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Class Outline

Objectives
Introduction to Power Transmission
What Is A Fluid?
What Is Fluid Power Transmission?
Hydraulic Fluids
Pneumatic Fluid
Fluid Power System Components
Hydraulic Pumps
Air Compressors
Fluid Control Components
Actuators
Fluid Conductors
Advantages of Fluid Power
Summary
Lesson: 1/14

Objectives
- Describe power transmission systems.
- Describe fluids.
- Describe fluid power.
- Describe the properties of hydraulic fluid.
- Describe pneumatic fluid.
- Describe fluid power system components.
- Describe a hydraulic pump.
- Describe an air compressor.
- Describe a control valve.
- Describe an actuator.
- Describe a fluid conductor.
- Describe the advantages of fluid power.

Fluid Power System Advantages
- Cost-efficient
- Convenient
- Greater multi-function control & accuracy
- Provides constant force
- Safer operation
- Established industry standards

Figure 1. Fluid power systems have many advantages over other forms of power transmission.

Figure 2. Control valves are designed to be used together to regulate pressure and control fluid flow.
Introduction to Power Transmission

Power transmission enables work by transforming energy into usable movement and delivering it from a source to a location. Some of the oldest modes of power transmission are the wheel and gear systems used by ancient civilizations. Figure 1 shows early wheel and gear technology. Humans and animals powered these devices. More recently, fluids such as pressurized water and compressed air were introduced as power sources and eventually replaced human and animal power in most industries. Today there are three major categories of power transmission systems:

- **Mechanical systems** use the physical interaction of instruments or tools to transmit power. Common components include levers, pulleys, gears, cams, bearings, and couplings.
- **Electrical systems** use the force of electron flow to transmit power. Common components include motors, solenoids, and electrical wiring.
- **Fluid systems** such as **hydraulic systems** and **pneumatic systems** use the force of flowing liquids to transmit power. Common components include pumps, motors, control valves, and pipes.

This class focuses on fluid power, which includes both hydraulic and pneumatic systems. In this class, you will learn about fluid power transmission and the basic principles of how fluids are used to convert energy into usable actions like bending metal or lifting a heavy load.

Figure 1. The wheel and gear system is one of the earliest forms of power transmission.
Lesson: 3/14

What Is A Fluid?
Hydraulic and pneumatic systems use fluids to transmit power. Fluids are characterized by their ability to flow and take on the shape of their container. When pressure is applied to a contained fluid, molecules can move around and change shape but the volume stays the same.

Hydraulic fluids are liquids, such as oil and water. A liquid is a state of matter in which molecules move around freely but do not separate. As illustrated in Figure 1, molecules can form a surface because of their ability to flow together in the same direction. All liquids seek to maintain a constant volume. When kept in a container, the liquid exerts an equal amount of pressure on all sides of the container. Factors such as temperature and pressure can affect a liquid's ability to flow and cause minor changes in volume.

Pneumatic fluid is gas, such as compressed air or inert gas. A gas is a state of matter in which molecules move around independently. There are no forces keeping them together or pushing them apart, as illustrated in Figure 2. Unlike liquids, gases do not have a fixed volume and expand to fill the space they occupy.

Fluids are generally liquids and gases. However, some fluids can contain solid particles called slurries. Sometimes dry powders also can be handled as fluids.

Figure 1. Liquid molecules flow freely but do not separate from each other.

Figure 2. Gas molecules move around randomly. There are no forces keeping them together or pulling them apart.
Lesson: 4/14

What Is Fluid Power Transmission?
Fluid power is used in manufacturing to produce work. Fluid power transmits energy from a source to a location by pressurizing contained liquids or gases. The brakes in a typical car are powered by a hydraulic system. Mechanical energy from depressing the brake pedal is converted to fluid pressure, which is converted back to mechanical energy that applies the brakes to the wheels.

The best way to grasp how fluids accomplish transfer of energy is by understanding Pascal's Law. Pascal's Law states that fluids under pressure produce an equal amount of force on all surfaces in contact with the fluid. The force of a contained fluid remains the same until an outside force, such as pressure, acts on it. When pressure acts on the fluid, it causes motion by converting potential energy to kinetic energy and produces work. The basic principles of Pascal's Law are illustrated in Figure 1.

Pressure is the main factor in fluid power. It is equal to the amount of force thrust upon a surface and divided by the area perpendicular to the applied force. If the same amount of force is applied to a greater surface area, the amount of pressure decreases. Pressure is measured in units of pounds per square inch (psi) or newtons per square meter (pascals).

![Figure 1. Pascal's Law states that pressurized fluid exerts equal force on all surfaces in contact with the fluid.](image-url)
Hydraulic Fluids
Understanding the importance of the actual hydraulic fluid in a system is critical. Although hydraulic fluids are often petroleum-based oils they can also be non-petroleum-based oils, or water-based. Hydraulic fluids must be able to transmit power and transfer heat, as well as act as a sealant and lubricant. Figure 1 shows a multi-purpose hydraulic oil.

Petroleum-based and non-petroleum-based oils are the first choice for hydraulic applications. The most important property influencing power transmission is viscosity, which is a fluid's ability to flow at specific temperatures. Hydraulic fluids are handled by the hydraulic pump, control valves, actuators, and conductors to create power and must be able to move through the system and ideally prevent wear and leakage. Figure 2 shows hydraulic fluid in a reservoir ready for use. Oil can cause problems in the system if it is too thick or too thin. The operating temperature will determine the oil you use for a specific application.

Oils naturally have properties that reduce wear and corrosion on system components, such as lubricity and the ability to separate from water, also known as demulsibility. Maintaining clean, debris-free fluids can also reduce wear and corrosion on fluid conductors and system components.

Water has limited application because it lacks the natural properties of oils, such as corrosion resistance and lubrication. Water is also vulnerable to temperature variations in the system, such as freezing or boiling, whereas oils are stable and perform well despite temperature variations.

Figure 1. Hydraulic fluids can be petroleum-based oils, non-petroleum-based oils, or water-based liquids.

Figure 2. The reservoir holds the hydraulic fluid that powers this workholding device.
Pneumatic Fluid
Air is the main fluid used in pneumatic systems. Air is ideal because it is free, but it requires preparation before use to increase efficiency and prolong life of pneumatic components. Air must be compressed, filtered, lubricated, regulated, and separated from moisture and debris. As illustrated in Figure 1, air goes through the following process before it is distributed into the system:

1. Air is pulled in from the ambient atmosphere through the intake.
2. Molecules are squeezed by an air compressor, which increases temperature.
3. An aftercooler, also called a drier, works to reduce the temperature of the air. Cooling the air prevents corrosion and sticking valves or parts.
4. Air is then separated from water or moisture, which can cause corrosion or vapor lock. Water and moisture are undesirable in pneumatic systems.
5. The compressed air is stored in an air receiver. The receiver tank creates a balance between the airflow and the capacity of the compressor.
6. Air then goes through an FLR-unit where it is filtered to remove particles that may cause obstructions and lubricated with a small amount of oil that is drawn in with the air. This ensures all mechanical parts function properly throughout the system. Pressure is also regulated by the FLR-unit.

Pneumatic systems are mainly used for low-pressure applications because air is not as powerful as hydraulic fluids. However, air is more efficient for applications near fire hazards and for high-speed applications.
Lesson: 7/14

Fluid Power System Components
Fluid power transmission systems require four components (Figure 1) that enable pressurized fluids to transmit energy:

1. **Hydraulic pumps** and **air compressors** introduce fluids into the system. These devices are powered by **prime movers** such as electric motors and diesel engines.
2. Fluid control components control fluid pressure and rate of flow. Examples include various control valves and regulators.
3. **Actuators** receive the pressurized fluid from the control components and generate usable motion. Examples include **hydraulic motors** or **fluid motors**, cylinders, grippers, clamps, and other **effectors**.
4. **Conductors** carry the fluid throughout the entire system. Examples include pipes, hoses, and tubing.

These components must be present in a fluid system, regardless of how simple or complex it is constructed. Both hydraulic and pneumatic systems have these four main components, but with some variation and differences in functioning.

**Figure 1.** A pump or compressor, control valves, actuators, and conductors are the four main components of fluid power systems.
Hydraulic Pumps
The **hydraulic pump** is considered the heart of the system because it is the energy source that allows the system to work. Hydraulic pumps operate by creating a partial **vacuum** at the inlet port. When the vacuum is created, **atmospheric pressure** forces liquid into the pump. The mechanical components inside the pump then push the fluid out into the system.

There are three basic designs of hydraulic pumps: the **gear pump** (Figure 1), the **vane pump** (Figure 2), and the **piston pump** (Figure 3). These pumps are considered **positive-displacement pumps**. Positive-displacement pumps push out the same volume of oil with each input revolution of the prime mover. The faster the pump operates, the greater the flow of fluid. Positive-displacement pumps push fluid as long as the pump is powered. This means that if the discharge opening is blocked, the fluid continues to flow and causes system failure. To prevent failure, hydraulic pumps are equipped with **pressure-relief valves** that allow fluid to escape back to the tank when the maximum setting is reached.

Hydraulic pumps have a wide variety of pressure ranges. The required operating pressure will determine which type of pump is used for a specific application. Gear and vane pumps are generally used for applications below 2,000 psi. Some gear pumps can operate up to 4,000 psi. Piston pumps are generally used for applications requiring operating pressure up to 10,000 psi.
Air Compressors
The independent nature of gas molecules requires air to be compressed before it can be used as a power source. Air compressors condense the air and send it to the receiver tank. An air compressor and a receiver tank are shown in Figure 1. During compression, the density, temperature, and pressure of the gas increase. This behavior is referred to as compressibility. Heat exchangers are often included in pneumatic systems to bring the temperature down.

There are three basic types of air compressors: the gear screw compressor, the vane compressor, and the piston compressor. Like hydraulic pumps, these devices are considered positive displacement devices.

In manufacturing, air compressors can supply air for one or more pneumatic systems in a plant. A similar "central hydraulic system" is not nearly as common.

![Figure 1. An air compressor and receiver tank.](image-url)
**Lesson: 10/14**

**Fluid Control Components**

Once fluid leaves the pump or air compressor, a **control valve** regulates fluid pressure and flow in the system. Hydraulic and pneumatic systems use the same types of control valves to perform one or more of the following functions:

- Start or stop flow.
- Regulate flow.
- Prevent reverse flow.
- Change flow direction.
- Limit fluid pressure.

Figure 1 shows various control valves that perform a few of the functions mentioned above.

Figure 2 shows two different types of control valves resting on a **manifold**. You can control most valves electrically with a solenoid or manually with a knob, handwheel, or lever handle. However, you may encounter conditions when the fluid flow or pressure is too great for manual control. In this case, an actuator must be used. These devices mechanically control the valve and allow for control from remote locations.

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**Figure 1.** Control valves that perform different functions.

**Figure 2.** Control valves are designed to be used together to regulate pressure and control fluid flow.
Lesson: 11/14

Actuators
Hydraulic and pneumatic systems use actuators, which are the devices that convert fluid energy into mechanical energy. Actuators convert potential energy to kinetic energy and create motion. There are three types of actuators:

- **Linear actuators** (Figure 1) are cylinders or slide valves that apply force in a straight line. The most common types are piston actuators and diaphragm actuators.
- **Rotary actuators** are circular controls that apply force in a circular motion. The most common type uses a vane and shaft. The rack-and-pinion actuator (Figure 2) converts linear motion to rotary motion.
- **Fluid motors** are like their electric and fuel-powered counterparts, except they run on fluid.

Actuators work by receiving fluid pressure and transmitting it into linear or rotary forces.

Figure 1. Linear actuators apply force that moves fluid in a straight line.

Figure 2. Rack-and-pinion actuators convert linear motion to rotary motion.
Fluid Conductors
Both hydraulic and pneumatic systems require conductors to channel fluid. There are three basic types of conductors used in fluid systems: pipe, tubing, and hose.

Pipe is used for linear routes. Pipe is generally inexpensive and can be connected to other components by threading, welding, or flanging. Manufacturers use pipe for permanent fixtures. Figure 1 shows pipe used in fluid power systems.

Tubing is used when non-linear routes are necessary. There are two types of tubing used in fluid systems: metallic and plastic. Metallic tubing is bendable and can accommodate higher pressure levels. Plastic tubing is also flexible, but mainly used for lower pressure levels. Figure 2 shows metallic tubing.

Hose is the preferred material for non-linear routes because it can flex and bend. In manufacturing plants, you normally see hoses connected to an air supply. The fittings are designed to disconnect quickly, making hose a convenient choice. Hose is durable and can be installed permanently. Hose can also be reused. The inside of the hose is rubber, and the outside is reinforced with woven yarn, fiber, or wire. It is common to have a third outside layer of colored rubber or PVC to protect the support weaving and gain visual differentiation. It comes in a range of sizes from 3/16 in. to 3 inches. Figure 3 shows some various types and sizes of hose. The pipe, tubing, or hose must be large enough to carry the maximum amount of fluid and strong enough to withstand internal pressure.
Lesson: 13/14

Advantages of Fluid Power
Fluid power systems have many advantages over other types of power systems. Some advantages of fluid power include, but are not limited to the following:

- Cost efficiency. Hydraulic and pneumatic systems are inexpensive to maintain as long as they are kept in good working condition. Moving parts should be oiled and the system kept free of water or elements that may cause corrosion.
- Convenience. Fluid power systems can be operated hydraulically, pneumatically, or electrically and from remote locations.
- Greater control and accuracy. Control valves and actuators work together to control high linear and rotary forces. Hydraulic actuators can deliver more force per pound than any other mechanical system.
- Multi-function control. The prime movers can control one or more machines.
- Constant force. Pumps and compressors are positive displacement devices that provide constant fluid flow as long as they are powered.
- Safety. Both hydraulic and pneumatic systems can be designed to create just enough force to perform a task without structurally harming machinery framework. Specific designs can accommodate high temperature environments.
- Established standards and engineering. Organizations such as the National Fluid Power Association, the American National Standards Institute, and the International Organization for Standardization have developed performance standards for hydraulic and pneumatic devices.

Fluid Power System Advantages
- Cost-efficient
- Convenient
- Greater multi-function control & accuracy
- Provides constant force
- Safer operation
- Established industry standards

Figure 1. Fluid power systems have many advantages over other forms of power transmission.
Summary
Power transmission enables work by transforming energy into useable movement and delivering it from a source to a location. Hydraulic and pneumatic systems use fluids to transmit power. It is a fluid’s ability to flow that enables it to withstand large amounts of stress without breaking down. Hydraulic systems use fluids such as petroleum or non-petroleum based oil and water. Pneumatic systems use fluids such as compressed air and neutral gases.

Pascal’s Law describes how pressurized fluids transmit energy. Pascal’s Law states that fluids under pressure produce an equal amount of force on all surfaces in contact with the fluid. The force of a contained fluid remains the same until an outside force, such as pressure, acts on it. When pressure acts on the fluid, it causes motion by converting potential energy to kinetic energy and produces work.

In fluid power systems, fluid is brought into the system by a hydraulic pump or an air compressor. In hydraulics the fluid is stored in a tank. In pneumatics, the air is brought in from the outside atmosphere. Pumps and compressors are powered by prime movers such as electric motors and engines. The fluid passes through a filter and strainer that blocks particles that may cause obstruction. From the filter, the fluid passes by a series of control valves that control fluid pressure and rate of flow. There are numerous types of valves operated by actuators that use energy to generate motion and send fluid to various parts of the system. Fluid power systems also include fluid conductors, such as pipe, hose, or tubing through which the fluid travels.

Fluid power systems offer many advantages over other forms of power transmission. Hydraulics and pneumatics offer greater control, cost efficiency, safety, convenience, and the advantage of performance standards and standardized devices.
Class Vocabulary

**Actuator** Components that directly help convert hydraulic or pneumatic energy into mechanical energy. Actuators are also known as effectors.

**Aftercooler** A heat exchanger that reduces the temperature of the air discharged from an air compressor.

**Air Compressor** A mechanical device that pressurizes gas in order to create power.

**Air Receiver** An air storage tank used with pneumatic systems that balances the air compressor capacity and airflow demand.

**Ambient Atmosphere** The environment surrounding the air receiver.

**American National Standards Institute** A private, non-profit organization that administers and coordinates voluntary standards and systems.

**Atmospheric Pressure** The weight of the atmosphere. Atmospheric pressure refers to the amount of pressure exerted by the air.

**Compressibility** The ability of fluids to decrease in volume as a result of applied pressure.

**Conductor** The components such as pipes, tubes, and hoses that convey fluids throughout a hydraulic or pneumatic system.

**Control Valve** Mechanisms that control fluids in a pneumatic or hydraulic system. Control valves direct fluid movement and regulate the amount of pressure exerted in the fluid system.

**Cylinder** A type of linear actuator that uses a piston to produce motion in a straight line. A cylinder is also known as a piston actuator.

**Demulsibility** The resistance of a hydraulic fluid to emulsification, or how well a hydraulic fluid resists mixing with water.

**Diaphragm Actuator** A type of linear actuator that has a chamber divided in half by a diaphragm that separates areas with different pressure levels.

**Effector** Components that directly help convert hydraulic or pneumatic energy into mechanical energy. Effectors are also known as actuators.

**Electrical System** A power transmission system that uses the force of flowing electrons to transmit power.

**Energy** The measure of being able to produce work.

**Flanging** An operation that bends the edge of a part to add stiffness. Flanging most often creates a 90° bend in the metal.

**FLR-Unit** A device that conditions air for use in pneumatic systems. A filter-lubricator-pressure-regulator is commonly called an FLR-unit.

**Fluid** A state of matter that has the ability to flow. Fluids can be liquids or gases.

**Fluid Motor** A device that converts the energy from fluid flow into mechanical motion. Hydraulic and pneumatic motors are fluid motors.

**Fluid Power** Power derived from the motion and pressure of a fluid, such as water or air. Hydraulics and pneumatics are sources of fluid power.
Fluid System A power transmission system that uses the force of flowing liquids and gases to transmit power. Fluid systems include hydraulic systems and pneumatic systems.

Force The push or pull that changes an object’s state of motion.

Gas A fluid without a fixed volume that has the ability to flow and fill the space it occupies.

Gear Pump A hydraulic pump that uses meshed gears that rotate and move liquid through a hydraulic system.

Gear Screw Compressor An air compressor that uses meshed gears that rotate and move air or gas through a pneumatic system.

Heat Exchanger Hydraulic components that help relieve the excessive heat that builds up in a hydraulic system.

Hydraulic Motor A device that converts the energy from liquid flow into mechanical motion. A hydraulic motor is a type of fluid motor.

Hydraulic Pump A mechanical device used to move liquids in a hydraulic system.

Hydraulic System A power transmission system that uses the force of flowing liquids to transmit power.

International Organization For Standardization The International Organization for Standardization. ISO establishes documented standards, rules, and guidelines to ensure that products, processes, and services are fit for their purpose.

Kinetic Energy Energy existing due to an object’s motion.

Linear Actuator A valve actuator that produces motion in a straight line.

Linear-To-Rotary Actuator A valve actuator that converts linear motion to rotary motion.

Liquid A fluid with a fixed volume that has the ability to flow and take the shape of its container.

Lubricity The property that diminishes friction and increases smoothness and slipperiness.

Manifold A standard block component used in fluid power systems that enables the use of multiple control valves.

Matter A substance that has mass and exists as a solid, liquid, or a gas.

Mechanical System A power transmission system that uses forces created by the physical interaction of instruments or tools to transmit power.

Molecule The smallest unit into which a material can be divided without changing its properties. A molecule consists of a group of atoms held together by strong primary bonds.

National Fluid Power Association A national organization consisting of manufacturers, distributors, customers, vendors, and educators who work together for the advancement of fluid power technology and development of the industry.

Newtons Per Square Meter A unit of pressure. A newton per square meter is also known as a Pascal, which is derived from the International System of Units (SI).

Non-Petroleum-Based Oil A hydraulic fluid that contains no petroleum. Non-petroleum based oils are ideal for hydraulic systems that are used near a fire hazard.

Pascal’s Law A hydrostatic principle that states when pressure is applied to a contained fluid, the force is transmitted equally in all directions.

Petroleum-Based Oil A hydraulic fluid developed from petroleum. Petroleum-based oils are the most common hydraulic fluids.

Piston Actuator A type of linear actuator that uses a piston and rod to produce motion in a straight line. A piston actuator is also known as a cylinder.

Piston Compressor An air compressor that uses a piston and inlet and outlet check valves to allow fluid through a pneumatic system.
### Fluid Systems

Fluids are generally liquids and gases. However, some fluids can contain solid particles called slurries. Fluids are used in a wide range of applications to transmit energy and power.

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Fluid</strong></td>
<td>A substance that flows.</td>
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<tr>
<td><strong>Lubricity</strong></td>
<td>Oils naturally have properties that reduce wear and corrosion on system components, such as metals.</td>
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<tr>
<td><strong>Kinetic Energy</strong></td>
<td>The energy of motion.</td>
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<tr>
<td><strong>Potential Energy</strong></td>
<td>Energy that is stored in an object.</td>
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<tr>
<td><strong>Pounds Per Square Inch</strong></td>
<td>A unit of pressure. Pounds per square inch is derived from the English system of measurement and is abbreviated psi.</td>
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<tr>
<td><strong>Power Transmission</strong></td>
<td>The movement of energy from a source to a location.</td>
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<tr>
<td><strong>Pressure</strong></td>
<td>The amount of force applied upon an object. Pressure is a derived unit that combines time, area, and mass.</td>
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<tr>
<td><strong>Pressure–Relief Valve</strong></td>
<td>A control valve that opens when set fluid pressure is exceeded.</td>
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<tr>
<td><strong>Prime Mover</strong></td>
<td>The main component of a pneumatic or hydraulic system that powers a pump or compressor.</td>
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<tr>
<td><strong>Rack-And-Pinion Actuator</strong></td>
<td>A linear-to-rotary actuator that uses a gear pinion and rack to convert linear motion to rotary motion.</td>
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<tr>
<td><strong>Rotary Actuator</strong></td>
<td>A valve actuator that produces circular motion.</td>
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<tr>
<td><strong>Shaft</strong></td>
<td>The component on the control valve that operates the flow control element.</td>
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<tr>
<td><strong>Slide Valve</strong></td>
<td>A type of control valve that uses a metal plate as a gate to control fluid flow.</td>
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<tr>
<td><strong>Slurries</strong></td>
<td>A liquid that contains suspended solids.</td>
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<tr>
<td><strong>Threading</strong></td>
<td>The process of cutting a long, spiraling groove into a workpiece with a single-point tool. Threading processes are essential for the creation of fasteners.</td>
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<tr>
<td><strong>Vacuum</strong></td>
<td>The state of negative pressure. A hydraulic pump works by creating a vacuum in the closed hydraulic system.</td>
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<tr>
<td><strong>Vane</strong></td>
<td>The component within a valve that traps or moves fluid through the valve.</td>
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<tr>
<td><strong>Vane Compressor</strong></td>
<td>An air compressor that uses a flat protrusion to trap and move air or gas through a pneumatic system.</td>
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<tr>
<td><strong>Vane Pump</strong></td>
<td>A hydraulic pump that uses a flat protrusion to trap and move liquid through a hydraulic system.</td>
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<tr>
<td><strong>Vapor Lock</strong></td>
<td>Rapid formation of vapor in fluid conductors that can obstruct fluid flow.</td>
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<tr>
<td><strong>Viscosity</strong></td>
<td>A hydraulic fluid’s resistance to flow. As temperature increases, viscosity decreases.</td>
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<tr>
<td><strong>Volume</strong></td>
<td>The amount of space that an object occupies. Solids and liquids have definite volume.</td>
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<tr>
<td><strong>Welding</strong></td>
<td>A joining process that uses heat, pressure, and/or chemicals to fuse two materials together permanently.</td>
</tr>
<tr>
<td><strong>Work</strong></td>
<td>The result of force applied to an object over a distance.</td>
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