Hydraulics & Pneumatics

Chapter 1: Hydraulics (Pressure, Force & Energy)

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Lesson Outcome

- By the end of this lesson, student should be able to calculate force, torque, pressure, work, energy, power and flow rate

Content

- Force
- Pressure
- Pressure Measurement
- Work, Energy & Power
- Flowrate
- Torque

Mass and force

- Force –Push or pull on an object occurred because of gravitational attraction of the object.
- This force is also known as **weight**

$$F = W = mg \ [kgms^{-2} \text{ or } N]$$

- m: mass [kg]

Force and pressure

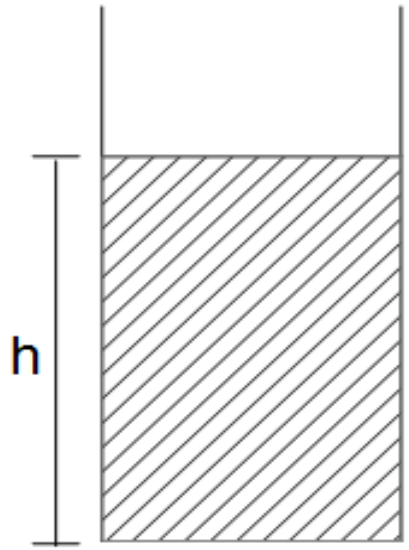
- Pressure in fluids: The force acting per unit area,

  $P = F/A$ [Pa or Nm^{-2}]
- 100 kPa = 1 atm = 1 bar
- Increase force, increase pressure.
- Decrease area, increase pressure.
- Pressure is produced when an F force on area A is given to fluid in an enclosed chamber

Pressure and weight

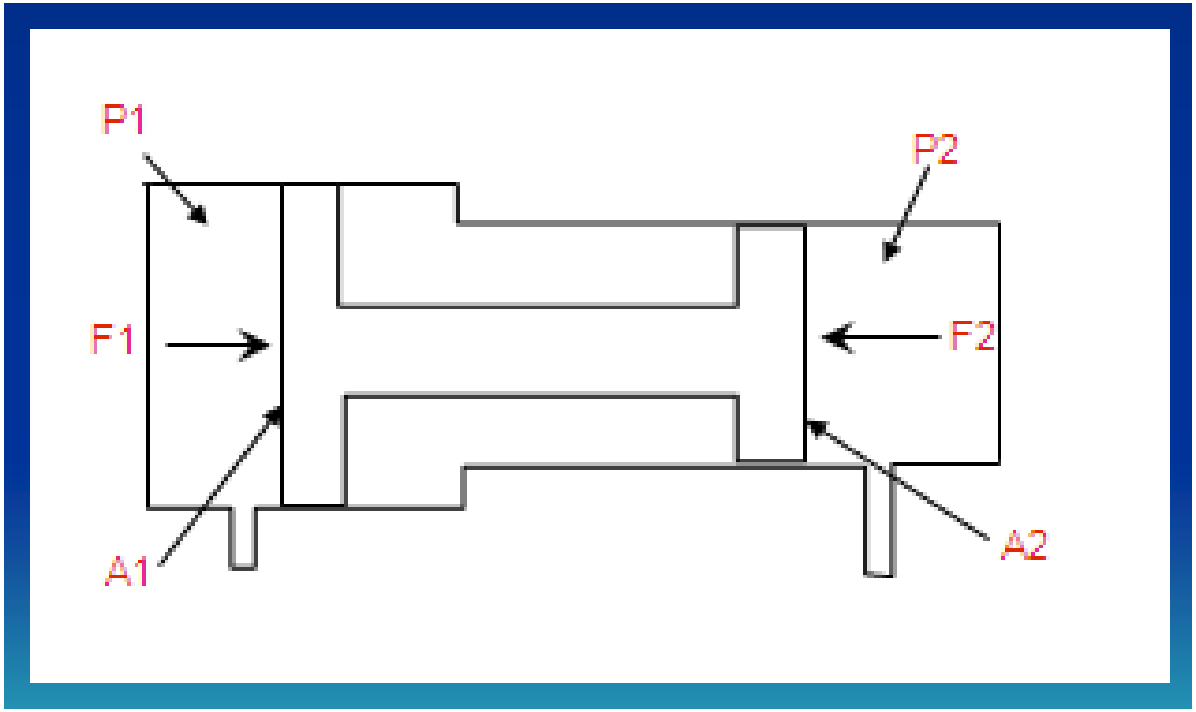
- Pressure arising in fluid from weight of fluid: Head pressure.
- Dependent of height (h) and density (ρ),

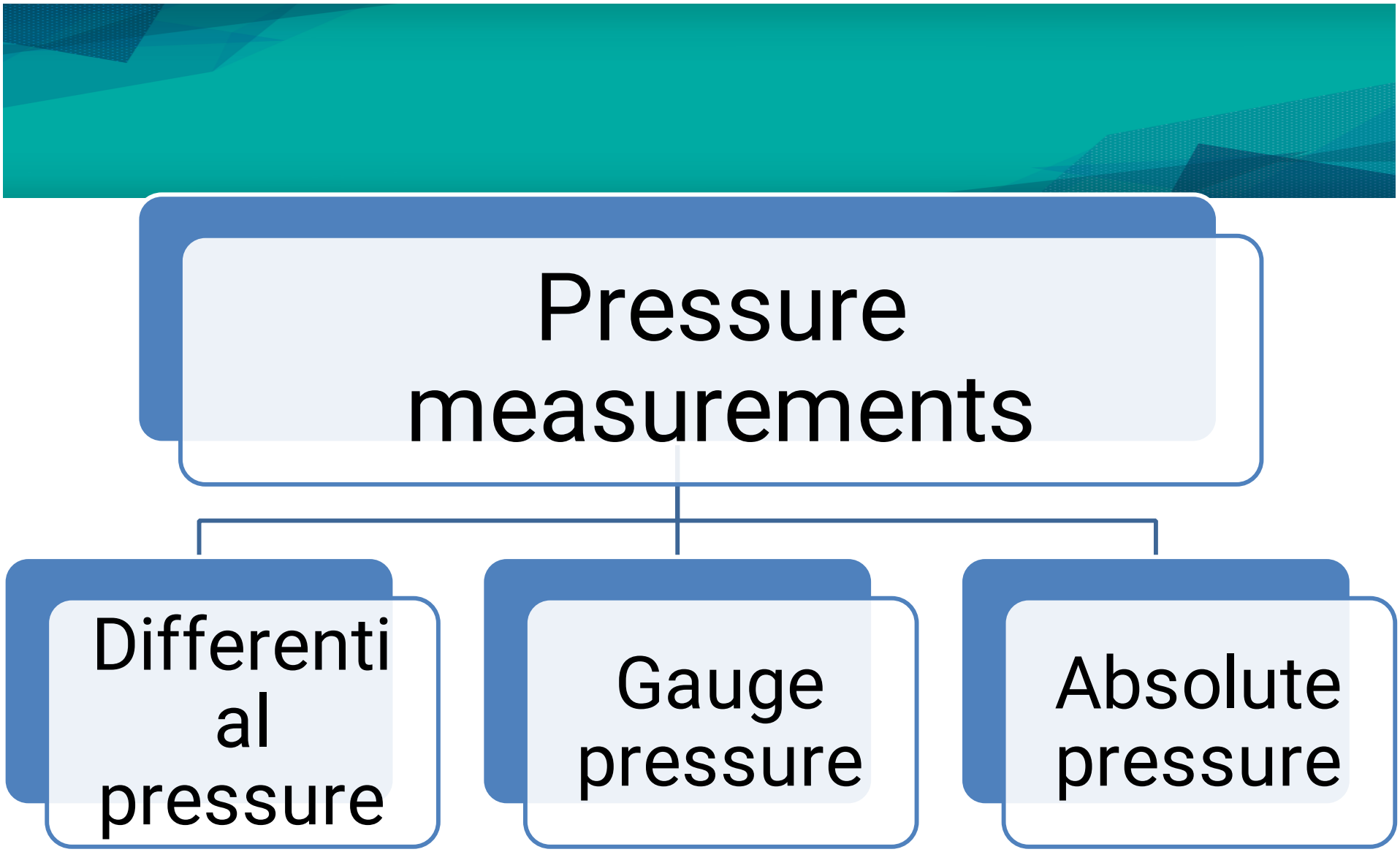
$$P = \rho g h$$



Pressure transfer

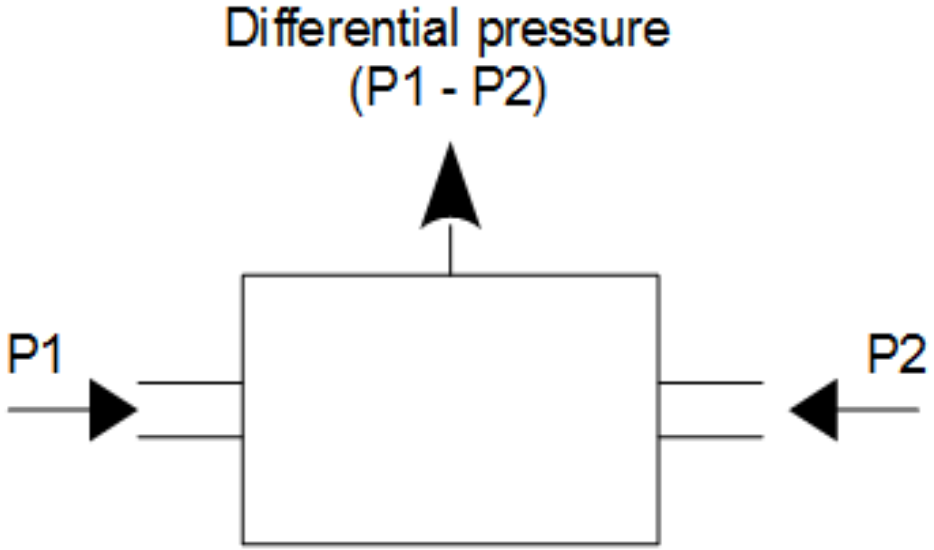
- What happen to the pressure in the system?
  - A – P1>P2
  - B – P1<P2
  - C – P1=P2




Pressure measurements
Differential pressure
Gauge pressure
Absolute pressure

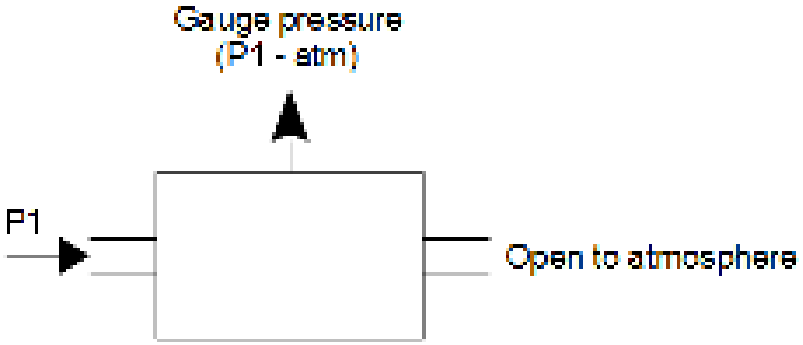
Differential pressure

- Differential pressure measure the pressure difference between two pressure ports.
- Pressure transmitter indicates P1-P2 (= ΔP)



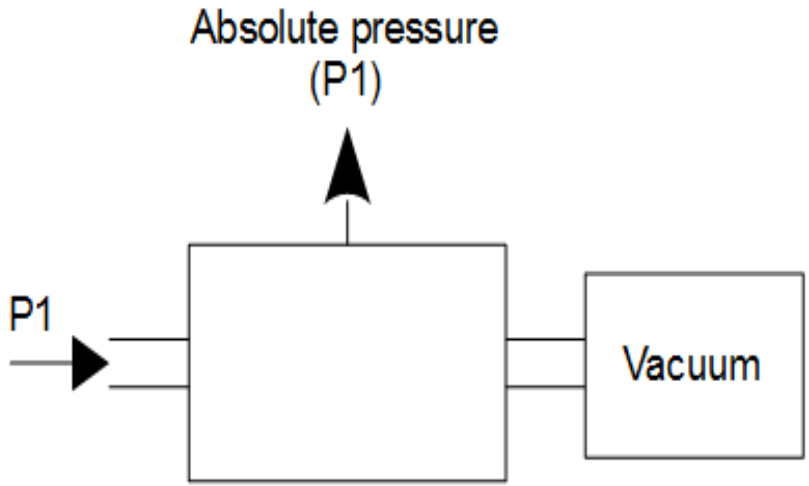
Gauge pressure

- Gauge pressure is the most common pressure measurement system used in hydraulics and pneumatics.
- One of the pressure port is open freely to the atmosphere. Pressure transmitter indicates pressure above atmospheric pressu



Absolute pressure

- Absolute pressure measure the pressure between the pressure source and vacuum.
- Important when compression of gases are considered.



Example

- A lifting is to lift a load of 15kN and is to have a system pressure of 75 bar. How large does the piston surface need to be?

Solution:

$P = F/A$

$A = F/P$

$= 15000N/(75x10^5\ Pa)$

$= 0.002\ m^2$

Work, Energy & Power

- Work (W) refers to the energy that transferred to move an object with a force within a particular distance (s),

  $W = F \times s$ [J or Nm]

- Power : Rate of work,

  Power = W/t (time) [Js^{-1} or Watt]

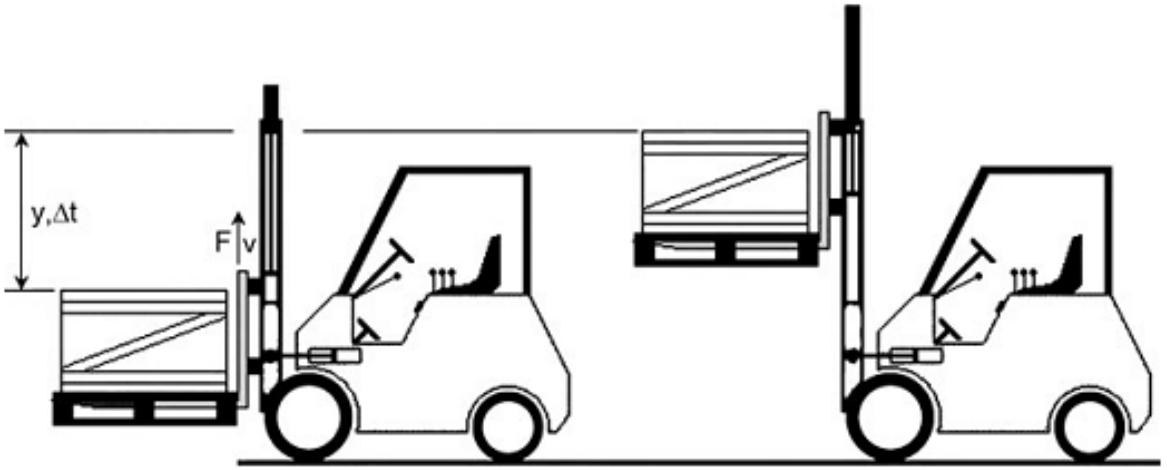
- 1 kW = 1.34 Hp
- Given Flow rate (Q) = Volume [m^3]/t [s],

Derive Power = P × Q

- Prove that Power = P × Q = W/t

Work, Energy & Power

- The energy and power conversion from hydraulic to mechanical (or vice versa) can be explained using this example. A forklift need to lift and move a load F for distance y i



Source: Rabie (2009)

Rabie, M.G. (2009), Fluid Power Engineering, McGrawHills, Singapore.

Work, Energy & Power

- The work done by the forklift is:

  $W=Fy$

- While, the delivered power is the work divided by the time taken to complete the work.

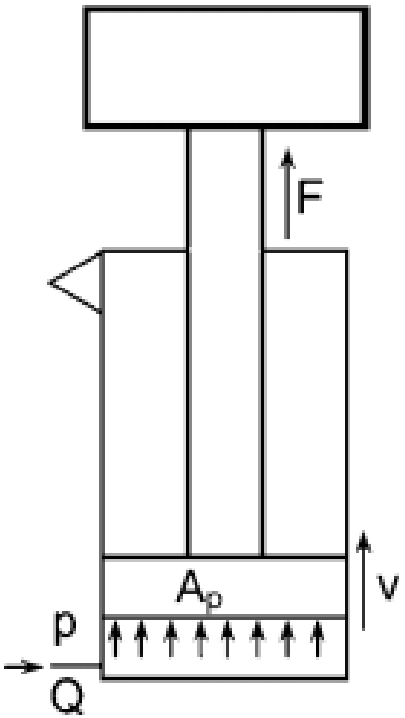
  $N = W/\Delta t = Fy/\Delta t$

- Meanwhile, the term $y/\Delta t$ is equivalent to the lifting speed, $v = y/\Delta t$. Therefore

  $N = Fv$

Flowrate

- The force in the hydraulic cylinder can be simply calculated by $F = pA_p$.
- The oil volume entered the cylinder to lift the load F in Δt time, is $V = A_p y$.
- Then, the flow rate Q is the fluid volume that flow in Δt time.



$$Q = \frac{V}{\Delta t} = \frac{A_p y}{\Delta t}$$

Flowrate

- The term ($y/\Delta t$) can be replaced with speed v.

  $Q = A_p v$

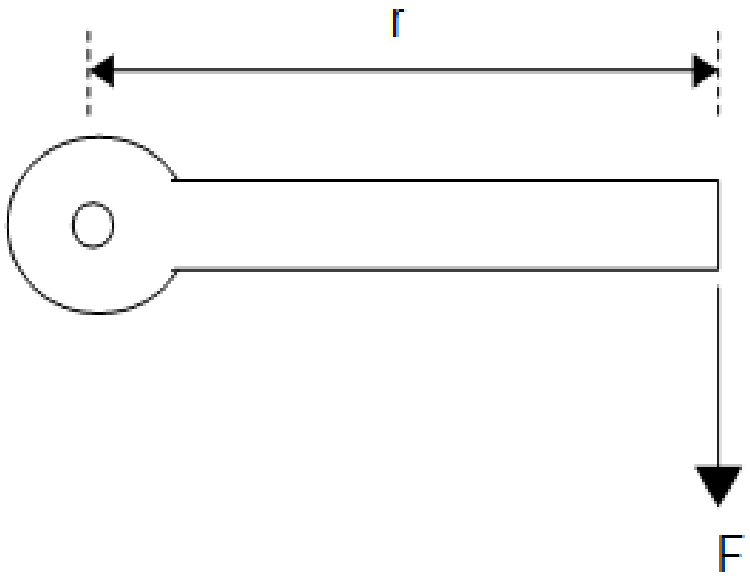
- Assuming an ideal cylinder, then the hydraulic power inlet to the cylinder is

  $N = Fv = pA_pQ/A_p = Qp$

Torque

- Torque (T) is a rotary force, a product of force (F) and the effective radius (r),

$$T = F \times r$$



Lesson Summary

- In this lesson, we have learn how to:
  - calculate force,
  - torque,
  - pressure,
  - work,
  - energy,
  - power and flow rate

  In hydraulic system

References

- Esposito A, 2013, Fluid Power with Applications, 7th Ed., Prentice Hall
- Parr, A. (2002). Hydraulics and Pneumatic: A Technician's and Engineer Guide. 2ed. Butterworth Heinemann.
- Rabie, M.G. (2009), Fluid Power Engineering, McGrawHills, Singapore.