APPLIED HYDRAULICS AND PNEUMATICS

UNIT-I-FLUID POWER SYSTEM AND FUNDAMENTALS

By,

Dr.S.SURESH,

Assistant Professor,

Department of Mechanical Engineering

OBJECTIVES:

- knowledge on the applications of **Fluid Power** in **Power transmission system**. .
- To study the fundamental principles, design and operation of **hydraulic and pneumatic machines**, components and systems and their application in recent automation revolution.
- Understanding of the **fluids and components** utilized in modern industrial fluid power system.
- To design, construction and operation of **fluid power circuits**.

FLUID POWER:

- The common methods of power transmission are

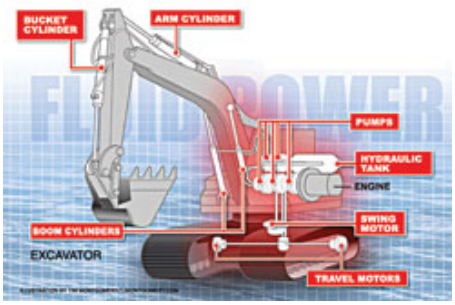
Electrical,

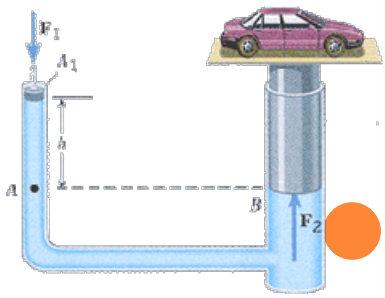
Mechanical, and

Fluid power.

FLUID POWER:

- It may be defined as the technology that deals with the generation, control and transmission of power using pressurized fluids.
- Use a fluid (liquid or gas) to transmit power from one location to another.
- Hydraulics - liquid (usually oil),
  Pneumatics - gas (usually compressed air).





ADVANTAGES OF FLUID POWER

- Easy and Accuracy to Control With the use of simple levels
- Multiplication of small forces to achieve greater forces for performing work
- It easily provides infinite and step less variable speed control which is difficult to obtain from other drives
- Accuracy in controlling small or large forces with instant reversal is possible with hydraulic systems
- As the medium of power transmission is fluid, it is not subjected to any breakage of parts as in mechanical transmission

CONT...

- The parts of hydraulic system are lubricated with the hydraulic liquid itself.
- Overloads can easily controlled by using relief valves
- Because of the simplicity and compactness the cost is relatively low for the power transmitted.
- No need of lubrication.

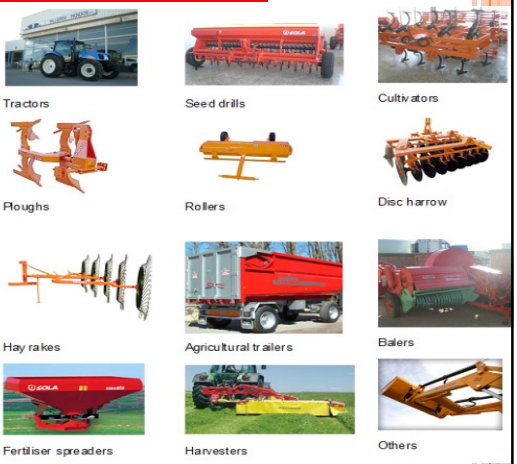
DISADVANTAGES:

1. Leakage of oil or compressed air
2. Busting of oil lines, air tanks
3. More noise in operation

APPLICATIONS OF FLUID POWER:

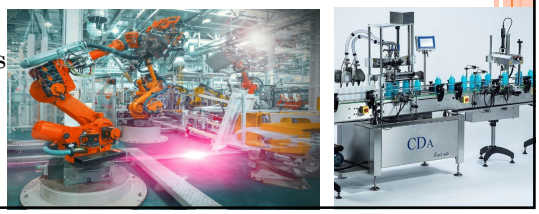
1. **Agriculture:**

Tractors and
farm equipments like ploughs, mowers, chemical sprayers, fertilizer spreaders, haybalers



2. **Automation:**

Automated transfer machines

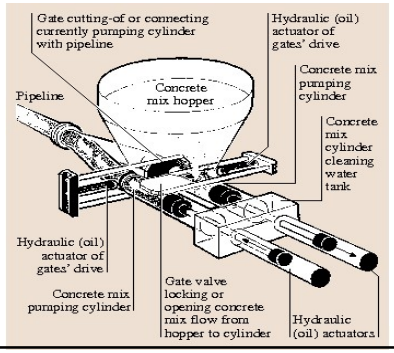


3. Aviation:

Fluid power equipments like landing wheels on aeroplane and helicopter, aircraft trolleys, aircraft engine testbeds.

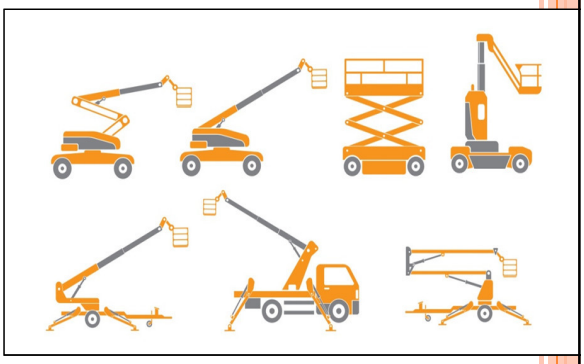
4. Building Industry:

For metering and mixing of concrete ingredients from hopper.



5. Construction Equipment:

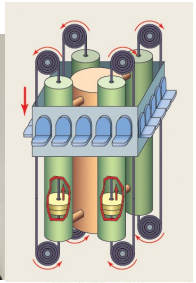
Earthmoving equipments like excavators, bucket loaders, dozers, crawlers, post hole diggers and road graders.



6. Defense :

Missile-launch systems and Navigation controls

7. **Entertainment:**
Amusement park entertainment rides like roller coasters

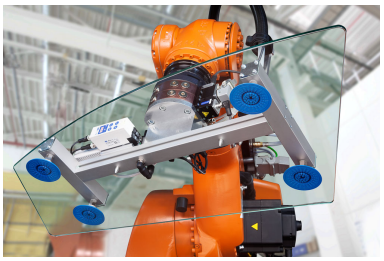


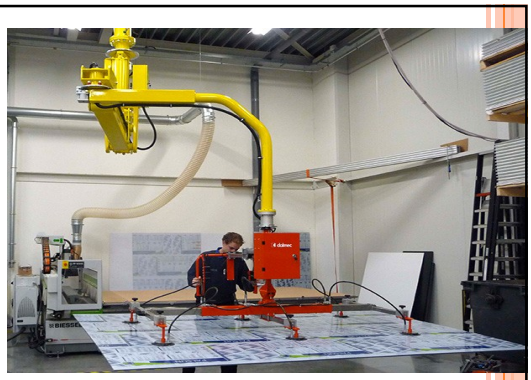
8. **Fabrication Industry:**
Hand tools like pneumatic drills, grinders, bores, riveting machines, nut runners

9. **Food and Beverage:**
All types of food processing equipment, wrapping, bottling

10. **Foundry:**
Full and semi automatic molding machines, tilting of furnaces, die casting machines

11. **Glass Industry:**
Vacuum suction cups for handling

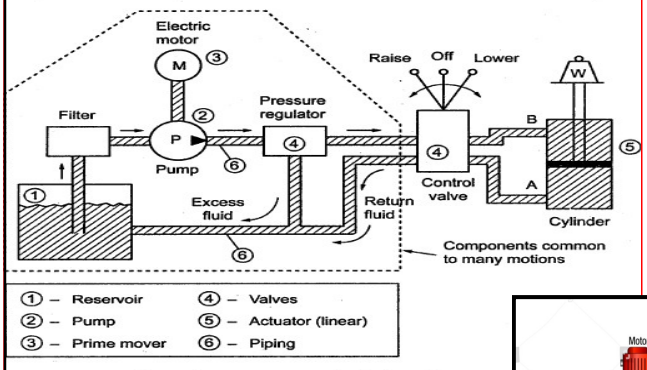




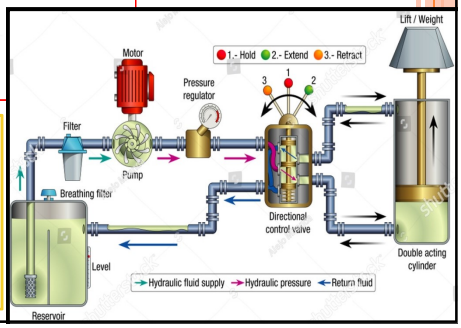
12. **Material Handling**:
Jacks, Hoists, Cranes, Forklift, Conveyor system

FLUID POWER SYSTEMS

1. HYDRAULIC POWER SYSTEMS



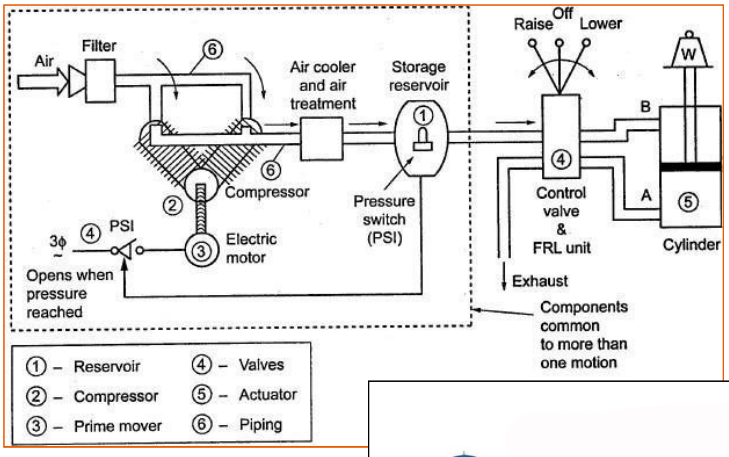
General arrangement of a hydraulic system

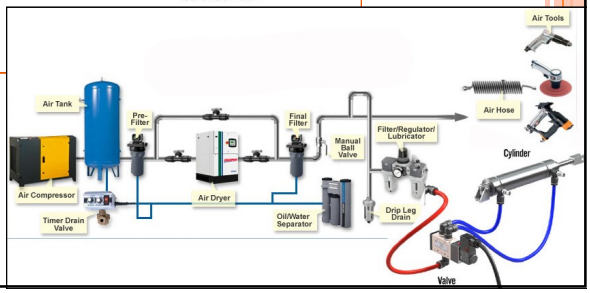


Basic Components of Hydraulic System

1. **Reservoir (Tank)**
2. **Pump**
3. **Prime mover**
4. **Valves**
5. **Actuators**
6. **Fluid-transfer piping**

2. Pneumatic Power Systems





Hydraulics Vs Pneumatics Vs Elecro-Mechanical power system System

Hydraulic System	Pneumatic System	Electro-Mechanical
Pressurized Liquid is used	Compressed Air is used	Energy is transmitted through mechanical components
Energy stored in Accumulator	Energy stored in Tank	Energy stored in Batteries
Hydraulic Valves are used	Pneumatic Valves are used	Variable Frequency drives
Transmission through Hydraulic cylinders, Actuators	Transmission through Pneumatic cylinders, Actuators	Transmission through Mechanical components like Gears, Cams

CONT…

Hydraulic System	Pneumatic System	Electro-Mechanical
More Precision	Less Precision	More Precision
Large force can be generated	Limited force can be achieved	Large force can be realized but poor in efficiency
Medium Cost	High cost	Low Cost
Dangerous and fire hazardous because of leakage	Noisy	Easy to work

FLUIDS AND THEIR PROPERTIES

FUNCTIONS OF FLUID POWER IN FLUID POWER SYSTEM

1. Transfer fluid power efficiently
2. Lubricate the moving parts
3. Absorb, Carry and Transfer heat generated within the system
4. Be compatible with hydraulic components
5. Remain stable against physical and chemical changes

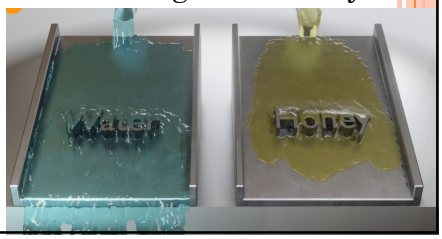
PROPERTIES OF HYDRAULIC FLUIDS

Density

- The density of a fluid is its mass per unit volume.
- Liquids are essentially incompressible
- Density is highly variable in gases nearly proportional to the pressure.

Viscosity

Viscosity is a measure of a fluid's resistance to flow. It determines the fluid strain rate that is generated by a given applied shear stress.



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Viscosity Index:

This value shows **how temperature affects the viscosity** of oil.

The viscosity of the oil decreases with increase in temperature and vice versa.

The rate of change of viscosity with temperature is indicated on an arbitrary scale called viscosity

Cohesion

- Intermolecular attraction between molecules of same liquid

Adhesion

- Attraction between molecules of liquid and molecules of solid boundary in contact with liquid.

- **Cavitation**

  Cloud of vapour bubble will form when liquid pressur drops below vapour pressure due to flow phenomenon.

- **Pour Point:**

  The lowest temperature at which the oil is able to flow easily.

- **Flash Point and Fire Point:**

  The minimum temperature at which the hydraulic fluid will catch fire and continue burning is called fire point.

- **Lubricity:**

  Wear results in increase clearance which leads to all sorts of operational difficulties including fall of efficiency.

REQUIRED QUALITIES OF GOOD HYDRAULIC OIL:

- Stable viscosity characteristics
- Good lubricity
- Compatibility with system materials
- Stable physical and chemical properties
- Good heat dissipation capability
- High bulk modulus and degree of incompressibility
- Good flammability
- Low volatility
- Good demulsibility
- Better fire resistance
- Non toxicity and good oxidation stability
- Better rust and corrosion prevent qualities
- Ready availability and inexpensive

TYPES OF HYDRAULIC FLUIDS

1. Water:

The least expensive hydraulic fluid is water.

Water is treated with chemicals before being used in a fluid power system.

Advantages: Inexpensive, Readily available, Fire resistance

Disadvantage: No lubricity, Corrosive, Temperature limitations

2. Petroleum Oils:

These are the most common among the hydraulic fluids

The characteristic are controlled by the type of crude oil used.

Naphthenic oils have low viscosity index so it is unsuitable where the oil temperatures vary too widely.

Advantages: Excellent lubricity, Reasonable cost, Non-corrosive

3. Water Glycols:

These are solutions contains 35 to 55% water, glycol and water soluble thickener to improve viscosity. Additives added to improve anticorrosion, anti wear and lubricity properties.

Advantages: Better fire resistance, Less expensive, Compatible with most pipe compounds and seals

Disadvantage: Low viscosity, Poor corrosion resistance, not suitable for high loads.

4. Water Oil Emulsions:

Water-oil mixtures.

Types: oil- in-water emulsions or water-in-oil emulsions.

The oil-in-water emulsion has water as the continuous base and the oil is present in lesser amounts as the dispersed media.

In the water-in-oil emulsion, the oil is in continuous phase and water is the dispersed media.

Advantages: High viscosity index, Oxidation stability, Film strength

Disadvantage: Depletion of water due to evaporation decreases fire resistance, Demulsification may be problem with water-in-oil emulsions.

5. Phosphate Ester:

It results from the incorporation of phosphorus into organic molecules. They have high thermal stability. They serve as an excellent detergent and prevent building up of sludge.

Advantages: Excellent fire resistance, Good lubricity, Non corrosive

Disadvantage: Not compatible with many plastics and elastomers, Expensive

FLUID POWER SYMBOLS

- Due to the rapid development of fluid-power applications, **standard fluid power symbols and specifications** are developed to facilitate communication and to provide a universal means of representing fluid-power symbols.
- Illustrate flow paths, connections and component functions.
- Basic Symbol Classifications

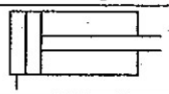
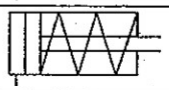
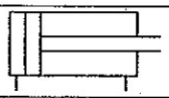
1. Pumps and motors;
2. Cylinders;
3. Directional control valves;
4. Pressure valves;
5. Flow control valves;
6. Non-return valves;
7. Operation/actuation methods;
8. Energy transmission;
9. Measuring devices;
10. Couplings, and
11. Combination of devices.

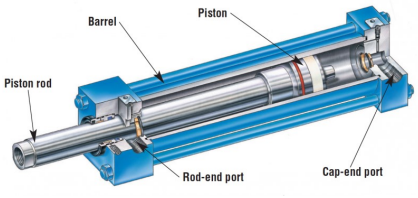
Pumps and Motors

Circle		Represents a pump, motor, or any rotary devices.
Filled triangle		Indicates the direction of flow for hydraulic fluid (system).
Unfilled triangle		Indicates the direction of flow for pneumatic fluid (system).
Line with an arrow		Indicates the variable displacement.

Description	Symbol	Diagram	
		Hydraulic	Pneumatic
Fixed displacement, unidirectional pump	S1		
Fixed displacement, bidirectional pump	S2		
Variable displacement, unidirectional pump	S3		
Variable displacement, bidirectional pump	S4		
Fixed displacement, unidirectional motor	S5		

Cylinders

Description	Symbol	Diagram
Single acting cylinder, returned by external force	S10	
Single acting cylinder, with spring return	S11	
Double acting cylinder with single piston rod	S13	



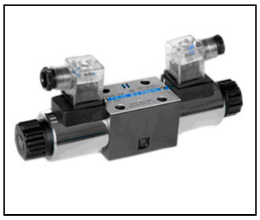
Directional control valve

To determine the path of the fluid through which it should travel within a given circuit.

Number of squares	–	Indicates the number of switching positions possible.
Arrow within square	–	Indicate the flow direction.
Lines	–	Indicate how the ports are inter-connected in the various switching positions.

Example : 4/3 valve has 4 ports and 3 switching positions.

Description	Symbol	Diagram
2/2 - way valve	S20	
3/2 - way valve	S21	
4/2 - way valve	S22	
4/3 - way valve	S23	

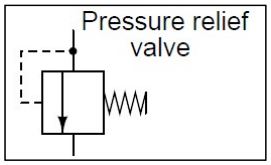


Pressure Relief Valve

- ✓ Used to product the fluid power system against over pressure.

Pressure valves are indicated using squares.

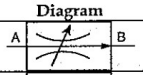
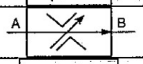
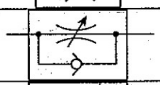
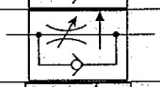
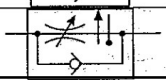
Arrow – Indicates flow direction



Flow Control Valve

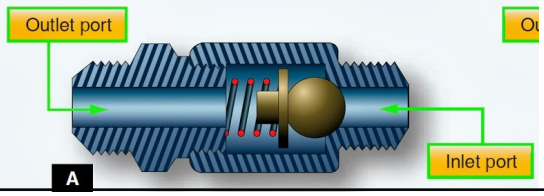
- The purpose of a flow control valve is **to regulate the flow rate in a specific portion of a hydraulic circuit**.
- In hydraulic systems, they're used to control the flow rate to motors and cylinders, thereby regulating the speed of those components.

Orifice	–	Flow control valves unaffected by viscosity.
Throttle	–	Constitute resistance in a hydraulic system.
Rectangle	–	Indicates flow control valve.
Diagonal arrow	–	Indicates that the valve is adjustable.

Description	Symbol	Diagram
Adjustable flow control valve with throttle	S27	
Adjustable flow control valve with orifice	S28	
Adjustable with bypass	S29	
Adjustable and pressure compensated with bypass	S30	
Adjustable temperature and pressure compensated	S31	

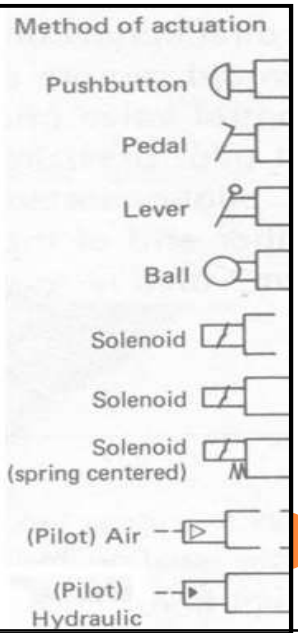
Non-return valve

Description	Symbol	Diagram
Spring loaded non-return valve	S32	
Unloaded non-return valve	S33	
Pilot controlled non-return valve	S34	
Shut-off valve	S35	



SWITCHING POSITION OF DIRECTIONAL CONTROL VALVE

- Manual Actuation
  - Push button
  - Lever
  - Pedal
- Mechanical Actuation
  - Spring
  - Ball and Cam
- Fluid (Pilot)
  - Air (pneumatic)
  - Oil (hydraulic)
- Electromagnetic (solenoid)



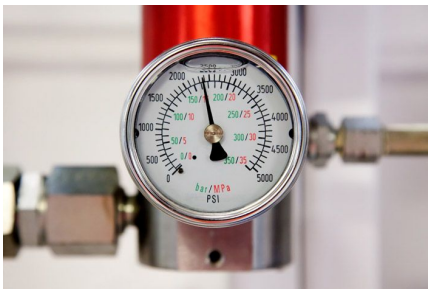
• ENERGY TRANSMISSION

Description	Diagram
Hydraulic pressure source	
Electric motor	
Non-electric drive unit	
Pressure, power, return line	
Control (pilot) line	
Drain line	
Plugged port	
Flexibtle line	
Line connection	
Line crossing	
Exhaust, continuous	
Quick-acting coupling connected with mechanically opening non-return valves	
Vented reservoir	
Pressurized reservoir	
Filter	
Cooler	
Heater	

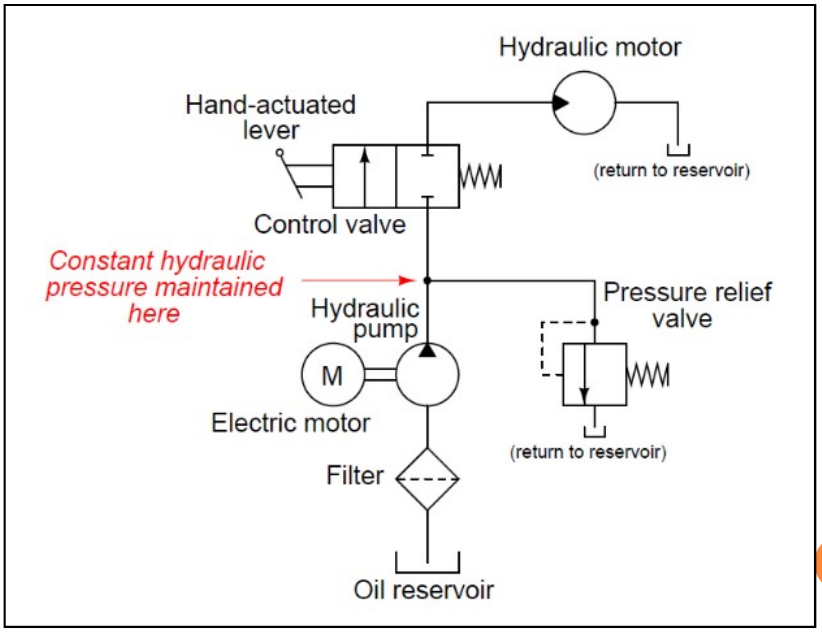
Description	Diagram
Accumulator	
Spring loaded accumulator	
Gas charged accumulator	
Weighted accumulator	

Measuring Devices

Description	Symbol	Diagram
Pressure gauge	S66	
Thermometer	S67	
Flowmeter	S68	
Filling level indicator	S69	



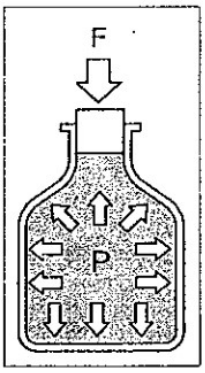
Sample Hydraulic System



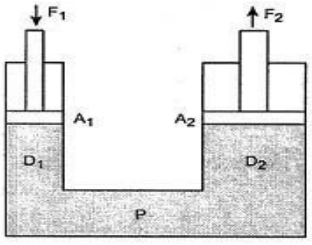
BASICS OF HYDRAULICS

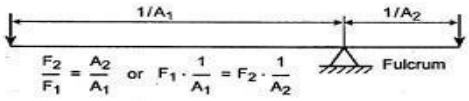
PASCALS LAW:

This law states that the pressure generated at any point in a confined fluid acts equally in all directions.



Consider two oil containers both in cylindrical form and connected together contain some oil, as shown Both the cylinders have a piston having different diameters says D_1 and D_2 respectively, where D_1 is smaller than D_2.





Principle of Bramah's press ***A hydraulic lever***

If a force F_1 is applied to the small-diameter piston, then this will produce an oil pressure P_1 at the bottom of the piston 1. Now this pressure is transmitted through the oil to the large-diameter piston 2. Because the piston 2 has a larger area (A_2), the pressure at the bottom of the piston 2 will be P_2. Now this pressure P_2 will push up the piston 2 to create an output force F_2.

We know that according to Pascal's law, $P_1 = P_2$

or $$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

or $$\boxed{\frac{F_2}{F_1} = \frac{A_2}{A_1}}$$

where A_1 = Area of the smaller piston $= \frac{\pi}{4} D_1^2$, and

A_2 = Area of the larger piston $= \frac{\pi}{4} D_2^2$.

FLUID FLOW:

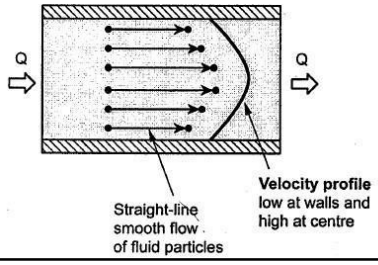
- **Laminar Flow:**

It is one in which paths taken by the individual partials **do not cross one another** and moves along well defined paths.

Characterized by the fluid flowing in **smooth layers** of lamina.

This type of flow is also known as **streamline or viscous flow**.

Examples: Flow of oil in measuring instruments



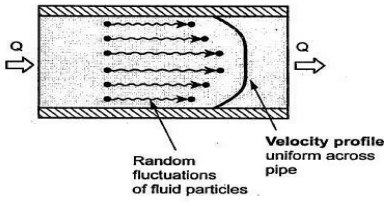
- **Turbulent Flow:**

It is that flow in which fluid particles move in a zigzag way.

Small fluctuations in the magnitude and direction of the velocity of the fluid particles.

It causes more resistance to flow, Greater energy loss and increase fluid temperature

Examples: High velocity flow in a pipe of large size



Turbulent flow

REYNOLDS NUMBER:

- Determines non-dimensional quantity
- Equation to determine whether the flow is laminar or turbulent.

$$Re = \frac{\rho V D}{\mu}$$

ρ = Density of fluid (kg/m^3)
V = Velocity of Flow (m/sec)
D = Inside diameter of pipe (m)
υ = Kinematic viscosity of fluid (m^2/sec)
μ = absolute viscosity of fluid (Ns/m^2)

1. *If Reynolds number (Re) < 2000, then the flow in pipes is* ***laminar.***
2. *If Reynolds number (Re) > 4000, then the flow in pipes is* ***turbulent.***
3. If Reynolds number is between 2000 and 4000, then the flow in pipes is unpredictable.

DARCY'S EQUATION

- The major energy losses (i.e., losses due to friction in the pipe) can be calculated by using Darcy's Equation.
- Head loss due to friction in pipes carrying fluids are derived as

$$H_L = f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)$$

where H_L = Loss of head due to friction in pipe in m,
f = Friction factor,
L = Length of pipe in m,
D = Inside diameter of the pipe in m,
V = Average velocity of liquid in m/s, and
g = Acceleration due to gravity in m/s^2.

LOSSES IN VALVES AND FITTINGS:

The loss of head in the various valves and fittings is

$$H_L = K\left(\frac{V^2}{2g}\right)$$

where K = Constant of proportionality called 'the *K-factor*'.

Valve or Fitting		K-Factor
Globe valve :	Wide open	10.0
	½ open	12.5
Gate valve :	Wide open	0.19
	¾ open	0.90
	½ open	4.5
	¼ open	24.0
Return bend		2.2
Standard tee		1.8
Standard elbow		0.9
45° Elbow		0.42
90° Elbow		0.75
Ball check valve		4.0