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ABSTRACT

These instructional materials provide an orientation to hydraulics for use at the postsecondary level. The first of 12 sections presents an introduction to hydraulics, including discussion of principles of liquids, definitions, liquid flow, the two types of hydraulic fluids, pressure gauges, and strainers and filters. The second section identifies and describes three types and three functions of accumulators. The third section covers the functions and size of reservoirs. The fourth section outlines pump classifications, types of pumps, and nine rating and selection factors. The fifth section reviews hydraulic piping, tubings, and requirements for line selection. The sixth section describes directional control valves. The seventh section describes check valve functions and pilot-operated check valves. The eighth section presents types of pressure control valves. The ninth section covers pilot-operated pressure control valves. The 10th section explores flow control valves. The 11th section describes cylinders: elements, types, types of construction and mounting; selection; and cushioning. The last section reviews the three types of hydraulic motors, eight rating and selection factors of motors, and seven types of rotary actuators. Examples are provided for each section of the guide. A quiz is included at the end of each section, except section nine. Answers to all of the quizzes are found at the end of the guide. (NLA)

# Hydraulics



**Name** ______________________________

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# HYDRAULICS

## I. INTRODUCTION TO HYDRAULICS

The word hydraulics is derived from the Greek words "hydro". which means water, and "aulis", which means pipe. It's original meaning referred to the study of water in its active state as well as at rest, then the meaning progressed to referring to the flow of water in pipes. It has since expanded to refer to any liquid flow within a system.

Within the hydraulic system, liquids are used to transmit and multiply force at different points. Liquids have several advantages over mechanical methods of operation within a system, including greater efficiency, economical considerations, and the compact size of hydraulic systems.

### A. Principles of Liquids

There are three basic principles that are important in regards to hydraulic systems. Liquids are shapeless and conform to the shape of their container. Although liquids have no shape, they cannot be compressed when force is applied to them. And finally, regardless of the shape of the container, every square inch has equal pressure exerted on it.

### B. Definitions

When discussing hydraulics, focus must fall on the factors that can either aid or hamper the work performed by machines in hydraulic systems. These factors include force, weight, mass, specific gravity, pressure, work, power, diffusion, and energy.

1. Force can be defined as either a push or pull applied to an object which results in a change of the object's position or direction of movement. Therefore, force consists of movement or resistance to movement. Examples of force would include starting, stopping, speed changes, and directional changes. For work to be accomplished within hydraulic systems, force must exist at all times. The greater the amount of work to be accomplished, the greater the amount of force required of the system.

2. Objects have weight due to the existence of gravitational pull on them. Weight is always a downward force. Whether in motion or standing still, hydraulic fluid has weight at all times within the system.

3. Mass can be defined as the amount of matter in an object and its inertia, or resistance to movement. Mass determines an object's weight and inertia determines the amount of force required to alter an object's movement.

4. Specific gravity is the density or mass of a liquid. The specific gravity is determined by comparing the weight of the fluid to the weight of an equal amount of water at the same temperature.

5. Pressure is defined as the amount of force (in pounds) divided by the area (in square inches) over which the pressure is distributed. Pounds per square inch (PSI) is the most common method used to measure pressure. The two kinds of pressure to be concerned with regarding hydraulic systems are atmospheric and hydraulic. Atmospheric pressure is constantly active on fluid reservoirs which are vented to the atmosphere. This pressure has a standard reading of 14.7 psi. Hydraulic pressure is that pressure which is created by the fluid pump. It acts on all the internal passages within the system on the discharge side.

6. Work occurs when an object is moved over any given distance by force. The following formula is used to calculate work: Work = force (lbs) x Distance (ft) Thus, work is expressed in foot-pounds.

7. Power is defined as the amount of work accomplished within a given time frame. Power is expressed in foot-pounds-per-minute, and is calculated by using the following formula:

$$\text{Power (P)} = \frac{\text{Work(ft-lbs)}}{\text{Time (Sec. or Min.)}} = \frac{\text{Foot-Pounds}}{\text{Sec. or Min.}}$$

The common unit of measurement for power is horsepower, which is calculated as follows:

$$\text{1 Horsepower} = \frac{\text{33,000 foot-lbs}}{\text{1 minute}}$$

8. Diffusion is the rapid mixing of gas or liquid molecules with one another. Hydraulic fluid has a slow evaporation rate, and so it can be placed in open containers without diffusion occurring. This is known as non-diffusion.

9. Energy must be expended to accomplish work or utilize power, and it is created when force causes a body to move. The Law of Conservation of Energy states that "Energy cannot be created or destroyed: It can only be transformed." There are five types of energy used within

hydraulic systems:

a. electrical energy--This energy is utilized to operate pump motors.

b. hydraulic energy--This is the energy that is produced by hydraulic pumps.

c. kinetic energy--This energy is produced when hydraulic fluid causes piston movement, and can be referred to as moving energy.

d. potential energy--This energy is produced when pistons raise an object, and is also known as stored energy.

e. heat energy--This is the energy produced by friction in hydraulic components.

C. Liquids Flow

Before discussion of the various parts and functions of the hydraulic system, fluid flow must be mentioned. Fluid (or liquid) flow has several characteristics, including volume, velocity, and the types of flow within hydraulic systems.

1. Volume refers to the amount (quantity) of liquid which will travel a given distance within a system in a given amount of time. Volume may be measured in numerous ways, but gallons per minute is the most common measurement.

2. Velocity is the rate or speed at which liquid moves throughout the hydraulic system. It also has several methods of measurement, but feet per second is commonly used. Liquid flow may be classified as either steady, unsteady, streamline or turbulent.

   a. steady flow--This refers to the constant rate at which liquid flows.

   b. unsteady flow--This refers to the continually changing flow rate.

   c. Streamline flow--This is also known as laminar flow or even flow. The fluid particles move parallel to each other as they progress through the system. The layer of fluid next to the pipe will move slowly because of the friction created between the fluid and the pipe. Each inner layer of fluid slides along the successive outer layer of fluid and as friction lessens, the fluid layers move more quickly. The center layer of the flow moves the fastest and has the least amount of friction.

d. Turbulent flow--This occurs because of high velocity, low fluid viscosity, or due to obstruction throughout hydraulic piping. The flow does not move throughout the system evenly, but rather possesses motion resulting in increases of friction and heat. Turbulent flow requires more power and places more wear on hydraulic equipment than does streamline flow. In addition, when turbulent flow releases air suspended in hydraulic oil, large bubbles in lines and components are formed. This is known as cavitation, and causes the system to work ineffectively.

D. Hydraulic Fluids

Hydraulic systems must have the correct fluid to operate effectively and efficiently. The main function of hydraulic fluid is to effectively transmit power (energy) between points within hydraulic systems. To achieve this, the fluid used must be able to withstand compression, as well as flow smoothly. Hydraulic fluid also lubricates components of the system, thus reducing friction between contacting surfaces, as well as acting as a sealant. Hydraulic fluid is considered the "blood" of hydraulic systems.

1. The properties of hydraulic fluids determine how well power is transmitted through the fluid. Knowledge of hydraulic properties and characteristics is critical to make qualified determinations of fluid performance and service life. The physical properties include the following:

   a. viscosity--This is the most important physical property a hydraulic fluid must possess. Viscosity measures the internal tension of fluids, and also refers to fluid's thickness and resistance to flow. Variations in viscosity affect fluid's ability to lubricate contacting surfaces. Therefore, viscosity must remain stable throughout ranging temperatures of hydraulic systems. Viscosity specifications are numerous. The most common method used to specify viscosity is the Saybolt Universal Second (abbreviated SUS or SSU). The American Society for Testing Materials also provides standard viscosity grades to aid in one's determination of fluid viscosity. Another related factor of viscosity concerns the viscosity index (VI). The viscosity index is a unitless number and was created to rate the changes in fluid viscosity in relation to increases or decreases in temperature. The viscosity index of a hydraulic fluid is determined by comparing the change in viscosity of a sample fluid with the viscosity change to two reference oils at 100°F and 210°F. A fluid with a high viscosity index exhibits a smaller change in viscosity when its temperature is altered, than does a fluid with a low viscosity index. When temperature changes occur within hydraulic fluids, it is important to have small changes in viscosity so that the fluids can perform effectively and efficiently. Changes in pressure will also affect fluid viscosity. Increased amounts of pressure on fluids tend to have a greater negative effect on viscosity at high pressures. This will also impact upon the performance of hydraulic fluids.

b. pour point--This physical property is merely the lowest temperature at which fluids will flow. The pour point should be at least twenty degrees below the lowest temperature to which the fluid will be exposed when stating. This is significant only if the hydraulic system in question must operate in low temperatures.

c. component protection--Components must be protected by hydraulic fluid so that they function effectively and do not undergo excessive wear. Without hydraulic fluid, two contacting surfaces will possess a great deal of friction, may wear out, or may fuse together due to the amount of heat generated by contact. Hydraulic fluids provide a lubricating film to protect metal surfaces from excessive wear. The lubricating film should be thick enough to prevent metal surfaces from coming into contact with one another whether in motion or not, and should also be present whether a light or heavy load exists. Film strength refers to the ability of hydraulic fluids to maintain their film under heavy loads. Conversely, fluids must possess the correct viscosity to be able to penetrate into minute areas between parts and remain there. The lubricity of fluids, or their ability to cling and be "slippery", aids in the reduction of friction between contact surfaces.

2. Hydraulic fluids also possess chemical properties. The addition of chemicals to hydraulic fluids determines the length of time hydraulic fluids will function as well as how well the fluids will operate before they must be replaced.

a. resistance to oxidation--This chemical property is considered to be the most important, because oxidation is the most common factor that shortens the life of hydraulic fluids. Oxidation is a chemical reaction that occurs as hydraulic fluid is exposed to air. When hydraulic oils undergo the oxidation process, soluble resins and additional compounds are created. These resins increase the oil's viscosity and also cause the oil to darken in color. This signals difficulties within the system which must be corrected. Soluble resin compounds come into contact with hot surfaces in the system, often forming hard coatings known as varnishes or lacquers. Particles of these varnishes may be suspended within the hydraulic fluid, resulting in their circulation throughout the system. Other resins, partially oxidized, are known as "gums", and these remain suspended in the fluid as well. Lastly, sludge may be formed by oxidation and settle in low system points, thus making itself available to mix with other contaminants within the system. Oxidation is also increased at points throughout the system where air is dissolved in or absorbed by the hydraulic fluid. Additionally, system contaminants such as dirt, grease, water, paint, and various compounds become catalysts, which increase oxidation of the fluid. Oxidation within hydraulic systems can be controlled if the system is adequately designed, an adequate preventive maintenance program is in effect so that contaminants can be removed on a regular basis and adequate maintenance continues to occur between fluid changes. In this manner, air can be continually removed from the system and fluid can be tested and checked regularly.

b. system contaminants--Oxidation is not the only contaminant within hydraulic systems. Other contaminants exist; including water, dissolved air, corrosion and rusting.

1. Water enters hydraulic fluid in the form of water vapor in the air, and then becomes suspended in the fluid. In this way, the vapor is emulsified and impurities are collected in the system. This causes increased friction and wear within the hydraulic system. Chemicals can be used to prevent emulsions from forming. A fluid that is said to have emulsification is a fluid that is able to resist the formation of emulsions and promote their breakdown.

2. The ability of a liquid to absorb or dissolve air at any pressure higher than a vacuum is known as air solubility. Air can enter the system through any number of leaks, exposure points, or openings

in the system. Dissolved air consists of many small air bubbles distributed throughout the hydraulic fluid. Significant amounts of air in the system can result in foam being present. Chemical foam depressants can reduce the amount of foam formed with hydraulic systems.

3. Corrosion is the deterioration of metallic surfaces due to acids or alkalis. Rusting is the oxidation of iron or steel surfaces due to the presence of moisture and oxygen in the atmosphere. Few alkalis are present in hydraulic systems, but oxidation causes acids to be formed. As the acid attacks the metal, corrosion occurs. Rusting is caused by air in the system which oxidizes the iron and steel surfaces when water is present. Both corrosion and rusting eat away at system components and passageways throughout the system. Monitoring temperature and pressure in relation to operating conditions will reduce both corrosion and rusting because air and water formations are controlled. Chemical additives can also be utilized, so that films are created on hydraulic components which will resist rust and corrosion.

E. Types of fluids

Many different types of hydraulic fluids exist. The following five types are most frequently utilized and their use depends greatly on the operation of the system in question.

1. Petroleum base hydraulic fluid is the most commonly used hydraulic fluid. Not merely oil, petroleum base fluid consists of additives as well. These additives provide the petroleum oil with certain characteristics that make it suitable for hydraulic system use, including additives to reduce viscosity, oxidation, and corrosion.

2. Oil-in-water emulsion is a fire resistant fluid consisting of oil mixed with a continuous water phase. The mixture can have varying percentages of oil and water, but the water content is always dominant.

3. Water-in-oil emulsion is a fire resistant fluid consisting of water mixed with a continuous oil phase. Oil is dominant, with the mixture usually consisting of 40 percent water to 60 percent oil. This type of fluid may also be referred to as an invert emulsion.

4. Water glycol is a fire resistant fluid consisting of a mixture of glycol and water. Generally the mixture

consists of 60 percent glycol (antifreeze) and 40 percent water.

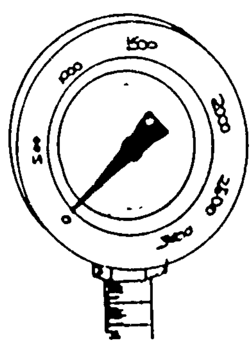
5. Synthetic base fire resistant fluids usually consist of phosphate esters, chlorinated hydrocarbons, or a mixture of the two. This type of man-made fluid is the most expensive.

F. Pressure Gauges

Pressure gauges are devices in hydraulic systems used to measure system pressures created with force and liquids, so that efficient and safe operating pressures can be maintained. There are two types of gauges that are commonly used in hydraulic systems.

1. The bourdon tube gauge measures pressure in pounds-per-square-inch (PSI), and gets its name from the tube that links the needle pointer to system pressure.

Example #1

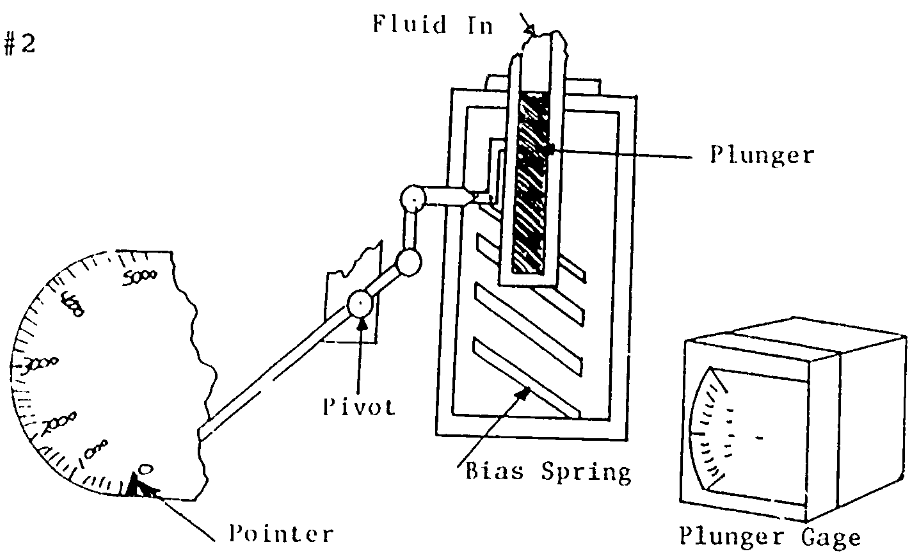


Bourdon Tube Gage

Elements made in a "C" spiral, or helical shape are used to determine amounts of pressure in the system. One end of the element is stationary, and the other can move freely. The element attempts to straighten as pressure builds. This causes the pointer to move to the correct pressure reading on the face of the gauge. The most commonly used bourdon element is the C-tube, because it is easy to manufacture and is more adaptable to small spaces than the spiral or helical elements. The gauge element to be used will depend upon the application and system requirements. See Example #1.

2. The plunger pressure gauge consists of a plunger connected to the system pressure, a bias spring, a reading pointer and a PSI scale. See Example #2.

Example #2



When pressure increases within the system, the pressure exerts itself against the bias spring, causing the plunger to move the pointer to the correct reading of pressure on the scale. Plunger gauges are durable and economical elements that can be utilized to measure system pressure.

G. Straining and Filters

Stainers and filters are required to aid in the maintenance of clean hydraulic fluid. Contaminants must be removed from the system in order to avoid serious damage to the hydraulic system. Contaminant removal can be achieved through various types of straining and filtering.

Both strainers and filters are constructed so that they allow certain sizes of particles to pass through while stopping other particles. Strainers remove larger particles while filters remove smaller particles. Typical strainer and filter openings stop roughly 98 percent of the particles that are of a certain size or larger. The remaining two percent cannot easily be stopped through the use of typical strainers or filters. The degree of filtration of filters and strainers refers to their ability to remove particles from fluids. The amount of particles or dirt removed from the system, determines the performance of the strainers and filters. Strainer openings are roughly all the same size while filter openings are smaller in size and are not uniform. Filters have greater particle removal than do strainers. Dirt capacity refers to the relationship between the size of openings and the size of contaminating particles and this is also a factor of performance. Often, both strainers and filters are used in hydraulic systems so that both large and small particles can be eliminated. Each will be described separately.

1. The majority of strainers utilize porous wire mesh to remove large contaminants from hydraulic fluid. The mesh of a screen refer to the number of openings within each square inch of area (i.e. a 50-mesh screen has 50 openings per square inch). Wire thickness determines opening size, which therefore determines the size of particles that will be allowed to pass through the screen.

   Strainers are considered to be both economical and well suited to many applications, but they do have limitations as well. These imitations include the range of particles which can be removed, the smallest size of particles which can be removed, and the capacity to hold large amounts of particles on a single surface.

Strainers are used primarily as pump suction inlet screens that function to protect the hydraulic pump from large contaminant particles which may cause system damage. These inlet strainers filter out large particles without causing pump starvation.

2. Filters may best be described as a series of strainers, with hydraulic fluid first passing through large openings and then continuing to pass through successively smaller openings. Filters can pick up smaller contaminant particles than strainers. Each filter component has its own random pattern of openings, which allows greater removal of particles as the fluid proceeds through the filter.

QUESTIONS -INTRODUCTION-HYDRAULICS

1. Liquids have which of the following principles that affect their use in hydraulic systems?

   a. Incompressibility
   b. Shapelessness
   c. Applied pressure equally transmitted
   d. All of the above
   e. None of the above

2. ______ is defined as movement or resistance to movement of an object.

   a. Mass
   b. Weight
   c. Force
   d. Gravity

3. ______ is defined as force divided by area.

   a. Force
   b. Pressure
   c. Power
   d. Work

4. Which of the following is <u>not</u> one of the five types of energy used in hydraulic systems?

   a. Electrical
   b. Heat
   c. Potential
   d. Kinetic
   e. None of the above

5. The quantity of liquid which will travel a given distance in a given amount of time refers to:

   a. Velocity
   b. Work
   c. Flow
   d. Volume

6. Which of the following are properties of hydraulic fluid?

   a. Pour point
   b. Cavitation
   c. Viscosity
   d. A and B
   e. A and C

7. Which of the following is not a contaminant that exists within hydraulic systems?

   a. Rusting
   b. Dissolved air
   c. Corrosion
   d. All of the above
   e. None of the above

8. _____ is the most common type of hydraulic fluid.

   a. Water glycol
   b. Oil-in-water emulsion
   c. Petroleum base
   d. Water-in-oil emulsion

9. Contaminant removal can be achieved through the use of:

   a. Cleanser
   b. Filters
   c. Strainers
   d. A and B
   e. B and C

II. Accumulators

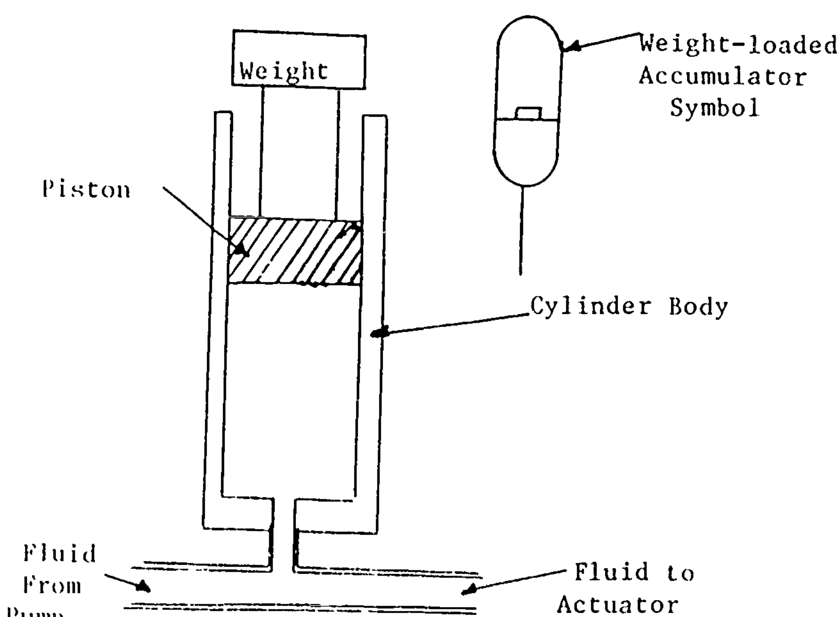
Hydraulics is used to perform work, thus signifying that energy must be applied to an object. In hydraulic systems, this is often achieved with accumulators. Accumulators are merely cylinders used to confine liquids and movable pistons, which are used to apply force to the liquid. Accumulators store potential energy in the form of hydraulic pressure, which is converted into working energy when the system needs it. More simply, accumulators store hydraulic fluid under pressure until it is needed within the system.

A. Types of Accumulators

There are various types of accumulators, each different in construction and design, but all similar in operation.

1. Weight-loaded accumulators are known as the gravity accumulator. This accumulator consists of a long vertical steel cylinder fitted with a piston. Heavy weights are utilized to apply force through the piston, thus maintaining constant fluid pressure within the cylinder. The weights may be made of such materials as concrete or iron and may remain constant, exerting consistent pressure for the duration of the piston stroke. System pressure determines the amount of weight to be used. This type of accumulator generally must be mounted vertically because of its large size. Although weight-loaded accumulators are capable of servicing numerous machines simultaneously, they are seldom used because of their large size, cost, and their slow response time to changes in fluid demand. See Example #3.

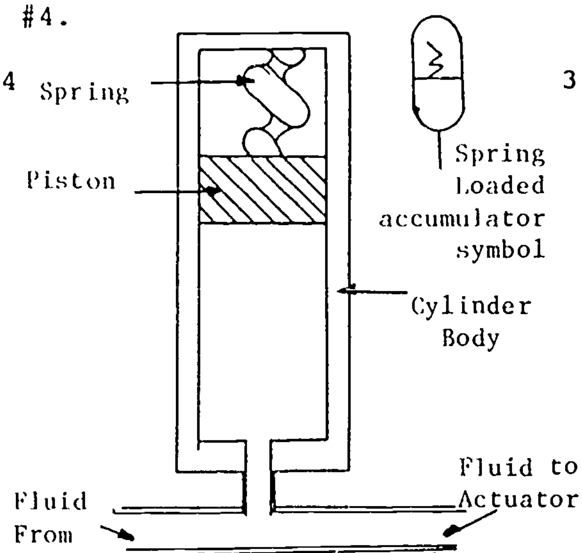
Example #3




Weight-loaded Accumulator

2. Spring-loaded piston accumulators consist of a cylinder body and a movable piston. A force is applied to the piston through the spring, which results in liquid pressure being maintained. When excess system fluid enters the cylinder, the piston raises and compresses the spring. The pressure is determined by the compression rate of the spring. When fluid is required in the system, the spring expands, forcing the piston downward and pushing fluid out into the system. The amount of fluid in both the cylinder and the system, which is regulated by a pressure switch, determines when minimum and maximum pressures are reached within the accumulator. This type of accumulator is flexible and can be mounted in any position to accommodate various machines. Though possessing low maintenance costs, these accumulators are large and expensive to operate. They are best used with small volume and low pressure applications. See example #4.

Example #4

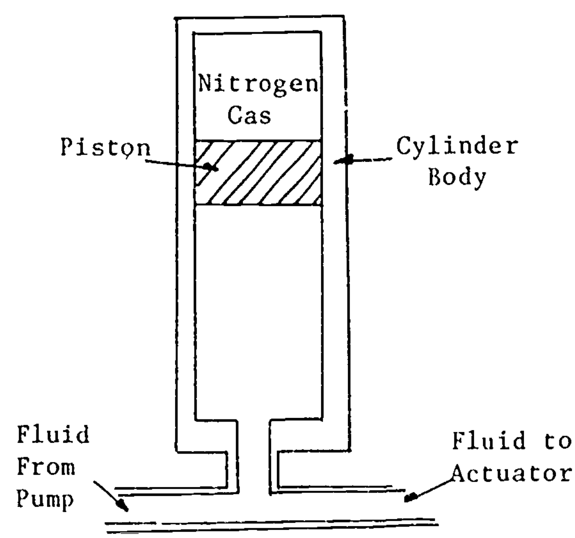


Spring-loaded Accumulator

3. The hydro-pneumatic accumulator uses a compressed gas to apply force to a liquid, and is the most commonly used accumulator in industrial hydraulic systems. The compressed gas usually used in industry is dry nitrogen, and acts as a spring inside the cylinder. There are three types of hydro-pneumatic accumulators used in hydraulic systems.

a. piston-type accumulator- In this type of accumulator, the piston separates the gas and the liquid within the cylinder body. The gas above the piston is compressed as the cylinder body is charged with liquid. The gas and system pressure will be equal when the accumulator is filled to capacity. See example #5.

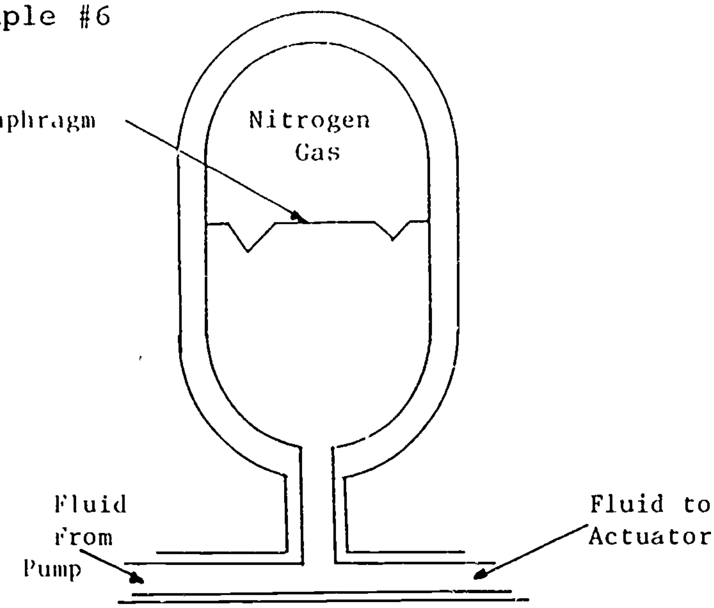
Example #5



Piston Type Accumulator

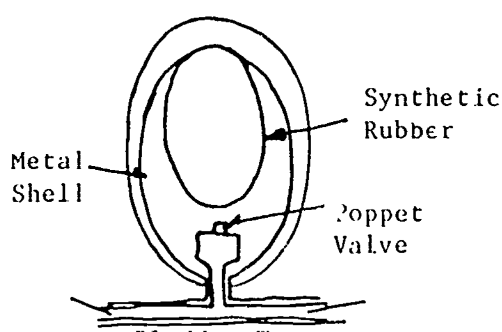
b. diaphragm type accumulator-- This type of accumulator does not have a cylinder body, but has two metal hemispheres separated by a rubber diaphragm. Gas is compressed in the top chamber as liquid enters the bottom chamber. See Example #6.

Example #6




Diaphragm Type Accumulator

Example #7




Bladder Type Accumulator

c. bladder type accumulator-- This type of accumulator consists of a metal shell which encases a synthetic rubber bladder that is filled with compressed gas. At the discharge port, a poppet valve restrains the bladder from being released into the hydraulic system.

B. Functions of Accumulators

Accumulators are capable of performing a variety of functions with hydraulic systems. The following are three of the functions accumulators perform.

1. In an emergency, an accumulator can maintain system pressure so that work materials will not be destroyed if pumps should fail to function. An accumulator can maintain pressure if circuits fail, and can also compensate for pressure lost due to leakage.

2. Accumulators are sources of energy in hydraulic systems and they store potential energy within themselves. This stored potential energy can be used to develop system flow when the demand of the system is greater than pump delivery and additional flow is required for the system to operate effectively.

3. An accumulator may be used to absorb system shock in some instances. The accumulator will absorb some shock and reduce the amount of shock that would be transmitted throughout the hydraulic system.

## QUESTIONS-ACCUMULATORS

1. This accumulator is also known as the gravity accumulator:

   a. Weight-loaded accumulator
   b. Spring-loaded accumulator
   c. Flexible accumulator
   d. Piston accumulator

2. The most commonly used accumulator is industrial hydraulic systems is:

   a. Bladder
   b. Piston
   c. Hydro-pneumatic
   d. Diaphragm

3. Which of the following is <u>not</u> a type of hydro-pneumatic accumulator:

   a. Piston
   b. Diaphragm
   c. Bladder
   d. Gear
   e. None of the above

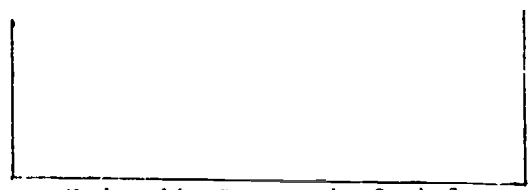
4. Which of the following are functions of accumulators?

   a. To develop system flow
   b. To maintain system pressure
   c. To increase system efficiency
   d. To absorb system shock
   e. A, B, and D

## III. Hydraulic Reservoirs

Hydraulic reservoirs store hydraulic fluid within the systems at a constant rate, even when the system demands are changing. A reservoir stores extra hydraulic fluid so that the system can meet its changing demands. Reservoirs are important system components, and consist of four walls, a dished bottom, a flat top with a mounting plate, four legs, suction lines, return lines, drain lines, a drain plug, an oil level gage, a filler/breather cap, cleanout covers, and a baffle plate. Shown in example #8 is the symbol for a hydraulic reservoir.

Example #8



Hydraulic Reservoir Symbol

Operation of a reservoir occurs as fluid returns to the reservoir. When the fluid returns, a baffle plate prevents the returning fluid from proceeding directly to the suction line. This allows dirt to settle out of the fluid, air to rise to the surface of the fluid, and heat to be dispersed to the walls of the reservoir.

### A. Functions

1. To accumulate and store an adequate supply of hydraulic fluid for the entire system at atmospheric pressure.

2. To break up any foam generated in the system, and separate dissolved air from the fluid.

3. To settle out heavy dirt particles, sludge, and water from the fluid.

4. To help cool the fluid and keep its operating temperature steady in the 100° to 130° F temperature range.

5. To provide a firm, accessible mounting platform for the pump, motor, intake filter, and other equipment in the power unit of the system.

### B. Size

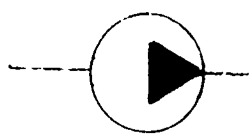
Reservoir size is determined by its liquid capacity. The rule for capacity determines what a reservoir should hold, at the minimum, enough hydraulic fluid to allow the pump to operate for three minutes. This will allow the fluid level to stabilize and thus the system operates efficiently. Rectangular reservoirs are most commonly used with various reservoir dimensions and capacities depending upon the application.

The desirable fluid temperature within hydraulic systems falls within the range of 110°F to 120°F. The appropriate temperature may be difficult to maintain due to the large amount of heat generated by pump activity. Excess heat can be eliminated, and the system can run at its appropriate temperature if the following conditions exist: sufficient fluid is in the system, the surface of the reservoir properly radiates heat and has good circulation, a quality baffle has been installed in the reservoir, and the hydraulic is placed in a relatively cool location.

## IV. Hydraulic Pumps

Hydraulic pumps convert mechanical energy into working hydraulic energy. This occurs as the kinetic energy of a rotating pump shaft is converted into the kinetic energy of fluid flow. To further explain, pumps generate an increasing volume at their suction side while also generating decreasing volume at their pressure side. This creates the same pumping action of all pumps, no matter what their construction. Therefore, pumps merely transfer energy from one source to another.

Hydraulic pump logic symbol:



### A. Pump Classification

There are basically two types of pumps that can be classified on the basis of their principles of operation: Non-positive displacement and positive displacement types.

1. Non-positive displacement pumps do not possess an internal seal to prevent slippage or leakage of the pumps. Because the seal is not present, slippage occurs and pump delivery is reduced as the system back pressure increases. Non-positive displacement pumps deliver continuous flow, but are not often used in hydraulic systems.

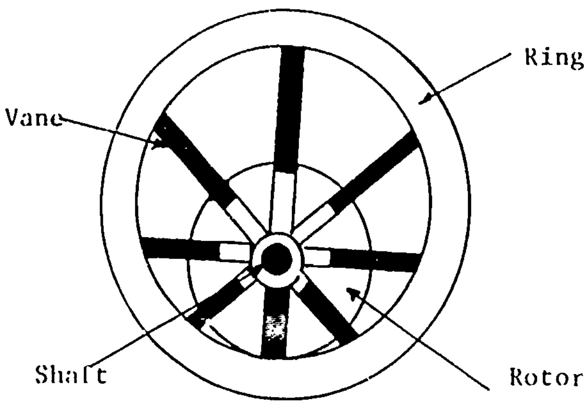
2. Positive displacement pumps possess mechanical seals (gears, vanes, or impellers) between the inlet and outlet which reduce the possibility of internal leakage or slippage. Positive displacement pumps deliver a pulsating flow, and are commonly used in virtually all hydraulic systems. These types of pumps have either fixed or variable displacement.

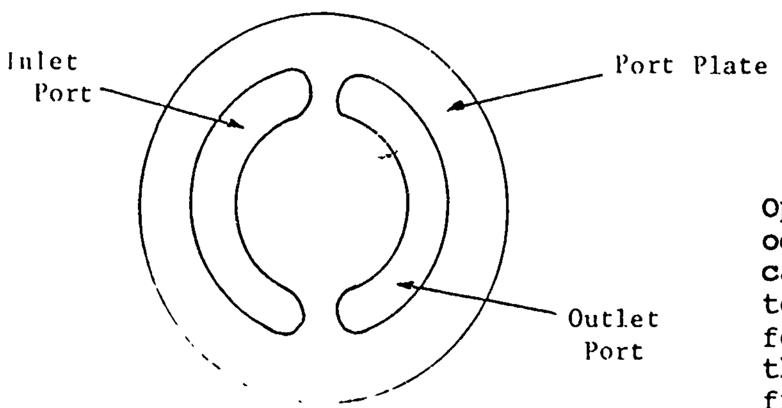
### B. Types of Pumps

The most common types of pumps used in hydraulic systems are vane, gear, and piston pumps. These types of pumps are classified as positive displacement pumps, which transmit fluid by changing the volume of the pump interior. Each type of pump varies in its construction and how it alters pump volume.

1. Vane pumps consist of a rotor, vanes, a ring, a shaft connected to a prime mover, and a port plate that has kidney-shaped inlet and outlet ports. (Example #10)

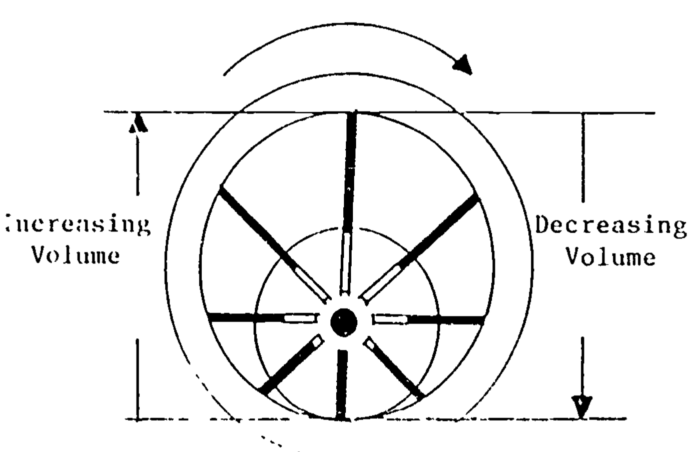
Example #10



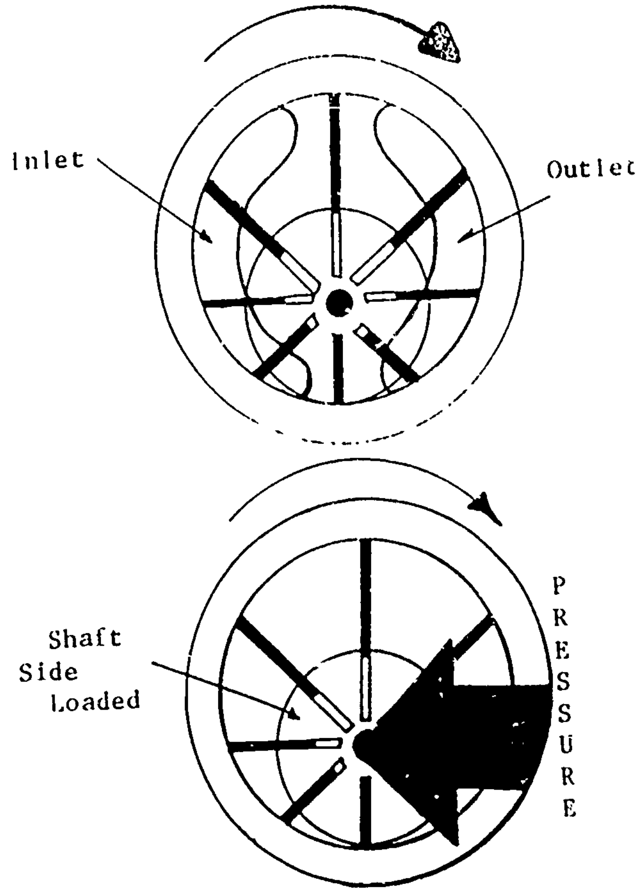

Operation of vane pumps occur as the rotor turns, causing the vanes to extend to the ring by centrifugal force. This draws fluid into the pump and removes air from the inlet area of the pump. The vanes track along the ring, causing a positive seal to be formed between the tips of the vane and the ring. Fluid trapped by the vanes is then pushed towards the discharge port. Since the rotor is positioned off-center to the ring, upon its rotation increasing and decreasing volumes are created within the ring.

Example #11




Note: Rig Doe Not Rotate

Example #12

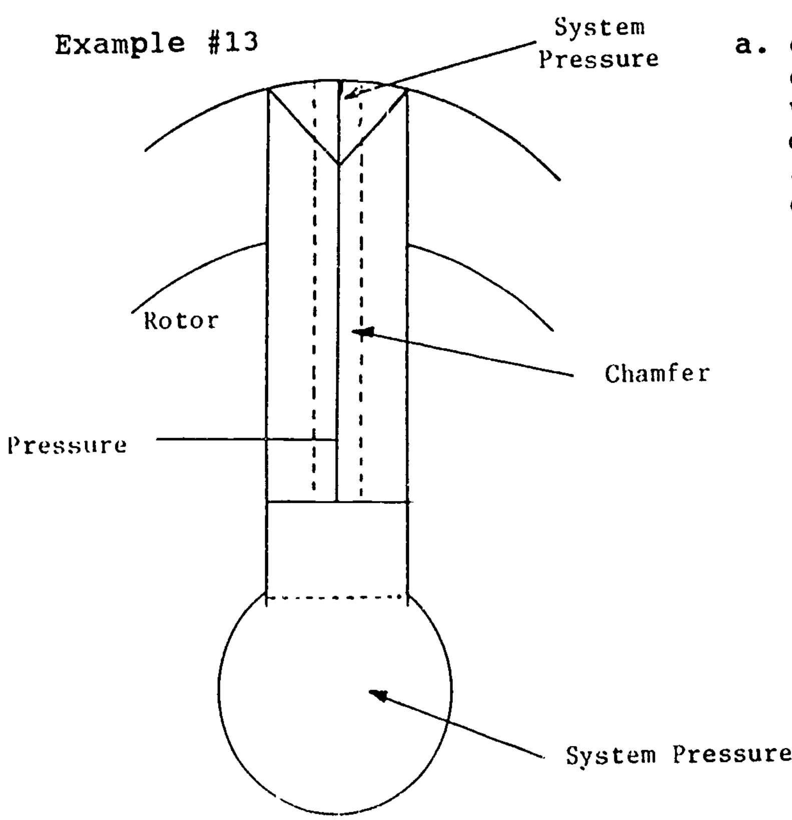





A port plate is utilized to separate all fluids entering and exiting the pump. The port plate fits over the ring, rotor, and vanes. The inlet portion of the plate is positioned where increasing volume is created, while the outlet portion of the plate is positioned where the decreasing volume is created. (Example #12)

There are typically five different types of vane construction:

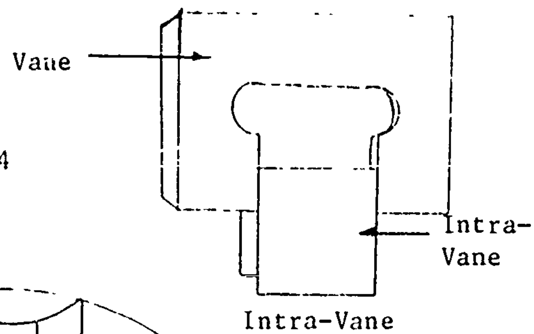
Example #13



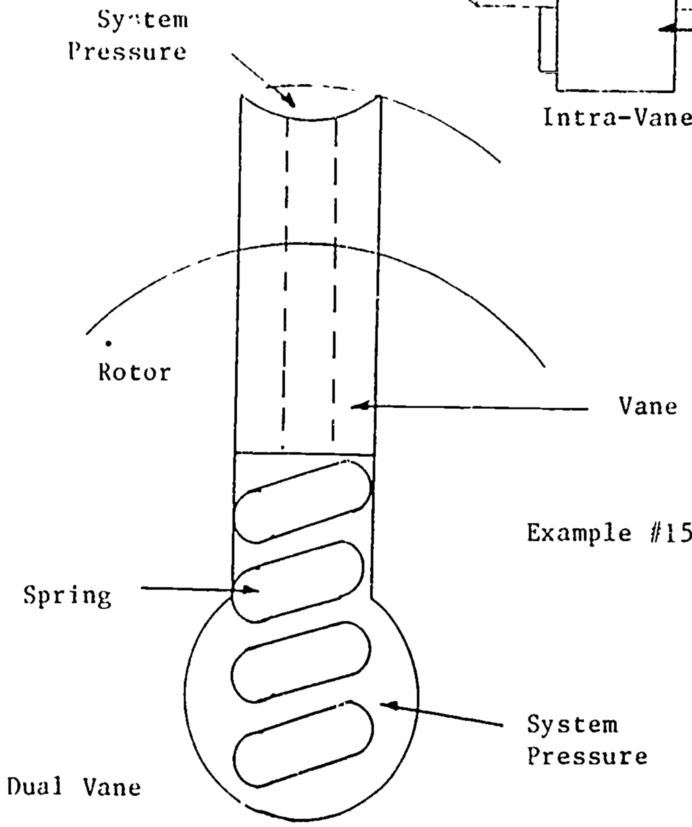

Dual Vane

a. dual vane--This vane consists of two vanes within each vane slot, creating a good seal and almost perfect balance of the vanes.

Example #14



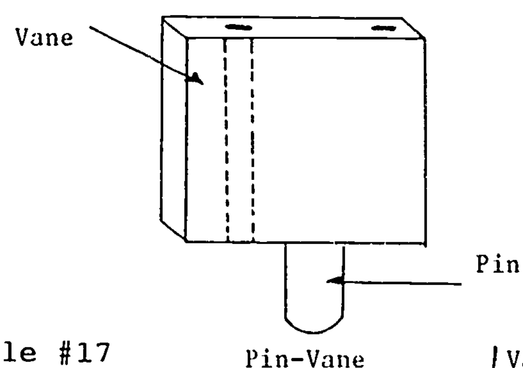

b. intra-vane--This vane consists of a small vane within a larger, beveled-edged vane. The system pressure is directed to the area above the small vane.




Example #15

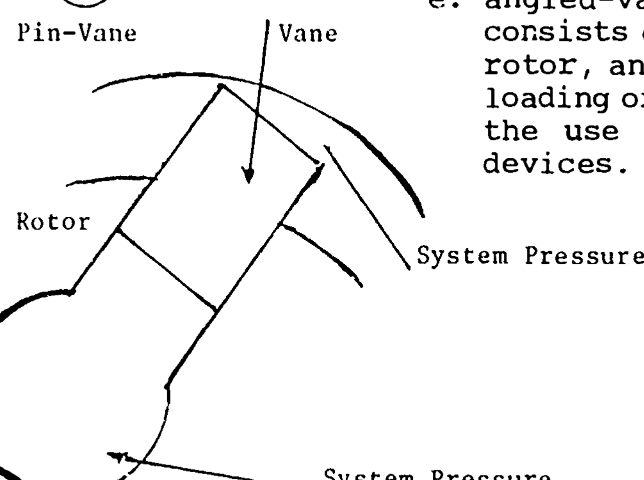
c. spring-loaded vane--This vane possesses spring within the vane, which results in spring pressure at the bottom of the vane to aid in vane loading.

Example #16




d. pin-vane--This vane consists of a pin which forces the vane outward against the cam ring. The system pressure is directed underneath the pin.

Example #17

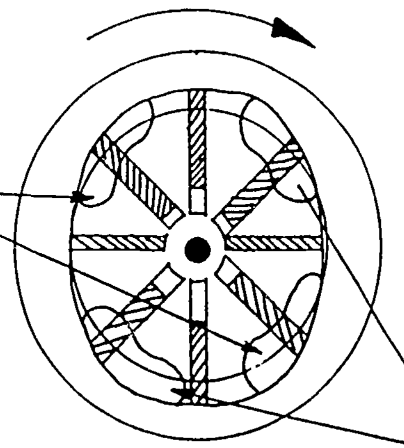



Angled Vane

e. angled-vane--This vane consists of vanes in the rotor, angled to create loading of vanes without the use of additional devices.

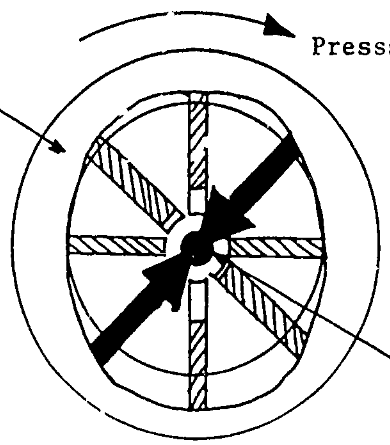
The shape of vanes will vary, depending upon the different applications of vane pumps. In addition, vane tips are often grooved or split for better lubrication and allow for a small contact area at the pump housing. All types of vane pumps possess similar components, including a rotor which is slotted to receive vanes, vanes, a cam ring, seal plates, a housing, and end covers.

Example #18




Balanced Vane Pump

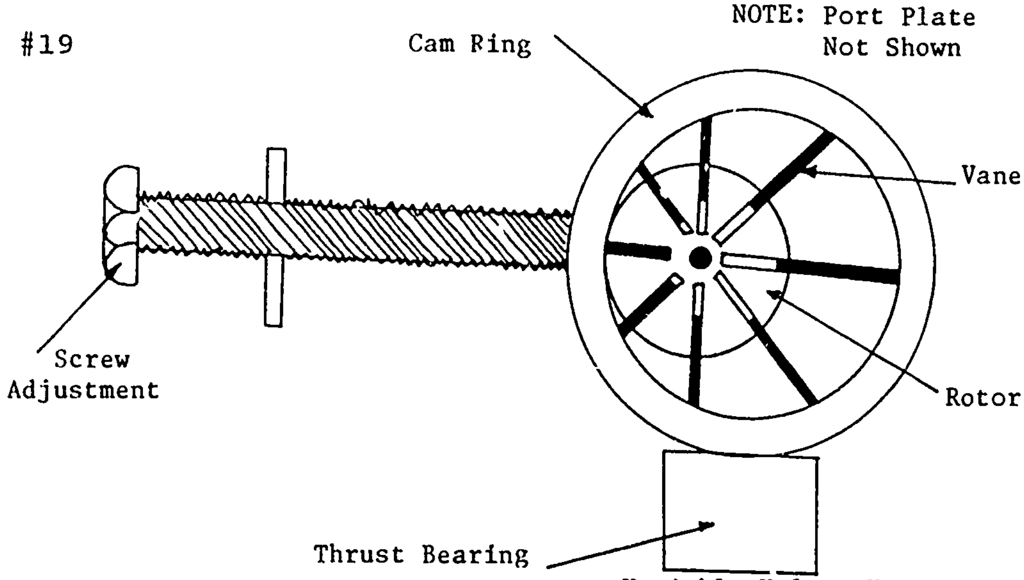
f. balanced vane pumps--This type of vane pump consists of a rotor, vanes, a cam ring, and a port plate with opposing inlet and outlet ports. The cam ring allows pump pressures to oppose each other, resulting in a balanced shaft.




g. double vane pumps--Double vane pumps consist of a housing that possesses two cartridge assemblies, one or two inlets, and two independent outlets. Thus, the double vane pump is simply two pumps in one housing. From each outlet, a double pump can unload two different flow rates. The two pump cartridges are connected to one common shaft. Due to this construction, only one electric motor is used to drive the entire unit. These pumps supply twice the flow of a single pump, and are utilized when one power unit supplies two different flow rates.

h. variable volume vane pumps--Variable volume vane pumps are those vane pumps that are designed so the distance that the vanes extend within the pump can be altered. This varies the amount of fluid which is displaced by the pump. This type of pump consists of one rotor, vanes, a free-moving cam ring, one port plate, a thrust bearing used to guide the cam ring, and a screw adjustment (or some other component) to adjust the cam ring position.

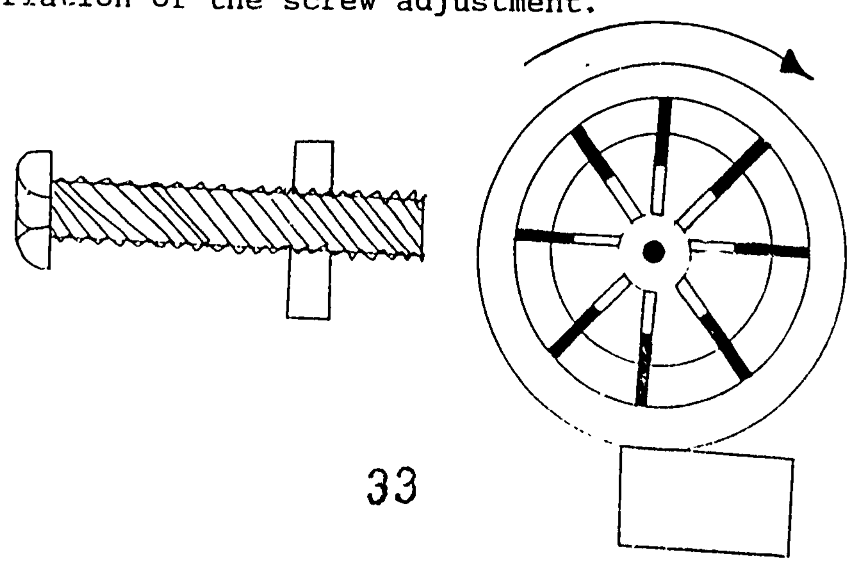
Example #19




Variable Volume Vane Pump

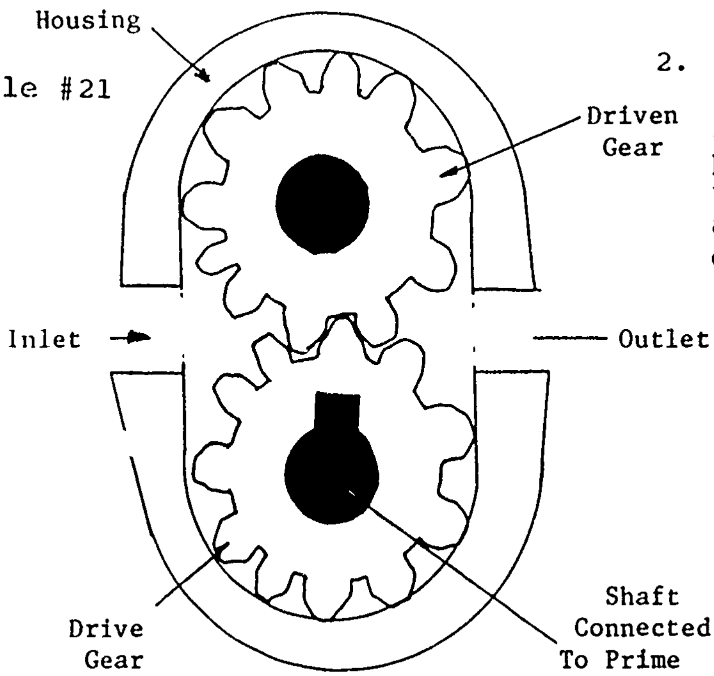
Operation of the variable volume vane pump occurs when the rotor turns, generating both increasing and decreasing volumes. The rotor is positioned off center of the cam ring by the screw adjustment. As the screw adjustment is loosened, the cam ring positions itself closer to the center of the rotor. The varying volumes are still generated but the flow is decreased. Also, the vane length at full extension decreases. When the screw adjustment is backed completely out and no tension exists, the cam ring and rotor are automatically centered. Neither increasing or decreasing volumes are generated and no pumping action occurs. The vane pump can adjust its output flow from maximum to zero flow simply through variation of the screw adjustment.

Example #20



i. pressure compensated variable volume vane pumps--Variable volume vane pumps are also generally pressure compensated, meaning that the pump will cease pumping when a predetermined pressure level is reached. These types of pumps possess the same structure and parts as variable volume vane pumps, with one addition; an adjustable spring is used to offset the cam ring. When the pressure exerting itself on the inner contour of the cam ring reaches a specified level which is great enough to overcome the force of the spring, it causes the ring to center and the pumping to cease.

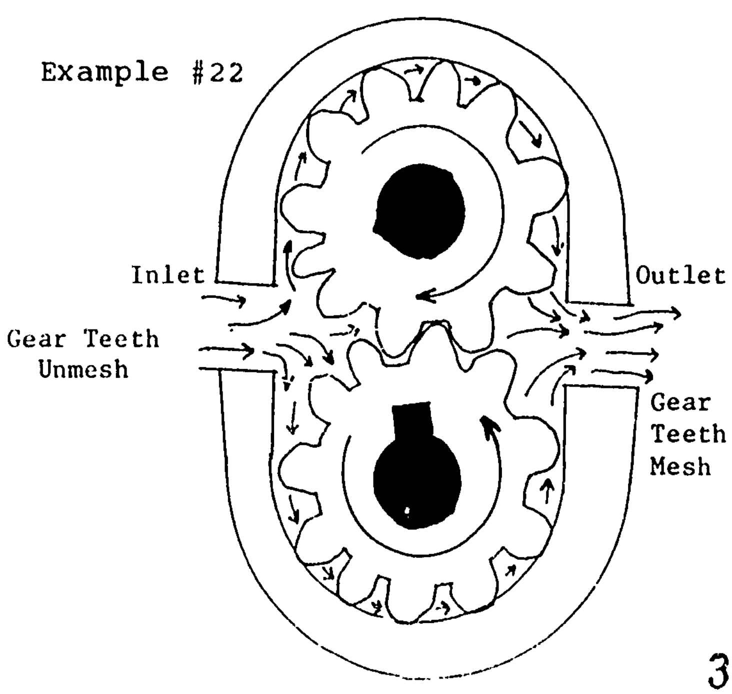
Example #21




Gear Pump

2. Gear pumps consist of inlet and outlet ports inside a housing, and a pumping mechanism made up of a drive gear and a driven gear. See example #21.

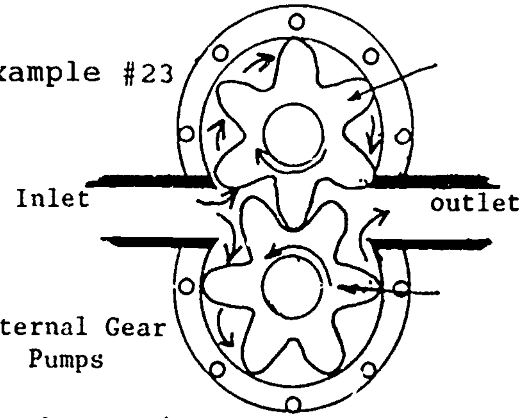
Example #22




Operation of the gear pump occurs as the two gears mesh together, causing a pumping action. The drive gear is attached to a shaft and is rotated by the prime mover. As it rotates, it meshes with the driven gear and causes that gear to rotate as well. See example #22.

At the inlet where the gear teeth unmesh, fluid enters the housing and volume is increased. The fluid is then trapped between the gear teeth and the housing and is directed towards the opposite side of the gear. Here the gear teeth mesh, causing a decrease in volume and the discharge of the fluid into the system. The fluid does not leak back because the clearance between the gears and the housing creates a seal. Generally, gear pumps possess an unbalanced design. There are three major classifications of gear pumps: external gear, internal gear, and axial flow.

Example #23

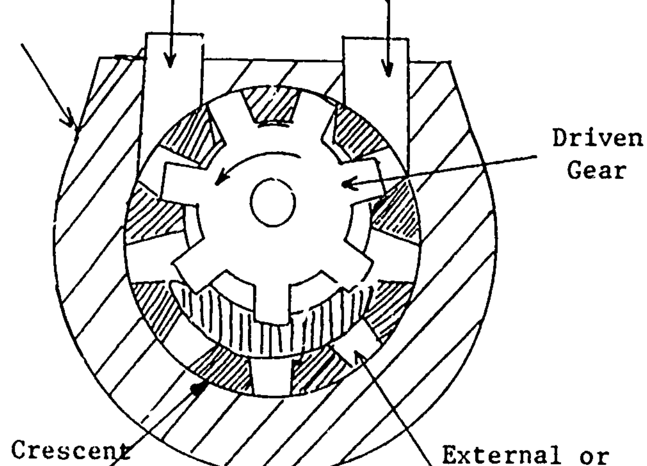



External Gear Pumps

a. external gear pumps-- External gear pumps are classified by their gear construction, in which the gear teeth extend outward from the center of the gear. These gear pumps are also known as gear-on-gear pumps.

The basic elements of an external gear pump are the drive and driven gears and the housing. The driving gear causes the driven gear to rotate in the opposite direction when the pump is in operation. Fluid enters the pump as the gears rotate and cause pressure to be reduced at the pump inlet. It travels through the pump between the gears and the housing until it reaches the discharge side. When gears mesh here, the fluid exits through the discharge port. The three types of gears used in external gear pumps are the spur, helical, or herringbone types, all of which operate in the same manner. Spur gears are most commonly used and are the least expensive. Helical gears possess smoother fluid flow, while herringbone gears are expensive and are of a better quality than the other two.

Example #24

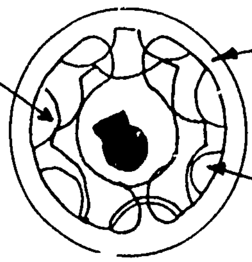



An Internal Gear Pump

b. internal gear pumps-- Internal gear pumps are similar to external gear pumps in their pumping action, but they differ in pump construction. An internal gear pump consists of an external gear that meshes itself within a larger gear. These are also known as gear-within-gear pumps.

During operation, the outer drive gear revolves within the pump housing, driving the inner gear. The stationary crescent aids in forming a fluid seal between inner and outer gear teeth. Fluid enters the inlet chamber and flows between inner and outer gear teeth on the way to the discharge chamber. A gerotor pump is a variation of the internal gear pump. Its internal gear has one less tooth than its external gear, and it does not possess a crescent separator. The inner gear is turned by a prime mover, rotating the outer gear. As gear teeth unmesh, increasing volume is created on one side of the pump, while on the other side of the pump decreasing volume is created.

Example #25



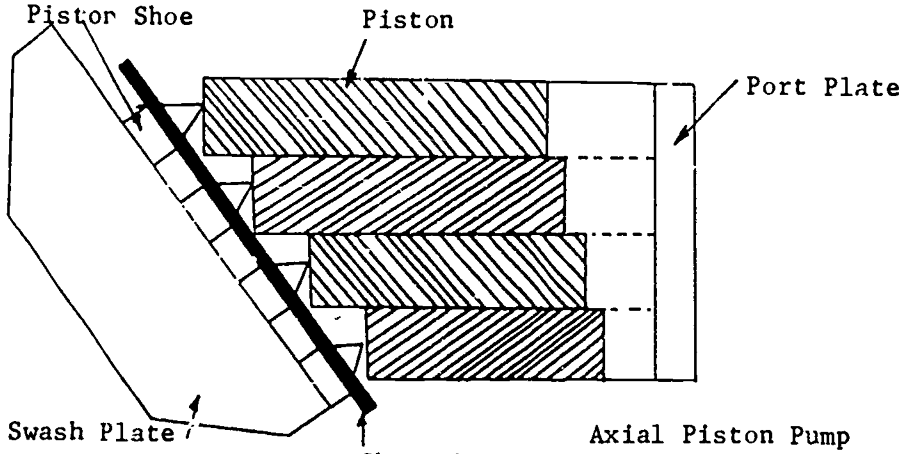

Gerotor Pump

c. axial Flow Pumps-These pumps are commonly referred to as screw pumps. Similar in operation to an external gear pump, the pump fluid moves axially along the housing and between rotor teeth. A small amount of clearance exists between the rotors and the housing, which creates a seal to prevent fluid from flowing back to the inlet side of the pump.

3. Piston pumps consist of a cylinder barrel, pistons with shoes, a swashplate, a shoeplate, a shoeplate bias spring, and a port plate. Piston pumps create a pumping action through the pistons reciprocating inside a piston bore. There are several different types of piston pumps used in hydraulic systems. The specific types of pumps are utilized according to the desired application.

a. axial piston pumps--These pumps are also know as in-line piston pumps, and they operate through the pistons rotating around the same axis as the pump shaft. In the illustrations below, one can see that a cylinder barrel with one bore is fitted with one piston. The shoe of the piston rides on the surface of the angled swashplate. During operation, the cylinder barrel rotates, causing the piston shoe to track along the immobile swashplate. The piston reciprocates inside the bore because the swashplate is at an angle. As the piston moves in and out of the cylinder barrel, volume is decreased and increased. A shoeplate and bias spring are utilized to force the piston shoes against the swashplate. A port plate is placed opposite the swashplate at the end of the cylinder barrel to separate the incoming fluid from the discharge fluid. Often the shaft which connects the cylinder barrel to the prime mover is located at the swashplate end of the barrel. These are the most common types of piston pumps used in industrial applications.

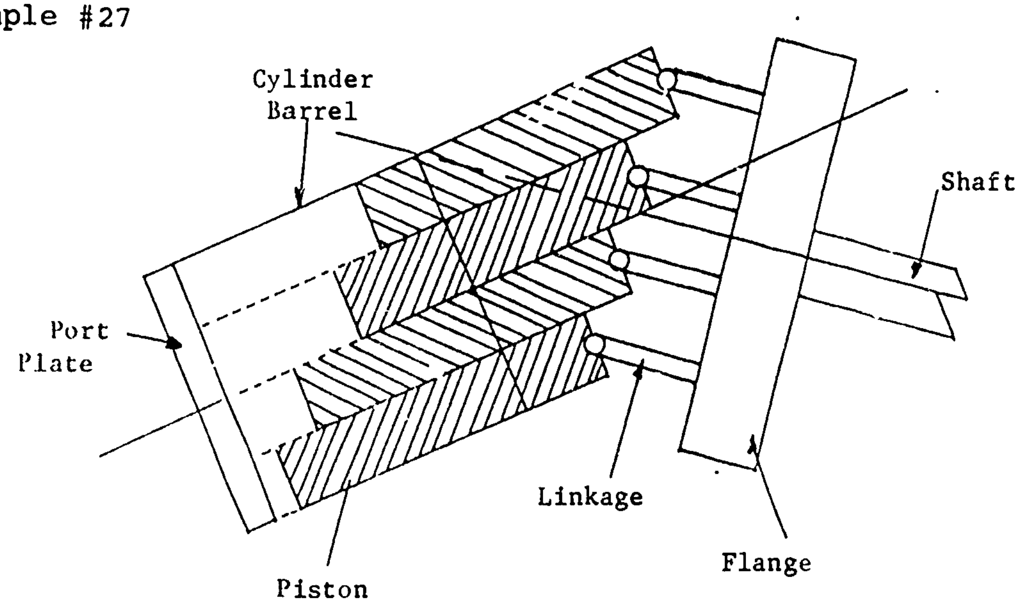
Example #26




Axial Piston Pump
Pumping Mechanism

b. bent-axis piston pump--This type of piston pump consists of a cylinder barrel, pistons, a port plate, flange, piston linkages, and a drive shaft. The cylinder barrel is at an angle to the shaft, resulting in the pistons being pulled out of the barrel when the shaft turns. In this manner, an increasing volume is generated. During the other half of the barrel rotation, the pistons are pushed inward, forming decreasing volume. The incoming and discharge fluids are separated by the port plate.

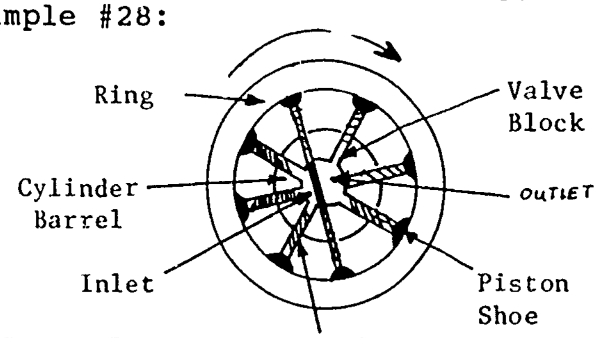
Example #27




Bent-Axis
Piston Pump

c. radial piston pump--This type of piston pump consists of a cylinder barrel, piston with shoes, a ring, and a valve block. The cylinder barrel is positioned off-center to the ring, causing increasing and decreasing volumes to be formed as rotation occurs. This pump uses pistons to track along the ring to produce the changing volumes. The valve block allows fluid to enter and exit the pump.

Example #28:




Radial Piston Pump

C. Rating and Selection Factors

Pump performance is evaluated on the basis of several factors. The following pump rating and selection factors must be taken into consideration when selecting a pump:

1. Capacity is also known as delivery rate, flow rate, or volumetric output, and is the primary rating of a pump. Capacity is usually measured in gallons or cubic inches per minute.

2. Pressure ratings of pumps are typically determined by a pump's ability to withstand pressure without damaging pump components or increasing internal leakage. Pressure ratings of pumps range from 100 to 5000 psi.

3. Pumps are generally rated at electric motor speeds of 1200 or 1800 rpm, although speeds as high as 4000 rpm may be reached under specific conditions.

4. Pump efficiency is determined by the change in flow rate of the pump. Volumetric efficiency refers to the ratio of the actual delivery rate to the theoretical displacement, while overall efficiency refers to the ratio of the pumps hydraulic power output to its mechanical power input.

5. The type of fluid to be pumped, and its viscosity, also affect the rating and selection process. Petroleum fluids with suitable viscosity and protective additives are often the best choice for pumps. Check manufacturers specifications for the proper fluid to use for specific pump applications.

6. Pump reliability is based on the compatibility of pump characteristics and hydraulic system requirements, as well as the maintenance time and service requirements.

Durability, ease of operation, and smooth production all affect pump reliability.

7. These are two main factors to be considered when selecting a pump. Pumps are often mounted above reservoirs, so reservoirs must be able to support such a load. Space limitations will also affect size and weight considerations.

8. Pump service life is rated in hours of operation. The number of hours of operation depend upon pump construction, design, and application. Hydraulic pumps may have a service life ranging from 10,000 hours (approximately one year) to more than 15,000 hours.

9. There are numerous cost considerations that exist when selecting a pump, including cost of the pump itself, installation, controls, maintenance, operation, and replacement component parts. These factors must be considered to allow one to select a quality pump to operate within the designed hydraulic system.

QUESTIONS-PUMPS

1. What are the two basic pump classifications?

   a. Positive nondisplacement
   b. Positive displacement
   c. Nonpositive displacement
   d. Nonadditive displacement
   e. b and c

2. What are the three most common positive displacement types of pumps used in hydraulic systems?

   a. Piston, gear, and vane
   b. Vane, spring-loaded, and gear
   c. Gear, rotary, and piston
   d. Gerotor, vane, and single-acting.

3. Which of the following identify the different types of vane construction?

   a. Pin-vane
   b. Dual-vane
   c. Outer vane
   d. Intra-vane
   e. a,b, and d

4. Which of the following types of vane pumps is designed so that the distance the vanes can extend can be altered?

   a. Pressure compensated variable volume vane pump
   b. Double vane pump
   c. Balanced vane pump
   d. Variable volume vane pump

5. What type of pump generally has an unbalanced design?

   a. Rotary
   b. Vane
   c. Gear
   d. Piston

6. Which of the following is <u>not</u> a pump rating and selection factor?

   a. Pressure
   b. Capacity
   c. Drive speed
   d. Service life
   e. None of the above

## V. Hydraulic Piping & Tubing

Various fluids are transferred throughout hydraulic systems through the use of piping, tubing, and fittings. These components must provide efficient paths throughout hydraulic systems in order for the system to achieve maximum efficiency and effectiveness.

### A. Hydraulic Piping

Hydraulic piping is often referred to as hydraulic lines. The type and size of piping utilized for specific hydraulic applications is determined by a number of factors. The most important factor to consider is the required flow rate capability through the line, while additional factors include the type of fluid used, pressure distance, and the direction of flow. Hydraulic pipe size is critical, for pipes must be large enough to prevent excessive fluid pressure losses between components while also being short enough to allow for ease of installation and a minimum number of bends and fittings. Smooth inside surfaces allow for faster and smoother fluid movement, and reductions or enlargements in the flow passageway should be eliminated.

### B. Hydraulic Tubing

Hydraulic tubing commonly consists of either steel or stainless steel, and must possess good bending and flaring properties for use in hydraulic lines. Made of malleable materials, tubing can be easily formed to meet specific applications. Hydraulic tubing is more flexible than pipe, and often has less leakage.

### C. Line Selection

Hydraulic lines are most often made from steel hydraulic tubing or black steel pipe. Line selection factors include flow velocity, and pressure.

1. Streamlined or laminar flow is desired in hydraulic lines. Laminar flow occurs when flow passages are smooth and the fluid velocity is slow.

2. To calculate fluid velocity through a pipe, flow rate (gpm) and the inside cross-sectional area of the pipe must be known.

Formula:

$$\text{Velocity} = \frac{\text{flow(gpm)} \times 0.321}{\text{pipe area (sq. in.)}}$$

Use the following formula to calculate the necessary flow area (in square inches) that a pipe should have to achieve the desired flow velocity (in feet/second):

$$\text{Area (sq in)} = \frac{\text{(Flow Rate, gpm)} \times (0.321)}{\text{Flow Velocity, ft/sec}}$$

If the exact inside diameter of a pipe is not available, the rule to follow is to select the next larger pipe size. Hydraulic line pipe is selected by the nearest nominal standard pipe size available. When using tubing, one must base selection on inside diameter availability.

3. Pressure requirements must also be taken into consideration when pipe selection occurs. Safe working pressure limits must not be exceeded. Piping must be strong enough to withstand syste… pressure.

## QUESTION-PIPING AND TUBING

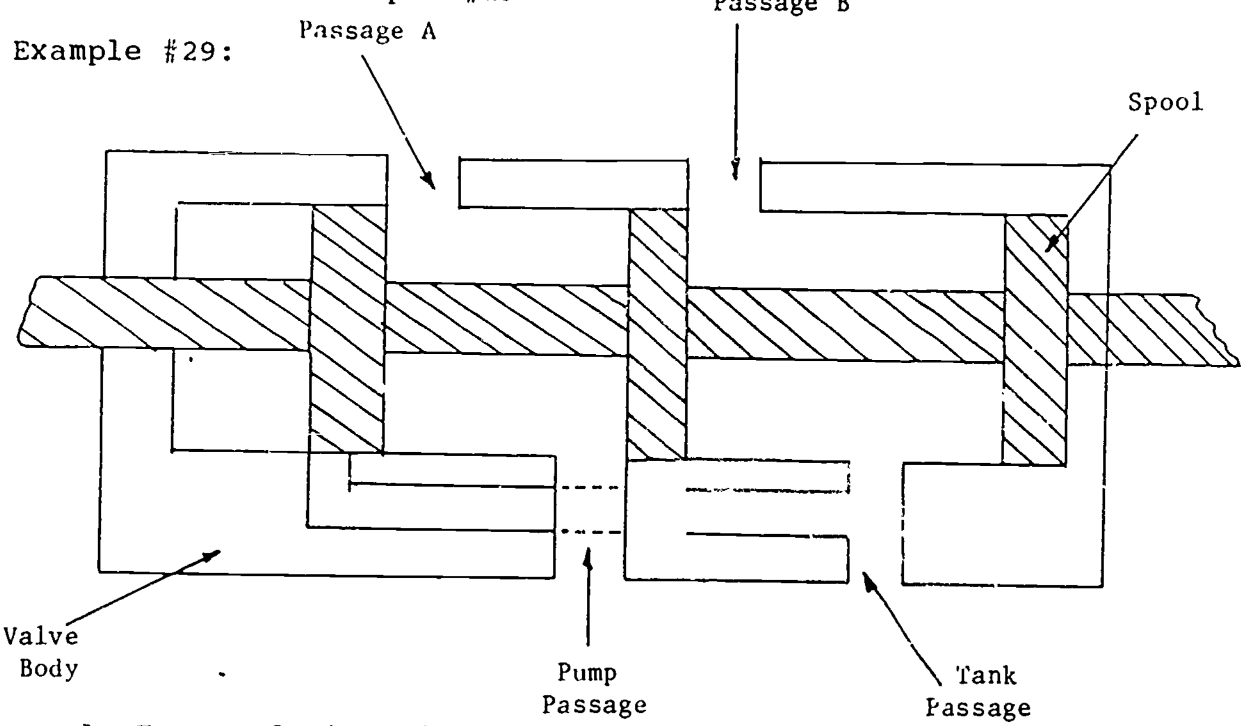
1. Which of the following are line selection factors?

   a. Flow
   b. Pressure
   c. Velocity
   d. a, b, and c
   e. None of the above

## VI. Directional Control Valves

Directional control valves control the direction of hydraulic lines, as well as starting, stopping, or changing the direction of motion within hydraulic cylinders and motors. Directional control valves consist of a valve body with various internal passages which are both connected and disconnected by a spool. The spool itself creates the most common type of directional valve. See example #29

Example #29:



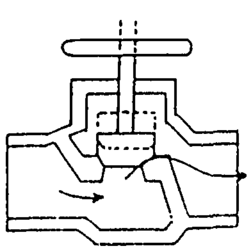

### A. Types of Directional Control Valves

Directional control valves can be classified in two ways; by the name of the valve and by the number of piping connections made to the valve body. These valves can be either manually or automatically operated.

1. There are several manually operated two-way valves that are used in hydraulic applications throughout industry.

   a. globe valves--These valves are used for air or fluid service for pressures up to 250 psi, and they regulate flow to a limited degree.

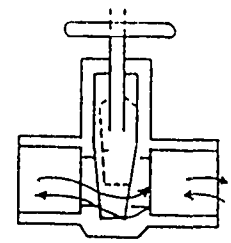
Example #30



Globe Valve

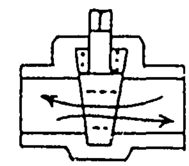
b. gate valves--These valves allow flow in either direction at both high and low pressure ratings.

Example #31



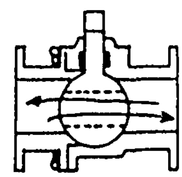
c. plug valves--These valves are only utilized when low pressures exist, and are also inexpensive. These valves require frequent maintenance because they tend to leak.

Example #32



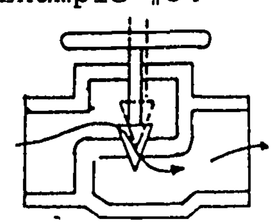
d. ball valves--These valves are similar to plug valves, but are utilized at medium pressures. Operation of this valve is easier than for the plug valve because of the nonmetallic contact between the ball and the seals.

Example #33



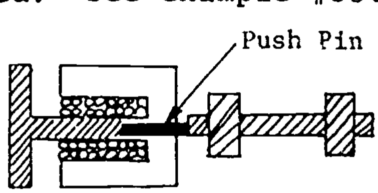
e. needle valves--These valves are often used as both throttling valves and shut-off valves, and are utilized at high pressures.

Example #34



2. The solenoid operated type of automatic two-way valve is the most common method of operation. A solenoid operates electrically, and consists of a free-moving plunger and a wire coil wound inside a "C" frame. The solenoid operates when an electric current passes through the wire coil. This generates a magnetic field, which attracts the plunger and pulls it into the coil. The plunger moves inward, contacts a push pin, and forces the directional valve spool into an extreme position. Solenoids are classified as either direct-acting or pilot-operated. See example #35.

Example #35

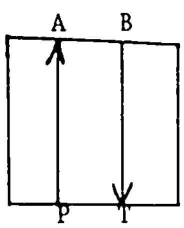


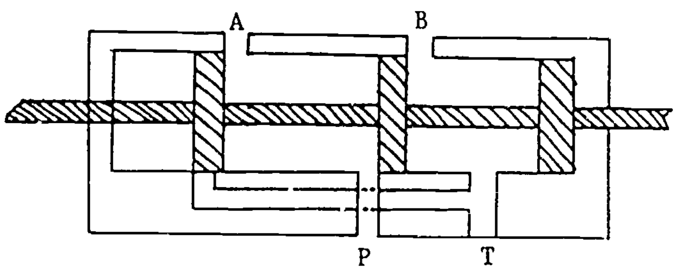

a. direct-acting solenoid valves--These types of valves are referred to as normally closed valves because the valve is closed (due to the plunger being held against the valve) when the coil is de-energized. When the electrical coil is energized, the plunger lifts from the seat, thus allowing fluid to flow through the valve.

b. pilot-operated solenoid valves--These types of valves control the hydraulic fluid which operates either the poppet valve or the piston. These valves are either classified as normally open or normally closed. When energized, the pilot plunger lifts, opening the bleed orifice and relieving the pressure above the piston. The hydraulic fluid pressure at the inlet passage lifts the piston and allows fluid to flow through the valve to the outlet. When deenergized, the pilot plunger drops back into place, closing off the bleed orifice. Thus fluid flow is only in one direction.

3. The four-way directional valve consists of four distinct passages inside its valve body: one pump, one tank, and two actuator passages.

Example #36

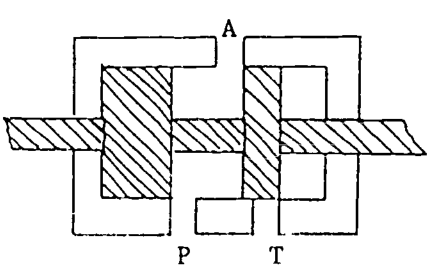


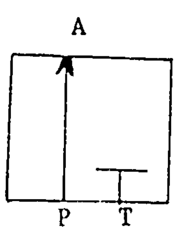




These valves reverse the motion of either a cylinder or a hydraulic motor. This occurs as the spool moves, directing the flow from the pump passage to one actuator passage while the remaining actuator passage is exhausted to the tank.

4. The three-way directional valve consists of one pump, one tank, and one actuator passage within the valve body.

Example #37

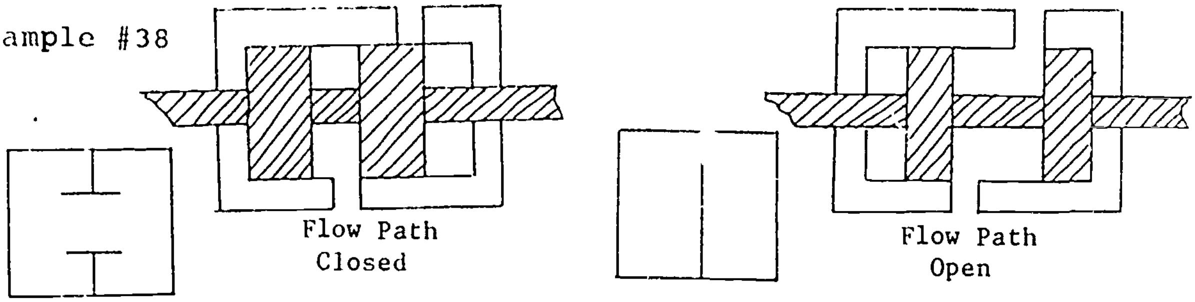



This valve pressurizes and exhausts its one actuator port when the spool is in its extreme positions.

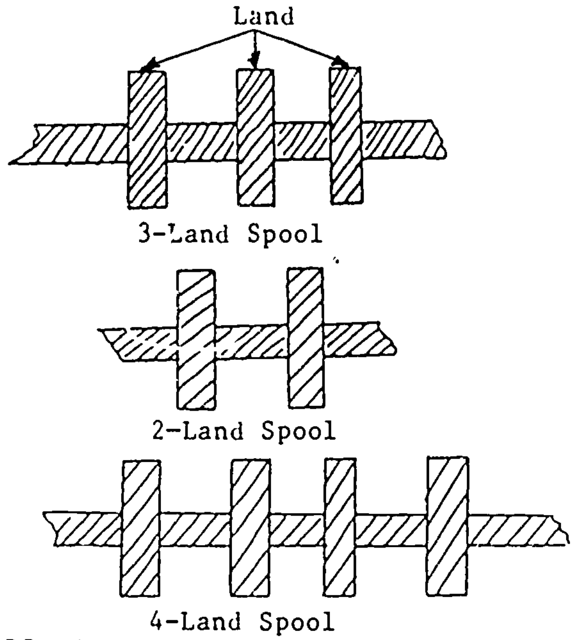
5. The two-way directional valve consists of only two connecting and disconnecting passages. In the extreme spool positions, the flow path is either open or closed.

Example #38




Directional valve spools in the directional valves consist of skirts (also known as lands) spaced evenly apart on a shaft. Most hydraulic directional valves have either 2-land or 4-land spools. 3-land spools are used in 4-way directional valves, and thus these directional control valves may be referred to as spool valves.

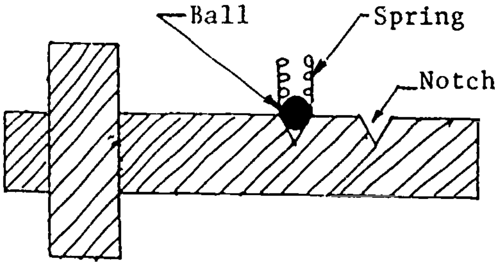
Example #39




a. spring offset valves--These valves are two position directional valves that use an actuator to move the directional valve spool to an extreme position and utilize a spring to return the spool to its original position. Spring offset valves can either be normally open or normally closed, and can be used as safety interlocks within hydraulic systems.

b. detents--Detents are locking devices used to keep spools in their desired positions. Notches or grooves are placed in the spool of a detented valve, and a spring-loaded movable part moves from notch to notch (or groove to groove). When the movable part is in a notch, the spool is held in one position. As the spool shifts, the movable part is forced out of one notch and into another.

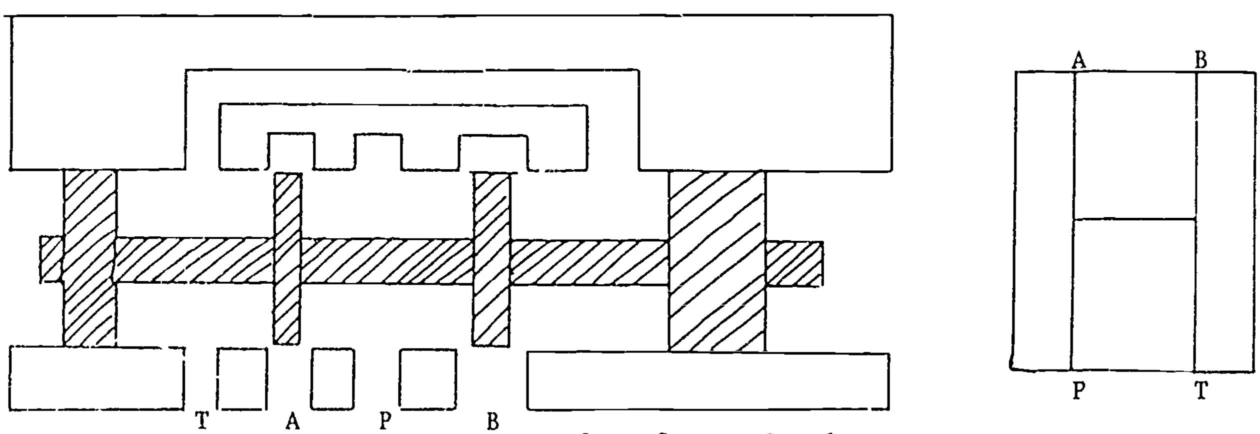
Example #40




c. center conditions--Not only does the spool move to extreme positions, but intermediate spool positions also exist between the extremes. As an example, four-way directional valves generally have three positions: two extreme positions control actuator movement and are known as the power positions of the valve. The center position exists to satisfy a requirement or condition of the hydraulic system. A directional valve's center position is also known as its center condition. The appropriate spool must be used within the valve body in order for the following center conditions to be achieved.

1. open center condition--A directional valve that has an open center spool is illustrated below. Its P, T, A, and B passages connect to each other when the spool is in the center position.

Example #41

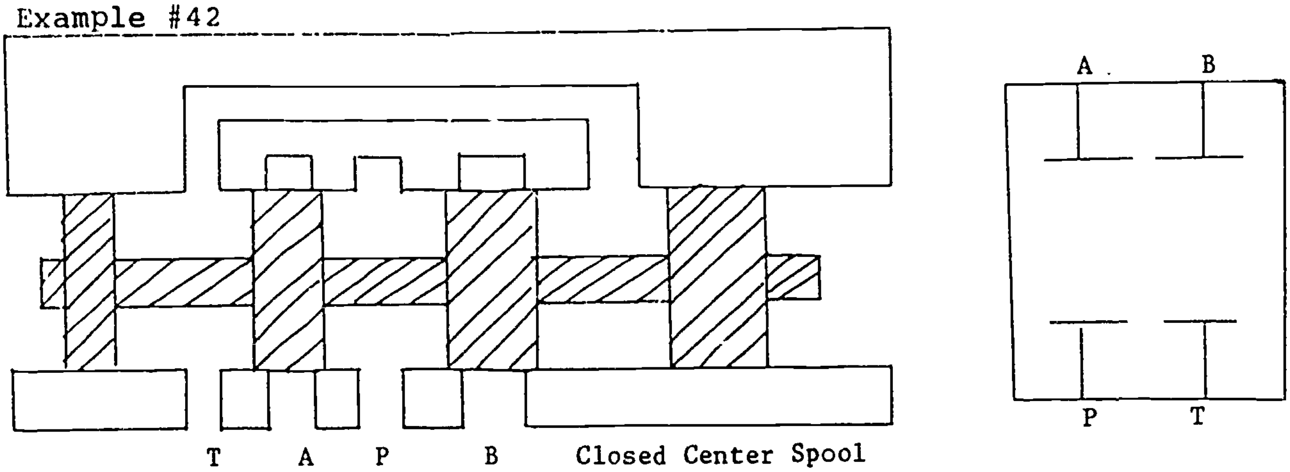



Open Center Spool

This condition allows free movement of the actuator . Pump flow returns to the tank under low pressure. This type of condition is often used within single actuator circuits. However, once the valve is centered, no other actuator may be operated.

2. closed center condition--This condition blocks the P,T,A, and B passages in the center position within the directional valve.

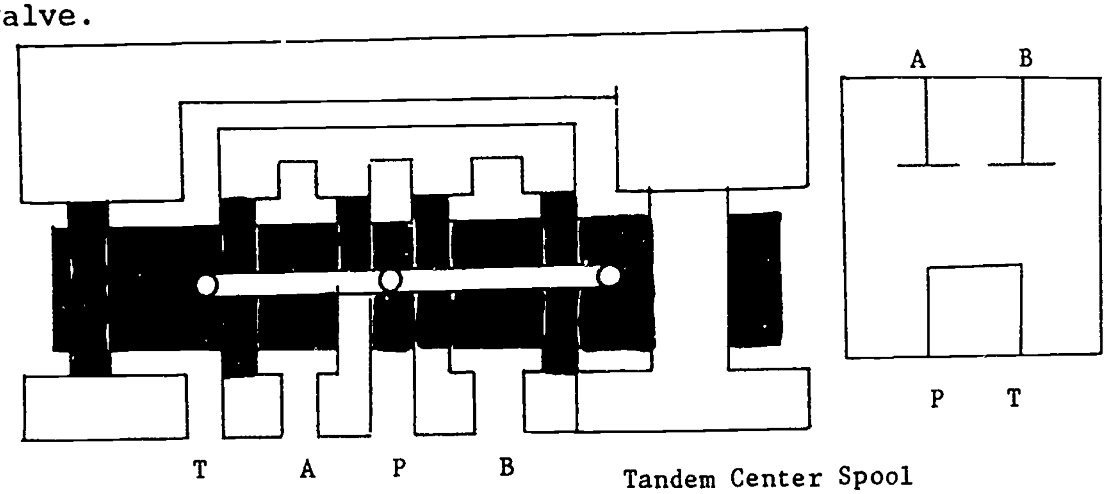
Example #42




The closed center condition terminates actuator movement, while, also, allowing the various actuators in the system to function independently from one power supply. This center condition does not allow pump flow to be unloaded to the tank through the directional valve while the actuator is idle. An additional hazard is that pressure will build in the actuator lines if the spool is under pressure for extended periods of time. This can cause leakage and damage to the hydraulic system.

3. tandem center condition--This condition occurs when the A and B passages are blocked in the center position when the P and T passages remain connected in the directional valve.

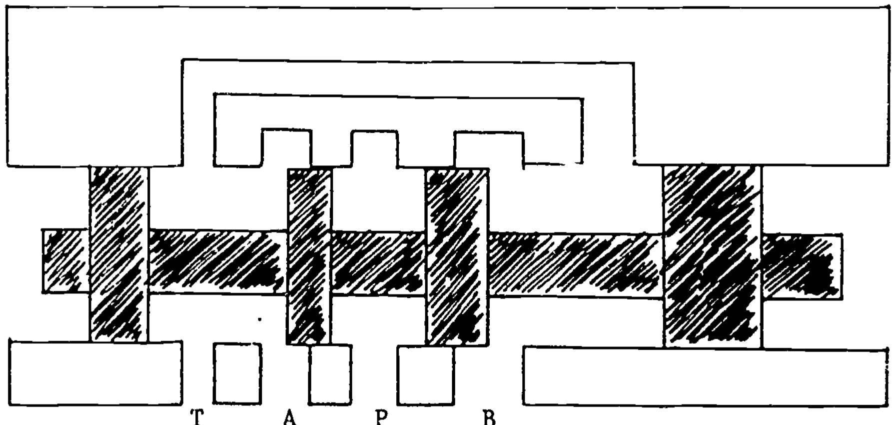
Example #43

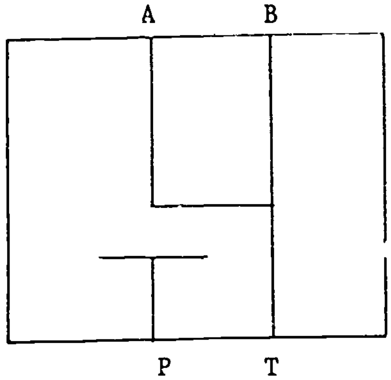



The tandem center condition terminates actuator movement while permitting pump flow to return to the tank without passing over the relief valve. The pump is unloaded while the spool is in the center position.

4. float center condition--This condition exists when the P passage is blocked and the remaining three passages (A, B, and T) are connected while the spool of the directional valve is in the center position.

Example #44




Float Center Spool

This float center condition permits the movement of individual actuators and also allows independent operation of actuators with the same power source. Directional control valves that possess three positions (two extreme and one center) must have the capability to keep the spool in the center position. This is achieved either with springs or through the use of hydraulic pressure.

a. spring centering--A spring centered valve has a spring placed at each end of the directional valve spool. When the valve is put into motion, the spool moves to one of the extreme conditions, compressing a spring. When the motion of the valve ceases, the spring returns the spool to the center position. This is the most common method of centering directional valve spools.

b. pressure centering--This occurs as fluid pressure is directed to the chambers at the ends of the spool. No matter which extreme position the spool is in, the spool will move and center itself under pressure.

## QUESTIONS-DIRECTIONAL CONTROL VALVES

1. True or False: There are two methods of classifying directional control valves.

2. Which of the following are manually operated two-way valves?

   a. Plug valves
   b. Globe valves
   c. Sequence valves
   d. Needle valves
   e. a, b, and d

3. ______ are locking devices used to keep spools in their desired positions in directional control valves.

   a. Skirts
   b. Centers
   c. Lauds
   d. Detents

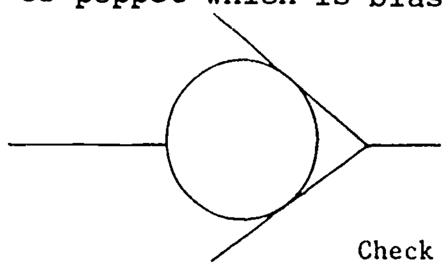
4. Which center condition terminates actuator movement while allowing other actuators to operate independently from the power supply?

   a. Tandem center
   b. Closed center
   c. Open center
   d. Spring center

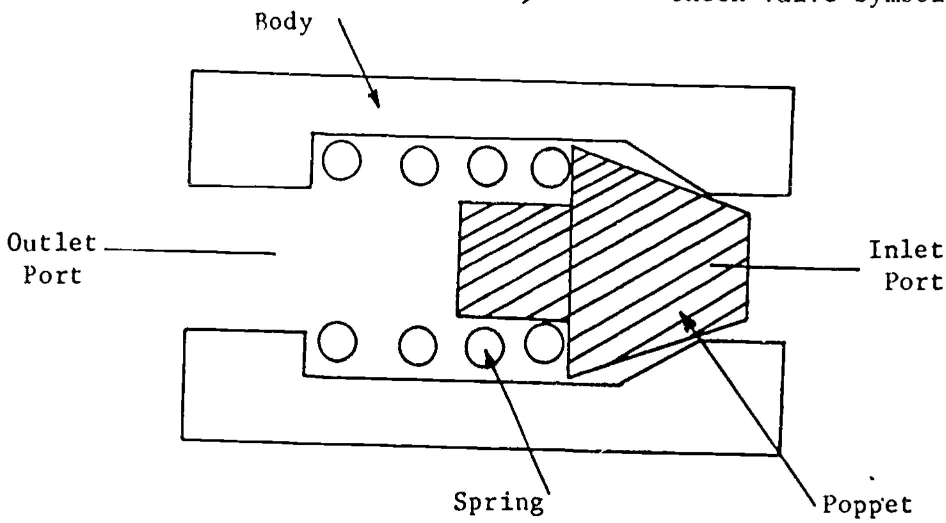
## VII. Check Valves

Check valves are a type of directional one-way valve. These valves only allow hydraulic fluid to flow in one direction, as indicated by the symbol on the outside of the valve body. Check valves consist of a valve body with both inlet and outlet ports and a ball or poppet which is biased by spring pressure.

Example #45



Check Valve Symbol




To allow flow through the valve, the system pressure at the inlet must be great enough to overcome the spring pressure that holds the poppet in place. The poppet will be pushed off its seat, and pressurized fluid will enter and pass through the check valve. This is referred to as the free flow direction of the check valve. Upon reduction of inlet pressure, the pressure in the outlet causes the poppet to close against its seat. This shuts off the reverse flow through the check valve.

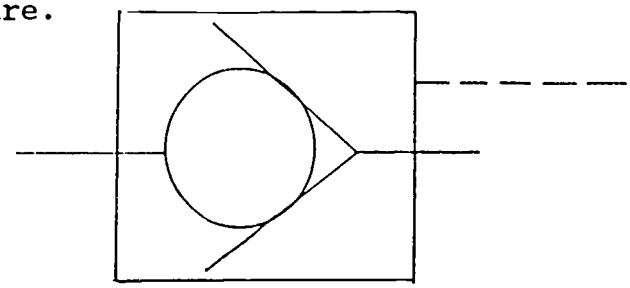
### A. Functions of Check Valves

Check valves can be viewed as both directional valves and pressure valves. Check valves are directional valves because they only allow flow in one direction, and they are pressure valves because their operation occurs only under the pressure of hydraulic fluid. Check valves can also act as bypass valves, directing fluid flow around components. As isolation elements, check valves can be used to isolate sections of a system as well as restricting overflow. Check valves can also be used to suspend loads for lengthy periods of time, because of their low leakage.

B. Pilot operated check valves

This type of check valve has the same valve body structure as an ordinary check valve, with both inlet and outlet ports and a poppet biased by a spring. Additionally, this type of valve has a plunger and a spring-biased plunger piston opposite of the poppet. When fluid flows through the pilot port, the plunger piston is able to sense the pilot pressure.

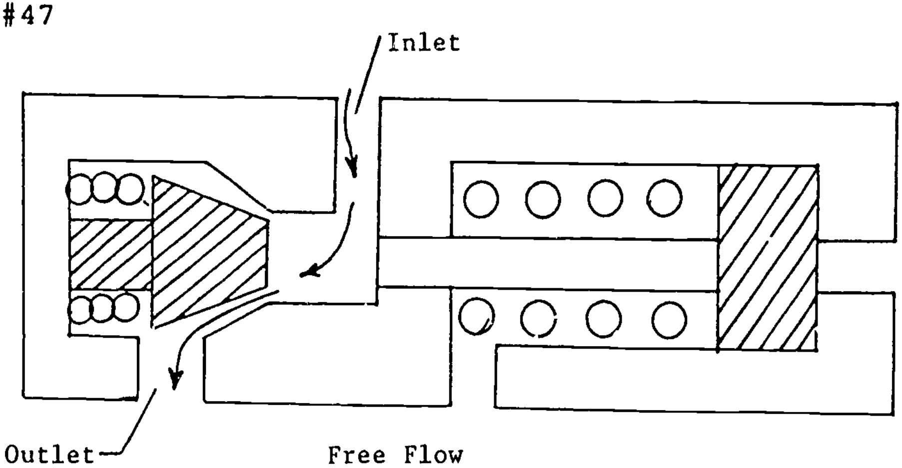
Example #46



Pilot Operated Check Valve Symbol

Pilot operated check valves operate by allowing free flow from the inlet port to the outlet port. This free flow is in only one direction when pilot pressure is exerted and unseats the check valve poppet.

Example #47



## QUESTIONS-CHECK VALVES

1. True or False: Check valves are two-way directional control valves.

2. Which of the following is <u>not</u> a function of check valves?

   a. Directional valves
   b. Bypass valves
   c. Pressure valves
   d. Isolation elements
   e. None of the above

VIII. Pressure Control Valves

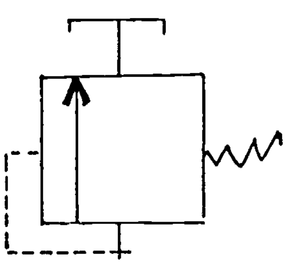
Within a hydraulic system, constant pressure must be maintained for the system to operate efficiently. If too much or too little pressure exists, damage can occur throughout the hydraulic system. Pressure control valves limit and regulate pressure within a hydraulic system, while also controlling fluid flow rates in that system. Spring pressure is often utilized in pressure control valves, while screw adjustments are also used to aid in the compression and decompression of the spring.

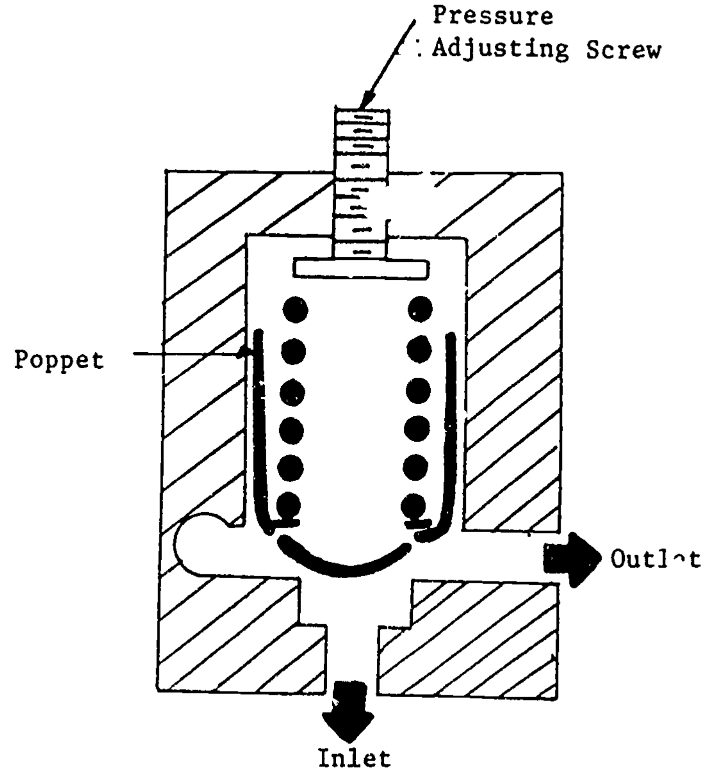
A. Pressure Relief Valves

Pressure relief valves protect hydraulic systems against excess pressure. These valves are designed to let the pressure of the fluid in a hydraulic system or a part of the hydraulic system rise to a set maximum value, and then hold the pressure at or below this maximum. The excess fluid returns to the reservoir. Most relief valves in hydraulic systems are either poppet valves or spool valves.

1. The direct-acting poppet relief valve consists of an inlet port connected to the hydraulic pressure line, and the outlet port connected to a return line leading back to the reservoir. A poppet spring holds the poppet on the valve seat.

Example #48



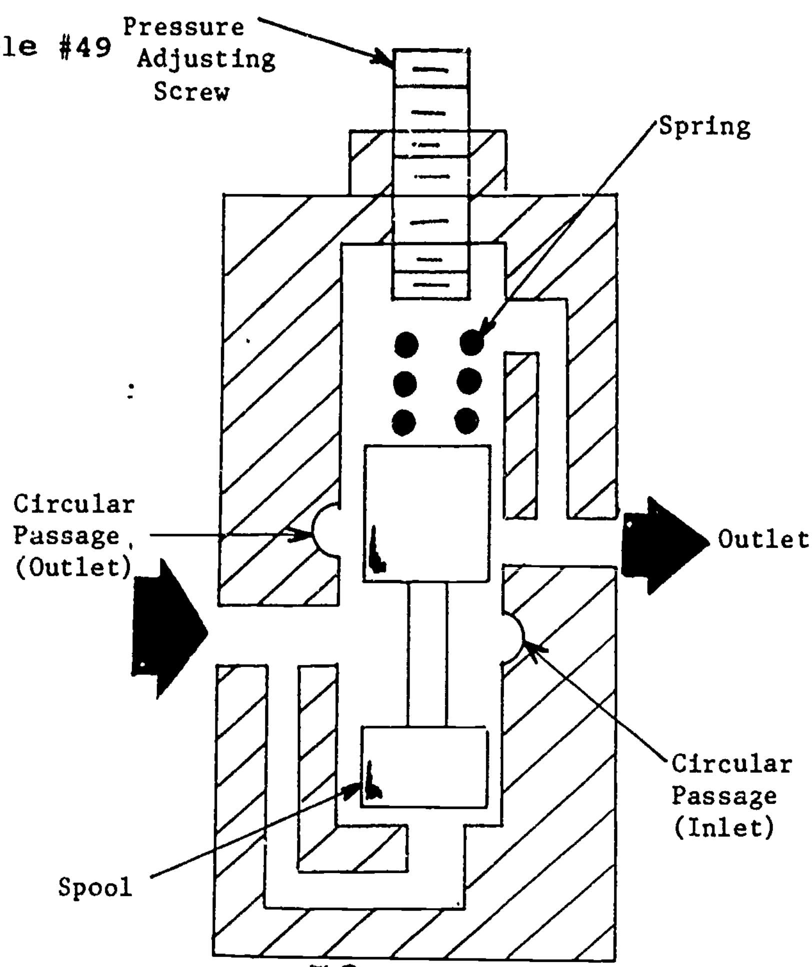


The pressure adjusting screw of the spring regulates the pressure setting of the valve. When fluid pressure under the poppet reaches the cracking pressure setting, the force of the fluid pushes the poppet open slightly against the spring. This allows some fluid to flow through the valve outlet and return to the fluid reservoir. With further increase of pressure, the poppet continues to open and allow more fluid to return to the reservoir. This continues to occur as line pressure increases, until the full-flow rating of the valve is reached.

The two-stage or compound poppet valve is simply a modification of the simple poppet valve. During operation, fluid at inlet pressure enters the orifice and holds the poppet shut against line pressure, which is adjusted by the pilot poppet spring. The pilot poppet opens once the fluid pressure has increased past the cracking point of the pilot poppet, allowing fluid to pass through the bypass and into the outlet.

2. The simple direct-acting spool valve consists of an inlet port connected to the hydraulic pressure line and an outlet port connected to the reservoir return line. The adjustable spring holds the spool in the closed position.

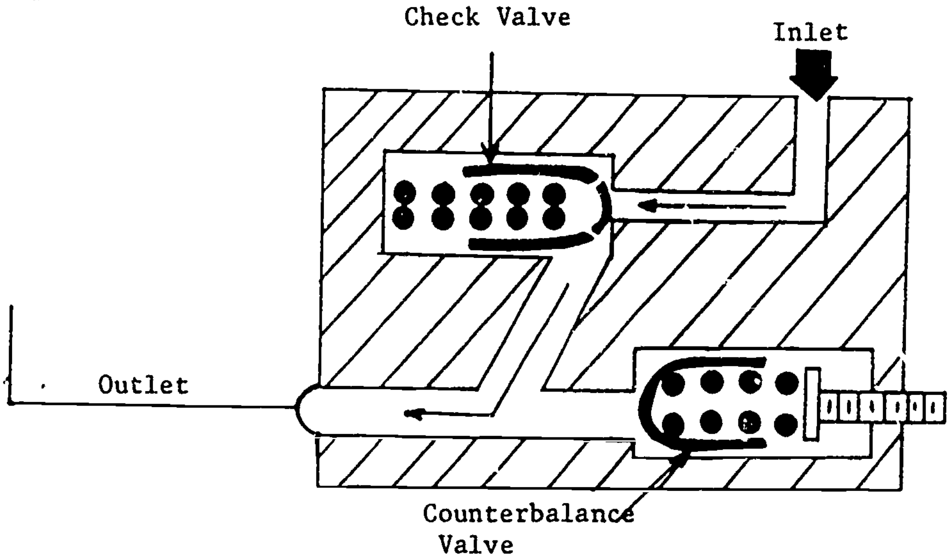
Example #49



C. Counterbalance Valves

Counterbalance valves are also known as foot braking, or back-pressure valves. These types of valves are often used to balance or counteract weight within a hydraulic system (i.e., raising or supporting a load). Counter balance valves are normally closed pressure control valves that have adjustable springs. During operation, hydraulic fluid enters the inlet and flows past the check valve. The valve remains seated due to the fluid pressure and heavy spring pressure acting on the valve. If, while the load is being raised, it should try to reverse, the check valve is caused to seat due to returning fluid pressure. When enough return fluid is applied to the counterbalance valve, it lifts and permits the fluid to flow out of the drain, and back to the reservoir.

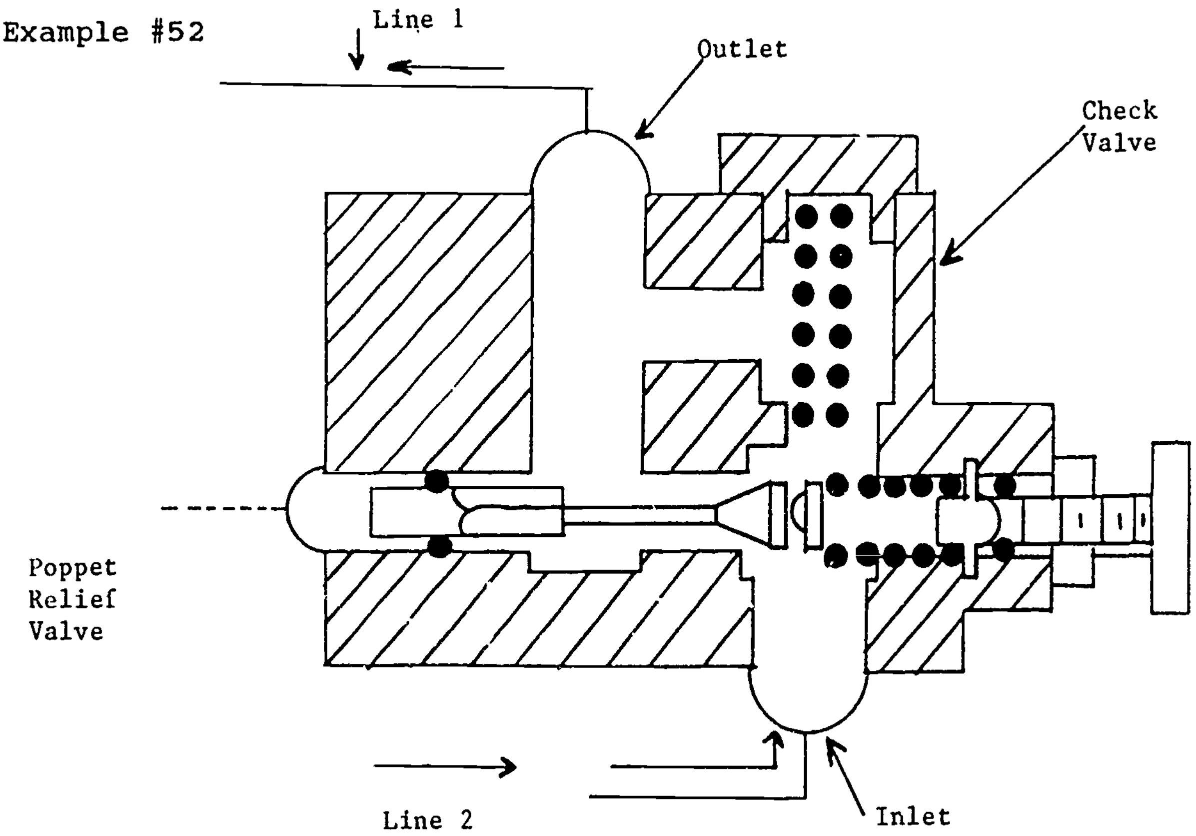
Example #51



D. Holding Valves

Holding valves offer less resistance to fluid flow than counterbalance valves. During operation, hydraulic fluid flows through the inlet and past the check valve to lift the load. While the load is being held, the poppet is in the closed position. When line two is pressurized, this added pressure allows the poppet to open and permits the fluid from line one to flow back to the reservoir.

Example #52



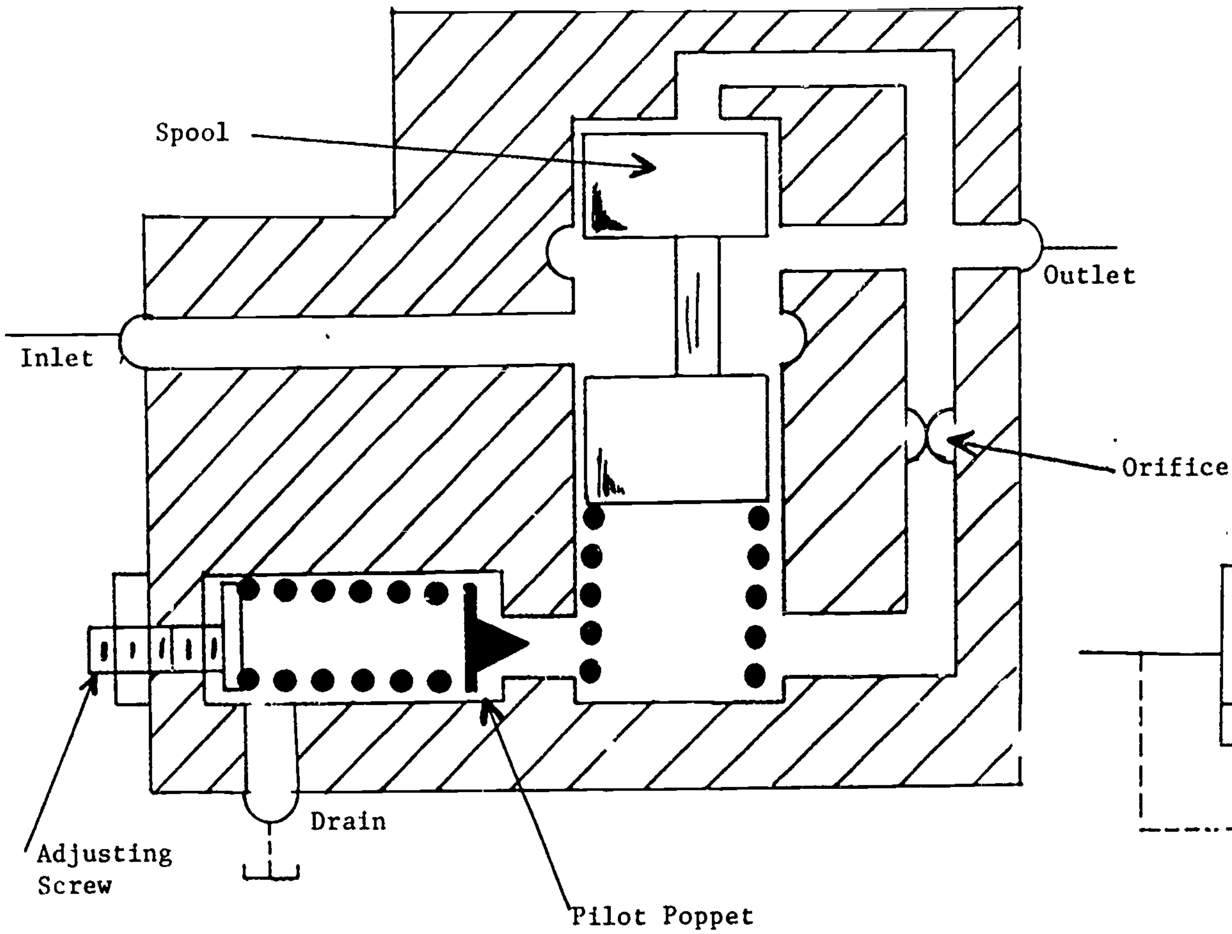

E. Unloading Valves

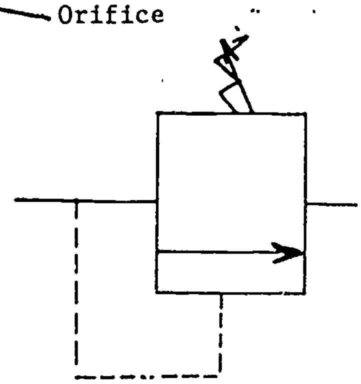
Unloading valves are remotely operated normally closed pressure control valves. These valves direct flow to the tank when system pressure reaches a certain level. The most common pilot-operated unloading valve is that which is used in a two-pump circuit. Within a two-pump circuit, a high-pressure, low volume pump and a low-pressure, high volume pump are used to fill and operate a system. The pilot piston is operated by high system pressure at the pilot port, causing the poppet to open. The main spool shifts to the left as the poppet opens, opening the outlet and allowing low-pressure flow to return to the reservoir. The pilot poppet closes as system pressure drops, also causing the main spool spring to shift to the right and close the passage between the inlet and outlet.

F. Pressure Reducing Valves

These types of flow control valves are utilized to limit the pressure in parts of the system. These valves are in the normally open position to control the pressure in the hydraulic system.

Example #53 (A and B)



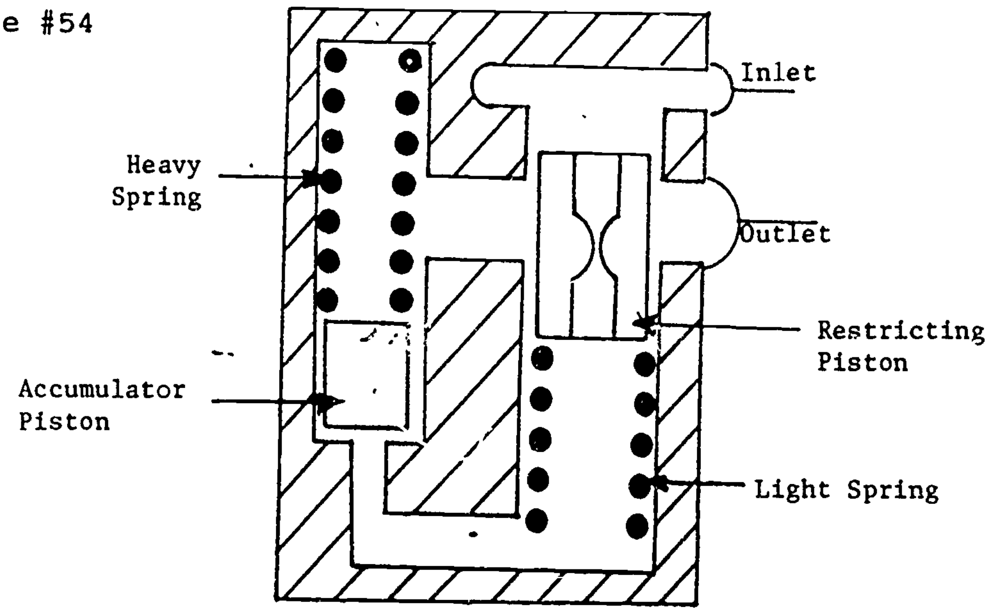



During operation, hydraulic fluid at main system pressure enters the inlet, flowing past the open spool towards the outlet. Near the outlet, the fluid is directed towards the spool ends. The orifice regulates the amount of fluid entering the control side of the spool as well as regulating the bleed off of fluid past the pilot poppet to the drain line. The spool is pushed down due to the high fluid pressure above it. This causes the high pressure flow to cease. Fluid bleed off and outlet pressure are determined by the pressure adjusting screw setting.

G. Shock Suppressors

Hydraulic shock may occur when high-pressure relief valves are unable to reduce the rapid pressure surge that occurs when a hydraulic system begins operation. Shock suppressors can be installed to prevent hydraulic shock from damaging the hydraulic system.

Example #54




Shock suppressors operate by detecting the beginning of sudden pressure rises in the system. Fast pressure rise enters the valve and partially flows through the restricting pistons. The fluid that passes through the restriction acts on the accumulator piston, compressing the accumulator spring, and allowing the fluid to return to the reservoir. High pressure also opens the restricting piston against the light spring pressure, allowing fluid to return to the reservoir. Once the shock has passed from the inlet, to the outlet, and back to the reservoir, the restricting piston is closed and the accumulator is reset and ready for the next hydraulic shock to occur.

## QUESTIONS-PRESSURE CONTROL VALVES

1. True or False: Pressure relief valves are types of pressure control valves.

2. What are the two common types of pressure relief valves?

   a. Screw
   b. Spool
   c. Poppet
   d. a and b
   e. b and c

3. Which type of valve is utilized when a system operation must occur either before or after another operation?

   a. Balance valve
   b. Sequence valve
   c. Prior valve
   d. None of the above

4. Counterbalance valves are also known as:

   a. Foot valves
   b. Back-pressure valves
   c. Braking valves
   d. All of the above

5. Which of the following valves are used to direct flow to tank when system pressure reaches a specified level?

   a. Loading valve
   b. Counterbalance valve
   c. Holding valve
   d. Unloading valve

6. True or False: Pressure reducing valves are utilized to increase pressure in system parts to a level above the main part of the system.

7. Hydraulic shock can be prevented with the use of shock ____.

   a. Suppressors
   b. Reducers
   c. Erasers
   d. Terminators

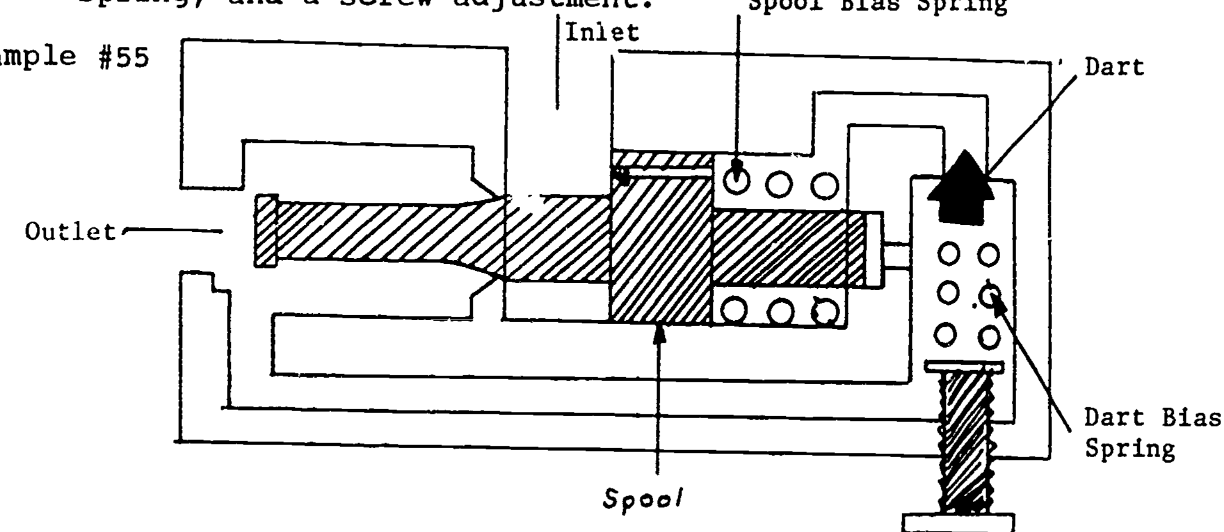
## IX. Pilot Operated Pressure Control Valves

Pilot operated pressure control valves possess spools biased by spring and fluid pressure, unlike direct operated pressure control valves which are biased only by spring pressure. The fluid and spring pressure eliminate both cracking pressure and override, which are so commonly found in direct operated pressure control valves.

### A. Pilot Operated Relief Valves

Pilot operated relief valves consist of a body with inlet and outlet ports, a spool with an orifice, and a spool bias spring. The pilot valve is made up of a dart, a dart bias spring, and a screw adjustment.

Example #55




Operation of the main valve occurs as system pressure exerts itself on the spool skirt. The spool is biased by a light spring, and the stem of the spool is attached to the outlet of the tank. When a designated system pressure is reached, the spool is pushed upwards and the flow will pass to the tank. Operation of the pilot valve occurs as system pressure exerts itself on the dart with such force that the dart is moved and the dart bias spring is retracted. High system pressures must be achieved for the dart to unseat and allow flow to pass to the tank. The main valve and pilot valve are merely spring-biased pressure controls. The main valve manages larger flows at low pressure while the pilot valve manages small flows at high pressures. Through the combined use of these two valves, large flows can be managed at high pressures without the hazards of cracking pressure and override. Additionally, sequence, counterbalance, unloading, and pressure reducing valves can also be pilot operated.

### B. Remote Pilot Adjustment

Remote adjustment can be utilized for pilot operated pressure control valves because they use fluid pressure to bias the main valve spool. By connecting another pilot valve to the spring chamber of a pilot operated control valve, the maximum pressure in the spring chamber of the additional valve will be restricted to the remote pilot valve setting if the setting is lower than the other pilot valve. Since this holds true, the remote pilot valve can easily be utilized by machine operators. Additionally, pilot operated valves such as the unloading, sequence, counterbalance, and pressure reducing valves can also be remotely adjusted with ease.

### C. Venting

Venting refers to the release of the fluid pressure that biases the main spool of pilot operated relief valves. Venting allows the pump to apply a low pressure to return its flow to the tank, because the only pressure holding the spool closed is the pressure of the light spring.

## X. Flow Control Valves

Flow control valves restrict and reduce the pump flow rate within a circuit. Pressure is applied to the hydraulic liquid in the system, and some of the liquid is forced to take another route. The pressure increase can be considered a source of potential energy that changes into kinetic energy as it determines the rate of flow of the hydraulic fluid. The rate of flow is determined by the flow control's orifice, which is merely an opening in the flow path that allows the fluid to move.

### A. Factors of Orifice

There are three factors of the orifice that affect flow:

1. The size of the orifice controls flow rate. The amount of flow which is allotted to various areas of the system depends upon the size of the opening.

2. The amount of pressure in and around the orifice affects flow through the orifice.

3. Orifice flow is affected by temperature. Changes in temperature affects liquid viscosity.

B. Flow Control Circuits

Often, flow control valves are present in a circuit adjacent to the actuator being utilized. Flow can also be measured within circuits.

1. Meter-in circuit is used to regulate actuator speed when a positive load is present. While an orifice controls fluid flow to an actuator, the pressure of the work load is positive. An example would be a load that is lifted in the vertical position.

2. Motor-out circuit is used to regulate the flow exiting an actuator when work loads change direction. This allows for control of the speed of actuators. An example would be when a drill breaks through a workpiece.

3. Bleed-off circuit is used to route a portion of the flow at existing system pressure to a tank for storage. This indirectly regulates actuator speed, and is not often recommended because of possible leakage difficulties.

## QUESTIONS-FLOW CONTROL VALVES

1. What determines the rate of flow in a flow control valve?

   a. Pressure
   b. Fluid temperature
   c. Orifice
   d. None of the above

2. Which of the following does not affect flow through the orifice?

   a. Orifice size
   b. Fluid velocity
   c. Pressure differential
   d. Fluid temperature

3. Which type of flow control circuit regulates actuator speed for positive loads?

   a. Bleed-in
   b. Meter-out
   c. Bleed-off
   d. Meter-in

# XI. Cylinders

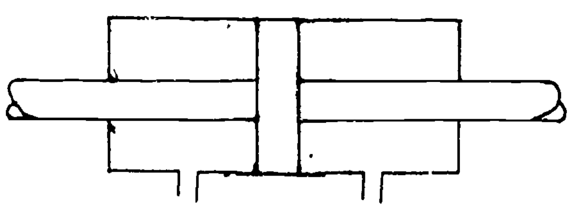
Cylinders are the most common fluid power actuator utilized in hydraulic systems, as they use the potential energy in hydraulic fluid to perform work. Hydraulic cylinders convert hydraulic pressure into mechanical force. Cylinders consist of a cylinder body with closures at each end, a piston rod, and a movable piston. The piston rod is supported by a rod gland as it moves in and out of the cylinder. The end of the cylinder through which the rod protrudes is known as the "head". The opposite end is known as the "cap".

## B. Types of Cylinders

There are numerous types of cylinders available for various applications in hydraulic systems. The types to be described include double-acting, single-acting, ram, telescoping, two-piston, and positional cylinders.

1. Double-acting cylinders are capable of exerting force in two opposite directions. When fluid is directed into port A, the piston moves to the right and the fluid in the cap end of the cylinder is pushed out through port B and is returned to the reservoir. When fluid is directed into port B, the piston then moves to the left and the fluid in the rod end of the cylinder is returned through port A to the reservoir. When the piston is moved to the left, thrust and fluid displacement are greater than when the piston moves to the right, because the rod takes up a greater amount of surface area of the piston in that position.

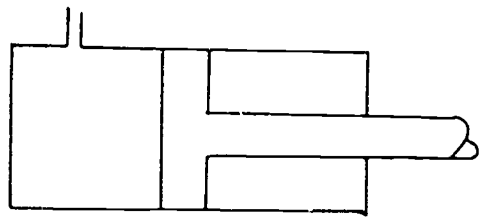
Example #56



The double-rod cylinder, a modification of the double-acting cylinder, has a piston rod extending out of both ends. Thrust and fluid displacement are equal in both directions because the area of the piston is the same on each side. This type of cylinder is used when a limited amount of space is available and motion is needed in two directions.

2. Single-acting cylinder possess many more modifications than do double-acting cylinders. Single-acting cylinders exert power in only one direction, usually on the extending stroke. When work is completed, external force returns the piston to its original position. The retracting stroke becomes the power stroke, if the fluid is directed to the rod end of the piston. If this is the case, the cylinder is known as a pull-type cylinder.

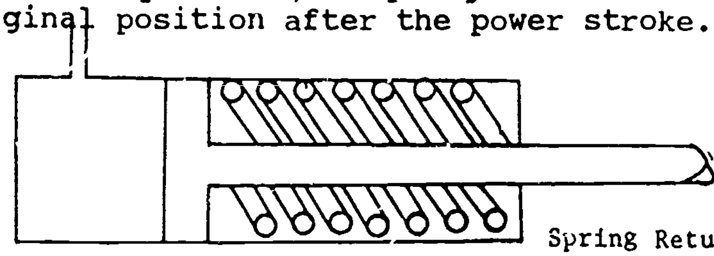
Example #57



Single Acting Load Return

There also exist single-acting spring-return cylinders. Within these cylinders, a spring returns the piston to its original position after the power stroke.

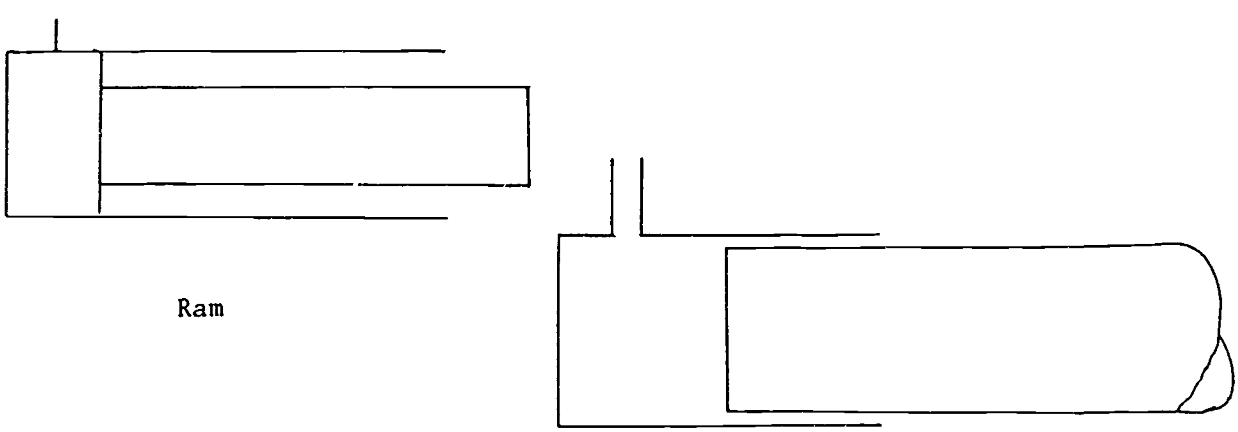
Example #58



Spring Return

3. Ram cylinders possess a large rod diameter, and often do not utilize pistons seals but instead use rod-packing for the ram. The ram can be returned to its starting position through the use of gravity, the weight of the load, springs, or by manual effort. A shoulder on the ram prevents it from exiting the cylinder as it strokes. This type of cylinder has applications for such uses as jacks and hydraulic presses.

Example #59 (A and B)



4. Telescoping cylinders are usually of the single-acting type. Telescoping cylinders possess sleeves that slide or rest together, ranging from two to six in number. During operation, the large sleeve extends first, with all the remaining sleeves extending in order of size and retracting in reverse order. The fewer the sleeves, the greater the lifting force of the cylinder.

5. Two-piston cylinders resemble double-end cylinders with the exception of possessing two independently moving pistons. Depending upon the application, these pistons may move simultaneously in unison or individually. During operation, fluid enters port A and the pistons move apart, forcing the fluid to return to the reservoir through ports B and C. The pistons close as the fluid is returned to the cylinder through the B and C ports. Only the right piston will move if the flow return from the left piston flows through port B and is blocked by port C. The left piston can be actuated in the same manner. The pistons can also be timed to move in sequence.

6. Positional cylinders are basically two-piston cylinders with one extended rod. During operation, the fluid on the left side of the positioning piston determines its location in the cylinder. Fluid enters port B, moves the piston to the right, and forces fluid out through port C. The amount of travel of the right piston is determined by the location of the positioning (left) piston.

C. Cylinder Construction

The majority of cylinders are constructed out of steel tubing which has been machined on its inner surface. Rod and cap ends are also made of steel, and are positioned either through the use of rods or threads or they may be welded to the cylinder itself. Pistons are usually made out of high grade cast iron or steel, while piston rings may be made out of cast iron, O rings, or rubber - like materials. Piston rods are made of either plain or stainless steel.

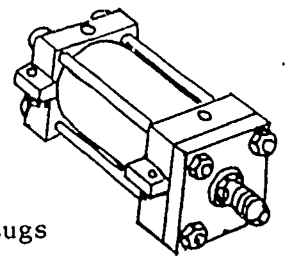
D. Cylinder Mounting

The different cylinder mounting techniques are classified into tow general categories--fixed and pivoted, with the fixed category further divided into both centerline and noncenterline mounting techniques.

1. Fixed centerline mounting is the type of cylinder mounting where force is absorbed on the centerline of the cylinder. The mounting may be accomplished with the use of flanges, tie rods, or centerline lug mounts, with the flange and tie rod mounting being done at either end of

the cylinder. Fixed centerline mounting prevents binding stress from developing in the cylinder and the mounting framework. For cylinders that have long strokes or are used for heavy duty applications, fixed centerline mounting is recommended.

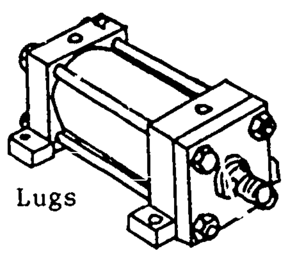
Example #60



Centerline Lugs

2. Fixed noncenterline mounting does not absorb force on the centerline of the cylinder, but instead creates off center loading in the supporting structure. Lugs, feet, and side-tapped holes are the mounting methods used. The side-mounted lug method is preferred, because it is durable and can be used for both thrust and tension loads. Cylinders with noncenterline mountings should not be used when large forces are in existence.

Example #61



Side Lugs

3. Pivoted cylinder mounting is utilized when cylinders are trunnion or clevis-mounted, meaning that the cylinders swing or pivot as they stroke. These mountings do not absorb force on the centerline, because the cylinders have no rigid support. Rod end connections must be pivoted so that the piston rod does not bend or bind when in operation. Trunnions consist of small stub cylindrical rods or shafts that protrude from some point on the cylinder.

E. Cylinder Selection

Many factors must be considered when one selects a hydraulic cylinder for use in a system. Installation of new cylinders requires different procedures than replacement of existing cylinders. To install a new cylinder, one must first ensure that the cylinder can withstand existing system pressure. In addition, one must determine the amount of force the cylinder must exert and the distance and speed at which the cylinder must travel. Lastly, the system must be assessed to determine if it is able to deliver the fluid quantity required of the cylinder for operation. To replace an existing cylinder, factors such as pressure, flow capacity, pump capacity, and hydraulic line capacity must be analyzed to ensure that extra flow requirements can be met. To begin selection of cylinders, one must determine cylinder size in relation to the load to be moved. The amount of piston force, piston area, and volume of fluid per foot of piston travel must be assessed. Manufacturers utilize both charts and formulas to take into consideration when selecting cylinders. If reference tables are not easily accessible, the amount of force a cylinder can exert can be calculated by the following formula--

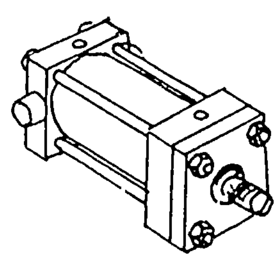
Cylinder Force (F) = Piston Area x Fluid Pressure

In addition, friction and piston acceleration are factors that must be considered in cylinder calculations. These factors aid in cylinder selection by making one aware of the forces required of cylinders in order for work to be accomplished. Fluid capacity should also be taken into consideration to determine if the cylinder will be able to move loads at given weights.

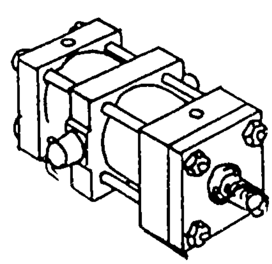
F. Cushioning

Cushioning devices are utilized to reduce the motion of the piston and the attached load as the cylinder approaches the end of its stroke. These devices can be attached to all cylinders and are known as spears or sleeves. Reducing piston speed decreases the possibility that mechanical or hydraulic shock will occur when the piston suddenly comes to a halt. The cushioning devices enter the cushion part as the piston rod approaches the end of its stroke, thus reducing the exiting fluid opening of the cylinder. The spear shape of the cushioning device determines the speed of the closure of flow passages as well as the reduction of flow velocity. Once the passage is closed, any remaining fluid in the cylinder is forced out through the cap restriction.

Example #62



Car Trunnion



Intermediate
Fixed Trunnion

## QUESTIONS-CYLINDERS

1. True or False: Cylinders are not the most common fluid power actuators used in hydraulic systems.

2. Which type of cylinder exerts force in two directions?

   a. Single-acting
   b. Positional
   c. Telescoping
   d. Double-acting

3. Which of the following is not a cylinder mounting technique?

   a. Fixed centerline
   b. Pivoted cylinder
   c. Fixed noncenterline
   d. Pivoted centerline

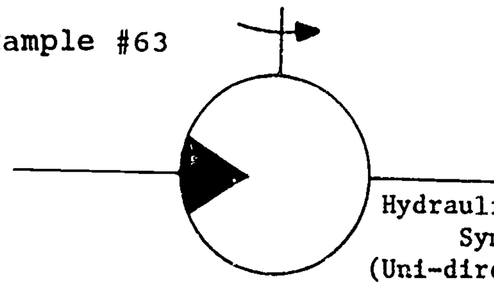
4. ________devices are used to reduce piston and load motion when the cylinder approaches the end of its stroke.

   a. Deceleration
   b. Restriction
   c. Cushioning
   d. None of the above.

# XII. Hydraulic Motors and Actuators

Hydraulic motors convert hydraulic energy into mechanical energy. Hydraulic motors operate by creating an imbalance in liquid flow, which results in shaft rotation of the motor. Hydraulic motors receive constant fluid flow, so that motor speed remains relatively constant, thus hydraulic motors are driven by hydraulic liquid. Since pressure does not affect motor speed, hydraulic motors can also be referred to as positive displacement devices.

Example #63



Hydraulic Motor Symbol (Uni-directional)

Generally, the construction of hydraulic motors is similar to that of hydraulic pumps, with the exception of alterations which allow the mechanisms to operate efficiently as motors. The mechanical output of motors should be as great as possible, because motors are designed for total efficiency. Hydraulic motor operation begins with a starting or breakaway torque that is great enough to begin rotation while fully loaded. The total starting friction of both the motor and the connecting load, as well as starting inertia, must be overcome for the motor to start and build speed for its operation.

## A. Types of Motors

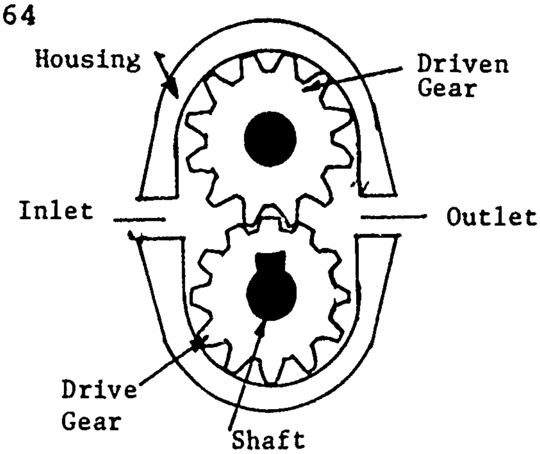
There are three basic types of hydraulic motors used in industrial systems: vane, gear, and piston. All these are constant displacement motors, and each motor functions by altering its fluid chamber volume. Each motor utilizes different methods to alter fluid volume, but the principles are similar.

1. Vane motors generally consist of a rotor, vanes, a ring, a shaft, and a port plate which has kidney-shaped inlet and outlet ports. The vanes can be either spring or pressure-loaded. Since all hydraulic motors operate by causing an imbalance that results in rotation of a shaft, the vane motor causes its imbalance by varying the vane areas exposed to hydraulic pressure. The rotor is positioned off-center to the ring, so that the area of vanes exposed to pressure increases and decreases with the top to bottom movement. During operation, pressurized hydraulic fluid enters the inlet port motor chamber. The rotor is rotated due to the force the incoming fluid exerts on the vanes in the inlet chamber. Torque is also developed at the motor shaft due to the increase in exposed area of the vanes or the increase in pressure. The rotor and shaft will turn once the torque

is great enough. Halfway through the motor chamber, the hydraulic fluid loses its pressure and is then discharged through the outlet port so it can return to the reservoir.

a. vane extension--Prior to operation, the vanes on a vane motor must be extended. One cannot rely on centrifugal force to throw the vanes out and create a positive seal between the vane tips and cam ring. There are two common methods of extending vanes in vane motors. The first method consists of spring loading the vanes through means of coil springs in the vane chambers, allowing the vanes to be continuously extended. Small wire springs attached to a post can also be used. The spring then moves with the vane as it travels in and out of the slot. In both types of spring loading, fluid pressure is applied to the underside of the vane as soon as torque is developed. The second method of vane extension is with the use of fluid pressure. Only when the vane is fully extended and a positive seal exists at the vane tip is fluid allowed to enter the vane chamber area. When fluid pressure increases to such a level that it can overcome the spring force biasing the internal check valve, the fluid will enter the vane chamber and will develop torque at the motor shaft.

Example #64




2. Gear motors simply consist of a housing with both inlet and outlet ports and a rotating group made up of a drive gear and a driven gear. The imbalance required to rotate the shaft in hydraulic motors is caused by the gear teeth unmeshing.

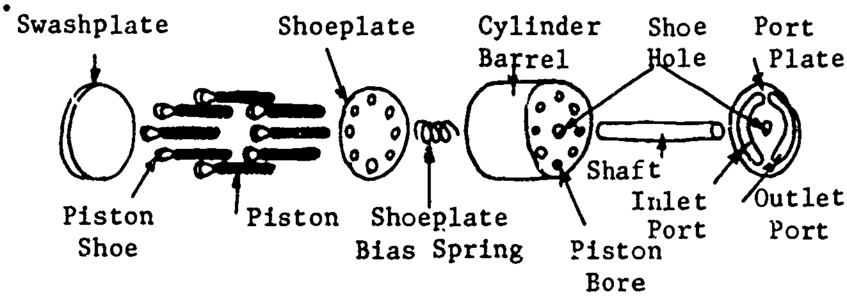
a. external gear motor--In this type of gear motor, which possesses two gears with teeth on their outer circumference, highly pressurized hydraulic fluid enters the inlet side of the motor (system pressure) and flows around the gears to the motor outlet (tank pressure). This causes the gears to rotate with the gear keyed to the output shaft transmitting the rotation motion to the shaft itself. As gear teeth unmesh, one can see that all teeth subjected to system pressure are hydraulically balanced except for the shaded area designating one side of one tooth on one gear. It is at this point within the motor that torque is developed. Thus, the larger the gear tooth or the greater the pressure, the greater the amount of torque produced.

Note: The gear teeth do not turn in the opposite direction because then they would mesh, rather than unmesh, and generate decreasing volume which would push fluid out of the housing.

b. internal gear motor--This type of gear motor consists of an external gear that meshes with the teeth on the inside circumference of a larger gear. An example of an internal gear motor is a gerotor motor. This type of motor has an inner drive gear attached to the shaft and an outer driven gear which possesses one more tooth than the inner gear. In a gerotor motor, the required imbalance for operation is due to a difference in the gear area exposed to hydraulic pressure at the motor inlet. Fluid enters the inlet port at high pressure, and exerts force on the gear teeth causing them to rotate. As the fluid pressure acts on the unequally exposed gear teeth, torque is created. The larger the gear or the greater the pressure, the greater the amount of torque created at the motor shaft. Fluid is discharged through the outlet port and returns to the reservoir.

3. Piston motors consist of a swashplate, cylinder barrel, pistons, shoeplate, shoeplate bias spring, port plate and shaft.

Example #65




The pistons fit inside the cylinder barrel, with the swashplate positioned at an angle to act as a surface for the piston shoes to travel on. The shoeplate and bias spring hold the piston shoes in contact with the swashplate. The port plate separates incoming and discharge fluids, while a shaft is connected to the cylinder barrel.

Operation of the piston motor occurs as fluid pressure acts on the piston, developing force which then causes the piston shoe to slide across the surface of the swashplate. Torque is developed at the shaft as the swashplate. Torque is developed at the shaft as the piston hose tracks across the swashplate. The amount of torque varies depending upon the angle of the slide in relation to the swashplate and the hydraulic pressure within the system. As long as the piston is pushed out of the cylinder barrel by fluid pressure, torque will be produced. As the piston passes over the center of the circle it is pushed by the swashplate back into the cylinder barrel. In the above example, only a single piston was used. A single piston in a piston motor develops torque for only half of the full circle of rotation of the cylinder barrel and shaft. In actuality, cylinder barrels of piston motors are fitted with numerous pistons, thus allowing the motor to rotate continuously and obtain maximum torque.

a. variable displacement axial piston motors--Piston motors are the only type of motors that are available in variable displacement. The displacement of an axial piston motor is determined by the distance the pistons are reciprocated in the cylinder barrel. To alter motor displacement and the stroke of the pistons, one need only vary the angle of the swashplate. A large swashplate angle allows the pistons to have long strokes in the cylinder barrel, while a short swashplate angle causes the pistons to have short strokes. When the swashplate angle is changed, shaft speed and torque output can also be altered.

b. overcenter axial piston motors--Overcenter axial piston motors are capable of reversing shaft rotation without changing the direction of flow through the motor, due to the swashplate crossing overcenter. This allows the pistons to slide in a different direction, causing the cylinder barrel and motor shaft to rotate in the reverse direction.

B. Rating and Selection Factors

There are many different factors that affect rating and final selection of motors for certain applications. Hydraulic motors are evaluated on overall performance, physical characteristics, general construction, operational problems, and speed. Other selection factors often considered are as follows.

1. Hydraulic motors are rated by their pressure range. The pressure range follows intervals from the minimum pressure needed to turn the motor to the maximum pressure the motor can withstand without causing internal motor damage. Motor pressure ratings vary from 100 to 5,000 psi.

C. Rotary Actuators

Rotary actuators produce high torque and are compact and efficient devices. Rotary actuators are not designed to make full revolutions like motors, rather they move in a series of arcs ranging from 90 to 330 degrees. Applications for rotary actuators include bending operations, rotation or lift of heavy objects, lever operation and machine tool indexing.

1. Types of Rotary Actuators

   a. linear cylinder--This rotary actuator consists of a cylinder that is swivel mounted at one end. The shaft is driven by a rod attached to a crank arm. A four-way directional valve controls the direction of the cylinder. This rotary actuator is the simplest in construction, flexible and inexpensive.

   b. shrouded cylinder--This type of rotary actuator is similar to the linear cylinder type, except it possesses a shrouded enclosure around the cylinder rod and crank arm.

   c. fail-safe cylinder--This type of rotary actuator utilizes a spring loaded cylinder to return the shaft to a safe position.

   d. rack and pinion--This type of rotary actuator is very common, and gives uniform torque in both directions and throughout the range of rotation. Fluid pressure drives a piston which is connected to a gear rack. This, in turn, rotates a pinion shaft.

   e. skotch yoke--This type of rotary actuator is similar to two cylinders that share a common rod. The cylinders may be either double-or single-acting.

   f. vane--This type of rotary actuator can possess either single or multiple vanes, and may have spring-return devices to reset vanes. Rotation may achieve almost complete revolutions.

   g. sprocket--This type of rotary actuator utilizes a drive piston, chain, and sprocket to rotate the shaft. A large piston typically pulls the chain while a smaller piston provides a seal to prevent fluid leakage.

## QUESTIONS-MOTORS AND ACTUATORS

1. True or False: Hydraulic motors convert hydraulic energy into mechanical energy.

2. What are the basic types of hydraulic motors used in industrial systems?

   a. Piston
   b. Gear
   c. Vane
   d. All of the above
   e. None of the above

3. Which of the following is <u>not</u> a motor rating and selection factor?

   a. Horse power
   b. Pressure range
   c. Torque
   d. Service life
   e. None of the above

4. True or False: Rotary actuators operate by making full revolutions, just as motors do.

5. Which type of rotary actuator is the most common?

   a. Linear cylinder
   b. Rack and pinion
   c. Vane
   d. Skotch yoke
   e. Sprocket

# ANSWERS TO QUESTIONS--HYDRAULICS

## Introduction

1. d
2. c
3. b

## Accumulators

1. a
2. c
3. d
4. e
5. d
6. e
7. d
8. c
9. e

## Resevoirs

1. c
2. b
3. c
4. e

## Pumps

1. e
2. a
3. e
4. d

## Piping and Tubing

1. d

## Direct Control Valves

1. true
2. e
3. d
4. b
5. c
6. e

## Check Valves

1. false
2. e

## Pressure Control Valves

1. true
2. e
3. b
4. d
5. d
6. false
7. a

## Flow Control Valves

1. c
2. b
3. d

## Cylinders

1. false
2. d
3. d
4. c

## Motors and Actuators

1. true
2. d
3. e
4. false
5. b

# END

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## Date Filmed
## July 24, 1991