# LEARNING OBJECTIVES

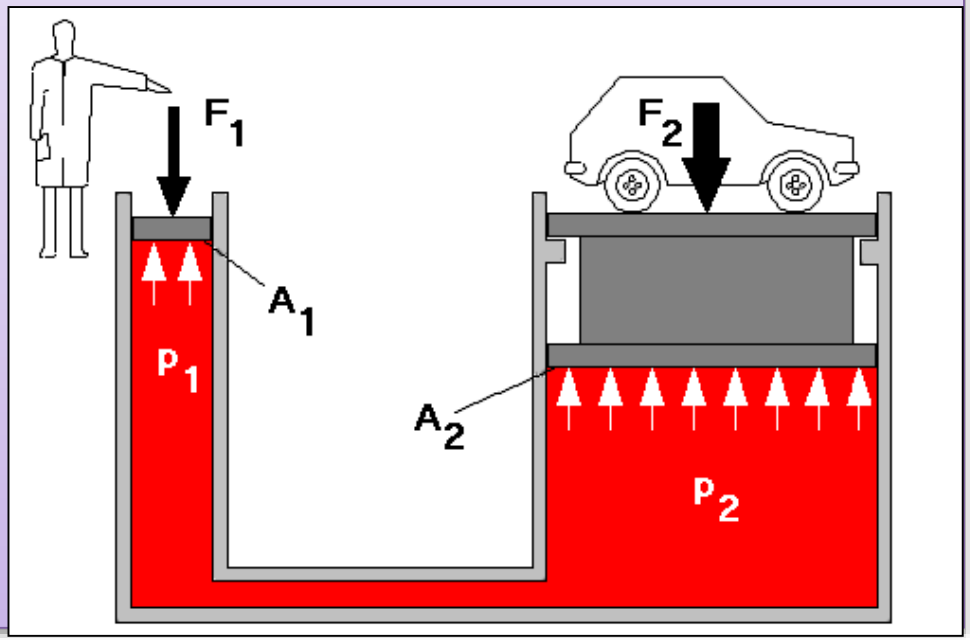
- Explain the **meaning** of fluid power.
- List the various **applications** of fluid power.
- **Differentiate** between fluid power and transport systems.
- List the **advantages and disadvantages** of fluid power.
- Explain the **industrial applications** of fluid power.
- List the **basic components** of the **fluid power**.
- List the **basic components** of the **pneumatic systems**.
- **Differentiate** between electrical, pneumatic and fluid power systems.
- Appreciate the **future of fluid power in India**.

# INTRODUCTION

- In the industry we use three methods for transmitting power from one point to another.
- **Mechanical transmission** is through shafts, gears, chains, belts, etc.
- **Electrical transmission** is through wires, transformers, etc.
- **Fluid power** is through liquids or gas in a confined space.
- In this PPT, we shall discuss a structure of hydraulic systems and pneumatic systems.

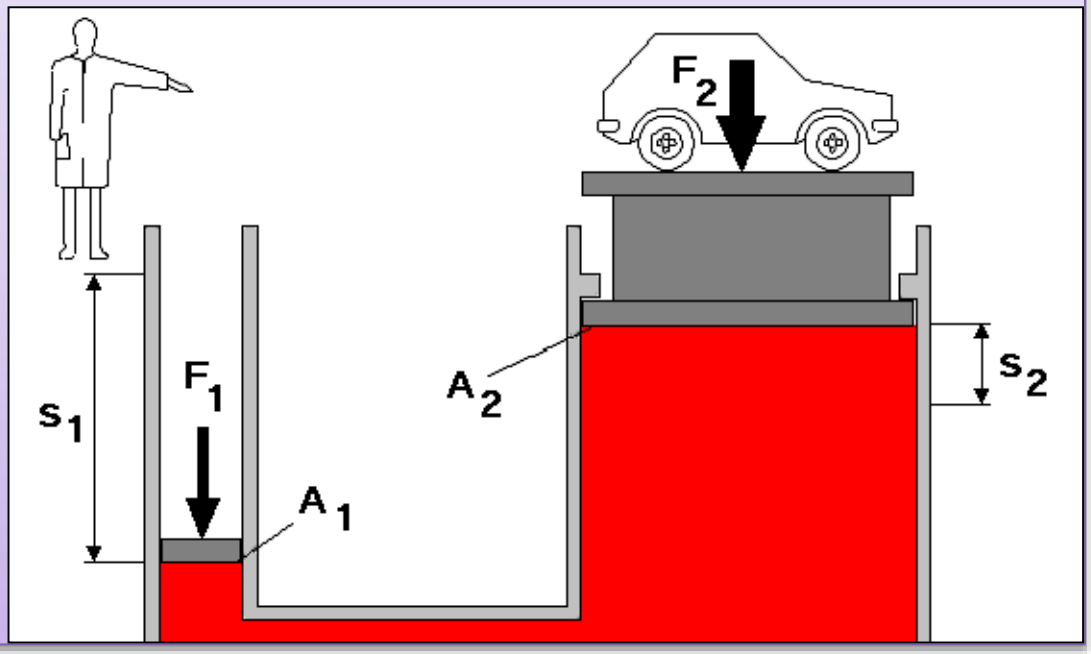
# HYDRAULIC FLUID TRANSMISSION

- Let : F = Force (N)
- P = Pressure (N/m2)
- A = Area (m2)

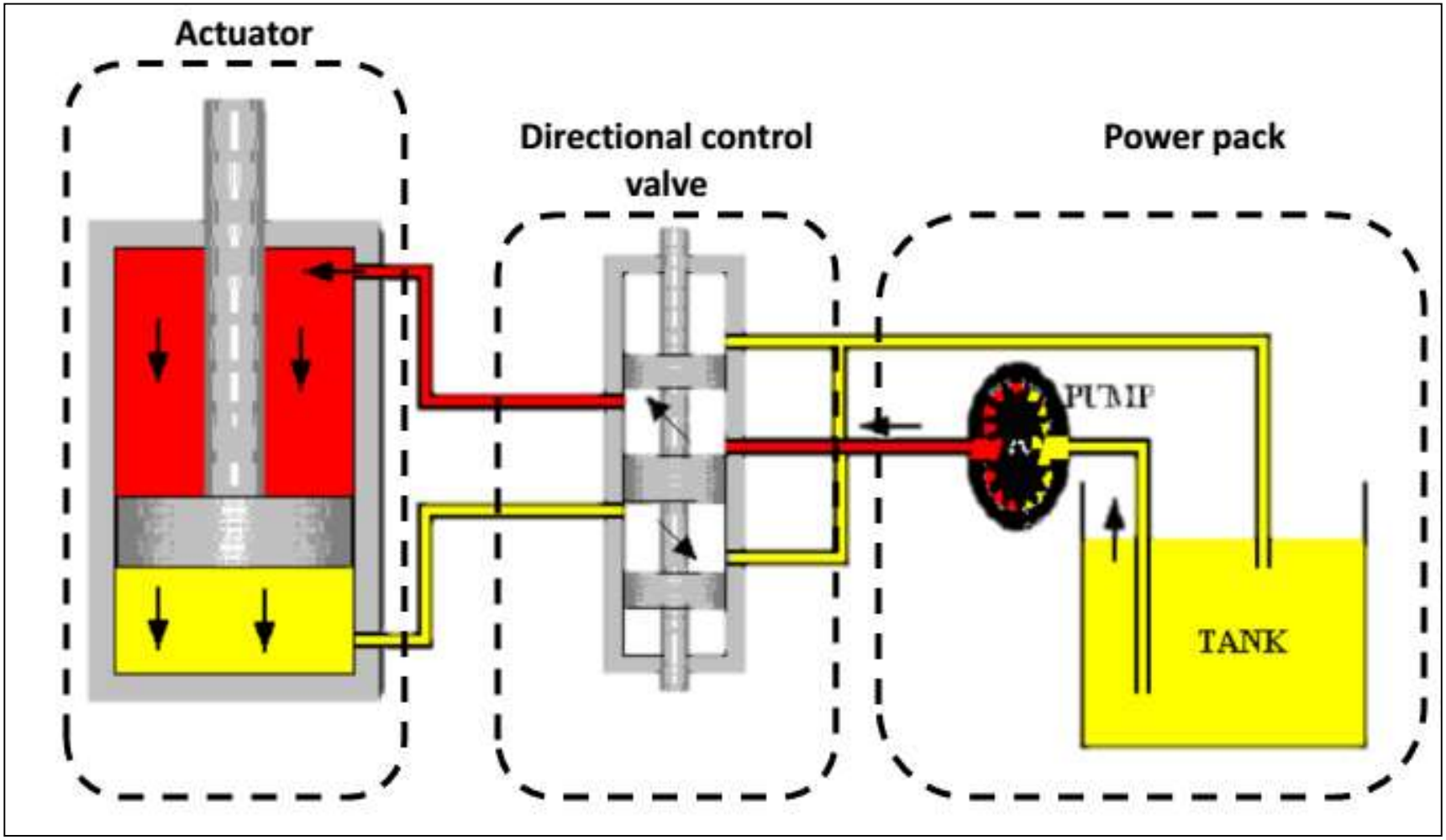


# HYDRAULIC FLUID COMPENSATION

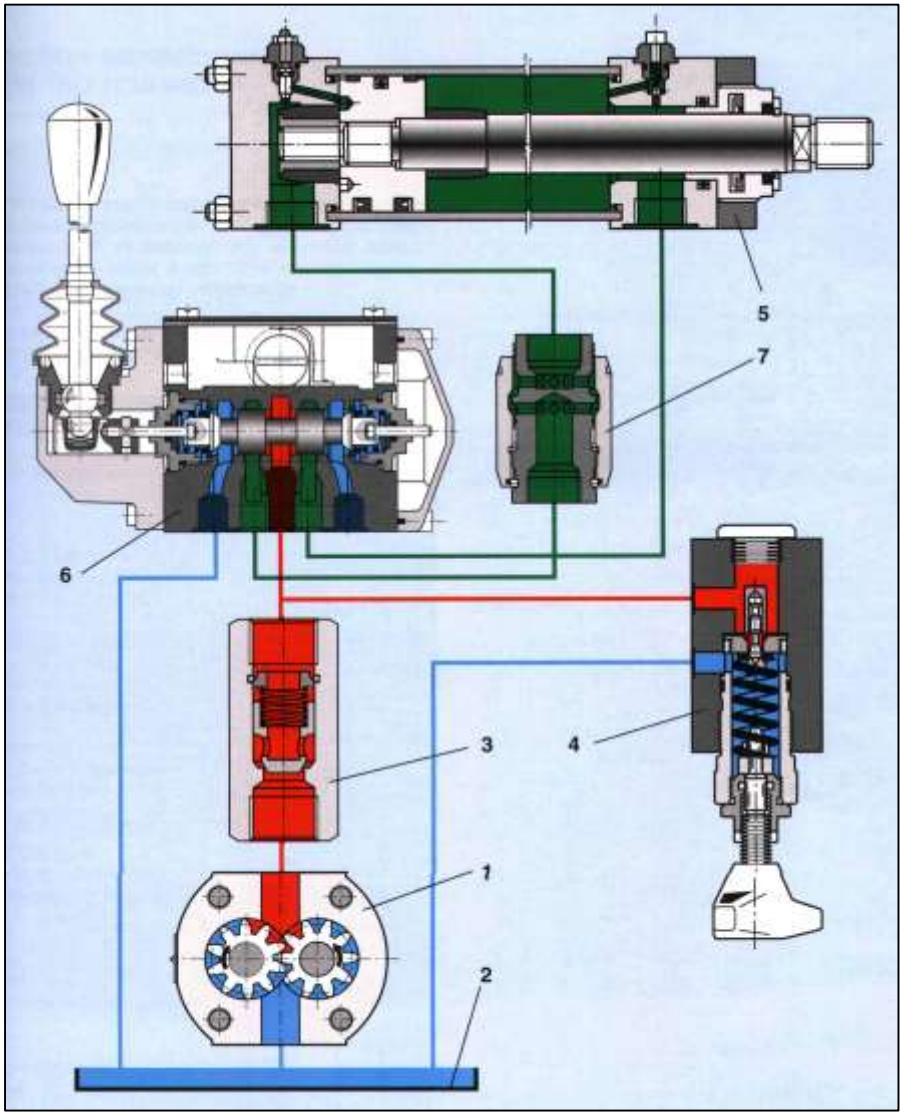
- Let : S = Displacement(m)
- A = Area (m2)

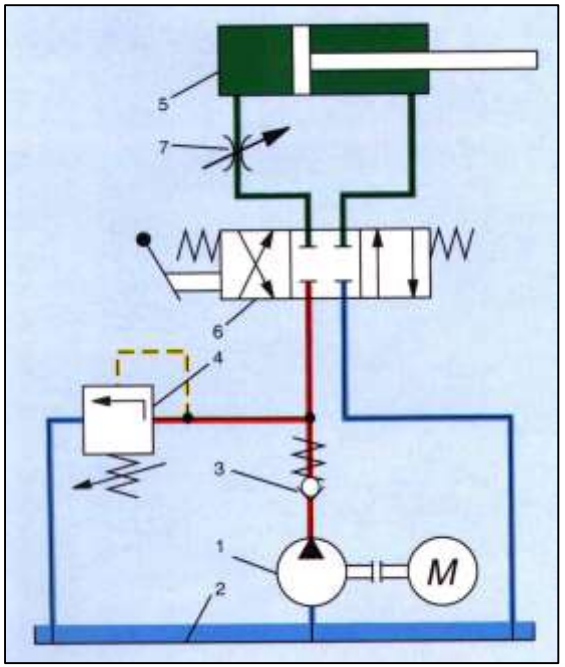


# HYDRAULIC SYSTEM



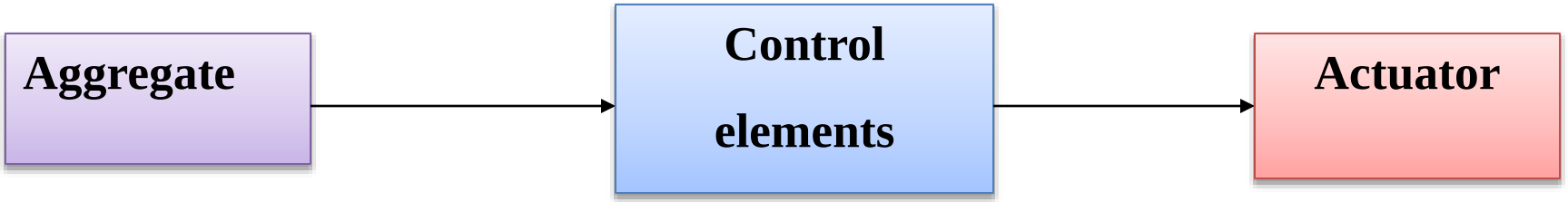
# A TYPICAL HYDRAULIC SYSTEM




1 – pump
2 – oil tank
3 – flow control valve
4 – pressure relief valve
5 – hydraulic cylinder
6 – directional control valve
7 – throttle valve

# STRUCTURE OF A HYDROSTATIC DRIVE




**Pump, motor**
**Fluid reservoir**
**Pressure relief valve**
**Filter**
**Piping**

**Valves, determining the path, pressure, flow rate of the working fluid**

**Elements doing work**

- **Linear**
- **Rotational**
- **Swinging**

**These components and their interaction is the subject of this semester**

# Fluid Power and Its Scope

- Fluid power is the technology that deals with the generation, control and transmission of forces and movement of mechanical element or system with the use of pressurized fluids in a confined system. Both liquids and gases are considered fluids. Fluid power system includes a hydraulic system (hydra meaning water in Greek) and a pneumatic system (pneuma meaning air in Greek). Oil hydraulic employs pressurized liquid petroleum oils and synthetic oils, and pneumatic employs compressed air that is released to the atmosphere after performing the work.
- the term "fluid" we refer to air or oil, for it has been shown that water has certain drawbacks in the transmission of hydraulic power in machine operation and control.
- The application of fluid power is limited only by the ingenuity of the
- designer, production engineer or plant engineer. If the application pertains to lifting, pushing, pulling, clamping, tilting, forcing, pressing or any other straight line (and many rotary)
- motions, it is possible that fluid power will meet the requirement.

# Fluid power applications

- Stationary hydraulics (remain firmly fixed in one position.)
- Machine tools and transfer lines.
- Lifting and conveying devices.
- Metal-forming presses.
- Plastic machinery such as injection-molding machines.
- Rolling machines.
- Lifts.
- Food processing machinery.
- Automatic handling equipment and robots.

# Fluid power applications Cont.

- Mobile hydraulics (move on wheels or tracks )
- Automobiles, tractors, aeroplanes, missile, boats, etc.
- Construction machinery.
- Tippers, excavators and elevating platforms.
- Lifting and conveying devices.
- Agricultural machinery.

# Industries base Application

| | |
|---|---|
| Agriculture | Tractors; farm equipment such as mowers, ploughs, chemical and water sprayers, fertilizer spreaders, harvesters |
| Automation | Automated transfer lines, robotics |
| Automobiles | Power steering, power brakes, suspension systems, hydrostatic transmission |
| Aviation | Fluid power equipment such as landing wheels in aircraft. Helicopters, aircraft trolleys, aircraft test beds, luggage loading and unloading systems, ailerons, aircraft servicing, flight simulators |
| Construction industry/equipment | For metering and mixing of concrete rudders, excavators, lifts, bucket loaders, crawlers, post-hole diggers, road graders, road cleaners, road maintenance vehicles, tippers |
| Defense | Missile-launching systems, navigation controls |
| Entertainment | Amusement park entertainment rides such as roller coasters |
| Fabrication industry | Hand tools such as pneumatic drills, grinders, borers, riveting machines, nut runners |
| Food and beverage | All types of food processing equipment, wrapping, bottling, |
| Foundry | Full and semi-automatic molding machines, tilting of furnaces, die-casting machines |
| Glass industry | Vacuum suction cups for handling |

# Industries base Application

| | |
|---|---|
| Hazardous gaseous areas | Hydraulic fracturing technologies: It involves pumping large volumes of water and sand into a well at high pressure to fracture shale and other tight formations, allowing hazardous oil and gas to flow into the well. However, hydraulic fracturing has serious environmental and water pollution related issues. |
| Instrumentation | Used to create/operate complex instruments in space rockets, gas turbines, nuclear power plants, industrial labs |
| Jigs and fixtures | Work holding devices, clamps, stoppers, indexers |
| Machine tools | Automated machine tools, numerically controlled(NC) machine tools |
| Materials handling | Jacks, hoists, cranes, forklifts, conveyor systems |
| Medical | Medical equipment such as breathing assistors, heart assist devices, cardiac compression machines, dental drives and human patient simulator |
| Movies | Special-effect equipment use fluid power; movies such as Jurassic park, Jaws, Anaconda, Titanic |
| Mining | Rock drills, excavating equipment, ore conveyors, loaders |
| Newspapers and periodicals | Edge trimming, stapling, pressing, bundle wrapping |
| Oil industry | Off-shore oil rigs |
| Paper and packaging | Process control systems, special-purpose machines for rolling and packing |
| Pharmaceuticals | Process control systems such as bottle filling, tablet placement, packaging |
| Plastic industry | Automatic injection molding machines, raw material feeding, jaw closing, movement of slides of blow molder |

# Industries base Application

| | |
|---|---|
| Press tools | Heavy duty presses for bulk metal formation such as sheet metal, forging, bending, punching, etc. |
| Printing industry | For paper feeding, packaging |
| Robots | Fluid power operated robots, pneumatic systems |
| Ships | Stabilizing systems, unloading and loading unit, gyroscopic instruments, movement of flat forms, lifters, subsea inspection equipment |
| Textiles | Web tensioning devices, trolleys, process controllers |
| Transportation | Hydraulic elevators, winches, overhead trams |
| Under sea | Submarines, under sea research vehicles, marine drives and control of ships |
| Wood working | Tree shearers, handling huge logs, feeding clamping and saw operations |

# CLASSIFICATION OF FLUID POWER SYSTEMS

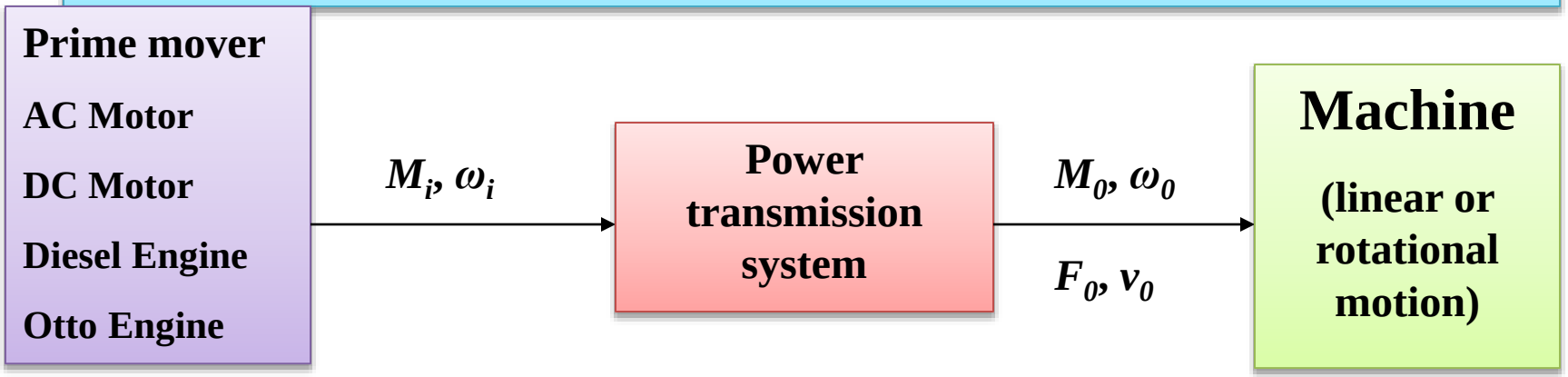
1. **Based on the control system**
   - a) **Open-loop system: no feedback**
   - b) **Closed-loop system: uses feedback**
2. **Based on the type of control (AND, NAND, OR, NOR)**
   - a) **Moving part logic (MPL)-**

     **diaphragms, disks and poppets**

     **Fluidics:- no moving parts and depend solely on interacting fluid jets**
   - b) **Electrical control (controlled by electrical devices.)**

     **programmable logic control (PLC) or microprocessor**

# POWER TRAIN




- **Mechanical power transmission:**
  - **Gears**
  - **Belt drive**
  - **Friction drive**
  - **Rigid couplings**
  - **Clutches**

**Properties:**

- Continuously variable drive is difficult
- The relative spatial position of prime mover is fixed
- If the motor is electrical (DC motor or AC motor with variable frequency), then the rotational speed can be continuously changed but they are expensive

# HYDROSTATIC & HYDRODYNAMIC SYSTEMS

- A hydrostatic system uses fluid pressure to transmit power. Hydrostatics deals with the mechanics of still fluids and uses the theory of equilibrium conditions in fluid. The system creates high pressure, and through a transmission line and a control element, this pressure drives an actuator (linear or rotational). The pump used in hydrostatic systems is a positive displacement pump. The relative spatial position of this pump is arbitrary but should not be very large due to losses (must be less than 50 m). An example of pure hydrostatics is the transfer of force in hydraulics.
- Hydrodynamic systems use fluid motion to transmit power. Power is transmitted by the kinetic energy of the fluid. Hydrodynamics deals with the mechanics of moving fluid and uses flow theory. The pump used in hydrodynamic systems is a non-positive displacement pump. The relative spatial position of the prime mover (e.g., turbine) is fixed. An example of pure hydrodynamics is the conversion of flow energy in turbines in hydroelectric power plants.

# HYDRAULIC POWER TRANSMISSION

- **Hydraulic power transmission:**

**Hydro = water, aulos = pipe**

**The means of power transmission is a liquid (pneumatic → gas)**

**Hydrodynamic power transmission:**

- **Turbo pump and turbine**
- **Power transmission by kinetic energy of the fluid**
- **Still the relative spatial position is fixed**
- **Compact units**

**Hydrostatic power transmission:**

- **Positive displacement pump**
- **Creates high pressure and through a transmission line and control elements this pressure drives an actuator (linear or rotational)**
- **The relative spatial position is arbitrary but should not be very large because of losses (< 50 m)**

✓ **A continuously variable transmission is possible**

**Most of this lecture will be about hydrostatic systems (in common language it is also called simply hydraulics)**

# HYDROSTATIC VS HYDRODYNAMIC SYSTEMS

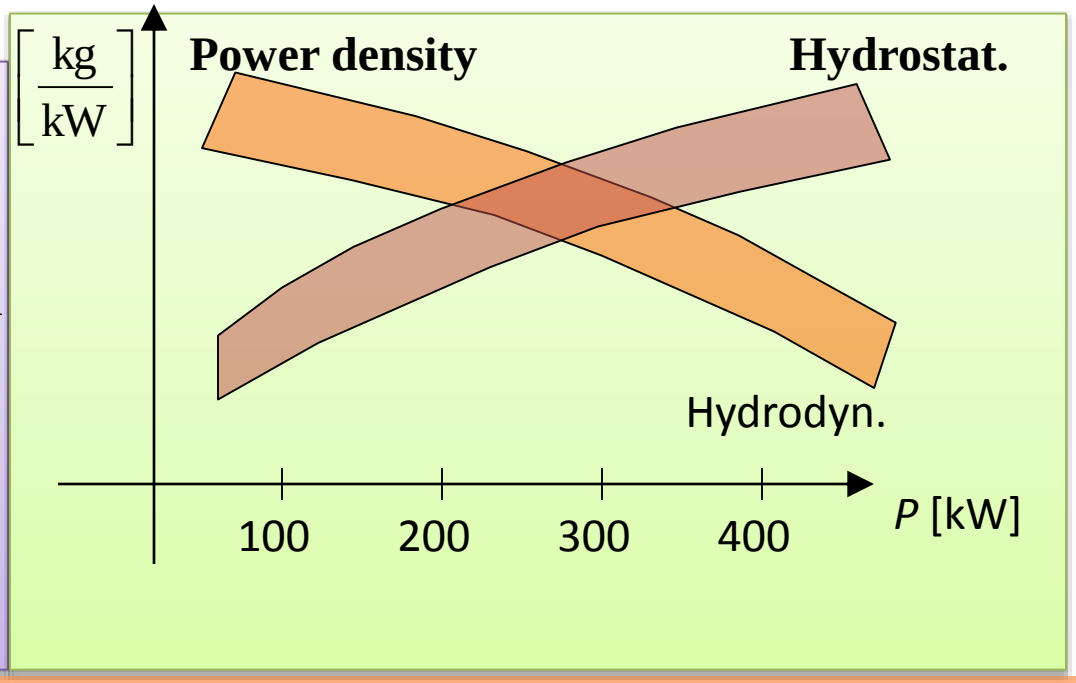
Roughly speaking:

$P = Dp \cdot Q$

Large $Q$, small $Dp$ → **hydrodynamic** transmission

Large $Dp$, small $Q$ → **hydrostatic** transmission.

But there is no general rule, depends on the task.




- Generally larger than 300 kW power hydrodynamic is more favourable.
- But for soft operation (starting of large masses) hydrodynamic is used for smaller powers either.

- ❑ Linear movement against large forces: hydrostatic
- ❑ Linear movement and stopping in exact position: also hydrostatic

# ADVANTAGES
# FLUID POWER SYSTEM

1. Fluid power systems are simple, easy to operate and can be controlled accurately
2. Multiplication and variation of forces
3. Multifunction control:
4. Low-speed torque
5. Constant force or torque
6. Economical
7. Low weight to power ratio
8. Fluid power systems can be used where safety is of vital importance

# ADVANTAGES OF HYDROSTATIC DRIVES

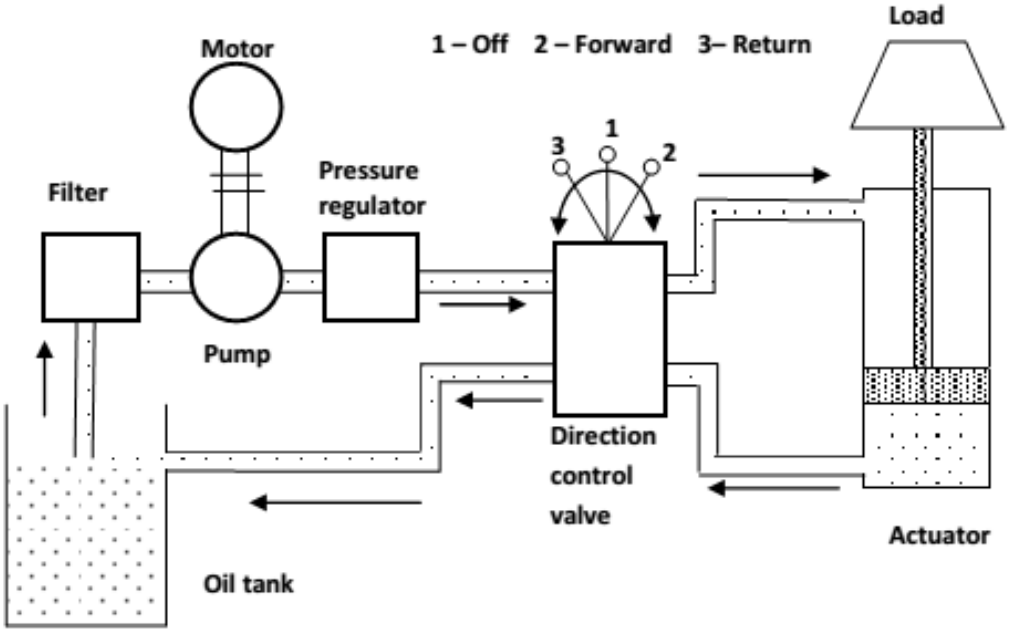
- Simple method to create linear movements
- Creation of large forces and torques, high energy density
- **Continuously variable movement of the actuator**
- Simple turnaround of the direction of the movement, starting possible under full load from rest
- Low delay, small time constant because of low inertia
- Simple overload protection (no damage in case of overload)
- Simple monitoring of load by measuring pressure
- Arbitrary positioning of prime mover and actuator
- Large power density (relatively small mass for a given power compared to electrical and mechanical drives)
- Robust (insensitive against environmental influences)

# DISADVANTAGES OF HYDROSTATIC DRIVES

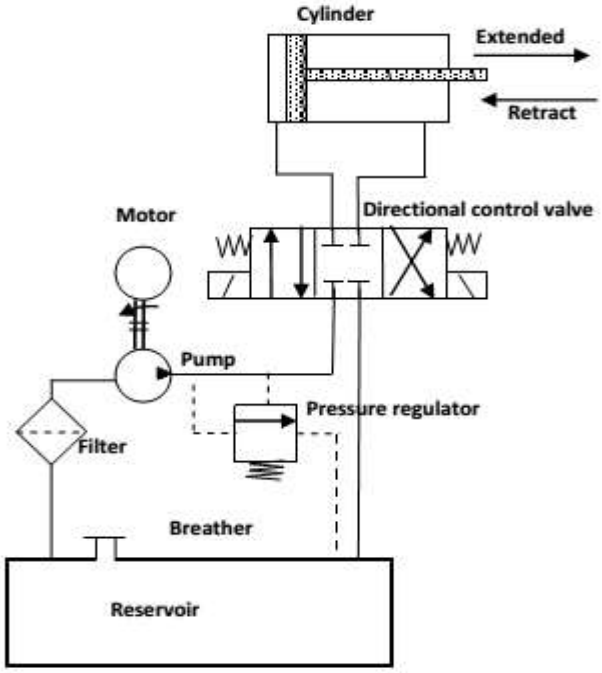
- Working fluid is necessary (leakage problems, filtering, etc.)
- It is not economic for large distances

# Basic Components of a Hydraulic System

- Hydraulic systems are power-transmitting assemblies employing pressurized liquid as a fluid for transmitting energy from an energy-generating source to an energy-using point to accomplish useful work. Figure 1.1 shows a simple circuit of a hydraulic system with basic components.




Components of a hydraulic system




Components of a hydraulic system (shown using symbols).

# HYDRAULIC FLUIDS - TASKS

**Primary tasks**:

- Power transmission (pressure and motion transmission)
- Signal transmission for control

**Secondary tasks**:

- Lubrication of rotating and translating components to avoid friction and wear
- Heat transport, away from the location of heat generation, usually into the reservoir
- Transport of particles to the filter
- Protection of surfaces from chemical attack, especially corrosion

# HYDRAULIC FLUIDS - REQUIREMENTS

- Functional
  - Good lubrication characteristics
  - Viscosity should not depend strongly on temperature and pressure
  - Good heat conductivity
  - Low heat expansion coefficient
  - Large elasticity modulus
- Economic
  - Low price
  - Slow aging and thermal and chemical stability $\Rightarrow$ long life cycle

# HYDRAULIC FLUIDS - REQUIREMENTS (CONTD.)

- Safety
  - High flash point or in certain cases not inflammable at all
  - Chemically neutral (not aggressive at all against all materials it touches)
  - Low air dissolving capability, not inclined to foam formation

- Environmental friendliness
  - No environmental harm
  - No toxic effect

# HYDRAULIC FLUID TYPES

1. Water (3%)
2. Mineral oils (75%)
3. Not inflammable fluids (9%)
4. Biologically degradable fluids (13%)
5. Electro rheological fluids (in development)

# HYDRAULIC FLUID TYPES (CONTD.)

1. Water:

- Clear water
  - Water with additives

  - Oldest fluid but nowadays there is a renaissance
  - Used where there is an explosion or fire danger or hygienic problem: Food and pharmaceutical industry, textile industry, mining

Advantages:

- No environmental pollution
- No disposal effort
- Cheap
- No fire or explosion danger
- Available everywhere
- 4 times larger heat conduction coefficient than mineral oils
- 2 times higher compression module than mineral oils
- Viscosity does not depend strongly on temperature

# HYDRAULIC FLUID TYPES (CONTD.)

1. Water:

- **Disadvantages:**

- Bad lubrication characteristics
- Low viscosity (problem of sealing, but has good sides: low energy losses)
- Corrosion danger
- Cavitation danger (relatively high vapour pressure)
- Limited temperature interval of applicability (freezing, evaporating)

Consequences: needs low tolerances and very good materials (plastics, ceramics, stainless steel) $\Rightarrow$ components are expensive

# HYDRAULIC FLUID TYPES (CONTD.)

**2. Mineral oil:**

- Without additives
- With additives
  - „Conventional" use, stationary hydraulics
  - Always mixtures of different oils, often with additives
    Additives:
    - decrease corrosion
    - increase life duration
    - improve temperature dependence of viscosity
    - improve particle transport

**Advantages:**

- Good lubrication
- High viscosity (good for sealing, bad for losses)
- Cheap

**Disadvantages:**

- Inflammable
- Environmental pollution

# HYDRAULIC FLUID TYPES (CONTD.)

## 3. Not inflammable fluids:

- - Contains water
  - - Does not contain water
  - mines, airplane production, casting, rolling, where there is explosion and fire danger
  - Water-oil emulsions (oil synthetic) or water-free synthetic liquids

Disadvantages:

- Higher density, higher losses, more inclination to cavitation
- Limited operational temperature < 55 °C
- Worse lubrication characteristics, reduction of maximum load
- Worse de-aeration characteristics
- Sometimes chemically aggressive against sealing materials

# HYDRAULIC FLUID TYPES (CONTD.)

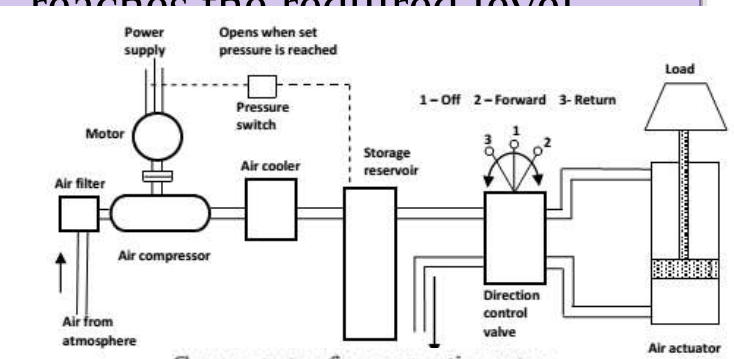
4. Biologically degradable fluids:

- Natural
- Synthetic
  - o Environmental protection, water protection
  - o Agricultural machines
  - o Mobile hydraulics

  - Characteristics similar to mineral oils but much more expensive.
  - If the trend continues its usage expands, price will drop.

# BASIC COMPONENTS OF A PNEUMATIC SYSTEM

- A pneumatic system carries power by employing compressed gas, generally air, as a fluid for transmitting energy from an energy-generating source to an energy-using point to accomplish useful work. Figure 1.3 shows a simple circuit of a pneumatic system with basic components.
- Air is drawn from the atmosphere through an air filter and raised to required pressure by an air compressor. As the pressure rises, the temperature also rises; hence, an air cooler is provided to cool the air with some preliminary treatment to remove the moisture. The treated pressurized air then needs to get stored to maintain the pressure. With the storage reservoir, a pressure switch is fitted to start and stop the electric motor when pressure falls and reaches the required level respectively.



Components of a pneumatic system.

# COMPARISON
# HYDRAULIC & PNEUMATIC SYSTEMS

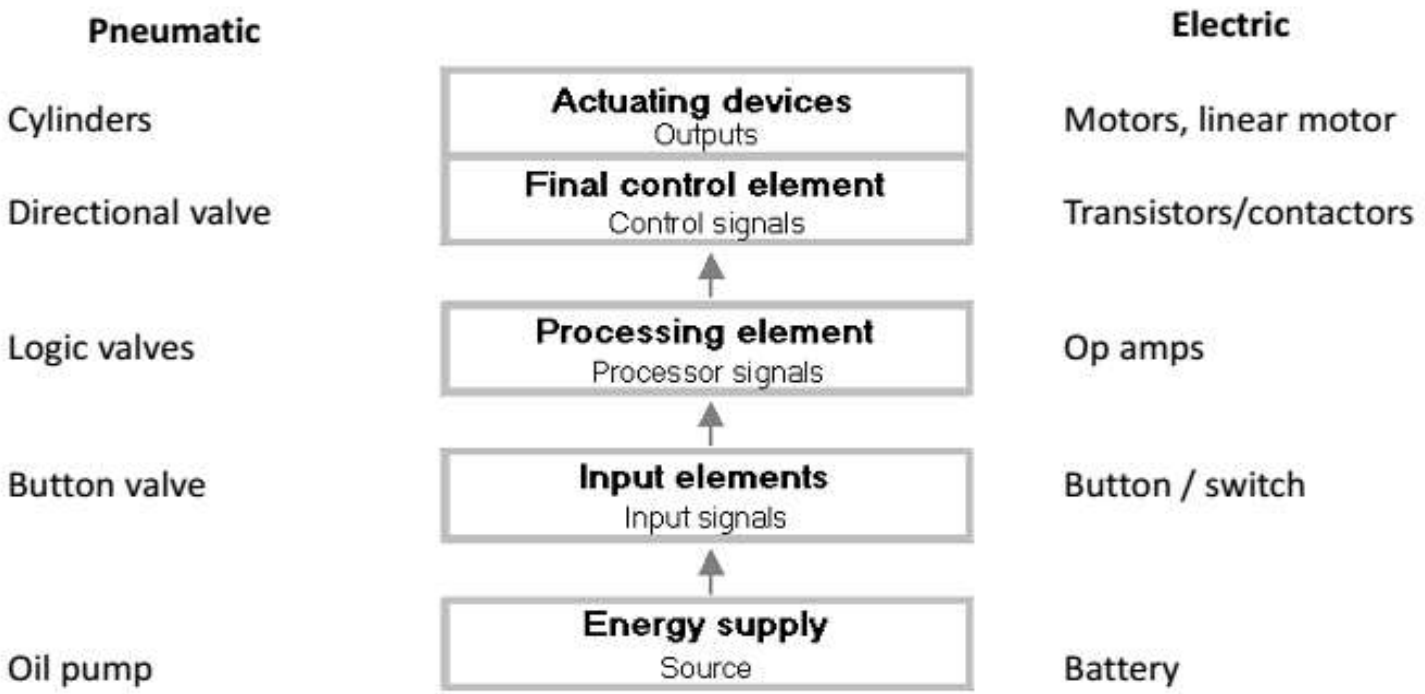
| S. No. | Hydraulic System | Pneumatic System |
|---|---|---|
| 1. | It employs a pressurized liquid as a fluid | It employs a compressed gas, usually air, as a fluid |
| 2. | An oil hydraulic system operates at pressures up to 700 bar | A pneumatic system usually operates at 5–10 bar |
| 3. | Generally designed as closed system | Usually designed as open system |
| 4. | The system slows down when leakage occurs | Leakage does not affect the system much |
| 5. | Valve operations are difficult | Valve operations are easy |
| 6. | Heavier in weight | Lighter in weight |
| 7. | Pumps are used to provide pressurized liquids | Compressors are used to provide compressed gases |
| 8. | Automatic lubrication is provided | Special arrangements for lubrication are needed |

# COMPARISON OF DIFFERENT POWER SYSTEMS

| Property | Mechanical | Electrical | Pneumatic | Hydraulic |
|---|---|---|---|---|
| Input energy source | I C engines<br>Electric motor | I C engines<br>Water/gas turbines | I C engines<br>Pressure tank | I C engines<br>Electric motor<br>Air turbine |
| Energy transfer element | Levers, gears, shafts | Electrical cables and magnetic field | Pipes and hoses | Pipes and hoses |
| Energy carrier | Rigid and elastic objects | Flow of electrons | Air | Hydraulic liquids |
| Power-to-weight ratio | Poor | Fair | Best | Best |
| Torque/inertia | Poor | Fair | Good | Best |
| Stiffness | Good | Poor | Fair | Best |
| Response speed | Fair | Best | Fair | Good |
| Relative cost | Best | Best | Good | Fair |
| Control | Fair | Best | Good | Good |
| Motion type | Mainly rotary | Mainly rotary | Linear or rotary | Linear or rotary |

# COMPARISION
# PNEUMATIC &ELECTRIC SYSTEM

## Comparison



# Future of Fluid Power Industry in India

- The automation market in India is estimated to be 1/10ththat of China. If India has to become one of the leading economies in the world, based on manufacturing, it will have to attain higher technological standards and higher level of automation in manufacturing.
- In the past 30 years, fluid power technology rose as an important industry. With increasing emphasis on automation, quality control, safety and more efficient and green energy systems, fluid power technology should continue to expand in India.
- Fluid power industry is gaining a lot of importance in Indian industry. According to a recent survey, it has shown a growth of 20% over the last 10 years and the size of market is estimated to be close to 5000 crores per annum. This makes it a sizable industry segment in India. The growth rate of this industry in India is typically about twice the growth of economy.
- The reasons for this are three-fold:
- 1. As the economy grows, this industry grows.
- 2. There is a lot of automation and conversion into more sophisticated manufacturing methods which increases the rate.
- 3. One of the interesting things happening in this industry is that India i s becoming an attractive destination for manufacturing and outsourcing of some of the products.
- So these three aspects together create a situation where the growth of this industry is twi ce the growth of GDP in India.

- The fluid power sector in India consists of many sophisticated Indian industries and partnership with number of global fluid power technology leaders that include Festo, Rexroth, Vickers, Eaton, Parker Hannifin, Norgen, , Saucer Donfos, Yuken, Siemens, Shamban, Pall and Gates, , Rotex, , Janatics, Maxwell, Wipro Dynamatic Technologies and many more.