Royal Commission for Jubail and Yanbu

Jubail University College

Department of Mechanical Engineering

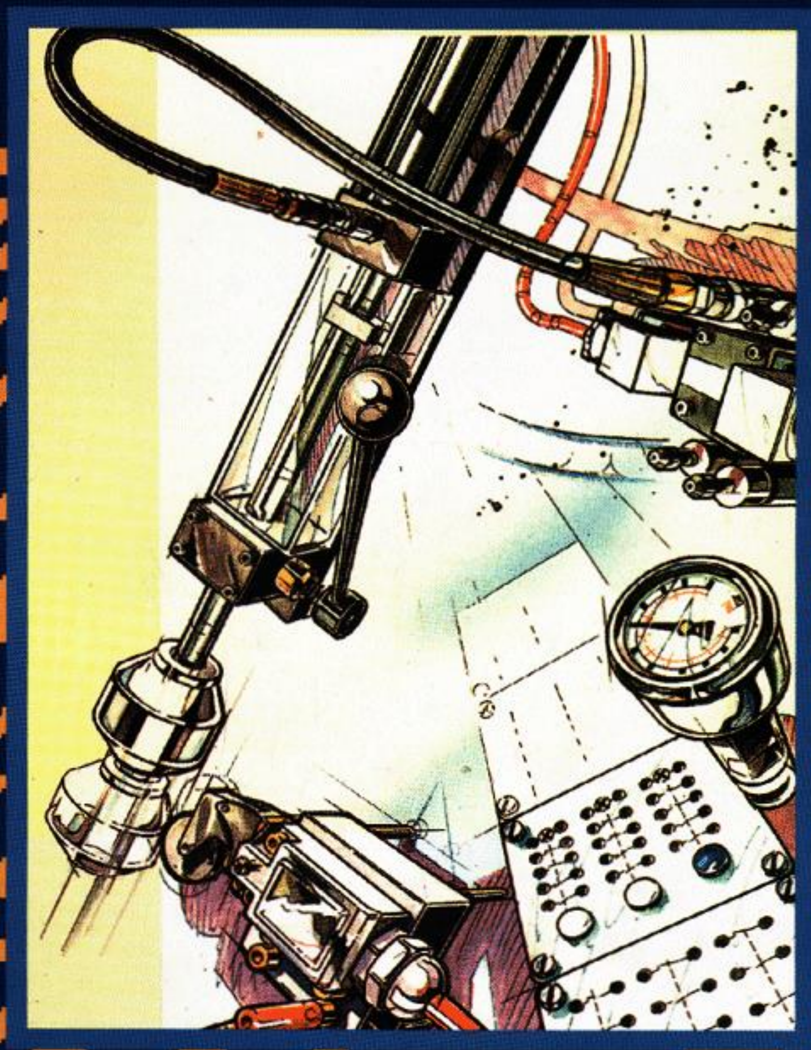
Fluid Power Systems

Dr. Syed Ameer Basha

ME 423

Student ID: **30110143**

Student Name: **Abdullah AL Yami**



ANTHONY ESPOSITO

FLUID POWER

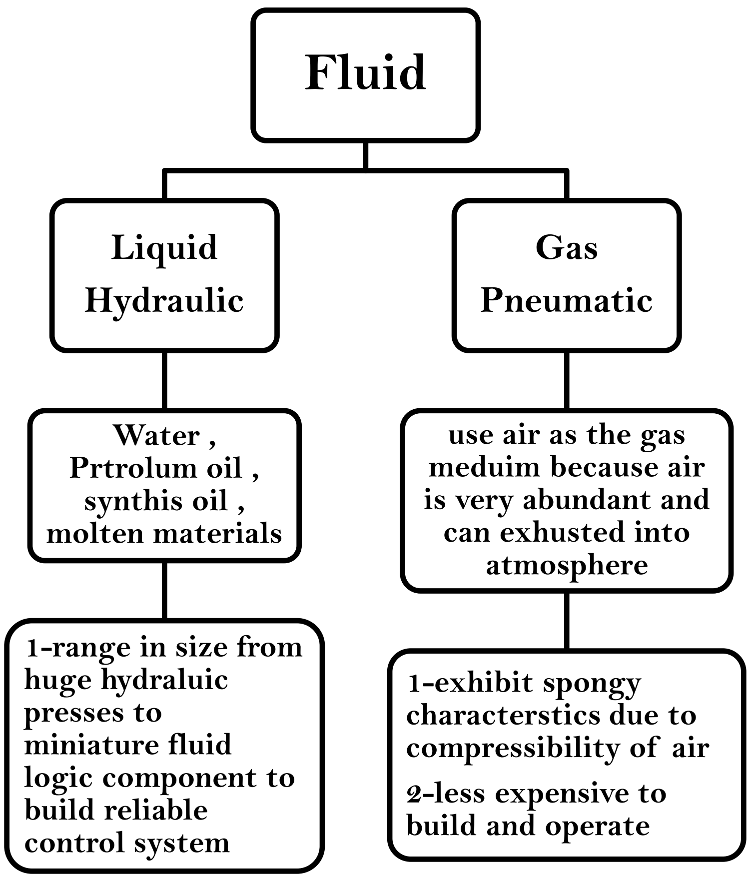
WITH APPLICATIONS

FOURTH EDITION

CHAPTER 1

INTRODUCTION OF FLUID POWER

- **Fluid power**: is the technology that deals with generation, control and transmission of power using pressurized fluids.
- Fluid power is used to **push, pull, regulate** or drive virtually all the machines of modern industry. For example : fluid power steers and brakes automobile s , launches spacecraft , moves earth , harvest crops , mines coal , drives machine tools and control airplane.



- **The first hydraulic fluid to be used was water because :**

1. It is readily available
2. Water has many deficiencies
3. It freezes readily
4. Is a relatively poor lubricant
5. Tends to rust metal component

- **Types of fluid system :**

1. **Fluid transport system**: have as sole objective the delivery of a fluid from one location to another to accomplish some useful purpose.
2. **Fluid transport system:** are designed specifically to perform work. The work is accomplished by a pressurized.

- Fluid power is probably as old as civilization itself. Ancient historical accounts show that water was used for centuries to produce power.
- **Pascal's law**: Pressure is transmitted undiminished in a confined body of fluid.
- There are 3 basic method of transmitting power: **electrical, mechanical and the fluid power.**
- Fluid system can transmit power more economically over greater distance than mechanical.
- Fluid system is restricted shorter distances than are electrical systems.
- The secret of fluid power success and widespread use is its **versatility and manageability.**

❖ Advantages of fluid power :

1. Ease and accuracy of control.
2. Multiplications of force.
3. Constant force or torque.
4. Simplicity, safety, economy.

❖ Application of fluid power :

1. Fluid power drives high wire overhead tram.
2. Fluid power is applied to harvest corn.
3. Hydraulics power brush drives.
4. Fluid power position and holds parts for welding.
5. Fluid power performs bridge maintenance.
6. Fluid power is the muscle in industrial lift trucks.
7. Fluid power drives front end loaders.
8. Fluid power preserves heartbeat of life.
9. Hydraulics power robotic dexterous arm.

❖ Components of hydraulic fluid :

1. Tank
2. Pump
3. Electric Motor
4. Valves
5. Actuator
6. Piping

❖ Types of fluid power control systems :

1. **Closed loop control system**: is used feedback and the device is called feedback transducer.
2. **Open loop control system:** does not use feedback.
3. **Electrical control system**: the fluid power system interacts with a variety of electrical components for control purpose.
4. **Fluid logic control system**: the fluid power system interacts with a fluid logic device.
5. **Programmable logic control system**: is a user friendly electronic computer designed to perform logic functions such AND, OR, NOT.

Chapter 2

Properties of Hydraulic Fluid

- **A Hydraulic fluid has 4 primary functions :**
  1. To transmit power.
  2. To lubricate moving parts.
  3. To seal clearance between mating parts.
  4. To dissipate heat.
- **A Hydraulic fluid properties :**
  1. Good lubricity
  2. Ideal viscosity
  3. Chemical and environmental viscosity
  4. Compatibility with system materials
  5. Large bulk modulus
  6. Good heat transfer capability
  7. Readily available
  8. Fire resistance
  9. Foam resistance
  10. Low density
  11. Low volatility
  12. Nontoxic
  13. In expensive

- Air is only gas commonly used in fluid power system because **it is inexpensive and readily available.**

Advantages	Disadvantages
1. It is fire resistant 2. It is not messy 3. It can be exhausted back into the atmosphere	1. Do to compressibility it cannot be usec in application 2. Because it comprisable it tends to sluggish 3. Air can be corrosive 4. High pressures cannot be used due explosion dangers

- **Pascal's law :**

⇨ $P_1 = P_2$ ⇨ $\frac{F_1}{F_2} = \frac{A_1}{A_2}$

⇨ $V_1 = V_2$ ⇨ $A_1 S_1 = A_2 S_2$ ⇨ $\frac{S_1}{S_2} = \frac{A_2}{A_1}$

$\therefore \frac{F_1}{F_2} = \frac{A_1}{A_2} = \frac{S_2}{S_1}$ ⇨ $F_1 S_1 = F_2 S_2$

⇨ $S_1 = The\ movement\ of\ postion\ 1\ or\ displacment\ 1$

⇨ $S_2 = The\ movement\ of\ postion\ 2\ or\ displacment\ 2$

- **Bulk Modulus**: is measure the incompressibility. The higher bulk modulus gives less compressible or stiffer the fluid.
- **Viscosity**: is probably single most important property of hydraulic fluid. It is a measure of sluggishness with which a fluid moves.
- The viscosity of fluid is usually measured by **Say bolt viscometer**.
- **Viscosity Index**: is empirical number indicating the rate of change in viscosity of an oil within a given temperature range.
- **Oxidation**: chemical reaction of oxygen from the air with particles of oil.
- **Rust**: chemical reaction between iron or steel and oxygen.
- **Corrosion**: chemical reaction between metal and acid.
- Most hydraulic fluids will burn in certain conditions. There are many hazardous applications where human safety requires the use of fire resistant fluid.
- **Characteristics of flammability :**
  1. **Flash point :** the temperature at which the oil surface gives of sufficient vapor to ignite
  2. **Fire point:** the temperature at which the oil will release sufficient vapor to support combustion.
- **There are 4 different types of fire resistant :**
  1. Water glycol solutions.
  2. Water in oil emulsions.
  3. Straight synthetics.
  4. High water constant fluids
- **Foam resistant fluids**: air can become dissolved or entrained in hydraulics fluids.
- Hydraulic fluids must have good lubricity to prevent wear between the closely fitted working parts.

❖ General type of fluid :

1. The first major category of hydraulic fluids is the petroleum based fluid.
2. The second category of fluids has been developed the fire resistant fluid.
3. Third category is the conventional most severe. This provides increased hydraulic system life due to better lubricity.
4. The forth category of fluid is air at self.

⇨ $F = W = mg$ ⇨ $\gamma = \frac{W}{V}$ ⇨ $\rho = \frac{m}{V}$ ⇨ $SG = \frac{\gamma_{air}}{\gamma_{water}}$ ⇨ $\gamma_{water} = 9810\ \frac{N}{m^2}$ ⇨ $SG = \frac{\rho_{air}}{\rho_{water}}$ ⇨ $\rho_{water} = 1000\ \frac{kg}{m^2}$ ⇨ $P = \frac{F}{A}$ ⇨ $P = \gamma H$ ⇨ $P = 0.433H\ SG$ ⇨ $P_{absolute} = P_{atm} + P_{gauge}$ ⇨ $P_{absolute} = P_{atm} - P_{vacum}$ ⇨ $1\ N = 1\ kg\ \times 1\ \frac{m}{s^2}$ ⇨ $1\ Pa = 1\ \frac{N}{m^2} = 0.000145\ psi$ ⇨ $P_{atm} = 101000\ Pa = 101\ KPa$ ⇨ $\beta = \frac{-\Delta P}{\frac{\Delta V}{V}}$ ⇨ $\tau = \mu \frac{dy}{dv}$ ⇨ $\tau = \frac{F}{A}$	⇨ $F = force = N$ ⇨ $W = weight = N$ ⇨ $m = mass = kg$ ⇨ $g = 9.81\ \frac{m}{s^2}$ ⇨ $\gamma =\ weight\ desity\ \ \frac{N}{m^3}$ ⇨ $\rho =\ mass\ desity\ \ \frac{kg}{m^3}$ ⇨ $V = volume =\ m^3$ ⇨ $SG = specific\ weight$ ⇨ $P = pressure = Pa$ ⇨ $A = area =\ m^2$ ⇨ $H = head\ or\ height =\ m$ ⇨ $\beta = bulk\ modulus = Pa$ ⇨ $\tau = shear\ stress = \frac{N}{m^2}$ ⇨ $\mu = visocity\ \frac{Ns}{m^2}$ ⇨ $dy = film\ thickness = m$ ⇨ $dv = velocity = \frac{m}{s}$

Chapter 3

Energy Power and Hydraulics System

- **Suction pressure:** when fluid enters the pump below the atmospheric pressure.
- As the fluid passes the pump , is potential energy increases evidenced by an increase in fluid pressure some of this energy is lost due to friction as the fluid flows through **pipes , valves** and **fitting** .
- At the output device hydraulic actuator the remaining energy is transferred to the load to perform useful work.
- A hydraulic system is not source energy. The energy source is the prime mover which drives the pump.

❖ Application of Pascal's law :

1. **Hydraulic jack:** on this system uses a piston type hand pump to power a single acting hydraulic system.
2. **Air to hydraulic pressure booster:** is supplying high pressure oil to hydraulic cylinder used to clamp a work piece to a machine tool table.

$$\Rightarrow Pressure\ ratio = \frac{output\ oil\ pressure}{input\ air\ pressure} = \frac{area\ of\ air\ piston}{area\ of\ hydraulic\ piston}$$

$$\Rightarrow A_1P_1 = A_2P_2 \qquad \Rightarrow \frac{P_1}{P_2} = \frac{A_2}{A_1}$$

- **Conservation of energy:** the energy can neither be created nor destroyed.
- **Bernoulli's equation**: is one the most useful relationship for performing hydraulic circuit analysis. Its application allows us to size components such as pumps, valves, piping for proper system operation.

$$\Rightarrow Z_1 + \frac{P_1}{\gamma} + \frac{{v_1}^2}{2g} = Z_2 + \frac{P_2}{\gamma} + \frac{{v_2}^2}{2g}$$

$$\Rightarrow Z_1 + \frac{P_1}{\gamma} + \frac{{v_1}^2}{2g} + H_P - H_m - H_L = Z_2 + \frac{P_2}{\gamma} + \frac{{v_2}^2}{2g}$$

$$\Rightarrow Z = elevation = m$$

$$\Rightarrow H_P = pump\ head = m$$

$$\Rightarrow H_L = head\ loss = m$$

- **The Siphon:** is tube translator fluid from higher level container to lower level container.

- **For the fluid to flow out of the free ends , two conditions must be met :**

  1. The elevation of the free end must be lower than the elevation of liquid surface inside the container.
  2. The fluid must initially be forced to flow up from the container.

⇨ $F = ma$ ⇨ $W = FS$ ⇨ $P = \frac{FS}{t}$ ⇨ $P = Fv$ ⇨ $T = FR$ ⇨ $HP = \frac{T\ N}{63000}$ ⇨ $\eta = \frac{P_o}{P_i}$ ⇨ $\gamma_1 A_1 v_1 = \gamma_2 A_2 v_2$ ⇨ $Q = Av$ ⇨ $H_P = \frac{3950\ HP}{Q\ SG}$ ⇨ $v_2 = \sqrt{2gh}$ ⇨ $v_2 = \sqrt{2g(h - H_L)}$ ⇨ $v_2 = \sqrt{2g(Z_1 - Z_2 - H_L)}$	⇨ $F = force = N$ ⇨ $m = mass = kg$ ⇨ $a = acceleration$ ⇨ $g = 9.81\ \frac{m}{s^2}$ ⇨ $W = work = Nm = Joule$ ⇨ $S = distence = m$ ⇨ $v = velocity = \frac{m}{s}$ ⇨ $P = Power = \frac{Nm}{s} = Watt$ ⇨ $T = Torque = Nm$ ⇨ $R = moment\ arm = m$ ⇨ $HP = hourse\ power$ ⇨ $N = rotational\ speed = rpm$ ⇨ $\eta = efficiency$ ⇨ $\gamma = weight\ desity = \frac{N}{m^3}$ ⇨ $A = Area = m^2$ ⇨ $Q = volume\ flow\ rate = \frac{m^3}{s}$ ⇨ $v_2 = jet\ velocity = \frac{m}{s}$ ⇨ $h = pressure\ head = m$

Chapter 5

Basics of Hydraulic Flow in Pipes

- **Suction pressure:** when fluid enters the pump below the atmospheric pressure.
- There are energy losses in valves and fitting such as **tees, elbows** and **bend.**
- The nature of the flow through valves and fitting is **very complex.**
- **Types of common valves and fittings :**
  1. Global valve
  2. Gate valve
  3. 45 elbow
  4. 90 elbow
  5. Tee
  6. Return bend
  7. Ball check valve

Valve or fitting	K factor
Globe vale wide open	10
Globe valve ½ open	12.5
Gate valve wide open	0.19
Gate valve ¾ open	0.9
Gate valve ½ open	4.5
Gate valve ¼ open	24
Return bend	2.2
Slandered Tee	1.8
Slandered Elbow	0.9
45° elbow	0.42
90° elbow	0.75
Ball check valve	4

- Darcy's equation shoes that the head loss in a pipe , due to fluid friction is **proportional** in the square the fluid velocity and the length of pipe

⇨ $H_L = \frac{Kv^2}{2g}$ ⇨ $H_L = \frac{P}{\rho g}$ ⇨ $\frac{Kv^2}{2g} = f\frac{L_e}{D} = \frac{v^2}{2g}$ ⇨ $L_e = \frac{KD}{f}$ ⇨ $Re = \frac{vD}{\nu}$ ⇨ $f = \frac{64}{Re}$	⇨ $K = constant\ of\ prportionality$ $or\ factor\ of\ valve$ ⇨ $v = velocity = \frac{m}{s}$ ⇨ $g = 9.81\ \frac{m}{s^2}$ ⇨ $L = eqvalent\ length\ = m$ ⇨ $f = froction\ factor$ ⇨ $D = diameater = m$ ⇨ $\nu = visocity = \frac{m^2}{s}$ ⇨ $Re = Renolds\ number$

Chapter 6

The Source of Hydraulic Power: Pump

- **Pump:** is converted mechanical energy into hydraulic energy.
- The mechanical energy is delivered to the pump via a prime mover such as an electric motor.
- The nature of the flow through valves and fitting is **very complex.**
- **There are two board classifications of pumps as identified :**

Non positive displacement	Positive displacement
1. Used for low pressure	1. high pressure capability up to 1000 psi
2. High volume flow application	2. Small , compact size
3. Maximum pressure capacity is limited t0 250 -300 psi	3. High volumetric efficiency
4. Is used for transporting fluids from one location to another	4. Small changes in efficiency
	5. Great flexibility of performance

- There are 3 main types of positive displacement pump: **gears, vane** and **piston.**
- All pumps operate of the principle whereby a partial vacuum is crated at the pump inlet due to the internal operation.

❖ Gear pump :

- One of the gears is connected to a drive shaft connected to the prime mover. The second gear driven as meshes with the diver gear.
- The suction side is where teeth come out of mesh and it is here where the volume expands.

⇨ $V_D = \frac{\pi}{4}\left[{D_i}^2 - {D_o}^2\right]L$	⇨ $D_i = inside\ diameater\ = m$ ⇨ $D_o = outsid\ diameater\ = m$ ⇨ $L = width\ = m$ ⇨ $V_D = displacment\ volume = \frac{m^3}{rev}$ ⇨ $N = \ pump\ speed = rpm$ ⇨ $Q_T = \ theoritical\ pump\ flow\ rate = \frac{m^3}{s}$ ⇨ $Q_A = \ actual\ pump\ flow\ rate = \frac{m^3}{s}$
⇨ $Q_T = V_D \times N$	

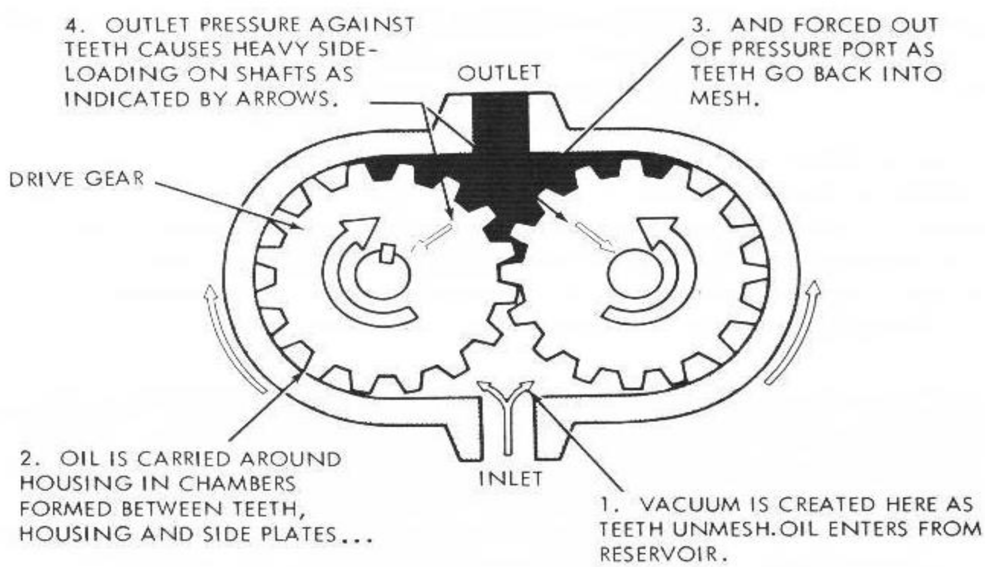


Figure 6-4. External gear pump operation. (*Courtesy of Sperry Vickers, Sperry Rand Corp., Troy, Michigan.*)

❖ Vane pump :

▪ The rotors which contains radial slots, is splined to the drive shaft and rotates inside cam ring. Each slot contains a vane designed to mate with the surface of the cam ring as the rotor turns.

⇨ $V_D = \frac{\pi}{4}\left[{D_C}^2 - {D_R}^2\right]L$	⇨ $D_C = cam\ ring\ diameater\ = m$ ⇨ $D_R = rotor\ diameater\ = m$
⇨ $e_{max} = \frac{D_C - D_R}{2}$	⇨ $L = width\ = m$ ⇨ $V_D = volumetric\ displacment\ = \frac{m^3}{rev}$
⇨ $V_{D_{max}} = \frac{\pi}{4}[D_C + D_R]2e_{max}L$	⇨ $V_{D_{max}} = maximum\ volumetric\ = \frac{m^3}{rev}$
⇨ $V_D = \frac{\pi}{2}[D_C + D_R]eL$	⇨ $N = rotor\ speed = rpm$ ⇨ $e = eccintricity = m$ ⇨ $e_{max} = maximum\ eccintricity = \frac{m^3}{s}$

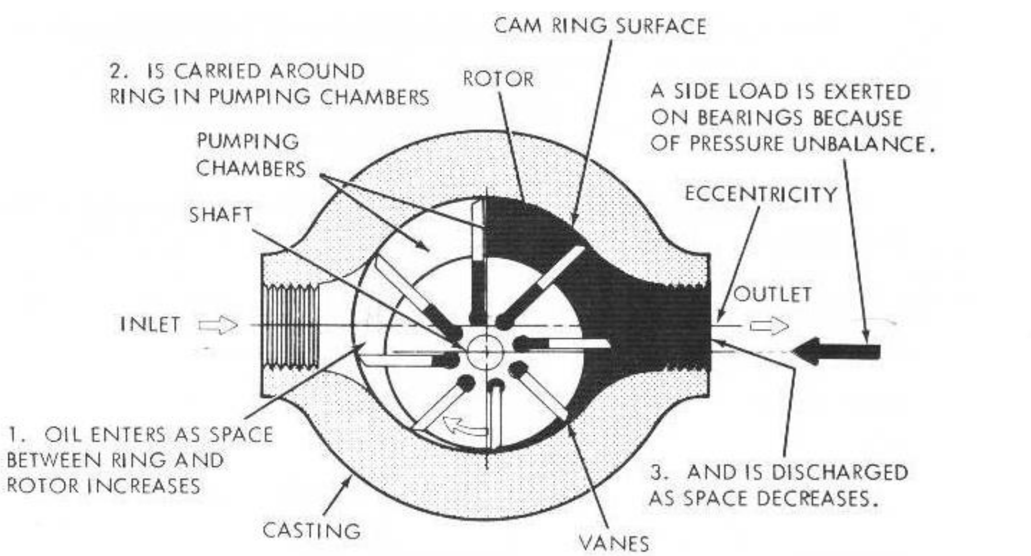


Figure 6-14. Vane pump operation. (*Courtesy of Sperry Vickers, Sperry Rand Corp., Troy, Michigan.*)

❖ Pump Performance can determined into 3 types :

1. Volumetric efficiency $\boldsymbol{\eta_v}$:

$$\Rightarrow \eta_v = \frac{actual\ flow\ rate\ produced\ by\ pump}{Theoretical\ flow\ rate\ pump\ should\ produced} = \frac{Q_A}{Q_T} \times 100$$

2. Mechanical efficiency $\boldsymbol{\eta_m}$:

$$\Rightarrow \eta_m = \frac{Theoretical\ power\ required\ to\ operate\ pump}{Actual\ power\ delivred\ to\ pump}$$

$$\Rightarrow \eta_m = \frac{Theoretical\ torque\ required\ to\ operate\ pump}{Actual\ torque\ delivred\ to\ pump} = \frac{T_T}{T_A} \times 100$$

$$\Rightarrow \eta_m = \frac{PQ_T}{TW} \times 100$$

- $\Rightarrow P = pressure\ = pa$
- $\Rightarrow T = torque = Nm$
- $\Rightarrow L = width\ = m$
- $\Rightarrow Q_T = thoritical\ pump\ flow\ rate\ = \frac{m^3}{s}$
- $\Rightarrow W = 2\pi N = watt$

3. Overall efficiency $\boldsymbol{\eta_o}$:

$$\Rightarrow \eta_o = \frac{\eta_v \times \eta_m}{100}$$

$$\Rightarrow \eta_o = \frac{P_o}{P_i} \times 100$$

- $\Rightarrow \eta_v = volumetric\ efficency$
- $\Rightarrow \eta_m = mechanical\ efficency$
- $\Rightarrow P_o = output\ power = W$
- $\Rightarrow P_i = inlet\ power = W$

$\Rightarrow 1\ hourse\ power = \mathbf{746}\ watt$

Chapter 7

Fluid Power Actuators

- Pumps perform the function of adding energy to a hydraulic system for transmission to some remote point.
- Fluid power actuators do the opposite.
- Actuators used to extract energy from fluid power and convert it to mechanical output to perform useful work.
- Fluid power can transmit through either linear or rotary motion by using linear actuators called **hydraulic cylinder** or rotary actuators called **hydraulic motors.**

❖ Hydraulic Pump Performance can determined into 3 types :

1. Volumetric efficiency η_v :

⇨ $\eta_v = \frac{Theoretical\ flow\ rate\ produced\ by\ pump}{Acual\ flow\ rate\ pump\ should\ produced} = \frac{Q_T}{Q_A} \times 100$

⇨ $Q_T = V_D \times N$

2. Mechanical efficiency η_m :

⇨ $\eta_m = \frac{Actual\ torque\ required\ to\ operate\ pump}{Theoretical\ torque\ delivred\ to\ pump} = \frac{T_A}{T_T} \times 100$

⇨ $T_T = \frac{V_D \times P}{6.28}$

3. Overall efficiency η_o :

⇨ $\eta_o = \frac{\eta_v \times \eta_m}{100}$

⇨ $\eta_o = \frac{T_A \times N}{P \times Q_A}$

❖ Advantages of hydrostatic transmission :

1. Infinitely variable speed and torque.
2. Extremely high horsepower to weight ratio.
3. Ability to be stalled without damage.
4. Low inertia of rotating.
5. Flexibility and simplicity of design.

Chapter 8

Control Components in Hydraulic Systems

- One of the most important considerations in any fluid power system is control. If control components are not properly selected.
- Fluid power is controlled primarily through the use of control devices called **valves**.
- The selection of these control devises involves not only the type but also **the size, the actuating techniques** and **remote control capability**.
- **Servo valves**: is a directional control valve that has infinitely variable positioning capability.

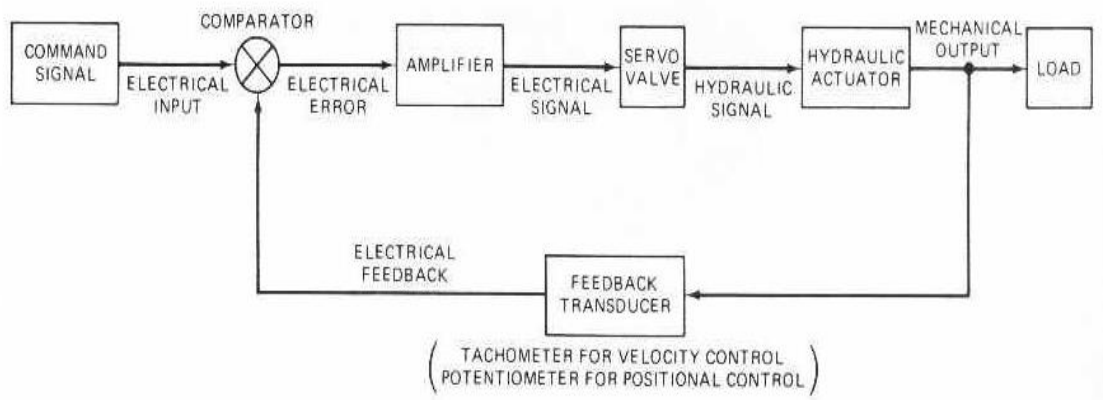


Figure 8-46. Block diagram of an electrohydraulic servo system (closed-loop).

❖ Advantages of Cartridge Valves :

1. Reduced number of fittings.
2. Reduced oil leakages.
3. Lower system installations.
4. Reduced service time.
5. Smaller space requirements.

There are 3 basic types of control devises

- **Directional control valves**
  - detrmine path throgh which a fluid traverses within a givin circit
  - are used to control the directional flow in hydraulic circuit

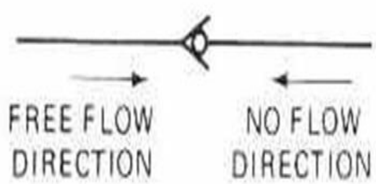


Figure 8-3. Symbol for a check valve with its free-flow direction defined.

- **Pressure control valves**
  - protect the system against the overpressure
  - the most widely used is pressure relief valve

- **flow control valves**
  - automitically adjust to changes in pressure drop to produce a constant flow rate
  - are used to regulate the speed of hydraulic cylinders and motors controling the flow rate to these actuators
  - Needle valves are designed to give fine control of flow in small diameater
  - There are 2 basic types :
    - 1- nonpressure compensated
    - 2- nonpressure compensated

CHAPTER 9

HYDRAULIC CIRCUIT DESIGN AND ANALYSIS

❖ **When analyzing or designing hydraulic circuit the 3 consideration must take :**

1. Safety of operation.
2. Performance of desired function.
3. Efficiency of performance.

► **ANSI = American National Slandered Institute**

- One of the gears is connected to a drive shaft connected to the prime mover. The second gear driven as meshes with the diver gear.
- **Hydraulic actuator:** is devise that stores potential energy of incompressible flow under presser by an external source against some dynamic force.

❖ **There are 3 basic type of accumulators used in hydraulic circuit :**

1. Weight loaded or gravity type.
2. Spring loaded type.
3. Gas loaded type.

- Gas loaded accumulator called hydro pneumatic accumulators have been found to more practical than weight loaded and spring loaded.

❖ **Gas loaded accumulator fall into 2 categories :**

1. Non separator type.
2. Separator type.

❖ **Classification Separator type :**

1. Piston type.
2. Diaphragm type.
3. Bladder type.

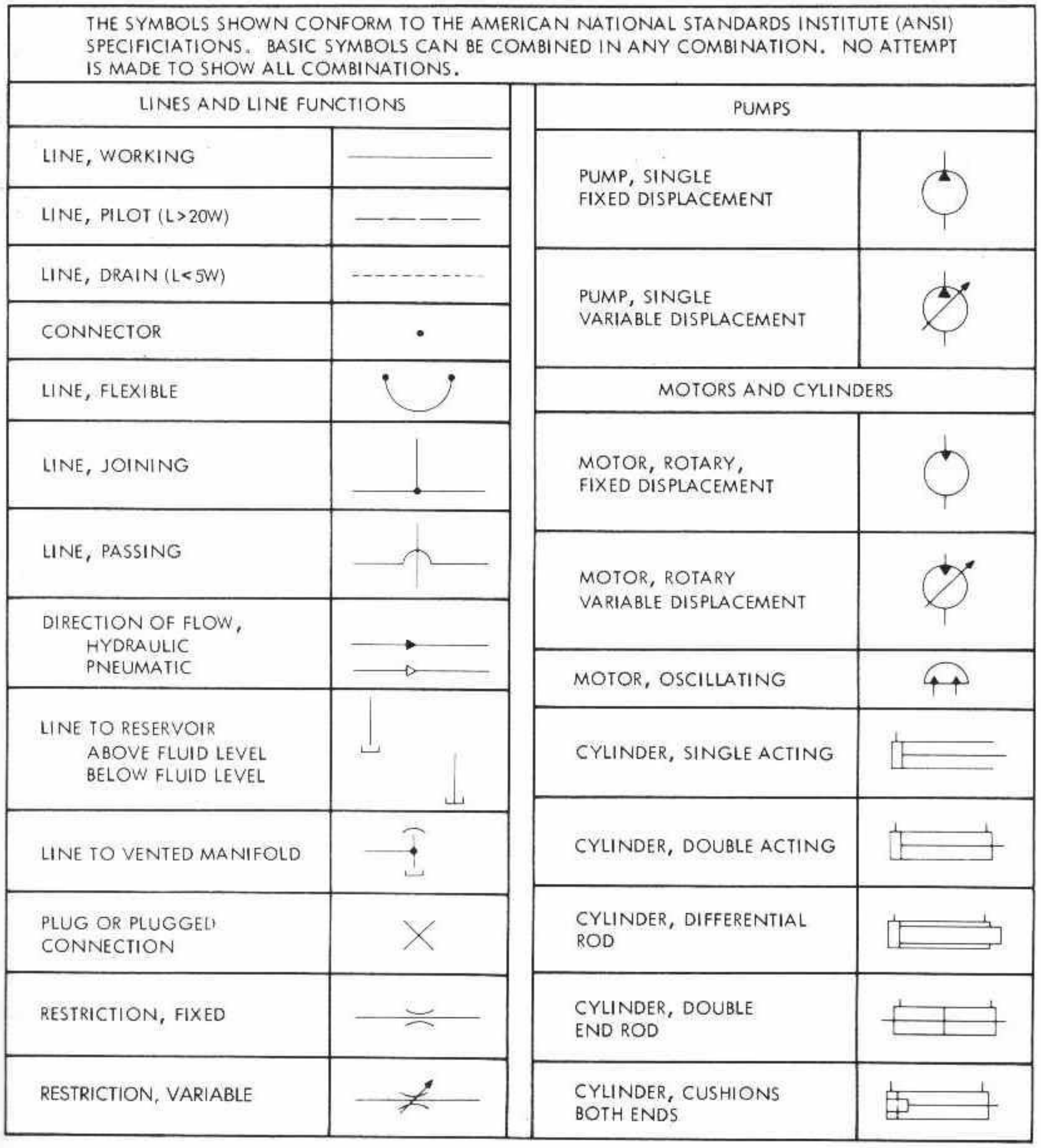
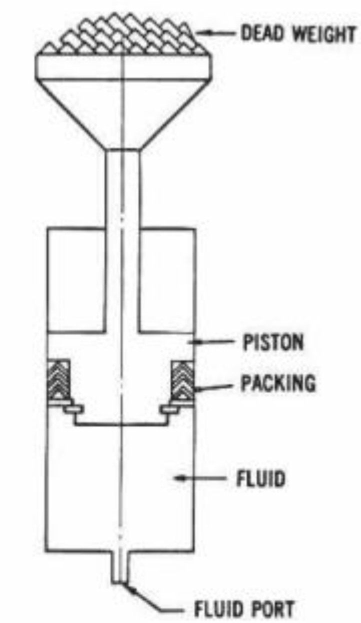


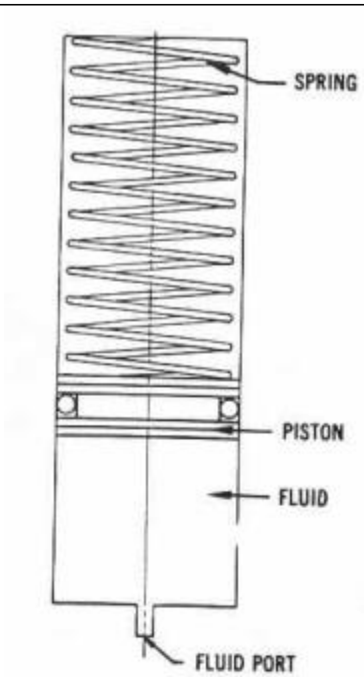
Figure 9-1. ANSI symbols of hydraulic components.

Weight Loaded Type



The weight-loaded type is historically the oldest. This type consists of a vertical, heavy-wall steel cylinder, which incorporates a piston with packings to prevent leakage. A dead weight is attached to the top of the piston (see Fig. 9-27). The force of gravity of the dead weight provides the potential energy in the accumulator. This type of accumulator creates a constant fluid pressure throughout the full volume output of the unit regardless of the rate and quantity of output. In the other types of accumulators, the fluid output pressure decreases as a function of the volume output of the accumulator. The main disadvantage of this type of accumulator is its extremely large size and heavy weight, which makes it unsuitable for mobile equipment. In this section we present the various types of accumulators and several of their common applications. The sizing of gas-loaded accumulators for given applications is covered in Chapter 11, after Boyle's law of gases is discussed.

Spring Loaded Type



A spring-loaded accumulator is similar to the weight-loaded type except that the piston is preloaded with a spring, as illustrated in Fig. 9-28. The spring is the source of energy that acts against the piston, forcing the fluid into the hydraulic system. The pressure generated by this type of accumulator depends on the size and preloading of the spring. In addition, the pressure exerted on the fluid is not a constant. The spring-loaded accumulator typically delivers a relatively small volume of oil at low pressures. Thus, they tend to be heavy and large for high-pressure, large-volume systems. This type of accumulator should not be used for applications requiring high cycle rates because the spring will fatigue and lose its elasticity. The result is an inoperative accumulator.

Chapter 14

Fluid Power Maintenance and Safety

❖ Most common causes of hydraulic system breakdown :

1. Clogged or dirty filters.
2. Inadequate supply of oil in this reservoir.
3. Leaking seals.
4. Loose inlet lines that causes the pump to take in air.
5. Incorrect type of oil.
6. Excessive of oil temperature.
7. Excessive of oil pressure.

- Seals are used in hydraulic cylinder to **prevent excessive internal** and **external leakage** and **to keep out communication**.

❖ Seals can divided into :

1. **Positive seals**: do not allow to any leakage external or internal.
2. **Non Positive seals:** such as clearance used to provide lubricating film between a valve and its permit to small amount of internal leakage.

❖ Seals can designed into :

1. **Static seals**: are used to between mating parts that do not have relative to each other.
2. **Dynamic seals:** are assembled between mating parts that move relative to each other.

❖ The most common materials used for seals are :

1. Leather
2. Buna N
3. Silicon
4. Neoprene
5. Tetrafluoroethylene
6. Viton

- The proper design of suitable reservoir for a hydraulic system is essential to the overall **performance** and **life of individual components**.
- The dissipation of heat is accomplished by a properly designed reservoir.

❖ The sizing of reservoir is based on following criteria :

1. It must make allowance for dirt and chips.
2. It must be able to hold all the oil.
3. It must maintain the oil level.
4. It should have surface area.

5. It should have adequate air space.

❖ Contamination may be in the form of liquid , gas or solid and can be caused by any of the following :

1. Built into system during components
2. General within system during operation
3. Introduced into system from external environment

- A filter with a nominal rating of $10\ \mu m$ is supposed to trap 95 % of the entering particles greater than $10\ \mu m$ in size.

$$\Rightarrow Beta\ Ratio = \frac{No\ of\ upstream\ particels\ of\ size\ greater\ than\ N\ \mu m}{No\ of\ downstream\ particels\ of\ size\ greater\ than\ N\ \mu m}$$