Hydraulic and Pneumatic System

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Introduction to Hydraulics

All machines require some type of power source and a way of transmitting this power to the point of operation.

The three methods of transmitting power are:

- Mechanical
- Electrical
- Fluid
- In this course we are going to deal with the third type of power transmission which is the **Fluid Power**

Introduction to Hydraulics

- **Fluid power** is the method of using pressurized fluid to transmit energy.

- **Liquid** or **Gas** is referred to as a **fluid.** Accordingly, there are two branches of fluid power; **Pneumatics**, and **Hydraulics**.

- **Hydraulic systems** use **liquid** to transfer force from one point to another.
- **Pneumatic systems** use **air** to transfer force from one point to another. Air is

Introduction to Hydraulics

- **Air** is **Compressible:**

(*This describes whether it is possible to force an object into a smaller space than it normally occupies. For example, a sponge is compressible because it can be squeezed into a smaller size*).

- **liquid** is **Incompressible:**

(*The opposite to compressible. When a "squeezing" force is applied to an object, it does not change to a smaller size. Liquid, for example hydraulic fluid, possesses this physical property*).

Introduction to Hydraulics

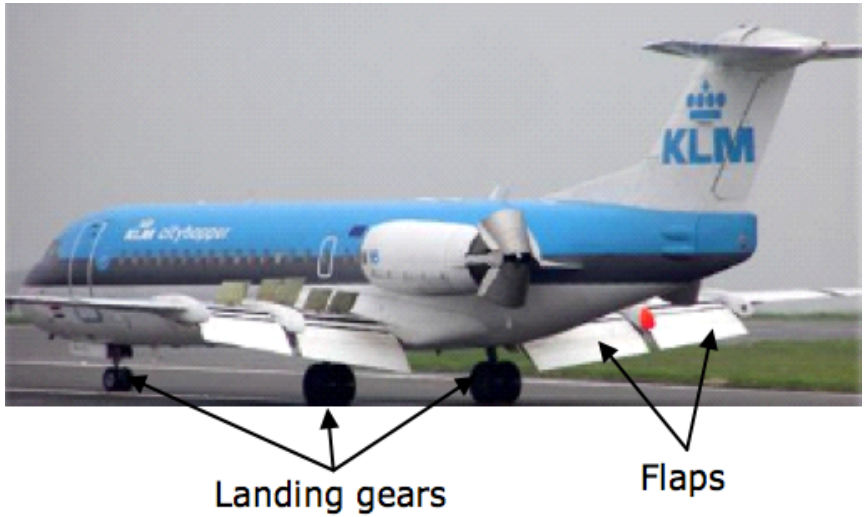
- Hydraulic systems are commonly used where mechanisms require large forces and precise control.
- Examples include vehicle power steering and brakes, hydraulic jacks and heavy earth moving machines.

Uses of Hydraulics

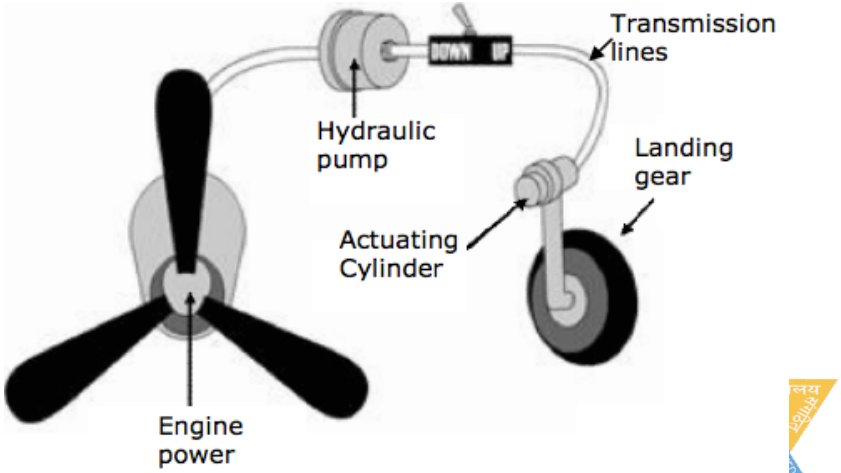
- Hydraulics plays an important role in many industries; there are a lot of hydraulic applications in manufacturing, transportation, and construction sectors.
- Hydraulics systems are used where large, precise forces are required.

Aircraft Hydraulic System

- All modern aircraft contain hydraulic systems to operate mechanisms, such as:
- Flaps (Fig. a)
- Landing gear (Fig. a)
- The hydraulic pump that is coupled to the engine provides hydraulic power as illustrated by Fig. b.
- Power is also distributed to systems through the aircraft by transmission lines.
- Hydraulic power is converted to mechanical power by means of an actuating cylinder or hydraulic motor.



(a) Landing gears and flaps

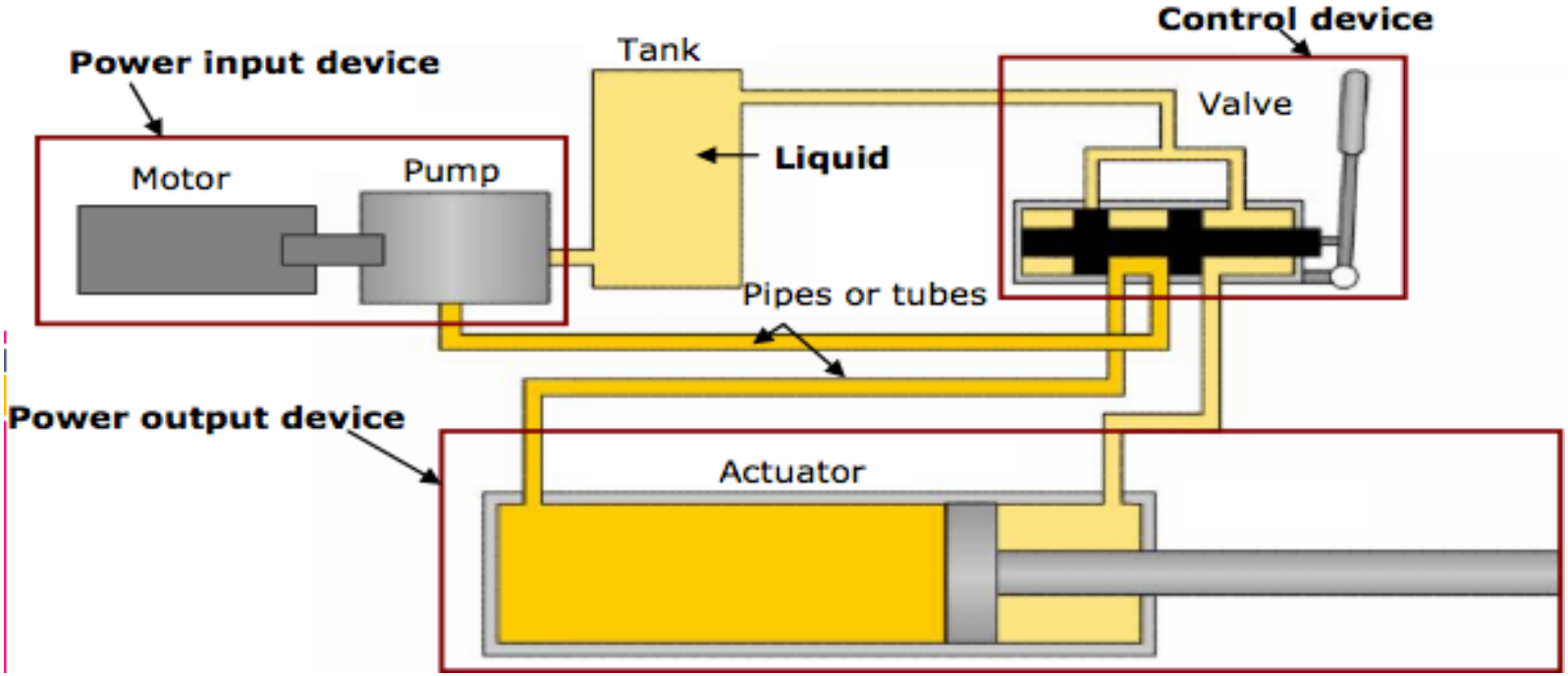


(b) Landing gear schematic diagram

Hydraulic system components

- All industrial hydraulic systems consist of the following basic components
- **Power input device:**

  The pump and motor together are called the power input device; the pump provides power to the hydraulic system by pumping oil from the reservoir/tank. The pump's shaft is rotated by an external force which is most often an electric motor as illustrated in Fig 1.5.



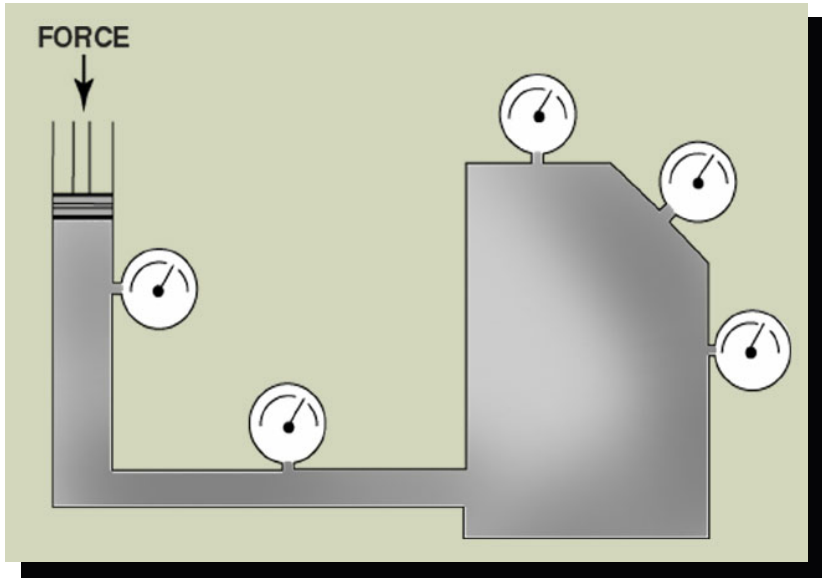
Hydraulic system components

- **Control device:** Valves control the direction, pressure, and flow of the hydraulic fluid from the pump to the actuator/cylinder.
- **Power output device:** The hydraulic power is converted to mechanical power inside the power output device. The output device can be either a cylinder which produces linear motion or a motor which produces rotary motion.
- **Liquid:** the liquid is the medium used in hydraulic systems to transmit power. The liquid is typically oil, and it is stored in a tank or reservoir.
- **Conductors:** The conductors are the pipes or hoses needed to transmit the oil between the hydraulic components.

Hydraulic systems and its components

The Average modern aircraft utilizes hydraulic systems to operate several systems.

- Landing gear
- Wing flaps
- Speed and wheel brakes
- Flight controls



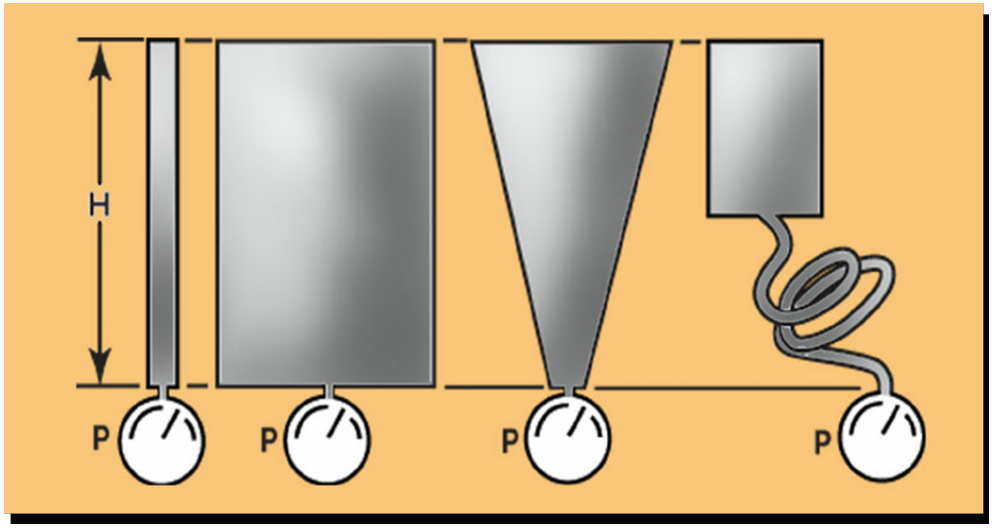
Pascal's Law

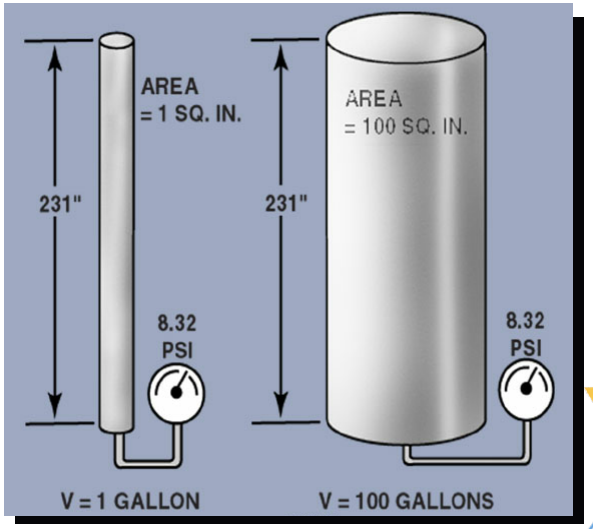
Pressure exerted on a fluid in an enclosed container is transmitted equally and undiminished to all parts of the container and acts as right angles to the enclosing walls.

Hydraulic systems and its components

Hydrostatic Paradox

- The pressure exerted by a column of liquid is determined by the height of the column and is independent of its volume.
- Neither the shape nor the volume of a container affects the pressure. Only the height of the column does this.

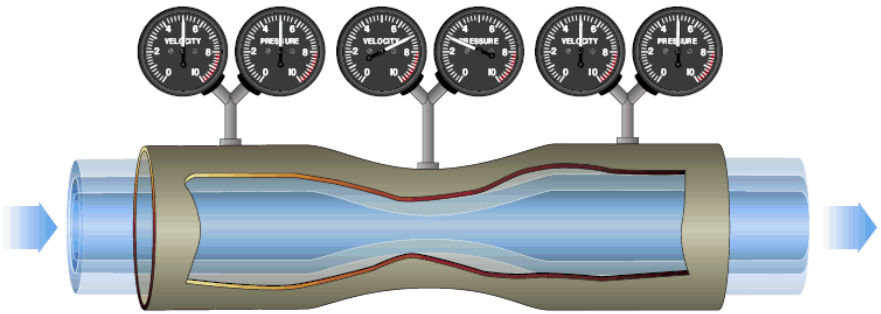




Hydraulic systems and its components

Changes in Velocity and Pressure (Bernoulli)

- When a fluid or gas is supplied at a constant flow rate through a duct, the sum of the pressure energy and velocity energy is constant.
- If pressure increases, velocity decreases proportionally or, if pressure decreases, velocity increases proportionally.
  - Kinetic Energy = Velocity (Ram Pressure)
  - Potential Energy = Pressure (Static Pressure)



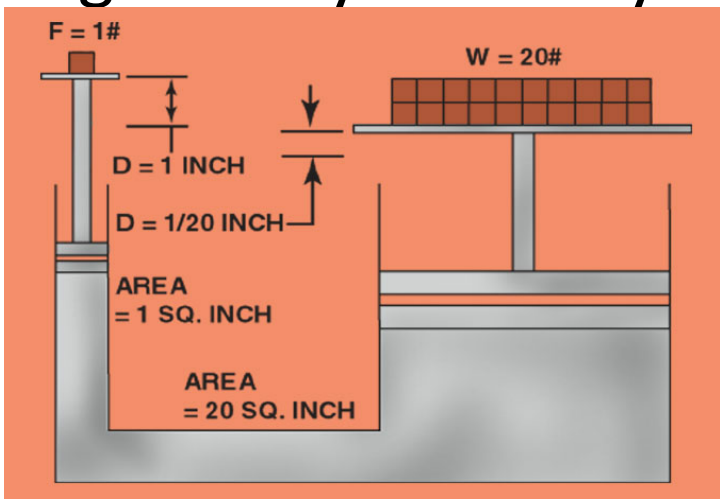
Hydraulic systems and its components

Aircraft Hydraulic Systems

Relationship Between Pressure, Force, And Area

- Pressure is a measure of the amount of force that acts on a unit of area.
- Pressure is measured in pounds per square inch (psi).
- Force = Pressure x Area

Mechanical Advantages in Hydraulic System



Hydraulic systems and its components

Mechanical Advantage In A Hydraulic System

- If a large amount of movement is need but only a small amount of force we can use a large piston to drive a smaller one.
- The fluid moved by the large piston will enter the cylinder with the small piston and move it a distance equal to the volume of fluid divided by the area of the small piston.
- All hydraulic systems are essentially the same, whatever their function.
- Regardless of application, each hydraulic system has a minimum number of components, and some type of hydraulic fluid.

Hydraulic Fluid Properties

- Incompressible
- Good lubricating properties
- Good Viscosity
- High boiling pint/ Low freezing point
- High flash point/ Non-flammable
- Chemically inert/Non-corrosive
- Resistant to evaporation
- Free from sludging and foaming
- Reasonably priced
- Readily available

Hydraulic systems and its components

- The fluid used in aircraft hydraulic systems is one of the system's most important parts.
  - The fluid must flow with a minimum of opposition.
  - Must be incompressible
  - Good lubricating properties
  - Inhibit corrosion and not attack seals
  - Must not foam in operation
- Some characteristics that must be considered.
  - Viscosity
  - Chemical Stability
  - Flash Point
  - Fire Point

Hydraulic systems and its components

Viscosity

- Viscosity is the internal resistance to flow.
  - Gasoline flows easily (has a low viscosity)
  - Tar flows slowly (has a high viscosity)
- A satisfactory liquid for a hydraulic system must have enough body t give a good seal at pumps, valves and pistons; but it must not be so thick that it offers excessive resistance to flow.
- The average hydraulic liquid has a low viscosity.

Hydraulic systems and its components

Chemical Stability

- Chemical Stability is the ability of the liquid to resist oxidation and deterioration for long periods.
  - Excessive temperatures have a great effect on the life of a liquid.
  - Liquids may break down if exposed to air, water, salt, or other impurities.

Flash Point

- Flash Point is the temperature at which a liquid gives off vapor in sufficient quantity to ignite momentarily when a flame is applied.
  - High flash point is desirable for hydraulic fluids.

Fire Point

Fire Point is the temperature at which a substance gives off vapor in sufficient quantity to ignite and continue to burn when exposed to a spark or flame.

High fire point is required of desirable hydraulic fluids.

Types of Hydraulic Fluid

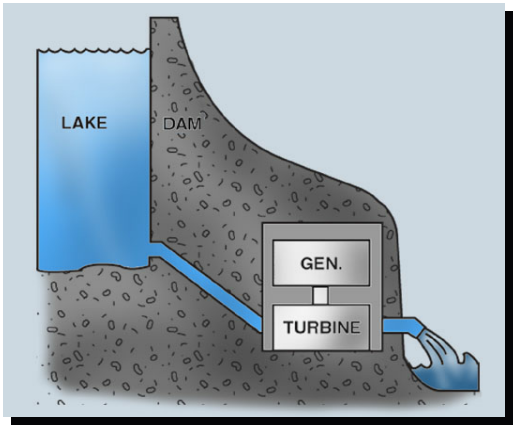
- Mineral Fluid
- H515 NATO
- MIL-H-5606F
- Coloured Red
- Used with synthetic Neoprene Rubber Seals
- Flammable

- Synthetic Fluid
- Colored Purple
- Used with synthetic Butyl Rubber Seals
- Damages skin and eyes
- Very high flashpoint
- Less prone to cavitation
- Flammable

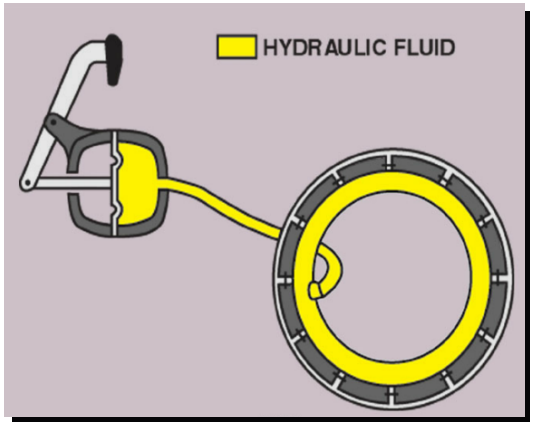
Types of Hydraulic Fluid

- Mineral-base Fluid
  - MIL-H-5606 is the most widely used hydraulic fluid in general aviation aircraft.
  - Kerosene-type petroleum product.
  - Dyed red for identification
- Synthetic Fluid
  - Non-petroleum base hydraulic fluid for use in high performance piston engine and turbine powered aircraft.
  - Most commonly used fluid of this type is Skydrol
  - Colored light purple.

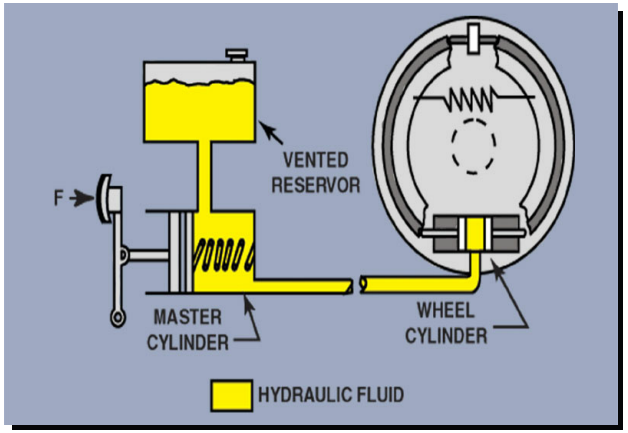
Hydraulic systems and its components



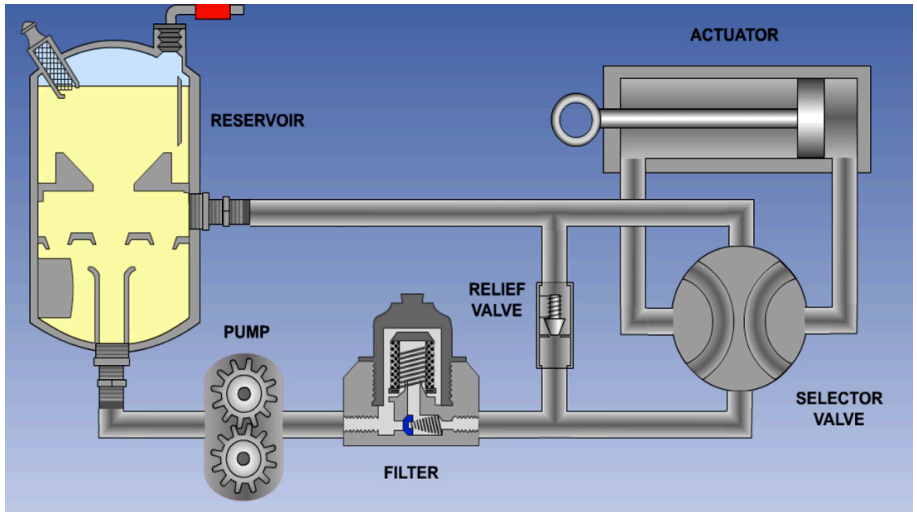
Open Hydraulic System



Closed Hydraulic Systems



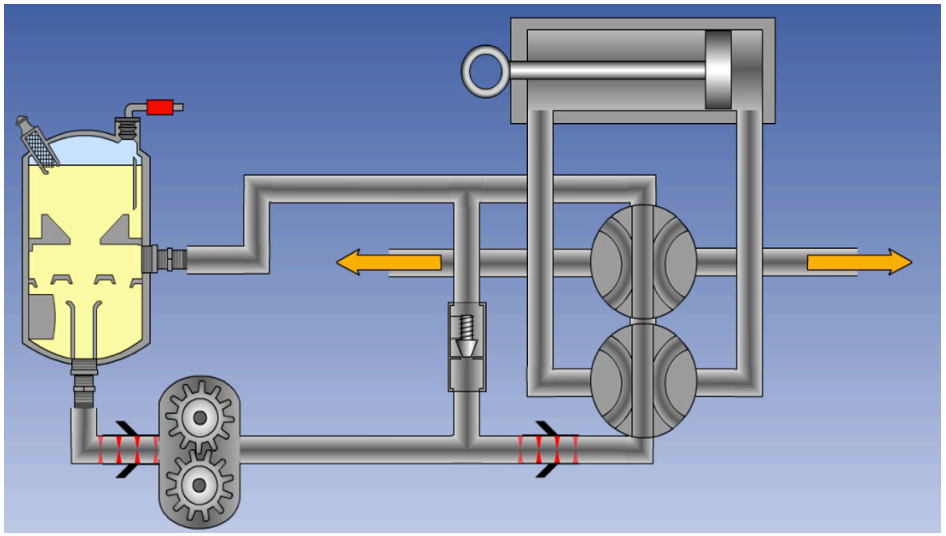
More modern brake system

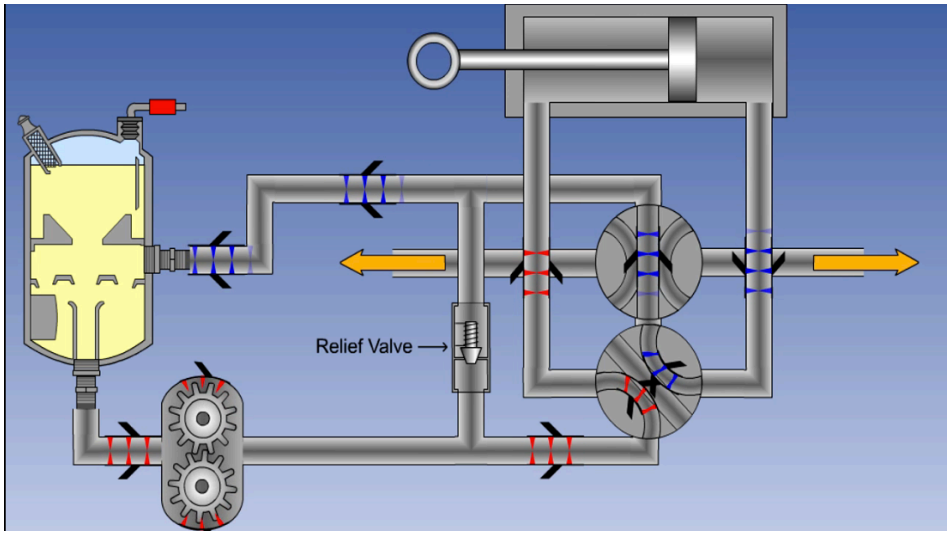


Basic Hydraulic Systems

Basic Hydraulic Systems

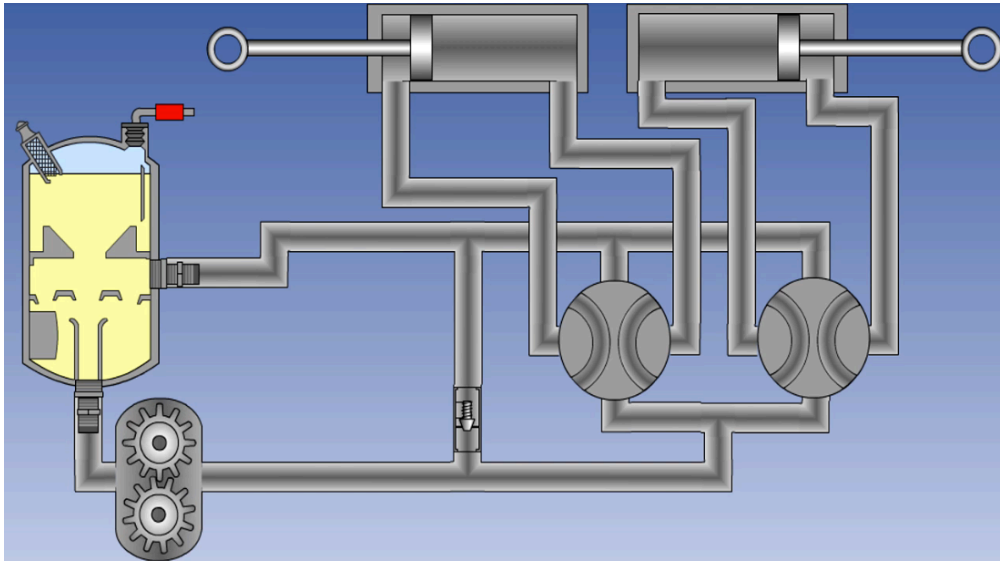
Open Center System

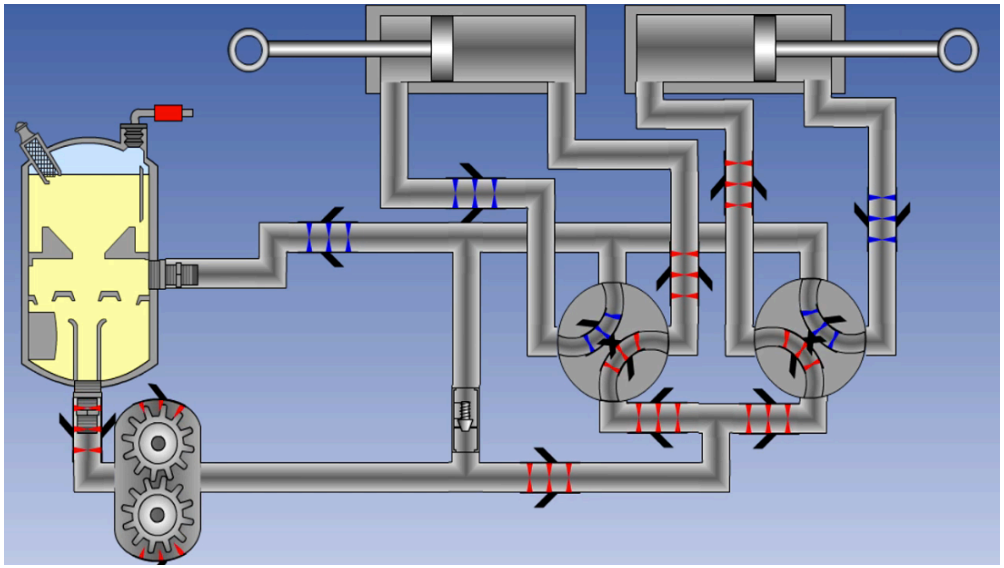




- Only one surface is operated at time.
- Fluid flows from the pump through the pressure filter to the first selector valve.
- Popular in many light aircraft.
- An open center system is one having fluid flow, but no pressure in the system when the actuating mechanisms are idle.
- Unlike the closed center system, the selector valves of the open center system are always connected in series with each other.
- When one of the selector valves is positioned to operate an actuating device, fluid is directed from the pump through one of the working lines to the actuator.

Closed Center System

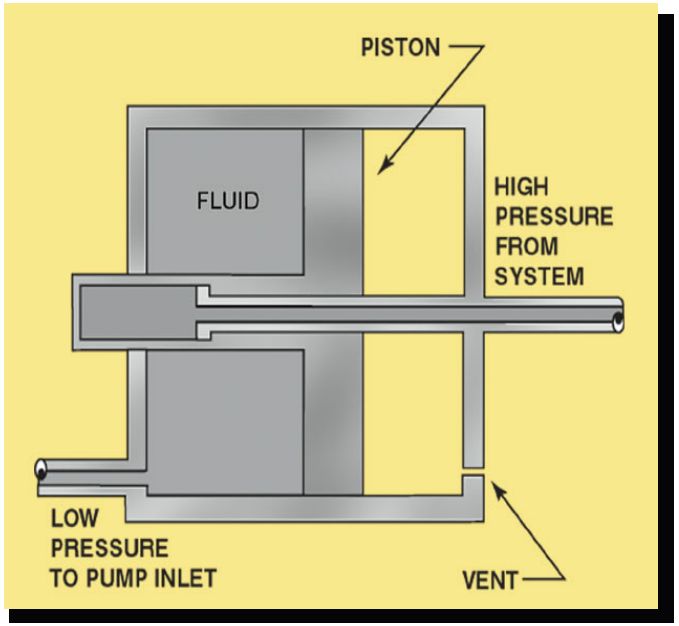




- Almost used in large aircraft system
- Multiple service can be operated at the same time
- Their use is only limited by the volume flow capacity of the pump
- In the closed-center system, the fluid is under pressure whenever the power pump is operating.
- This system differs from the open-center system in that the selector or directional control valves are arranged in parallel and not in series.
- An advantage of the open-center system over the closed-center system is that the continuous pressurization of the system is eliminated.

Hydraulic systems and its components

- System Components
  - Reservoirs
  - Pumps
  - Selector Valves
  - Check Valves
  - Hydraulic Fuses
  - Accumulators
  - Actuators



Reservoirs

- In an in-line reservoir, space is provided in the reservoir for fluid expansion and the escape of entrapped air.
- Jet aircraft that operate at altitudes where there is not enough air pressure to assure a positive feed of fluid to the pump have hydraulic reservoirs pressurized.
- Hydraulic reservoir pressurized by hydraulic system pressure.

Hydraulic Reservior

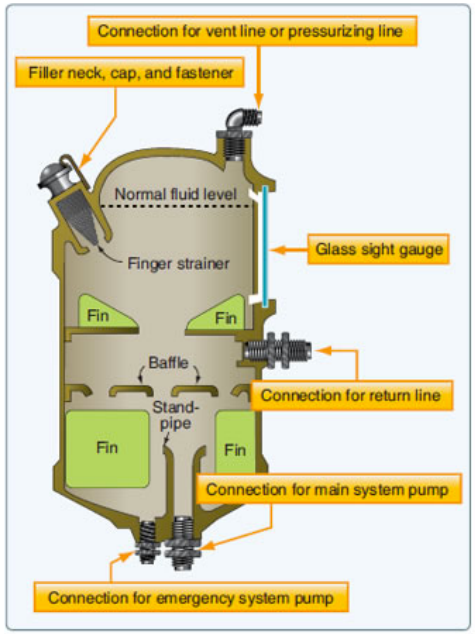
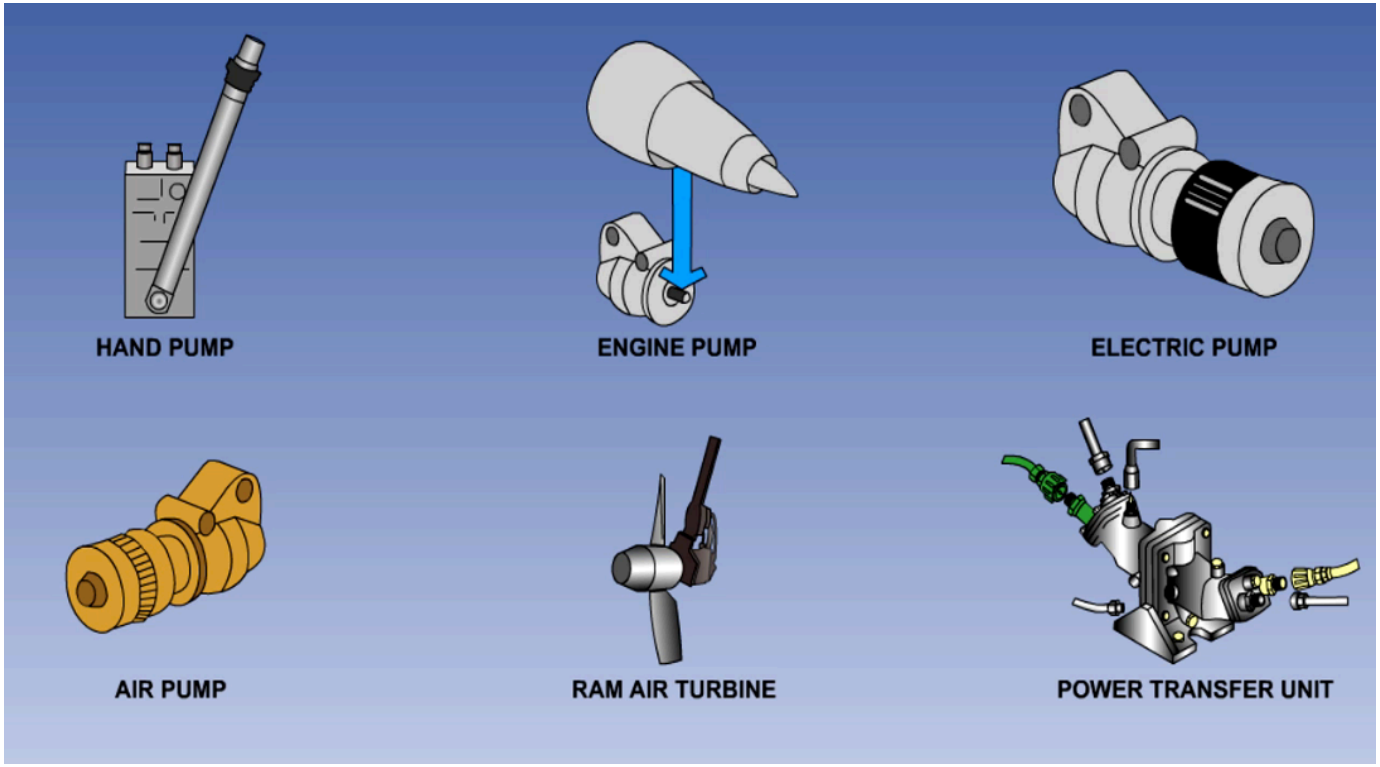


Figure 12-8. *Nonpressurized reservoir.*

Figure 12-9. *Air-pressurized reservoir.*

- The hydraulic reservoir is a container for holding the fluid required to supply the system, including a reserve to cover any losses from minor leakage and evaporation.
- The reservoir can be designed to provide space for fluid expansion, permit air entrained in the fluid to escape, and to help cool the fluid.
- Most reservoirs are designed with the rim at the filler neck below the top of the reservoir to prevent overfilling.
- Some means of checking the fluid level is usually provided on a reservoir.
- Hydraulic reservoirs are either vented to the atmosphere or closed to the atmosphere and pressurized.

Pumps



Hydraulic Pump Types

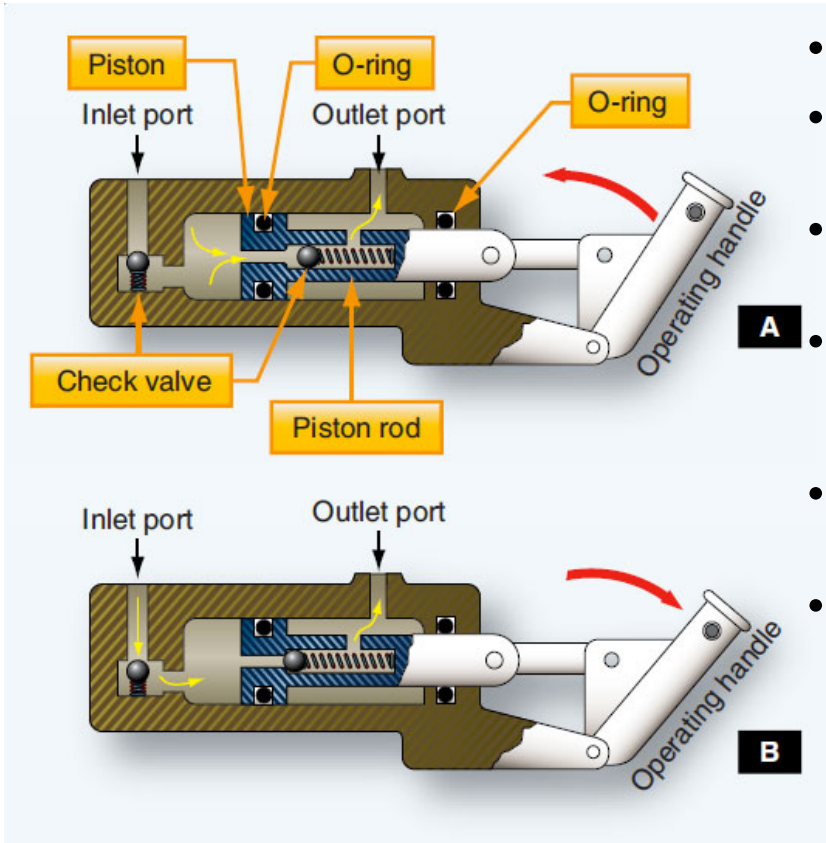
Checkball Hydraulic Pump

Powered Pumps

- Constant displacement moves a specific volume of fluid each time its shaft turns.
- Variable displacement does not move a constant amount of fluid each revolution, but only the amount the system will accept.

Hydraulic Pumps (Hand Pump)

The heart of any hydraulic system is the pump which converts mechanical energy into hydraulic energy. The source of mechanical energy may be an electric motor, the engine, or the operator's muscle.



Double action hand pump

- Pumps powered by muscle are called hand pumps.
- They are used in emergencies as backups for power pumps and for ground checks of the hydraulic system.
- The double-action hand pump produces fluid flow with every stroke and is the only type used on Army aircraft.
- The pump produces pressure on both strokes because of the difference in volume between the right and left chambers.
- The piston rod takes up a good share of the space in the right chamber.
- Therefore, the excess fluid is forced out of the pump and into the hydraulic system, creating fluid pressure.

Hydraulic Pumps(Power Driven Pump)

Engine-driven pump

Electrically-driven pump.

- Power-driven pumps receive their driving force from an external power source, such as the aircraft engine
- This force is converted into energy in the form of fluid pressure.
- The four basic types of power-driven hydraulic pumps are gear, vane, diaphragm, and piston.
- Piston pumps are further categorized as either constant delivery or variable delivery.

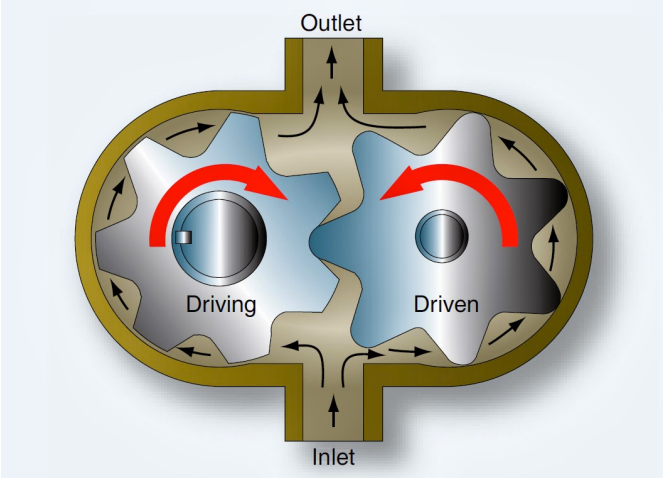
Hydraulic Pumps

Classification of Pumps

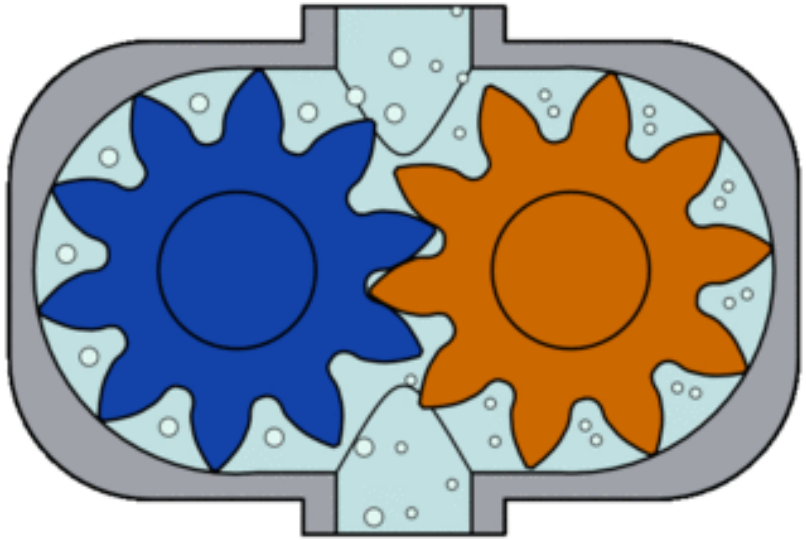
- Constant displacement Pumps
  - Gear Type Power Pump
  - Gerotor Pump
  - Piston Pump
  - Vane Pump

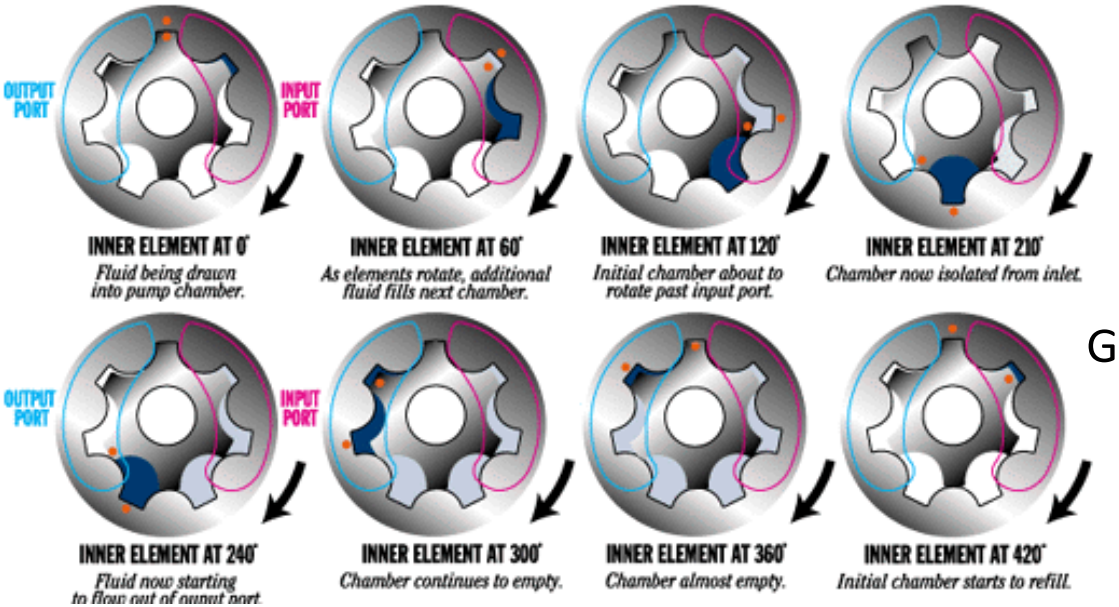
- Variable displacement Pumps
  - Normal Pumping mode
  - Depressurized mode

Hydraulic Pumps



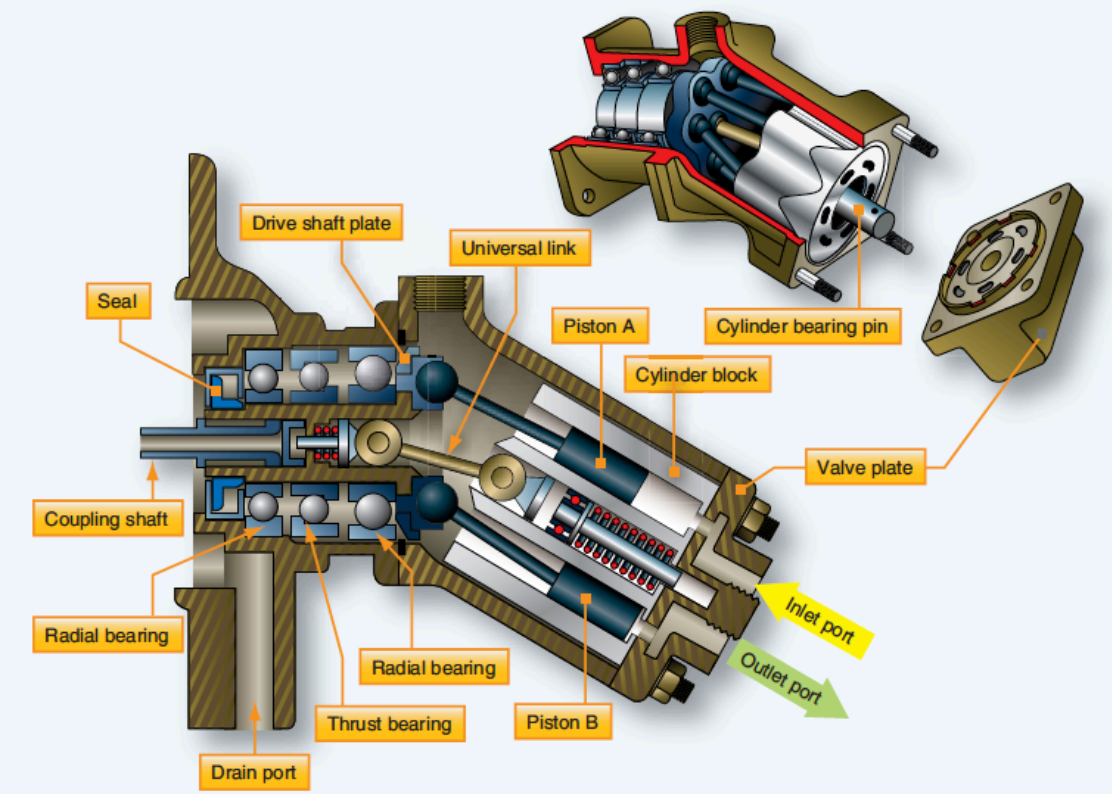
Gear Type Power Pump

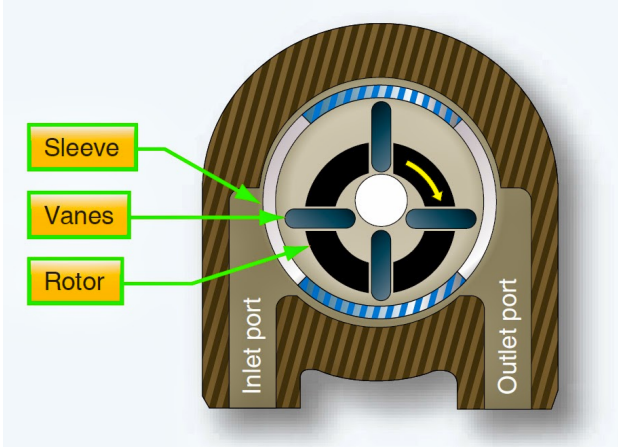




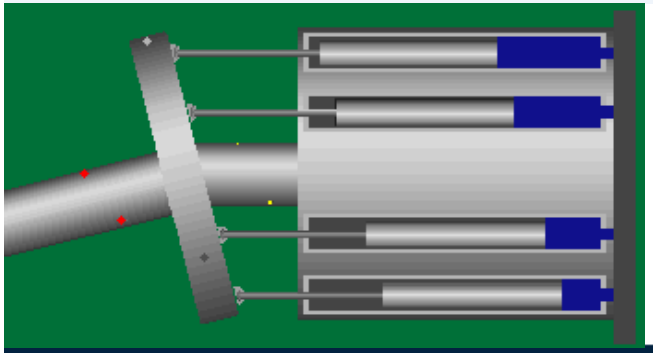
Gerotor Pump

Hydraulic Pumps

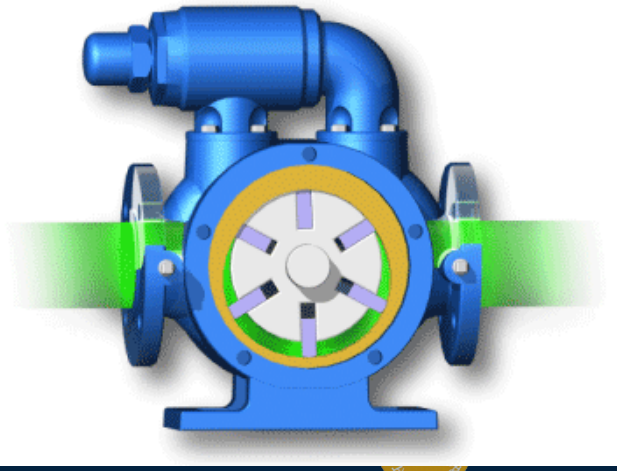




Vane Pump



Bent axis piston pump.



Valves

- Flow control valves control the speed and/or direction of fluid flow in the hydraulic system.
- They provide for the operation of various components when desired and the speed at which the component operates.
- Examples of flow control valves include:
  - selector valves
  - check valves
  - sequence valves
  - priority valves
  - shuttle valves
  - quick disconnect valves
  - hydraulic fuses.

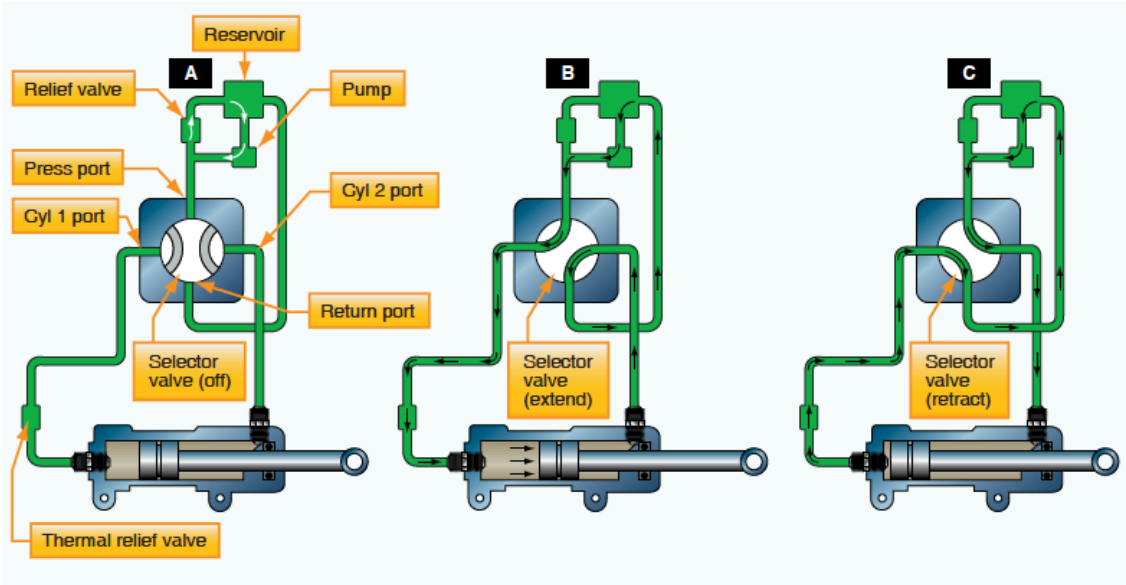
Directional Control Valve

Relief Valve

Single and Double acting cylinders

Selector Valves

- Used in hydraulic systems to control the direction of operation of a mechanism, selector valves are also referred to as directional control valves or control valves.
- They provide pathways for the simultaneous flow of two streams of fluid, one under pressure into the actuating unit, and the other, a return stream, out of the actuating unit.

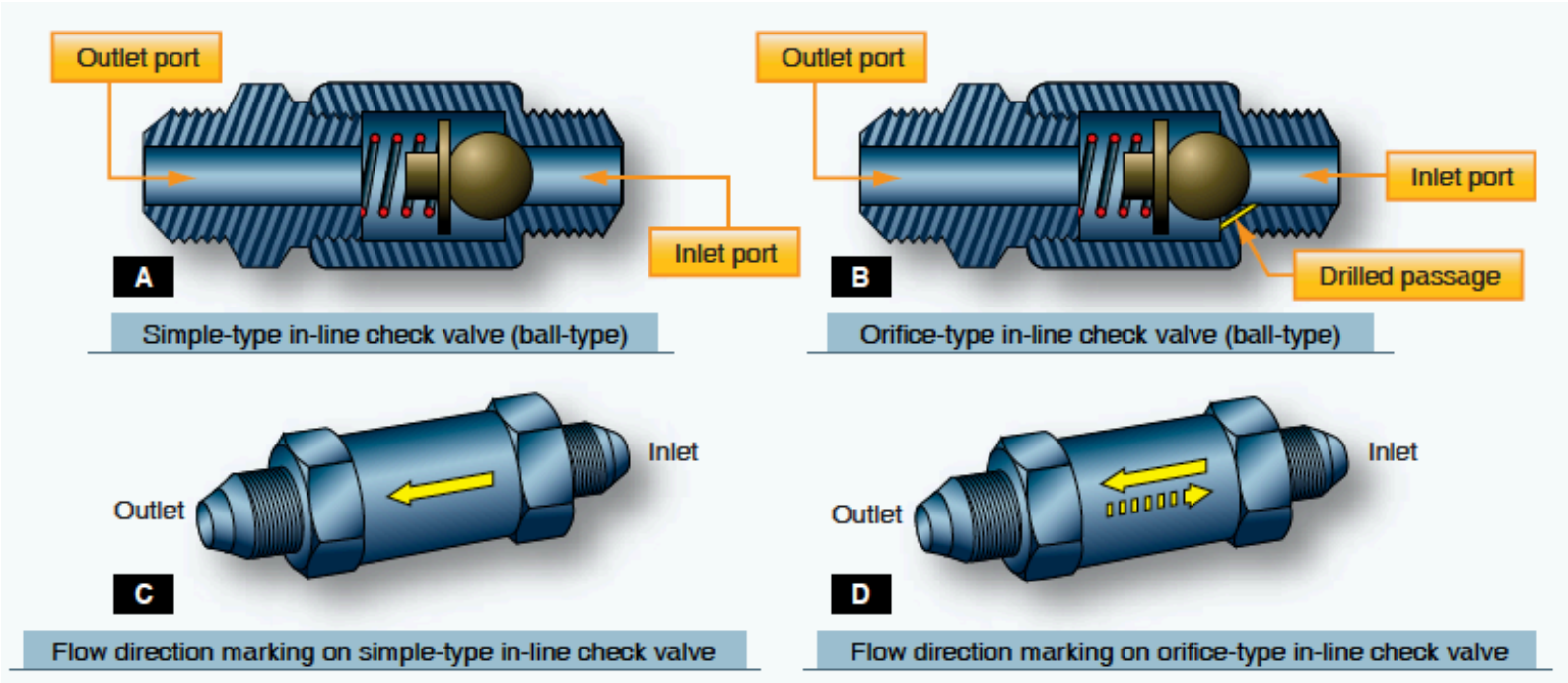


Operation of a closed-center four-way selector valve, which controls an actuator

- The selector valves have various numbers of ports determined by the requirements of the system in which the valve is used.
- Selector valves with four ports are the most commonly used; they are referred to as four-way valves.
- Selector valves are further classified as closed-center or open-center types.

Check Valve

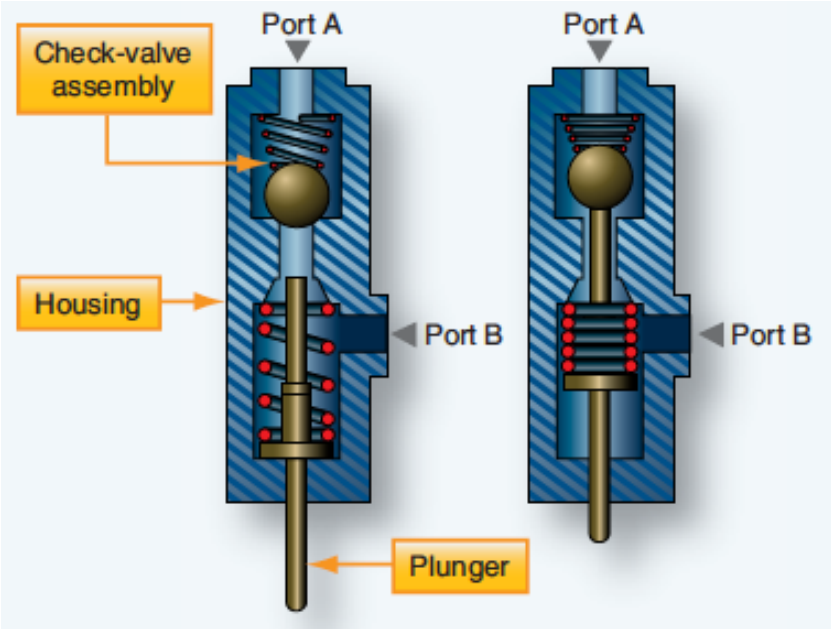
- A check valve is installed in a hydraulic system to control the direction flow of hydraulic fluid.
- The check valve allows free flow of fluid in one direction, but no flow or a restricted one in the other direction.
- A check valve may be an independent component situated in-line somewhere in the hydraulic system or it may be built-in to a component



An in-line check valve and orifice type in-line check valve.

Sequence Valve

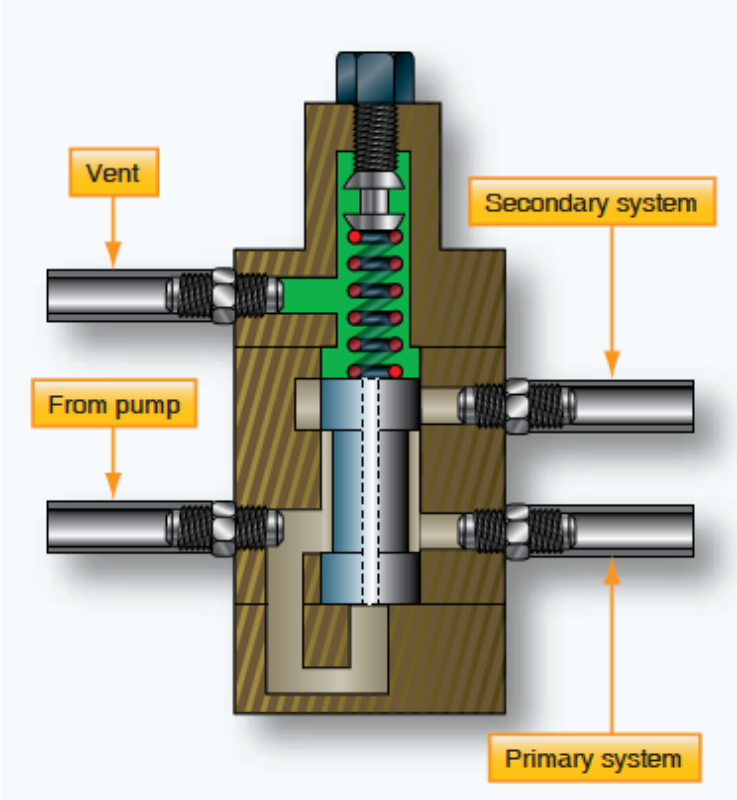
- A sequence valve is placed in a hydraulic system to delay the operation of one portion of that system until another portion of the same system has functioned.
- For example, it would be undesirable for the landing gear to retract before the gear compartment doors are completely open.
- A sequence valve actuated by the fully open door would allow pressure to enter the landing gear retract cylinder.
- The typical sequence valve is mechanically operated, or it can be solenoid-operated by means of micro switches.
- In either case, the valve is operated at the completion of one phase of a multiphase hydraulic cycle.



Mechanically operated sequence valve

Priority Valve

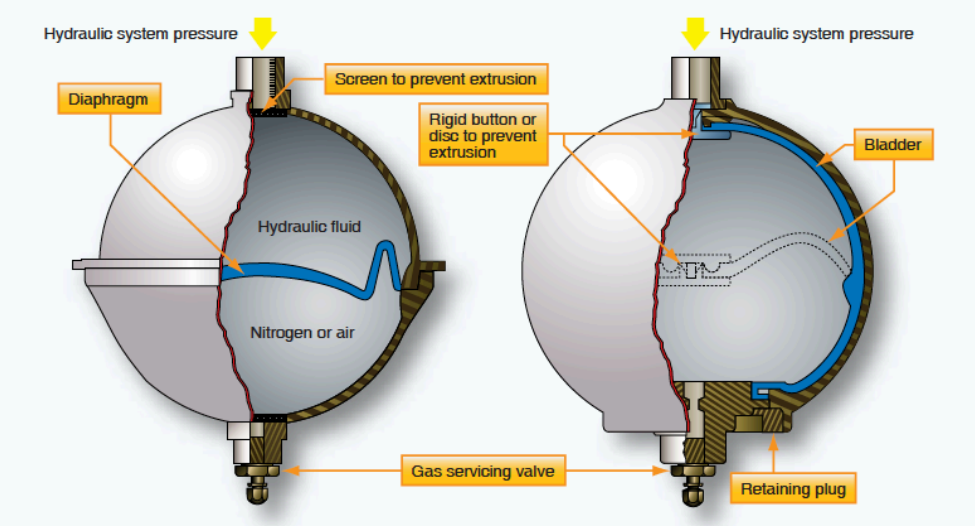
- A priority valve is installed in some hydraulic systems to provide adequate fluid flow to essential units.
- The valve is installed in the line between a nonessential actuating unit and its source of pressure.
- It permits free, unrestrained flow of fluid to nonessential units as long as system pressure is normal.
- When system pressure drops below normal, the priority valve automatically reduces the flow of fluid to the nonessential units.
- A spring acts against a hollow piston to maintain contact with a valve seat. With no system pressure, the priority valve is in the Spring-loaded position, closed.



Priority valve

Accumulators

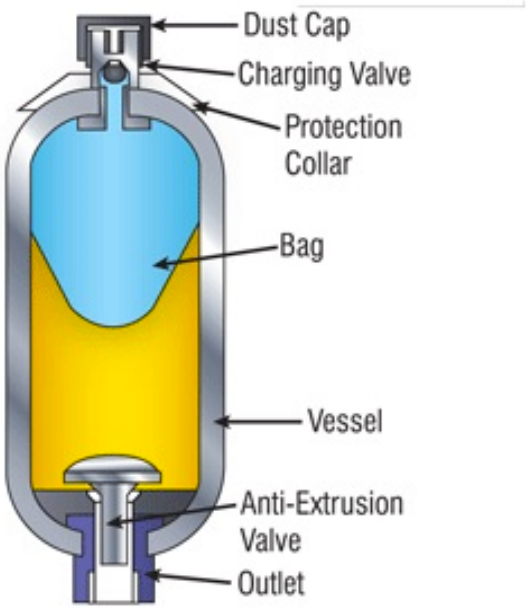
- The accumulator is a steel sphere divided into two chamber by a synthetic rubber diaphragm.
- The upper chamber contains fluid at system pressure, while the lower chamber is charged with nitrogen or air.
- Cylindrical types are also in high pressure hydraulic systems. Many aircraft have several accumulators in theused hydraulic system.
- There may be a main system accumulator and an emergency system accumulator.
- There may also be auxiliary accumulators located in various sub-systems.



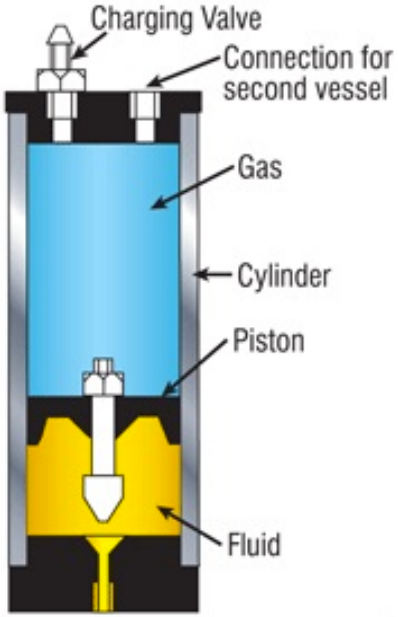
A spherical accumulator with diaphragm (left) and bladder (right).

Accumulators

The function of an accumulator is to:



Bladder Accumulator

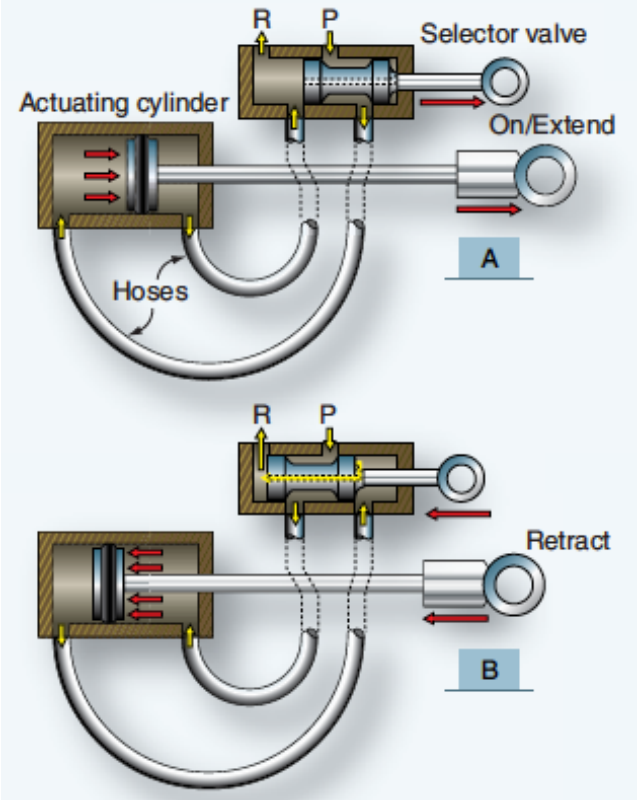


Piston Accumulator

- Dampen hydraulic shocks which may develop when pressure surges occur in hydraulic systems.
- Add to the output of a pump during peak load operation of the system, making it possible to use a pump of much smaller capacity than would otherwise be required.
- Absorb the increases in fluid volume caused by increases in temperature.
- Act as a source of fluid pressure for starting aircraft auxiliary power units (APUs).
- Assist in emergency operations.

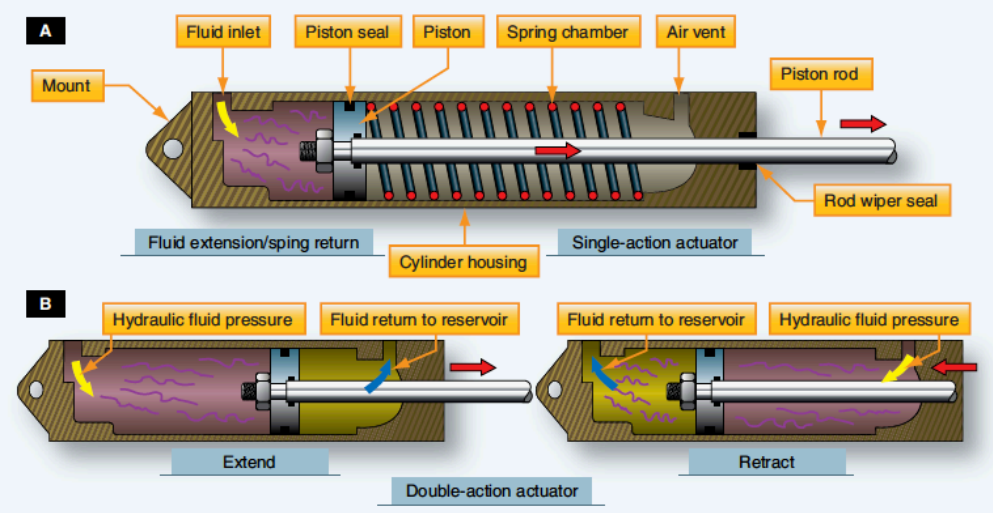
Actuators

- An actuating cylinder transforms energy in the form of fluid pressure into mechanical force, or action, to perform work.
- It is used to impart powered linear motion to some movable object or mechanism.
- A typical actuating cylinder consists of a cylinder housing, one or more pistons and piston rods, and some seals.
- Seals are used to prevent leakage between the piston and the cylinder bore and between the piston rod and the end of the cylinder.

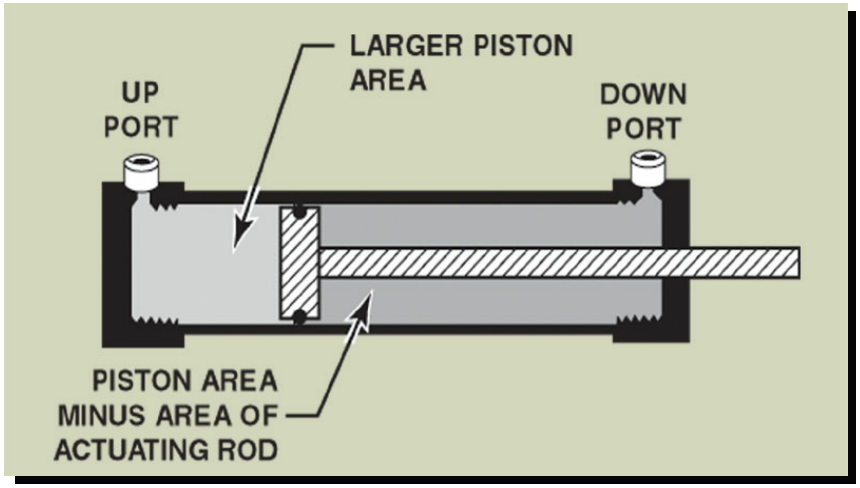


Linear actuator operation

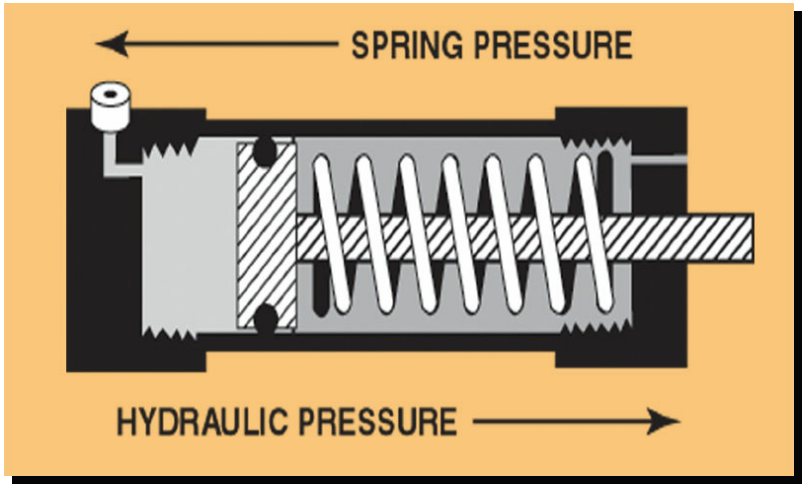
Actuators



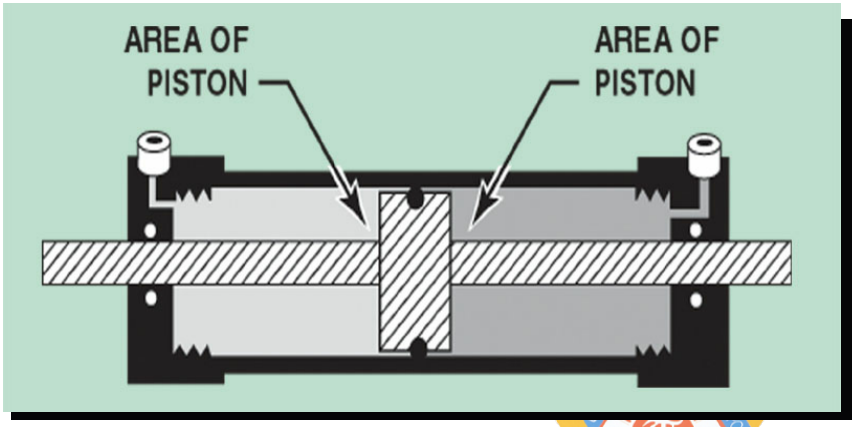
Linear actuator



Double-Acting Unbalanced Linear (Landing Gear)



Single-Acting Linear (Brakes)



Double-Acting Balanced Linear (Flight Controls)

Hydraulic Systems

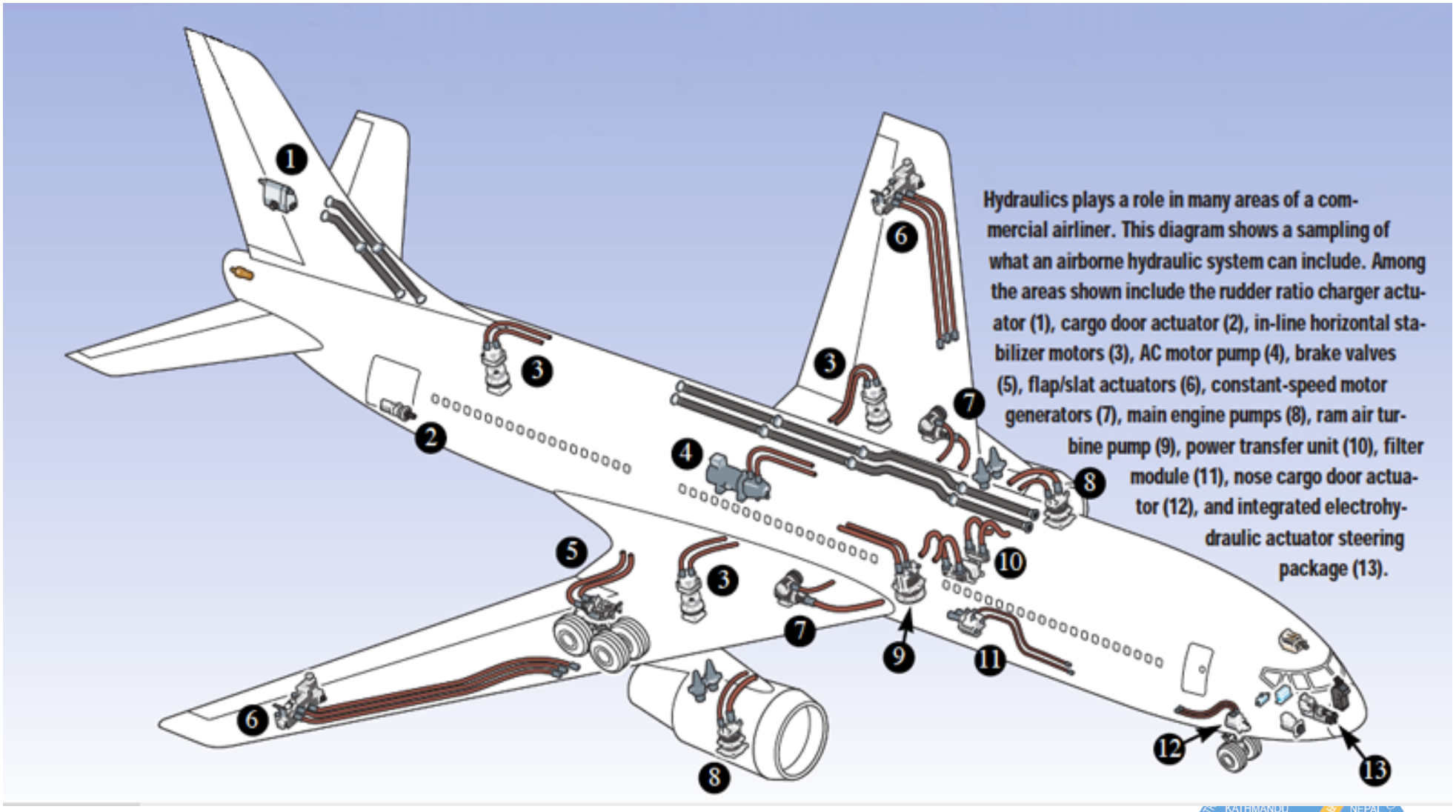
Some advantages of hydraulic transmission of power over mechanical transmission of power are as follows:

- Quick, easy speed adjustment over a wide range while the power source is operating at a constant (most efficient) speed
- Rapid, smooth acceleration or deceleration
- Control over maximum torque and power
- Cushioning effect to reduce shock loads
- Smoother reversal of motion

The hydraulic systems power the following aircraft systems

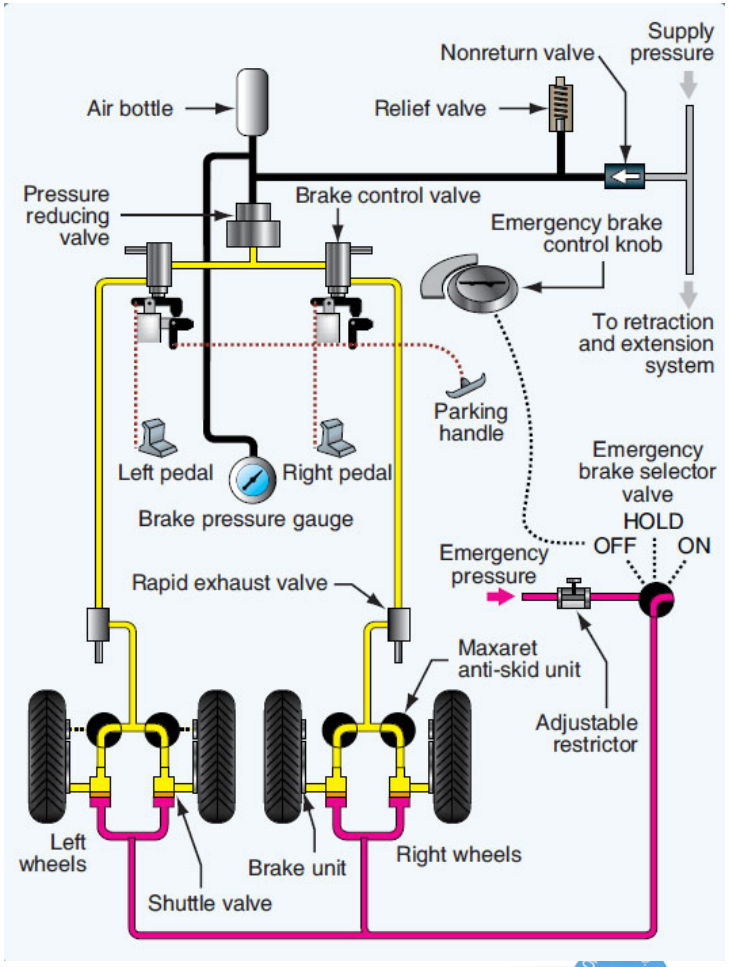
- Flight controls
- Leading edge flaps and slats
- Trailing edge flaps
- Landing gear
- Wheel brakes
- Nose wheel steering
- Thrust reversers
- Autopilots

Hydraulic Systems



Pneumatic system and its components

- Compressor
  - Pressurizes Air
  - Typically attached to tank for storage
  - Often is a centralized supply for multiple devices
- Check Valve
  - One way valve
  - Prevents backflow into compressor
  - Prevents compression loss when off
- Accumulator
  - Smooth air flow and unwanted disturbances
- Directional Valve
  - Direct Air flow
  - Stores energy and reduce turbulence
  - Electrical or manual operation
- Actuator
  - Transfers air energy into motion
  - Ex. Air Chisel



Pneumatic brake system.

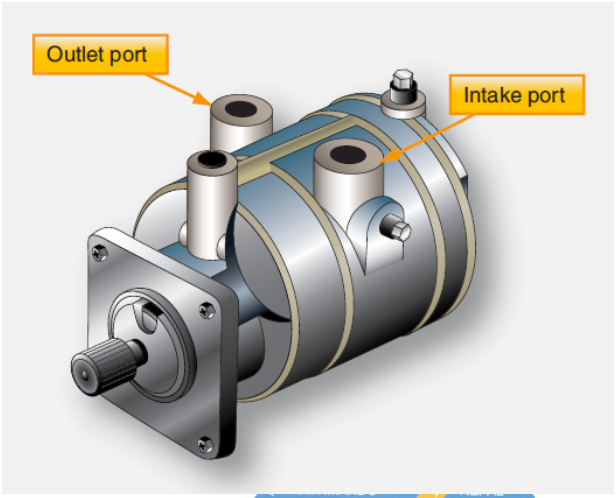
Pneumatic system and its components

- Pneumatic Air Filter
  - Prevent system contamination
  - Remove air particulates
  - Clean air is essential to good operation
- Pneumatic Pressure Regulator
  - Prevents System over pressurization
  - Insures proper calibration

- Air Pumps

Heart of pneumatic system is pressure or vacuum air pump (Usually engine driven)

- Two basic types :
  - Wet air pumps use engine oil to lubricate pump internally
  - Dry air pumps - more common –have graphite vanes inside pump casing - self-lubricate as pump rotates



Pneumatic system

Pneumatic systems work in a very similar way to that of hydraulic systems.

The major difference is that in pneumatic systems, high pressure air is used instead of hydraulic fluid.

- This is because air is much more compressible than fluid and it is much easier to store the pressure, using reservoirs.

This can give a reserve of power for short bursts of very heavy operation, or for emergency use if the system fails.

In an airframe, a pneumatic system can be used in place of a hydraulic system

Pneumatic system

Like the hydraulic system, the layout and complexity of a pneumatic system will vary based on it's primary function, but the principles and components of the system will be the same.

Typically, a pneumatic system will consist of;

- A Storage Cylinder – for the compressed air
- Pressure Gauges
- Pressure Valves – Non-Return, Reducing, Maintaining
- Pneumatic Air Lines
- A number of Pneumatic Selector Valves
- A number of Pneumatic Actuators

Pneumatic systems are sometimes used for:

- Brakes
- Opening and closing doors
- Driving hydraulic pumps, alternators, starters, water injection pumps, etc.
- Operating emergency devices

Pneumatic system

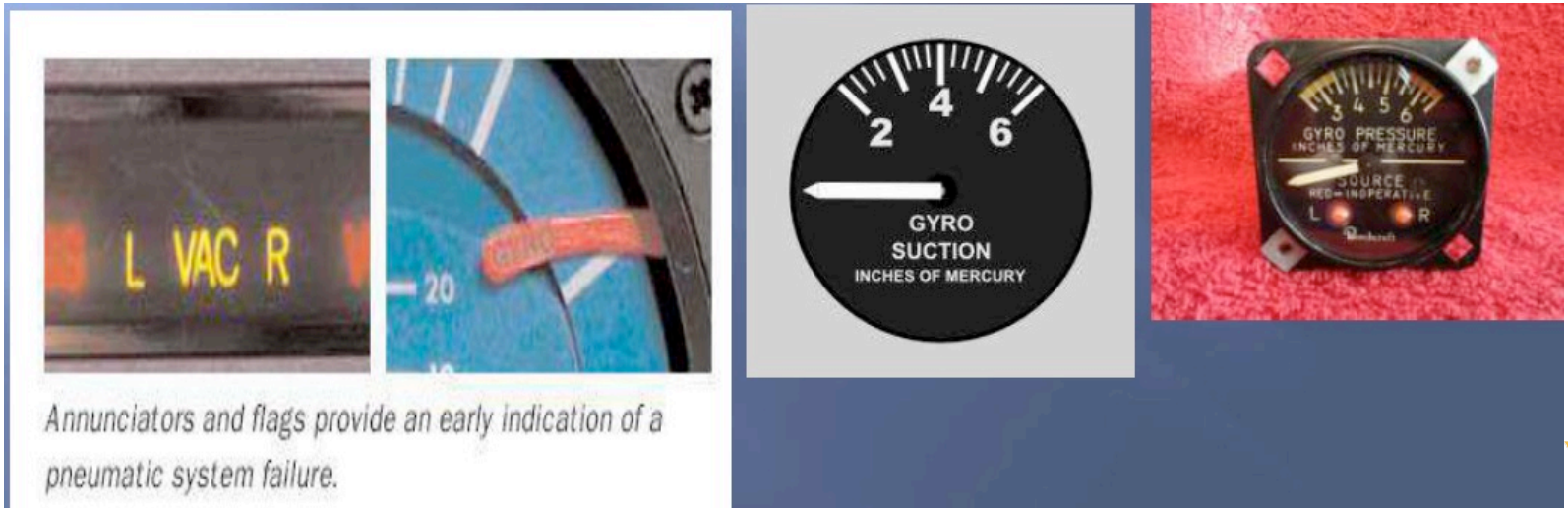
Failure Causes

- System Contamination
  - Solid particles in pneumatic system damage pump and plug valve openings
  - Liquids from oil, water, or engine cleaning solvents
- Restriction/ leaks within the system
  - A loose fitting or damaged hoses
  - Worn out, misused, or incorrectly routed hoses
- Sudden changes in engine speed
  - Abrupt engine deceleration
  - Sudden engine stoppage

Pneumatic system and its

Early Recognition

- Pneumatic System health can be determined by the indications on either the vacuum gauge or flags on the attitude indicator
- Inaccurate/conflicting Instrument information
- Suction/pressure gauge indicates outside normal operating (green) range
- Spotting pneumatic system failure early reduces chances of spatial disorientation



Annunciators and flags provide an early indication of a pneumatic system failure.

Disadvantages of Pneumatics

However, the compressibility of air can be a major disadvantage, as pneumatic systems lack the instant response that a simple hydraulic system can provide.

The rate of movement of pneumatic actuators depends strongly on the load, or the force which resists the movement.

This compressibility also means that the position of systems needing partial movements, such as control surfaces, cannot be controlled with any degree of accuracy.

Disadvantage of Pneumatics

Another major disadvantage of using pneumatic systems is the relative inefficiency in transmitting power in comparison with hydraulic systems

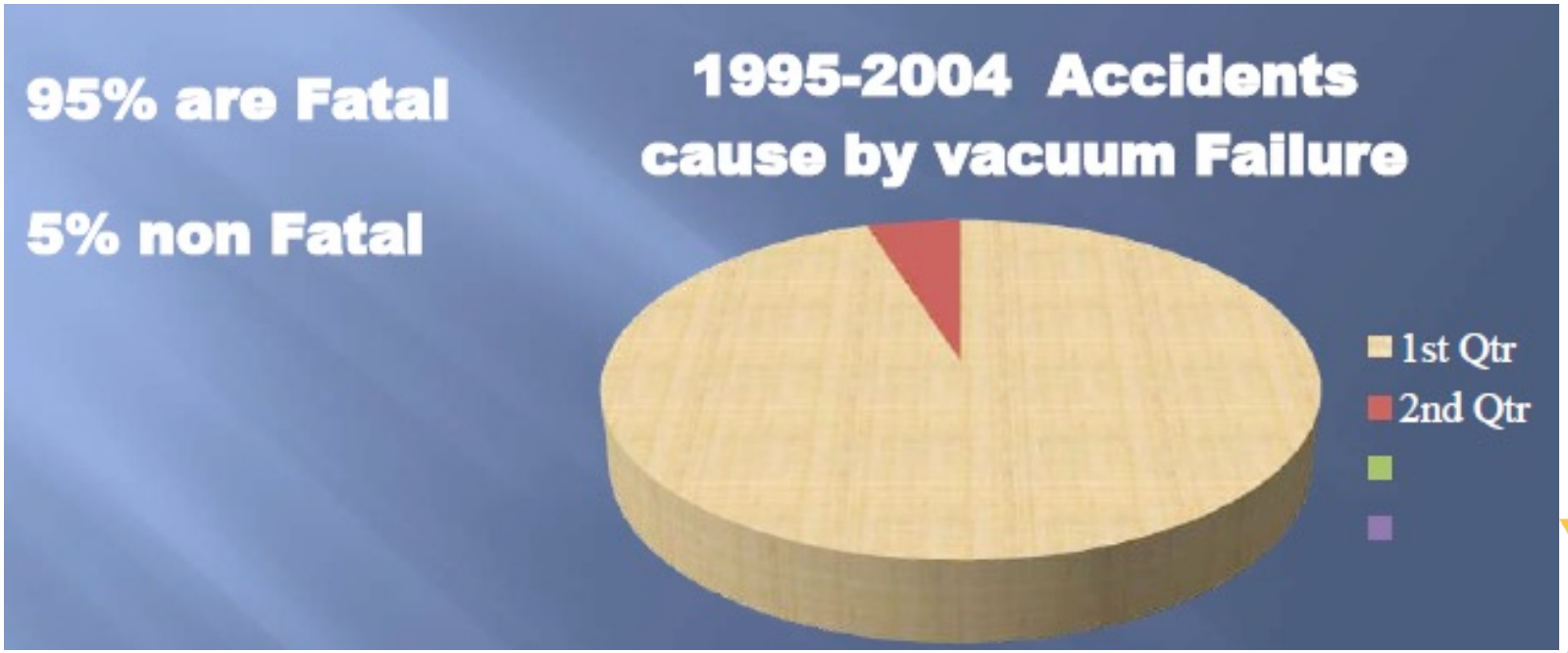
This is because energy is lost in compressing the air, a problem that does not occur with hydraulic fluid.

Because of these major disadvantages, many aircraft are not fitted with a pneumatic system.

Pneumatic system and its

Statistics

- While pneumatic system failures alone do not cause accidents, spatial disorientation does, and tragically these accidents are almost always fatal



Conclusions

You should now have a basic understanding of the hydraulic & pneumatic systems, their components and the areas where they are used on the airframe.

The hydraulic & pneumatic systems are simple, yet efficient means of transmitting power and/or motion