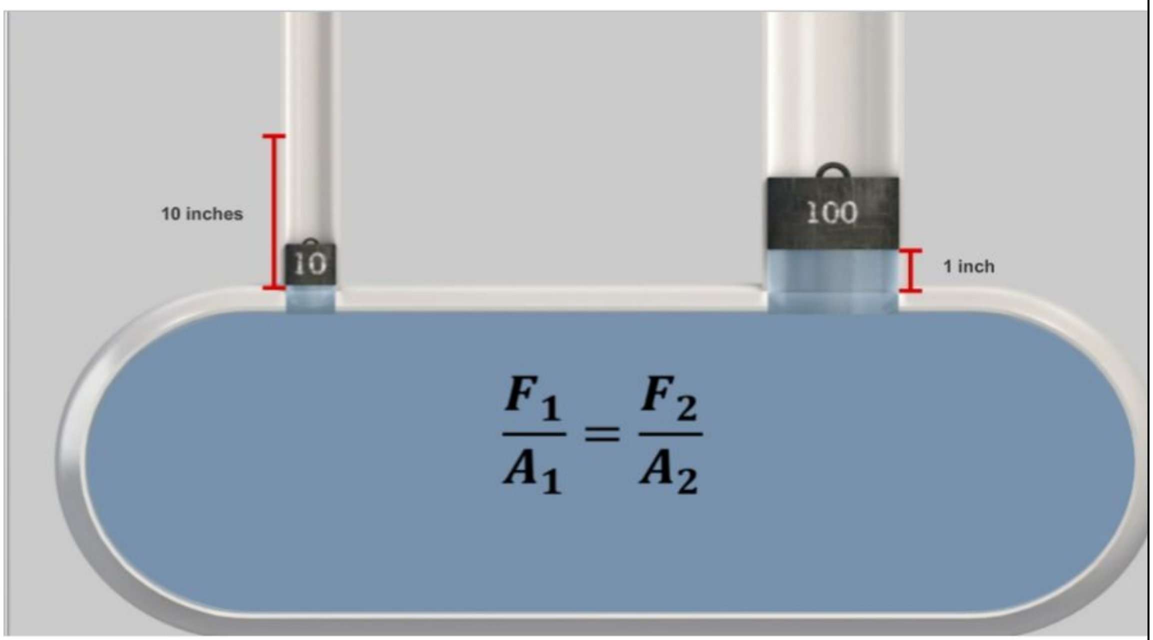

Figure 1-6. Force multiplication example. (*Courtesy of Ivy Tech Community College, Fort Wayne, Indiana*)

Boyle's Law

Another important law in fluid power is Boyle's Law. Boyle's Law relates to pneumatics and gases. It states that if a gas held at a constant temperature, then its volume is inversely proportional to its absolute pressure. This can be represented as an equation:

$$\frac{V1}{V2} = \frac{p2}{p1}$$

For example, assume there is a cylinder with a volume of 10 in^3 and an absolute pressure of 1 psi. If that cylinder was to be compressed to a volume of 1 in^3 then new pressure could be found using Boyle's Law:

$$\frac{10in^3}{1in^3} = \frac{p_2}{1\ psi}$$

$$\frac{10in^3}{1in^3} \bullet 1\ psi = p_2$$

$$10\ psi = p_2$$

Boyle's Law is used in the medical field with syringes. When the syringe is fully depressed there is no air in it and the pressure is up. When the syringe retracts it increases the volume and decreases the pressure creating a mini vacuum. This process is what allows the syringe fill with fluids.

Conclusion

Fluid power is used all around the world for many applications. However, there is one common goal; convert fluid pressure into mechanical force. This paper covered the basics of fluid power and a few of its many applications. Fluid power is versatile and with the application of fluid mechanics there are many technologies yet to be created.

Citations:

Esposito, Anthony. *Fluid Power with Applications*. Pearson, 2014.

Gillespie, Claire. "Advantages & Disadvantages of Hydraulic Systems." *Sciencing*, 2 Mar. 2019, sciencing.com/advantages-disadvantages-hydraulic-systems-7198601.html

London, Ernest. "How Do Hydraulic Systems Work? An Intro to Hydraulic Components." *Hydrauliconline.com*, 17 July 2018, www.hydrauliconline.com/hydraulic-pumps/hydraulic-systems-work-intro-hydraulic-components/.

NFPA. "What Is Fluid Power?" *What Is Fluid Power?*, www.nfpa.com/home/AboutNFPA/What-is-Fluid-Power.htm.

Yuken Kogyo Co., Ltd. *BASIC HYDRAULICS AND COMPONENTS*. Yuken Kogyo Co., Ltd, Jan. 2005, yuken-usa.com/pdf/special/Basic_Hydraulic_And_Components_(Pub._ES-100-2)_.pdf.