Applications of

Hydraulics

&

Pneumatics

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Control Systems

- Electricity
- Mechanics
- Hydraulics
- Pneumatics

- It is important to remember here that each technology has its own preferred application areas.

- The next table compares typical data for the three most commonly used technologies electricity, pneumatics and hydraulics.

	Electricity	Hydraulics	Pneumatics
Leakage		Contamination	No disadvantages apart from energy loss
Environmental influences	Risk of explosion in certain areas, insensitive to temperature.	Sensitive in case of temperature fluctuation, risk of fire in case of leakage.	Explosion-proof, insensitive to temperature.
Energy storage	Difficult, only in small quantities using batteries.	Limited, with the help of gases.	Easy
Energy transmission	Unlimited with power loss.	Up to 100 m, flow rate v = 2 – 6 m/s, signal speed up to 1000 m/s.	Up to 1000 m, flow rate v = 20 – 40 m/s, signal speed 20 – 40 m/s.
Operating speed		v = 0.5 m/s	v = 1.5 m/s
Power supply costs	Low	High	Very high
	0.25 :	1 :	2.5
Linear motion	Difficult and expensive, small forces, speed regulation only possible at great cost	Simple using cylinders, good speed control, very large forces.	Simple using cylinders, limited forces, speed extremely, load-dependent.
Rotary motion	Simple and powerful.	Simple, high turning moment, low speed.	Simple, inefficient, high speed.
Positioning accuracy	Precision to ±1 µm and easier to achieve	Precision of up to ±1 µm can be achieved depending on expenditure.	Without load change precision of 1/10 mm possible.
Stability	Very good values can be achieved using mechanical links.	High, since oil is almost incompressible, in addition, the pressure level is considerably higher than for pneumatics.	Low, air is compressible.
Forces	Not overloadable. Poor efficiency due to downstream mechanical elements. Very high forces can be realized.	Protected against overload, with high system pressure of up to 600 bar, very large forces can be generated F < 3000 kN.	Protected against overload, forces limited by pneumatic pressure and cylinder diameter F < 30 kN at 6 bar.

Advantages of Hydraulics

- Transmission of large forces using small components, i.e. great power intensity
- Precise positioning
- Start-up under heavy load
- Even movements independent of load, since liquids are scarcely compressible and flow control valves can be used
- Smooth operation and reversal
- Good control and regulation
- Favorable heat dissipation

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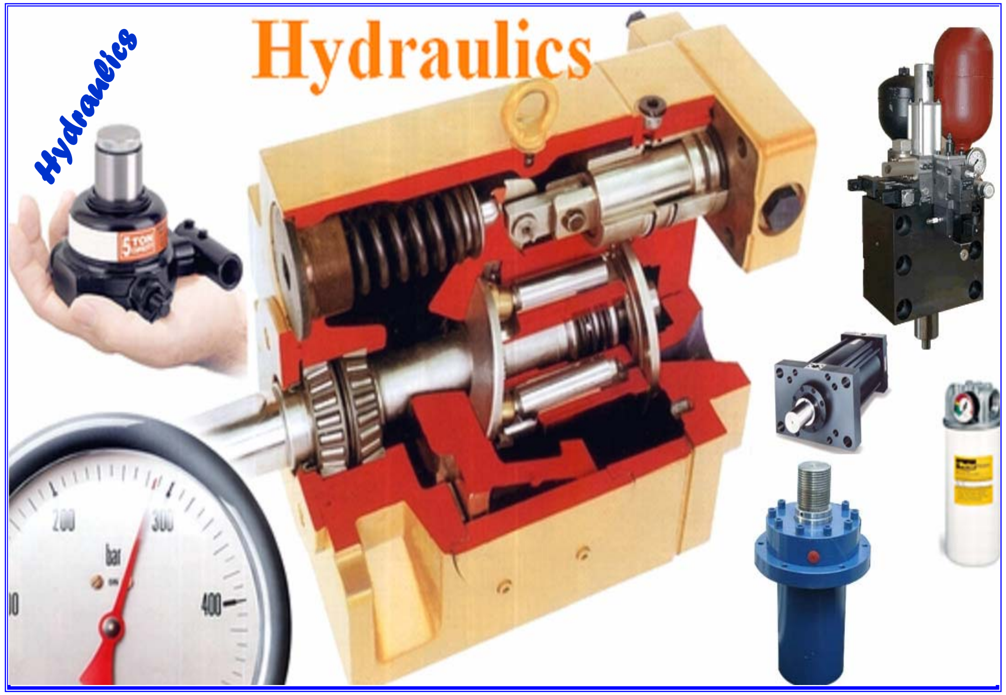
Disadvantages of Hydraulics

- Pollution of the environment by waste oil (danger of fire or accidents)
- Sensitivity to dirt
- Danger resulting from excessive pressures (severed lines)
- Temperature dependence (change in viscosity)
- Unfavorable efficiency factor

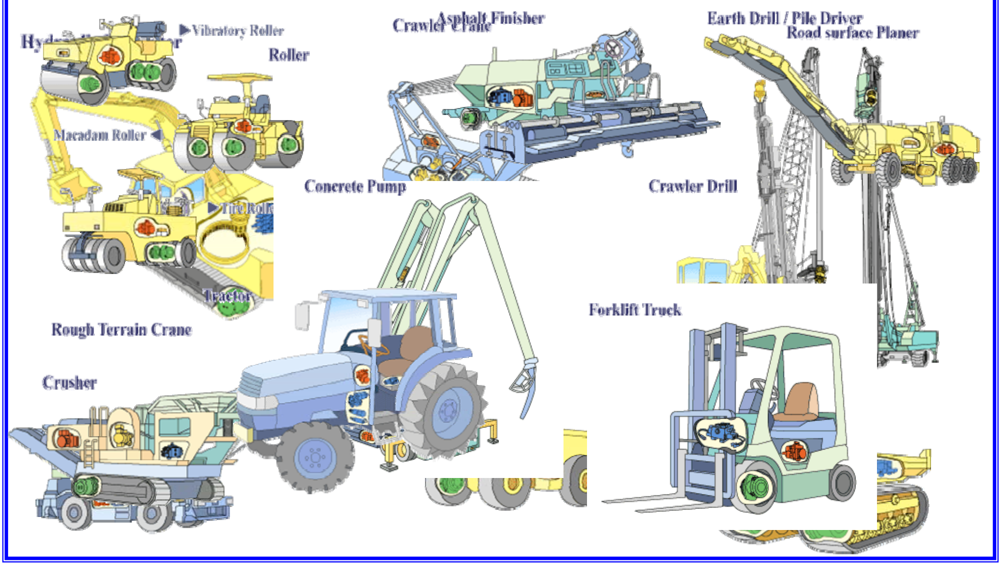


Applications : Mobile Hydraulics

Typical application fields for mobile hydraulics include:

- Construction machinery
- Tippers, excavators, elevating platforms
- Lifting and conveying devices
- Agricultural machinery

Applications : Mobile Hydraulics

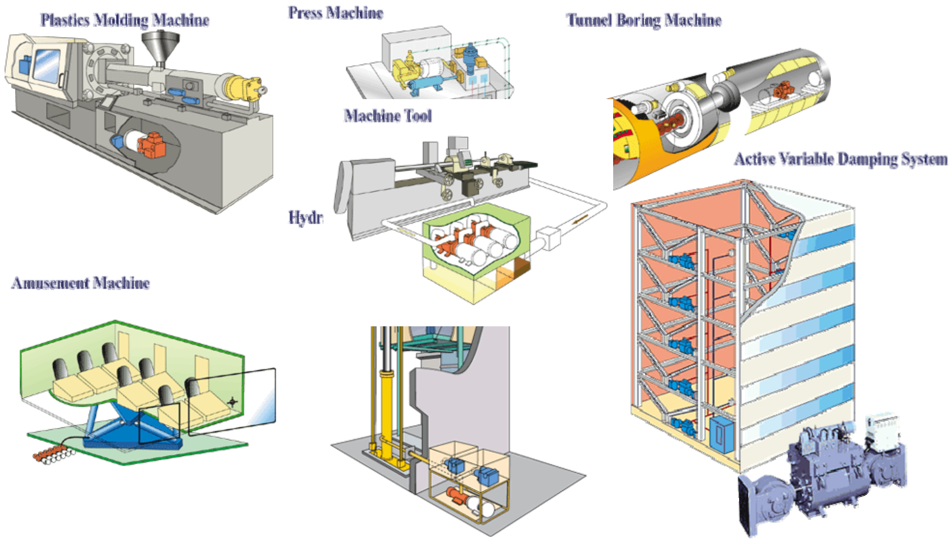


Applications : Industrial Hydraulics

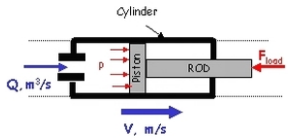
The following application areas are important for stationary hydraulics:

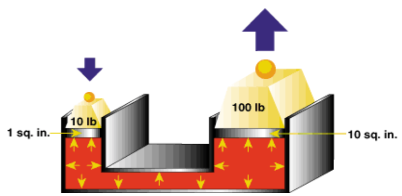
- Production and assembly machines of all types
- Transfer lines
- Lifting and conveying devices
- Presses
- Injection molding machines
- Rolling lines
- Lifts

Applications : Industrial Hydraulics



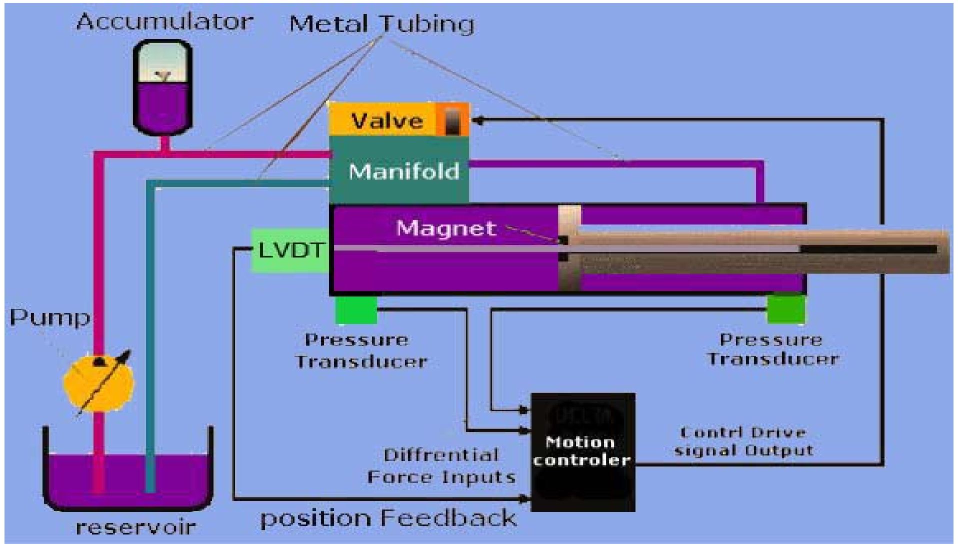
Fluid Power Theories & Physics





- Typical hydraulic system
- Pascal's Law
- Conversion of fluid pressure . . .
- Atmospheric and Gage Pressures
- Viscosity
- Continuity Equation
- Power Analogy
- Bernoulli's Equation

Typical Hydraulic System



Typical Hydraulic System

- ✓ ***Hydraulic pump:*** converts mechanical power to fluid power.
- ✓ ***Cylinder or motor:*** converts fluid power to linear or rotary mechanical power.
- ✓ ***Valves:*** control the direction, pressure and rate of flow.
- ✓ ***Filters, regulators and lubricators:*** condition the fluid.
- ✓ ***Manifolds, hose, tube, fittings, couplings, ... :*** conduct the fluid between components.
- ✓ ***Sealing devices:*** which help contain the fluid.
- ✓ ***Accumulators and reservoirs:*** which store the fluid.
- ✓ ***Instruments such as pressure switches, gauges, flow meters, sensors and transducers:*** are used to help monitor the performance of a fluid power system.

Flow Rate in System

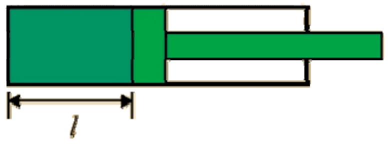
In hydraulics, the flow rate Q is measured in *gal/min* or *liter/min*. It is a measure of the displacement volume of fluid V, divided by the time t. The general formula for flow rate is

$$Q = \frac{Displacement}{time} = \frac{V}{t}$$

Consider a cylinder as shown in the figure

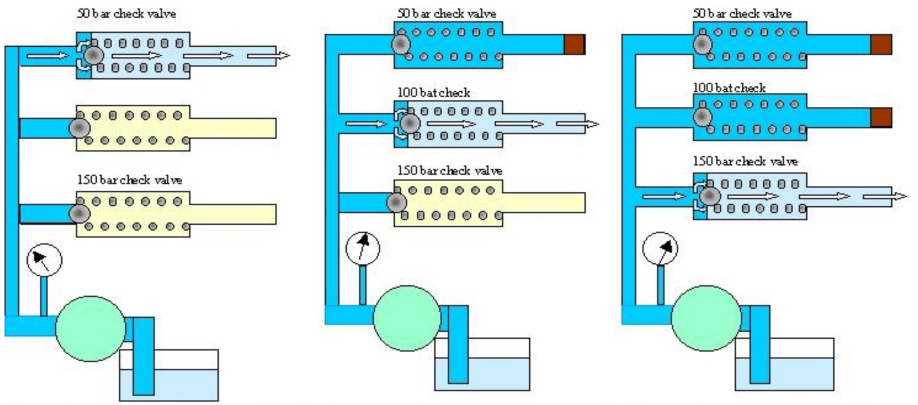
$$V = Al$$

$$Q = \frac{Al}{t}$$



where A is cross section of piston, and l is piston displacement.

Flow in Parallel Pipe Line



Oil tries flow towards path of least resistance. Here, to overcome spring tension of 50 bar, offers least resistance first. Hence oil would flow through 50 bar check valve.

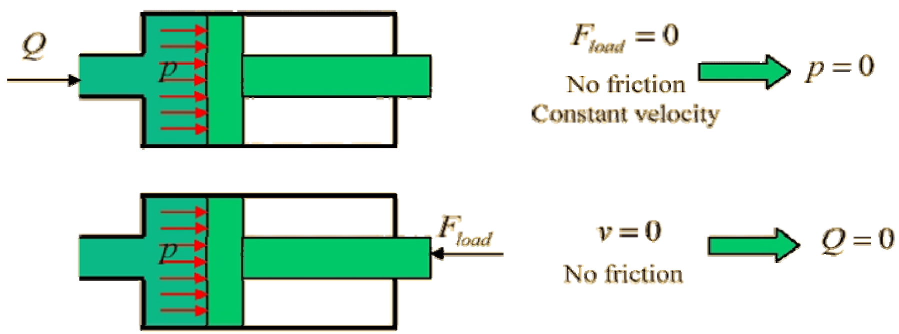
On blocking 50 bar check valve, next preference would be to overcome least resistance of the two remaining check valves. 100 bar check valve would open to allow flow through.

On blocking 50 bar as well as 100 bar check valves, oil would have to overcome resistance offered by 150 bar spring tension of the last check valve.

Effect of Pressure and Flow

Pressure causes Force in an actuator.

Flowrate causes Velocity in an actuator.



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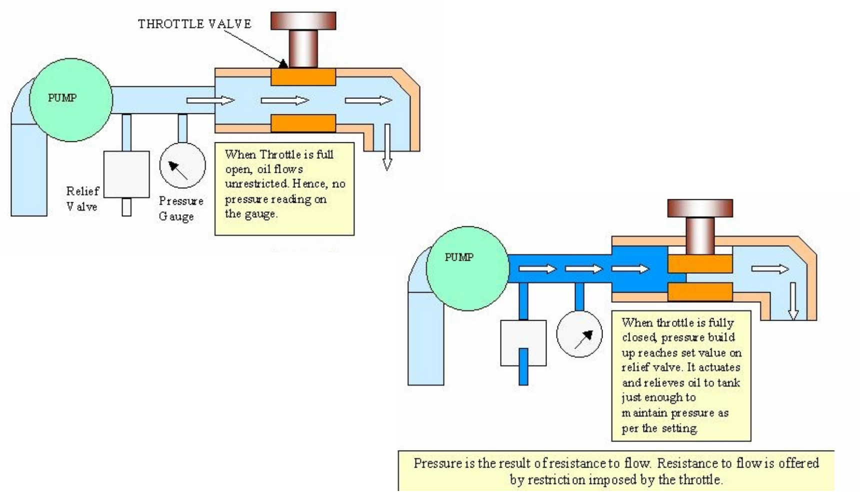
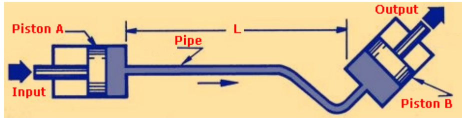
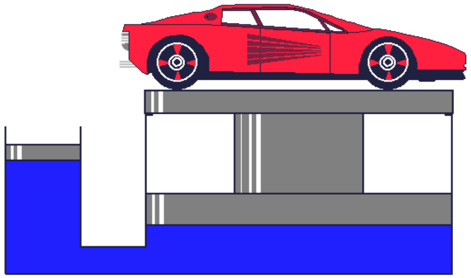
Development of Pressure



Pascal Law

- Blaise Pascal formulated the **basic law of hydraulics** in the mid 17th century





- He discovered that if a fluid in a closed system receives pressure at any one point, then this pressure is transmitted throughout the system. this is possible in all directions, even round bends and over great distances.

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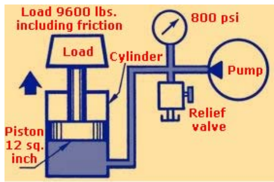
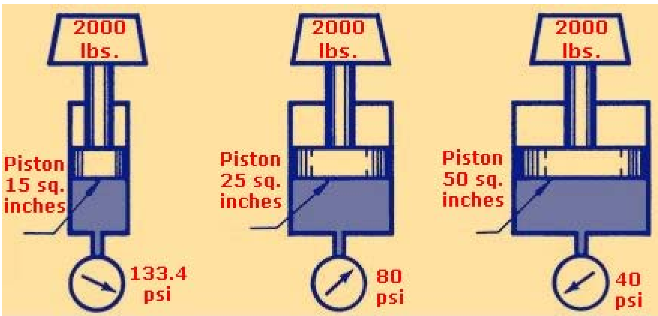
Conversion between Mechanical Force & Fluid Pressure

- **When a fluid pushes against a mechanical load, or a mechanical load pushes against a fluid column, a pressure is set up in the fluid equivalent to the mechanical load, but no more.**





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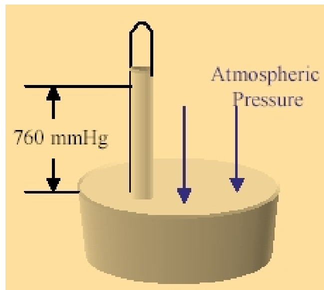
Absolute Pressure

- The relationship between the gage and absolute pressure can be represented by:

$$P_{abs} = P_{atm} + P_{gage}$$



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Viscosity

Viscosity is a measure of the resistance of the fluid to flow.

A low viscosity → oil leaks from the moving mechanical part

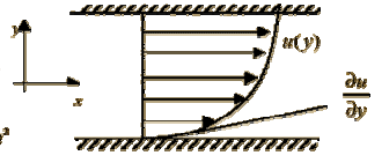
A high viscosity → loss of pressure in hydraulics pipes.

The ***absolute viscosity*** or ***dynamic viscosity*** μ *is defined as*

$$\mu = \frac{\text{shear stress}}{\text{shear rate}} = \frac{\tau}{\partial u / \partial y}$$

USC: $lb.s/ft^2$

SI: $dyn.s/cm^2$



In a Newtonian fluid the absolute viscosity is independent of the shear rate.

The ***kinematic viscosity*** ν is:

$$\nu = \frac{\mu}{\rho}$$

USC: ft^2/s

SI: m^2/s

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Continuity Equation

The continuity equation states that for steady flow in a pipeline, the weight flow rate (weight of fluid passing a given station per unit time) is the same for all locations of the pipe.

$$w_1 = w_2$$

$$\gamma_1 A_1 v_1 = \gamma_2 A_2 v_2$$

Weight Flow Rate

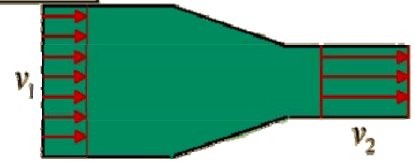
$$A_1 v_1 = A_2 v_2 = Q$$

Volume Flow rate

γ = Specific weight of fluid

A = cross section of pipe

v = velocity of fluid



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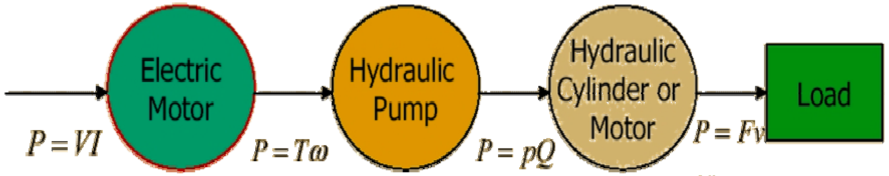
Power Analogy

Conversion of power from input electrical to mechanical to hydraulic to output mechanical in a hydraulic system will be



V = Voltage

I = Current

T = Torque

p = Pressure

F = Force

v = Velocity

ω = Angular Velocity

Q = Flowrate

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Bernoulli's Equation

In a hydraulic circuit, total potential and kinetic energy of the fluid at any location depends on pressure, flow (speed) and elevation. Change in total energy from one point to another is due to frictional forces or losses.

Assume there is no friction in the pipe, then

Type of energy at station 1:

mgZ_1

$mg\frac{P_1}{\gamma}$

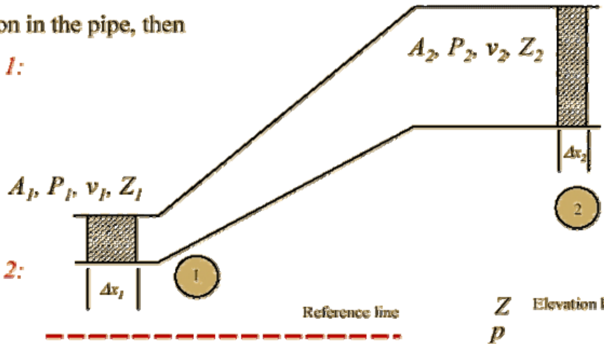
$\frac{1}{2}mv_1^2$

Type of energy at station 2:

mgZ_2

$mg\frac{P_2}{\gamma}$

$\frac{1}{2}mv_2^2$



$$Z_1 + \frac{P_1}{\gamma} + \frac{1}{2}\frac{v_1^2}{g} = Z_2 + \frac{P_2}{\gamma} + \frac{1}{2}\frac{v_2^2}{g}$$

Z Elevation head

$\frac{p}{\gamma}$ Pressure head

$\frac{v^2}{2g}$ velocity head

Bulk Module

- The characteristic value for Compressibility of fluid is the compression modulus K or B
- This modulus can be calculated in the usual pressure range using the following approximate formula:

$$K \approx V_0 \cdot \frac{\Delta p}{\Delta V} \quad \left[N/m^2 \text{ or } N/cm^2\right]$$

- V_0 = output volume
- ΔV = volume reduction