Instrumentation-Sensors (what)

- Introduction: principles and fundamentals of Process Measurement and Instrumentation
- Pressure Measurement
- **Flow Measurement**
- Level Measurement
- Temperature Measurement
- Sensors

Flow Measurement

Commonly Used Flow Measuring Devices

Dirrerential Pressure (Head) Type

- Orifice plate
- Venturi tube
- Flow Nozzles
- Elbow
- Pitot Tube
- Variable Area (Rotameter)
- Wedge Meter
- V-Cone

Masse Type: Measures Direct Masse Flow

- Coriolis
- Thermal

Velocity Type

- Magnetic
- Ultrasonic
- Turbine
- Votrex

Open Channel Type

- Weir
- Parshall Flume

Other Types

- Positive Displacement
- Target

What is a fluid?

- A substance in the liquid or gas phase is referred to as a **fluid.**
- **Fluid:** A substance that flows, deforms, and changes shape when subject to a force, or stress.
- t has no fixed shape, but adapts its surface to the shape of its container.
- In solids stress (Contrainte) is proportional to *strain (Déformation)*, but in fluids stress is proportional to *strain rate*. When a constant shear force is applied, a solid eventually stops deforming, at some fixed strain angle, whereas a fluid never stops deforming and approaches a certain rate of strain.

Flow Measurement-Terms

- **Density**

  A measure of mass per unit of volume (Kg/m^3)

- **Specific Gravity**

  The specific gravity of a fluid, designated as SG, is defined as the ratio of the density of the fluid to the density of water at some specified temperature.

- **Compressible Fluid**

  Fluids (liquids, gases), where the volume changes with respect to changes in the pressure. These fluids experience large changes in density due to changes in pressure.

- **Non-compressible Fluid**

  Fluids (Generally liquids) which resist changes in volume as the pressure changes. These fluids experience little or no change in density due to pressure changes.

Flow Measurement-Terms

- **Linear**

  Transmitted output in directly proportional to the flow input.

- **Square Root**

  Flow is proportional to the square root of the measured value.

- **Beta Ratio (d/D)**

  Beta Ratio is the ratio between the line inner diameter to bore size of the orifice. The flow coefficient is found to be stable between beta ratio of 0.2 to 0.7 below which the uncertainity in flow measurement increases.

- **Pressure Head**

  Pressure head in fluid mechanics is the pressure exerted by a liquid column on the base of the container. It is represented as the height of the liquid column. Pressure head is also called static head or static pressure

Flow Measurement-Units

Flow Rate Conversions						
	To Convert to					
Given Value	***gpm***	***gph***	***l/min***	***m^3/hr***	***cm^3/min***	***ft^3/min***
gpm	1	gpm × 60	gpm × 3.785	gpm × 0.2271	gpm × 3785	gpm × 0.1337
gph	gph × 0.01667	1	gph × 0.06309	gph × 0.003785	gph × 63.09	gph × 8.022
l/min	l/min × 0.2642	l/min × 15.85	1	l/min × 0.06	l/min × 1000	l/min × 0.0353
m^3/hr	m^3/hr × 4.403	m^3/hr × 264.2	m^3/hr × 16.67	1	m^3/hr × 16,667	m^3/hr × 0.5886
cm^3/min	cm^3/min × 0.0002642	cm^3/min × 0.01585	cm^3/min × 0.001	cm^3/min × 0.00006	1	cm^3/min × 0.0000353
ft^3/min	ft^3/min × 7.479	ft^3/min × 0.1247	ft^3/min × 28.31	ft^3/min × 1.699	ft^3/min × 28,312	1

gpm=gallons per minute, **gph** = gallons per hour

Flow Measurement-Units

Problem 1: Compute the flow rate of fluid if it is moving with the velocity of 20 m/s through a tube of diameter 0.03 m.

Answer:

Velocity of fluid flow v =20m/s

Diameter of pipe d=0.03m

Area of cross-section of the pipe, $A = \frac{\pi}{4}d^2$

A={(3.14)/4}(0.03)(0.03)

A =(0.785)(0.0009)

A $= 0.000706m^2$

Flow rate is given by Q = vA=(20)(0.000706)

Q= $0.014139m^3/s$

PHYSICAL PROPERTIES

The most important factors affecting fluid flow are the properties of the fluid:

- ✓ Density,
- ✓ Specific gravity,
- ✓ Viscosity,
- ✓ The Reynolds number describing the type of flow,
- ✓ and the compressibility of the fluid.

Density and Specific Gravity

- ***Density*** is mass per unit volume. Common units of density are grams per cubic centimeter (g/cm^3). Density varies with changes in temperature.

- **Specific gravity** is the ratio of the density of a fluid to the density of a reference fluid. For liquids, the reference fluid is usually water. For gases, the reference fluid is usually dry air.

Viscosity

Dynamic viscosity is the resistance to flow of a fluid and has units of centipoise (cP). (1 Ns/m^2 = 1 Kg/ms = 10 P = 1000 cP)

Kinematic viscosity is the ratio of dynamic viscosity to fluid density and has units of centistokes (cS). (1 m/s^2 = 10000 St = 10 cSt)

The viscosity of many commercial fluids, like oils, is commonly specified as an allowable range at a certain temperature

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

ν	Kinematic viscosity
η	Dynamic viscosity
ρ	Density of fluid handled

Typical Liquid Viscosities

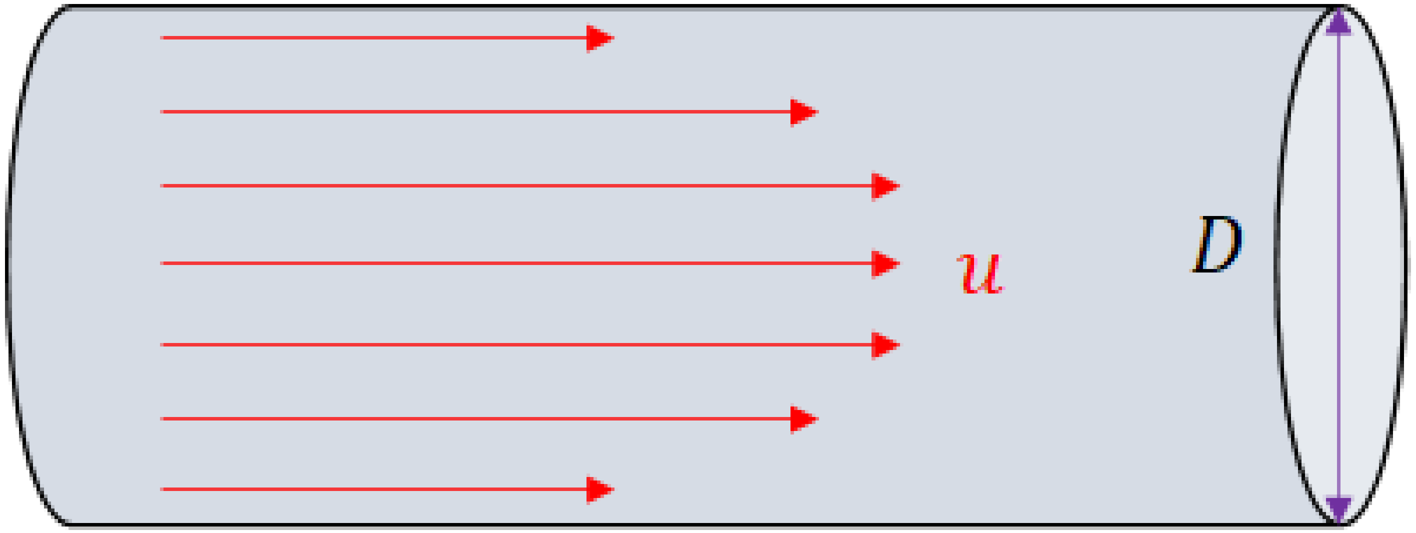
	Specific Gravity, SG	Absolute Viscosity, Centipoise	Kinematic Viscosity, Centistokes
Water	1.0	0.98	0.97
Gasoline	0.71	0.48	0.67
Ethylene Glycol	1.1	20	18
SAE 30 Motor Oil	0.91	96 (100°F)	106 (100°F)
No. 6 Fuel Oil	0.88	850 (68°F) 335 (122°F)	966 (68°F) 379 (122°F)
95% Sulfuric Acid	1.84	26.6	14.5
25% Sodium Chloride	1.2	2.9	2.4
Acetic Acid	1.05	1.2	1.15
Glycerin	1.3	1000	770
Acetone	0.79	0.33	0.42
n-Propyl Alcohol	0.80	2.2	2.75
Corn Oil	0.93	26.5 (130°F)	28.7 (130°F)
Molasses	1.43	430 to 7000 (100°F)	300 to 5000 (100°F)
Freon	1.33	0.20	0.15

*at room temperature unless otherwise noted

Figure 18-2. Liquid viscosities vary over a wide range.

Reynolds Number

A **Reynolds number** is the ratio between the inertial forces moving a fluid and viscous forces resisting that movement. It describes the nature of the fluid flow.



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

Reynolds Number

Problem 1- Calculate Reynolds number, if a fluid having viscosity of 0.4 Ns/m^2 and relative density of 900 Kg/m^3 through a pipe of 20 mm with a velocity of 2.5 m.

Solution 1 – Given that,

Viscosity of fluid μ

$$\mu = \frac{0.4Ns}{m^2}$$

Density of fluid ρ

$$\rho = 900Kg/m^2$$

Diameter of the fluid

$$L = 20 \times 10^{-3} m$$

$$R_e = \frac{\rho VL}{\mu}$$

$$= \frac{900 \times 2.5 \times 20 \times 10^{-3}}{0.4}$$

$$= 112.5$$

Laminar Vs turbulent flow

- At low velocities, fluids flow through pipes in a regular manner with no vertical mixing across the wave front. This is termed **laminar flow (Re<2000)**.
- At high fluid velocities, eddy currents are formed which lead to random mixing throughout the flow cross-section. This is called **turbulent flow (Re>4000)**. The velocity at which the transition between laminar and turbulent flow occurs is related to viscosity

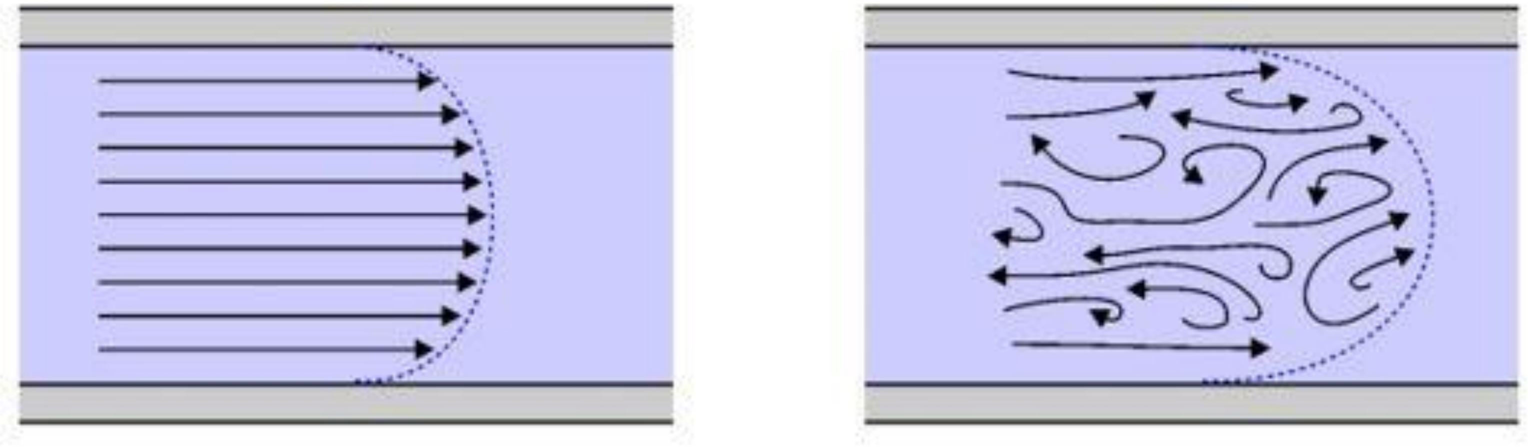
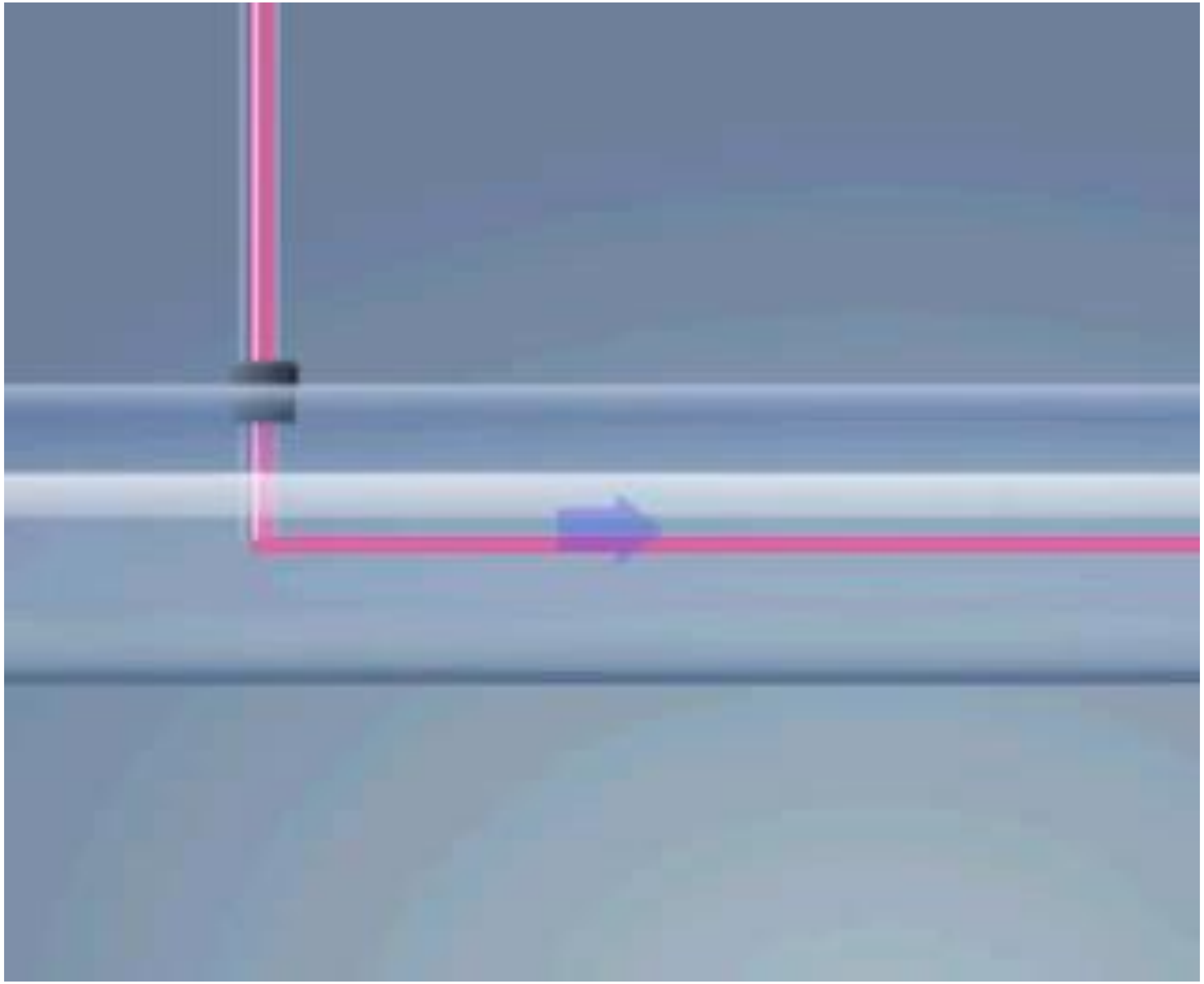


Figure 1 Laminar flow (left) and turbulent flow (right)

Laminar Vs turbulent flow

https://youtu.be/xmNcHsvEDRE

Laminar Vs turbulent flow



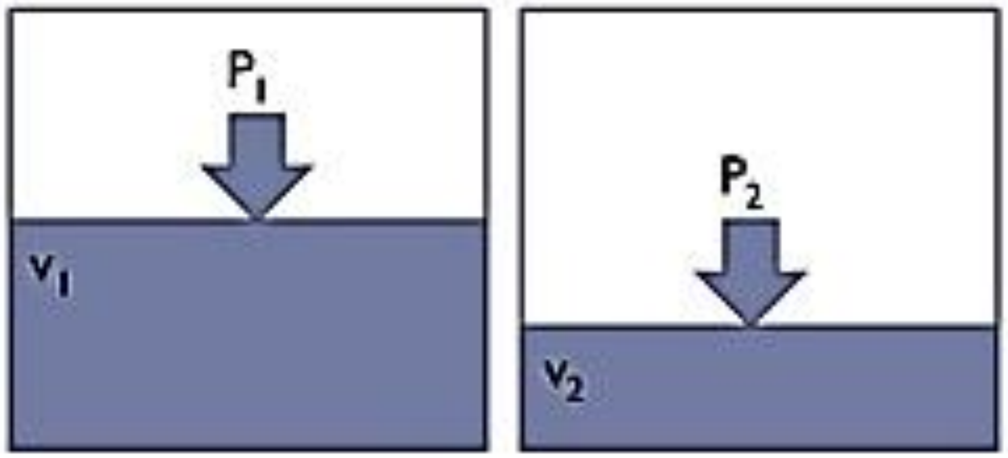
https://youtu.be/pae5WrmDzUU

Good to Remenber

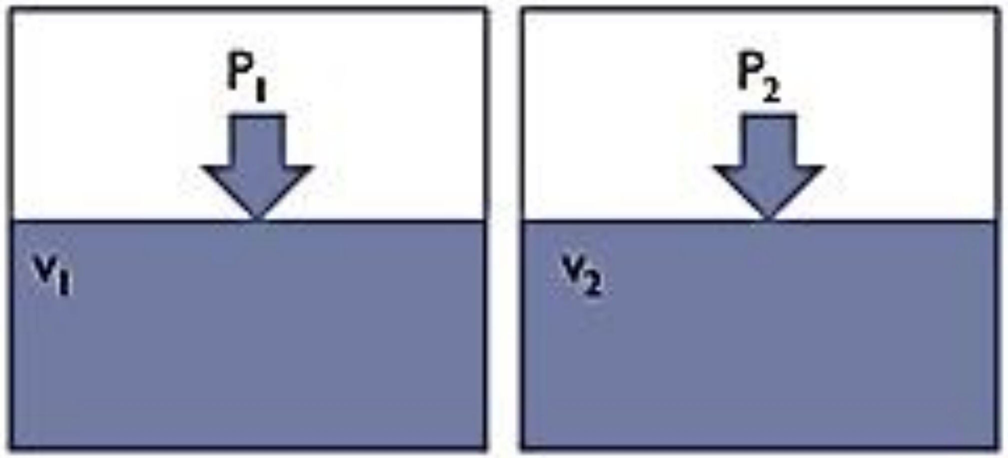
Many flowmeters require **turbulent flow** and specify Reynolds numbers **above 10,000** to ensure that turbulent flow is the prevailing condition.

Compressibility

- A **compressible fluid** is a fl uid where the volume and density change when subjected to a change in pressure.
- An **incompressible fluid** is a fl uid where there is very little change in volume when subjected to a change in pressure.



Compressible fluid



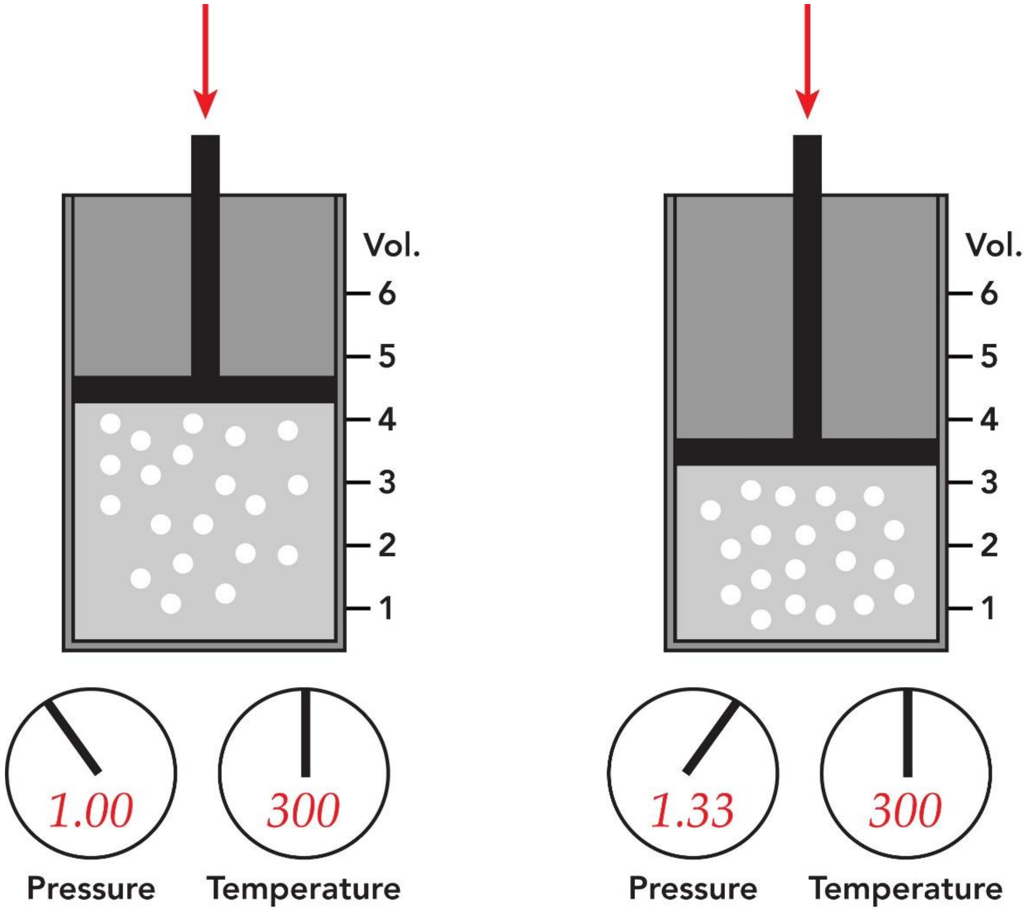
Incompressible fluid

Flowing Conditions

A ***flowing condition*** is the pressure and temperature of the gas or vapor at the point of measurement.

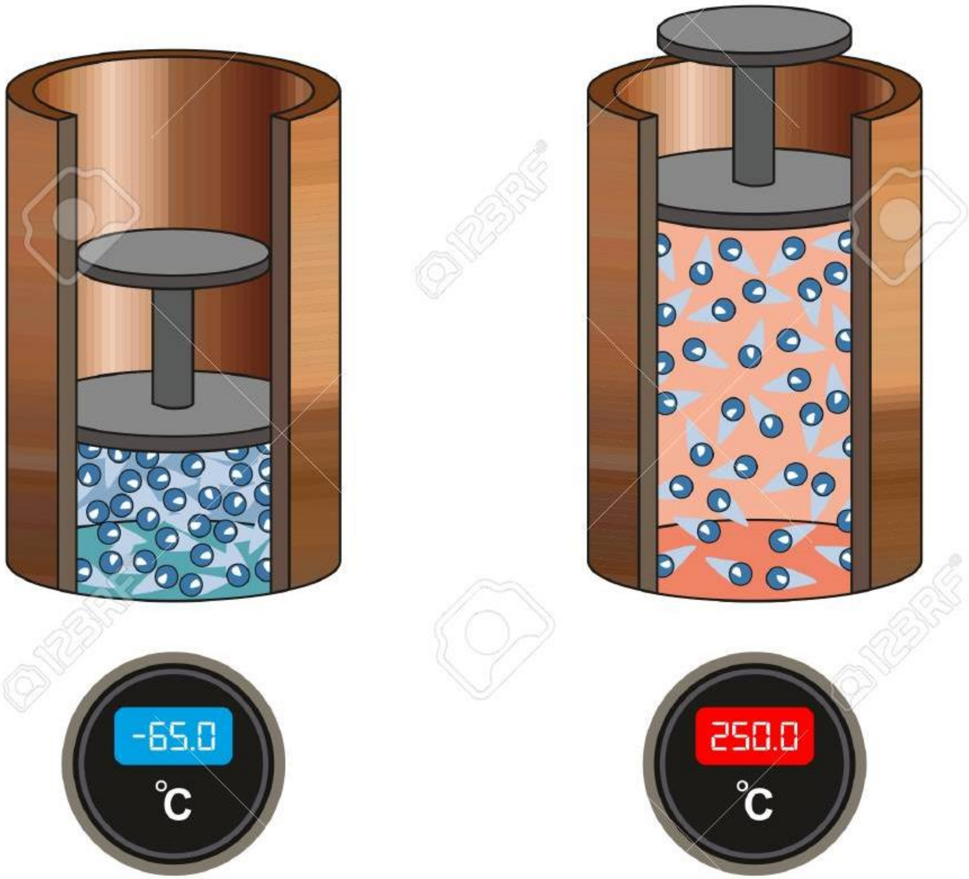
GAS LAWS

Boyle's Law for Compressing a Gas at Constant Temperature



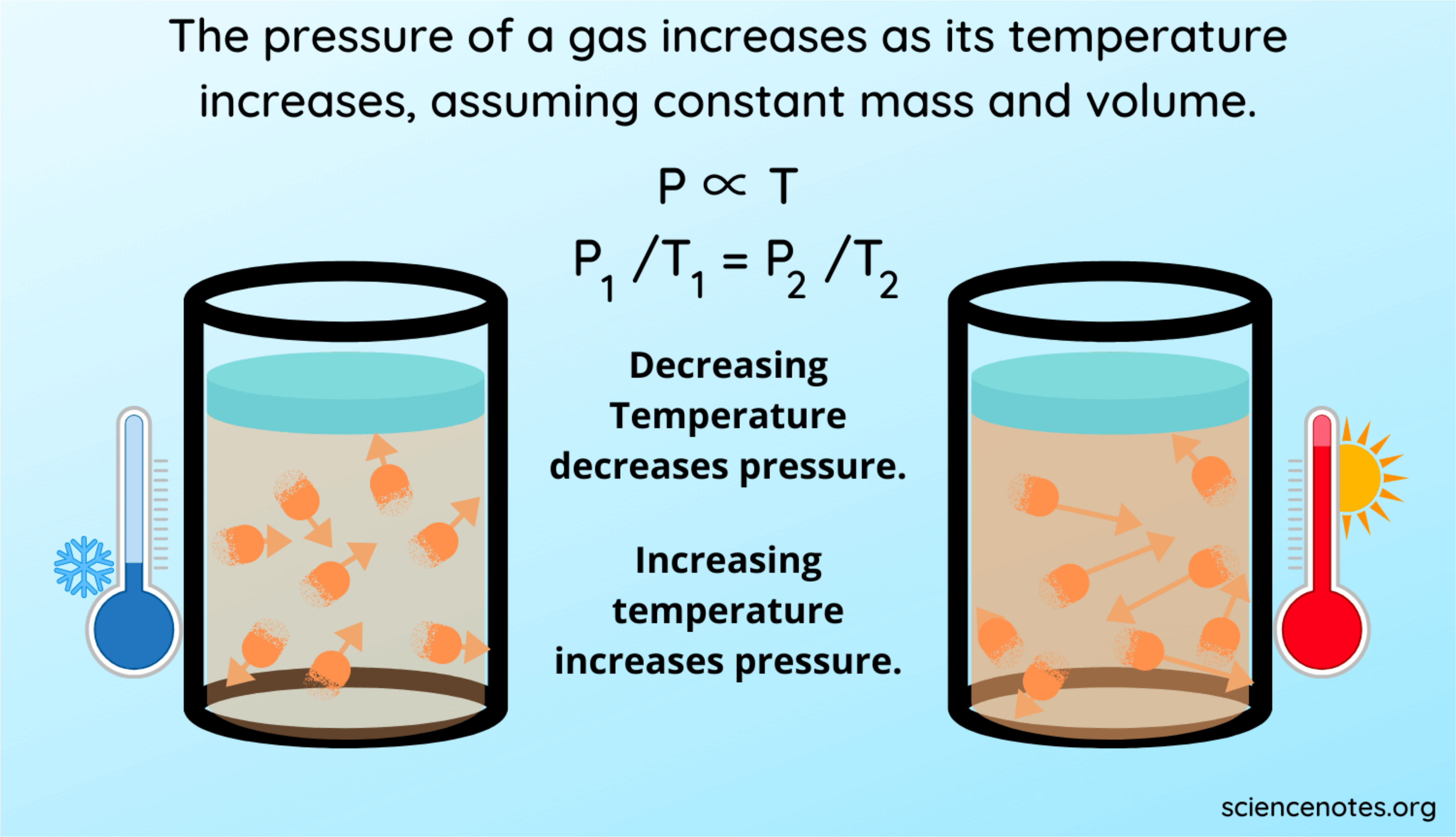
$$pV = k$$

Charles' Law for Heating a Gas at Constant Pressure

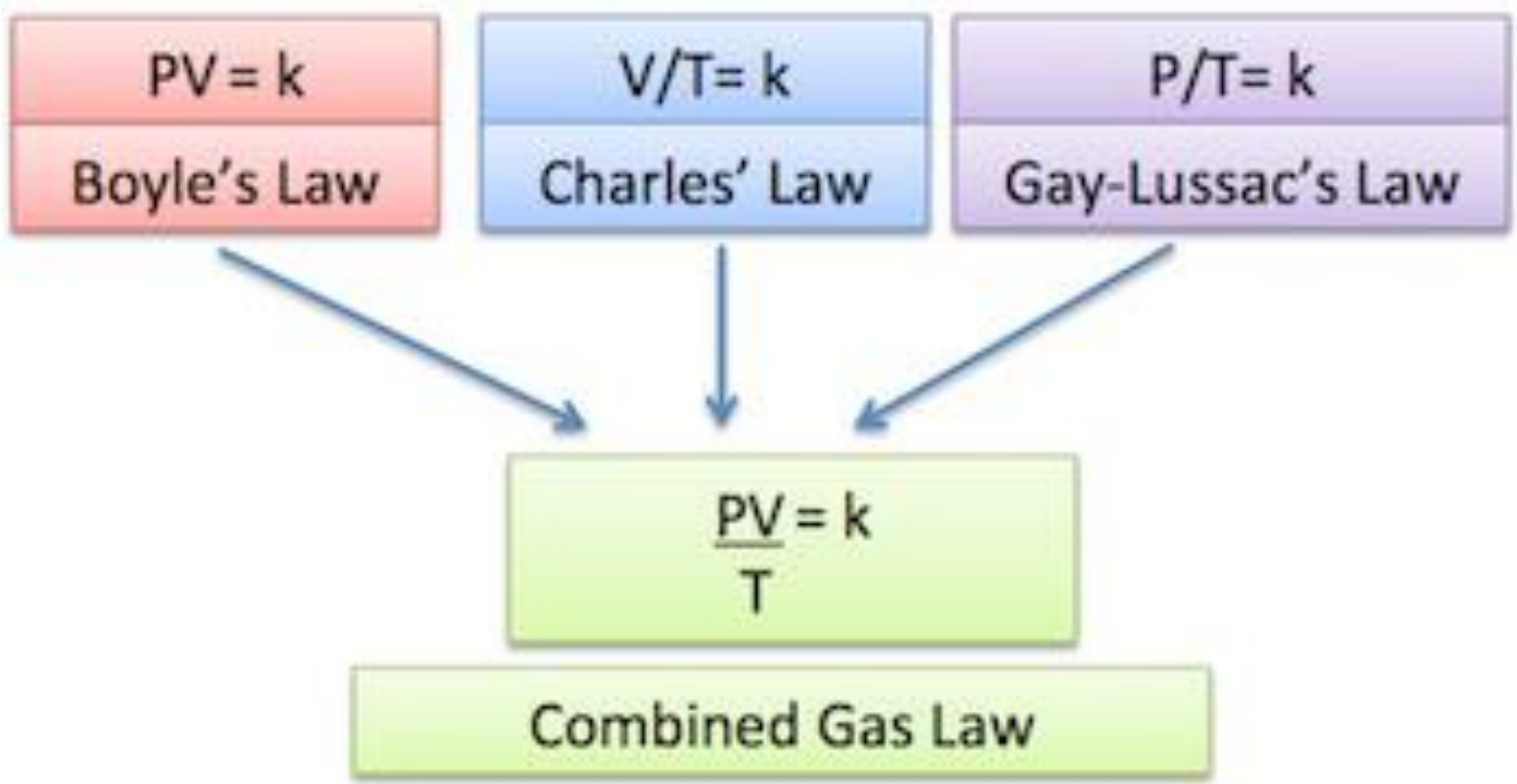


$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$ = Constant, when the pressure is kept constant.

Gay-Lussac's Law for Heating a Gas at Constant Volume



Combined Gas Law



KEY TERMS

- *flow rate*
- total flow
- Density
- specific gravity
- Dynamic viscosity
- kinematic viscosity
- Reynolds number
- laminar flow
- turbulent flow
- incompressible fluid
- compressible fluid
- standard condition
- flowing condition
- Boyle’s law
- Charles’ law
- Gay-Lussac’s law

Instrumentation-Sensors (what)

- Introduction: principles and fundamentals of Process Measurement and Instrumentation
- Pressure Measurement
- **Flow Measurement**
- Level Measurement
- Temperature Measurement
- Sensors

Instrumentation

Flow measurement importance in industry

Different industries that use flowmeters:

- **Oil & Gas**: refinery plant.
- **Water & Wastewater**: water treatment
- **Chemical**: chemical flask.
- **Food & Beverage**: a bottle.
- **Pharmaceutical**: medicine bottle.
- **Power Generation**: lightning bolt.
- **Pulp & Paper**: paper plant.
- **Mining**: A mining pick or helmet.
- **Agriculture**: A plant or irrigation system.

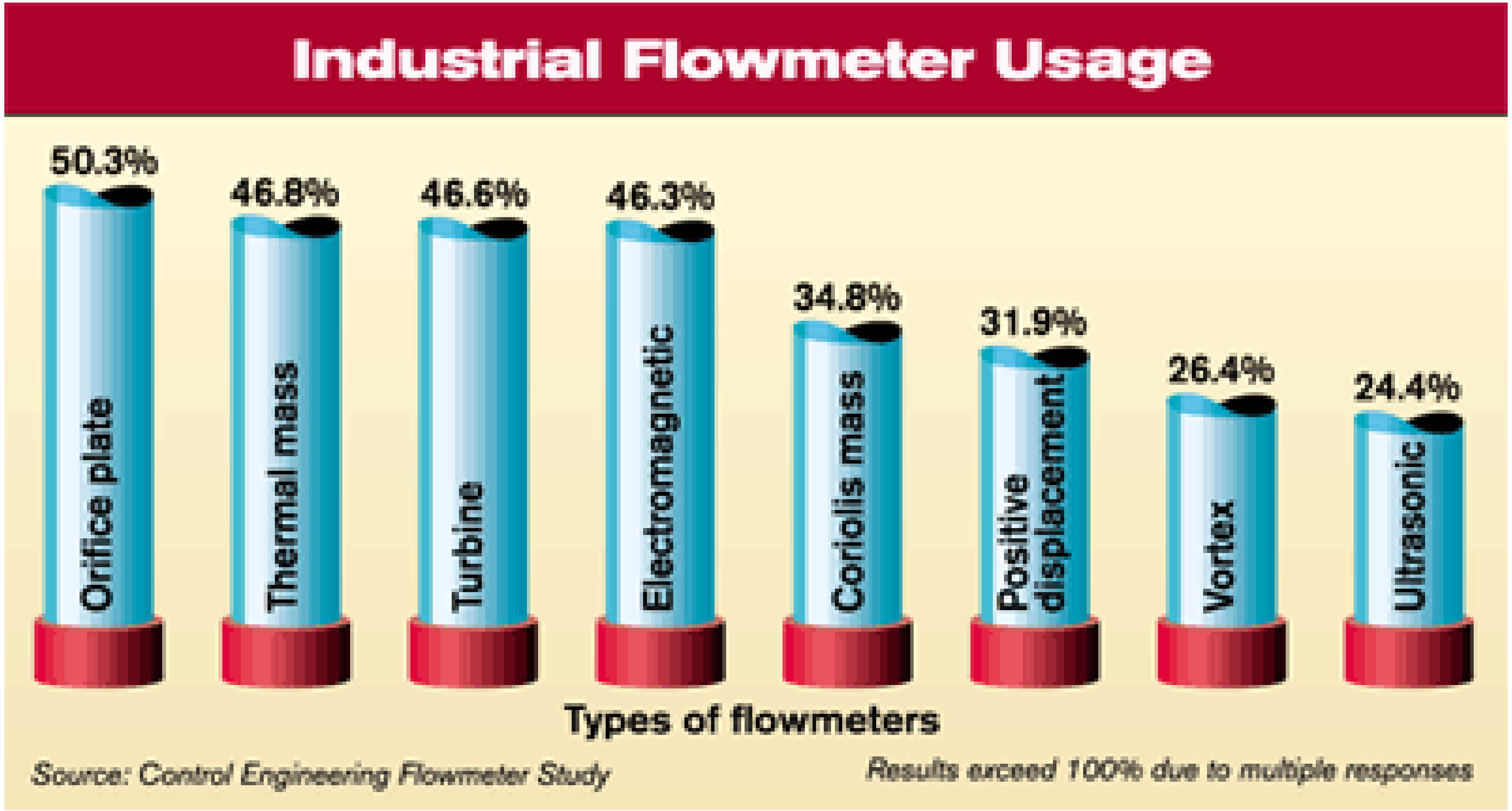
The importance of flow measurement in industry

The importance of flow measurement in industry can be summarized in several key points:

- ✓ Process Control and Optimization
- ✓ Safety
- ✓ Economic Efficiency
- ✓ Regulatory Compliance
- ✓ Energy Conservation
- ✓ Quality Assurance

Type of Flowmeters

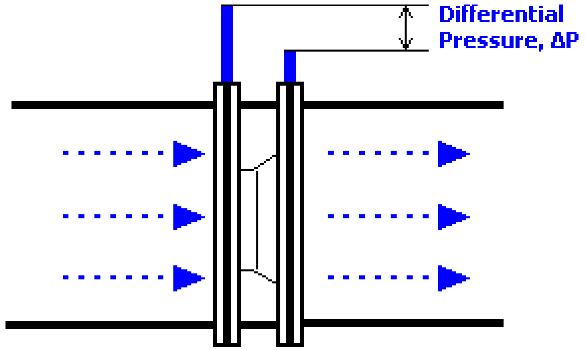
Industrial Flowmeter Usage

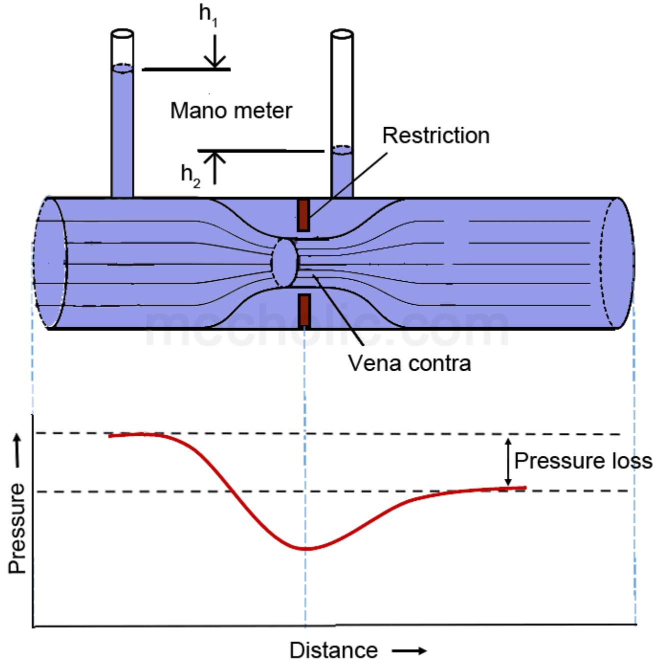


Differential Pressure Flowmeters

Differential Pressure (DP) flowmeters

- **Differential Pressure (DP)** flowmeters are devices that measure the flow rate of a fluid by determining the **pressure drop** over an obstruction inserted in the flow path.
- The underlying principle of DP flowmeters is based on **Bernoulli's Equation**, which describes the conservation of energy in a flowing fluid.



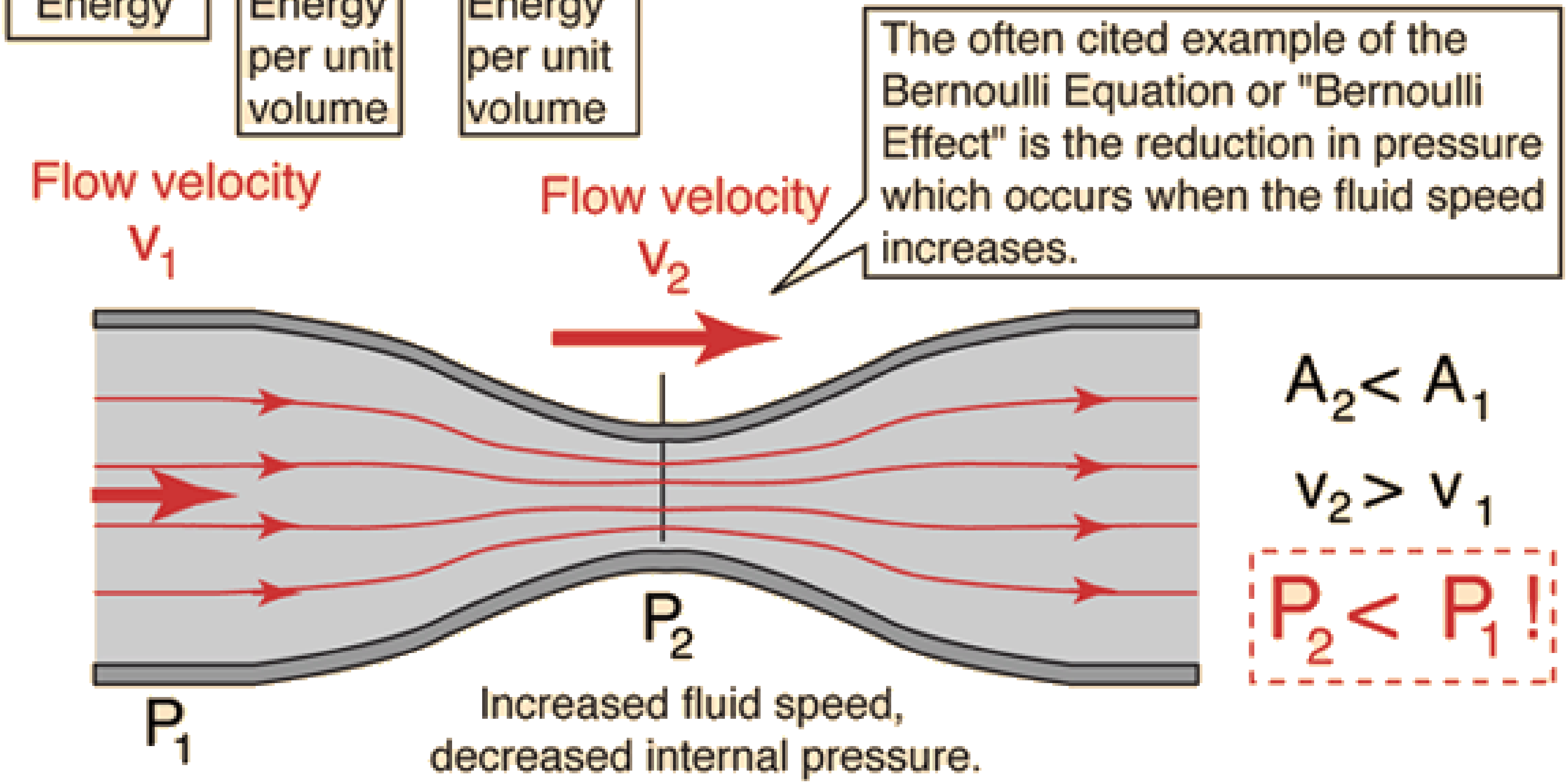


Bernoulli's Equation

Energy per unit volume before = Energy per unit volume after

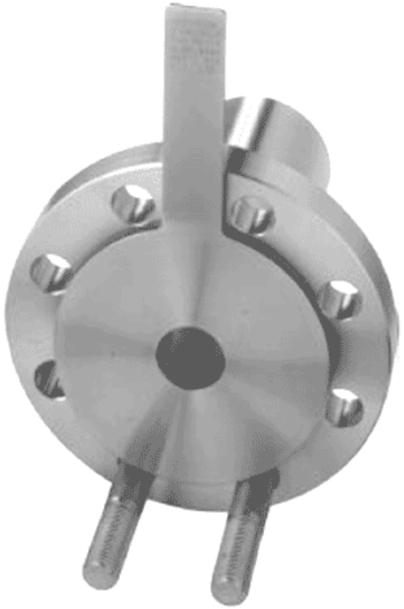
$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

Pressure Energy | Kinetic Energy per unit volume | Potential Energy per unit volume



Orifice Plate Flowmeters

Orifice Plate: A flat plate with a precise, sharp-edged hole drilled in it. It's the most common and inexpensive type of Differential Pressure flowmeter.



Video link: https://youtu.be/AIgiLBwjA0c

Orifice Plate Flowmeters

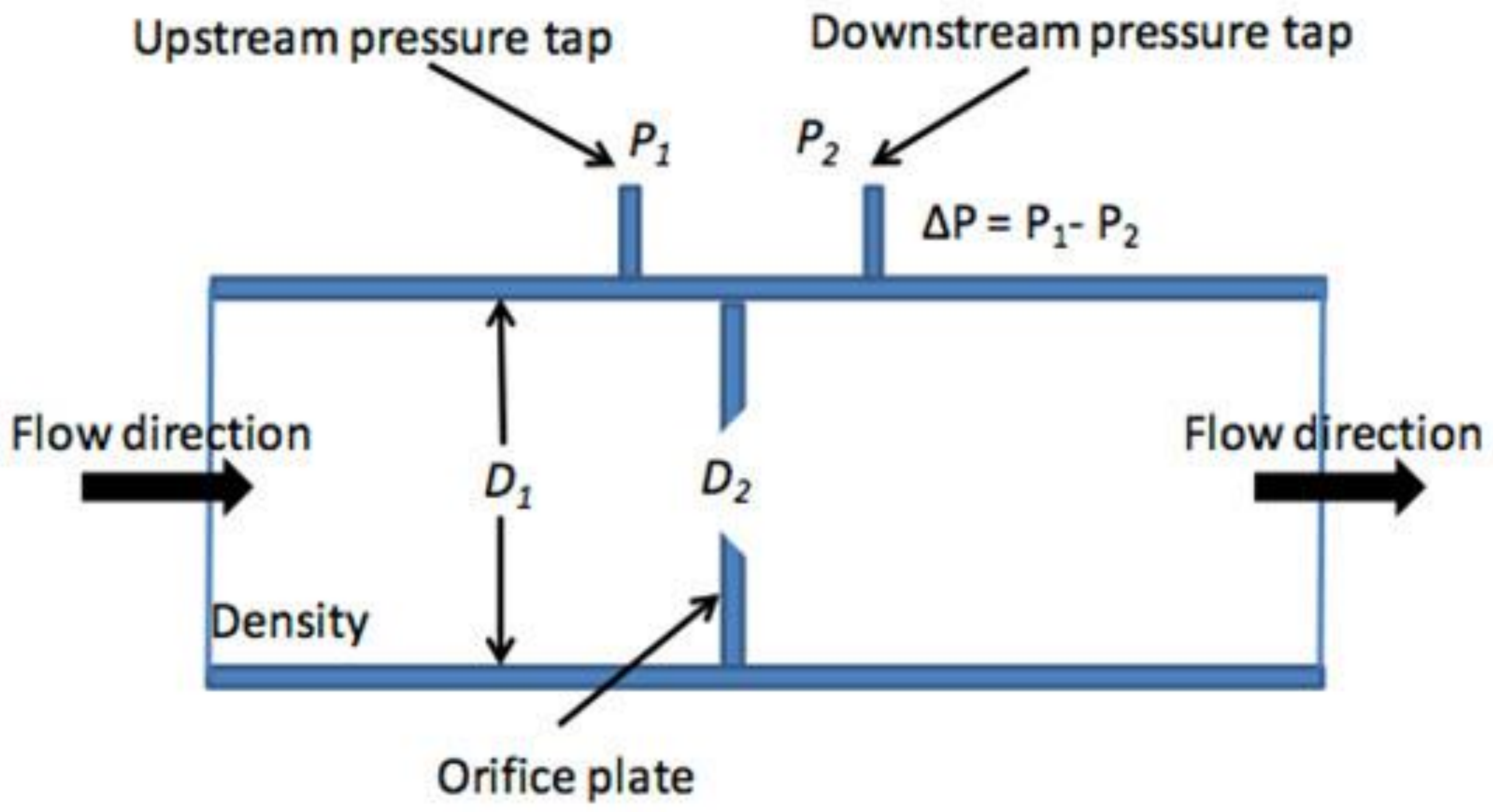


Figure. Elements of a Differential Pressure flow measurement.

The mathematical equation used to calculate the flow rate (*Q*) using an orifice plate flowmeter

Incompressible Fluids

$$Q = CA_o\sqrt{\frac{2\Delta P}{\rho}}$$

Where:

- *Q:* is the volumetric flow rate.
- *C:* orifice plate flow coefficient [unitless]
- *A:* is the area of the orifice opening, with *d* being the diameter of the orifice.
- Δ*P:* is the differential pressure across the orifice plate (pressure drop).
- *ρ:* is the density of the fluid.

Exemple

Let's consider an example calculation for a non-compressible fluid (like water) flowing through an orifice plate.

Here's the setup for our example:

- Orifice plate diameter (d): 50 mm (0.05 m)
- Pipe diameter (D): 100 mm (0.1 m)
- Differential pressure (ΔP): 25000 Pa (25 kPa)
- Water density (ρ): 1000 kg/m³ (at room temperature)
- orifice plate flow coefficient (C_d): 0.6

Solution

$$Q = C_d A \sqrt{\frac{2\Delta P}{\rho}}$$

First, we need to calculate the area of the orifice (A):

$$A = \frac{\pi d^2}{4} = \frac{\pi \times (0.05m)^2}{4} = 0.00196m^2$$

$$Q = C_d A \sqrt{\frac{2\Delta P}{\rho}}$$

$$Q = 0.6 \times 0.00196m^2 \times \sqrt{\frac{2 \times 25000Pa}{1000kg/m^3}}$$

$$Q = 0.001176m^2 \times \sqrt{\frac{50000}{1000}}$$

$$Q = 0.001176m^2 \times \sqrt{50}$$

$$Q = 0.001176m^2 \times 7.071$$

$$Q = 0.008317m^3/s$$

$$Q = 0.008317m^3/s \times 3600s/h$$

$$Q = 29.94m^3/h$$

The mathematical equation used to calculate the flow rate (*Q*) using an orifice plate flowmeter

Compressible Fluids

For gases or steam (compressible fluids), the density can change significantly with pressure and temperature, making the calculations more complex. In such cases, the equation needs to include an expansibility factor (*Y*) to account for the change in density as the gas expands through the orifice:

$$Q = C_d A Y \sqrt{\frac{2\Delta P}{\rho_1}}$$

Where:

- Y is the expansibility factor (a function of the upstream and downstream pressures).
- ρ_1 is the upstream density.

Exemple

Assume the following conditions for a gas (Air):

•Orifice plate diameter (d): 50 mm (0.05 m)

•Pipe diameter (D): 200 mm (0.2 m)

•Upstream pressure (P_1): 500 kPa (absolute)

•Downstream pressure (P_2): 400 kPa (absolute)

•Differential pressure (ΔP): $P_1 - P_2$ = 100 kPa

•Gas temperature (T): 300 K

•orifice plate flow coefficient (C_d): 0.6 (as before, this should be determined experimentally)

•Gas constant for air (R): 287 J/kg·K (as an example, we'll use air)

Density of air at upstream conditions using the ideal gas law (ρ_1): $\rho_1 = \frac{P_1}{RT}$

Solution

First, calculate the upstream density (ρ_1):

$$\rho_1 = \frac{P_1}{RT} = \frac{500{,}000 Pa}{287 J/kg{\cdot}K \times 300 K} = 5.80 kg/m^3$$

Next, compute the area of the orifice (A):

$$A = \frac{\pi d^2}{4} = \frac{\pi \times (0.05 m)^2}{4} = 0.00196 m^2$$

Now, let's apply the flow rate equation for compressible fluids:

$$Q = C_d A Y \sqrt{\frac{2 \Delta P}{\rho_1}}$$

Solution

Assuming Y is approximately 1:

$$Q = 0.6 \times 0.00196m^2 \times \sqrt{\frac{2 \times 100{,}000Pa}{5.80kg/m^3}}$$

$$Q = 0.001176m^2 \times \sqrt{\frac{200{,}000}{5.80}}$$

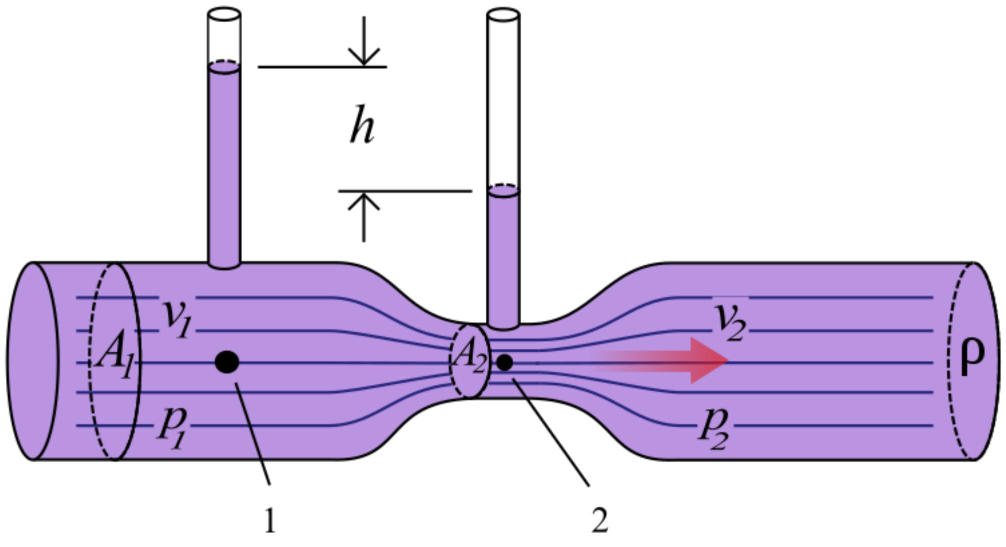
$$Q = 0.001176m^2 \times \sqrt{34482.76}$$

$$Q = 0.001176m^2 \times 185.7$$

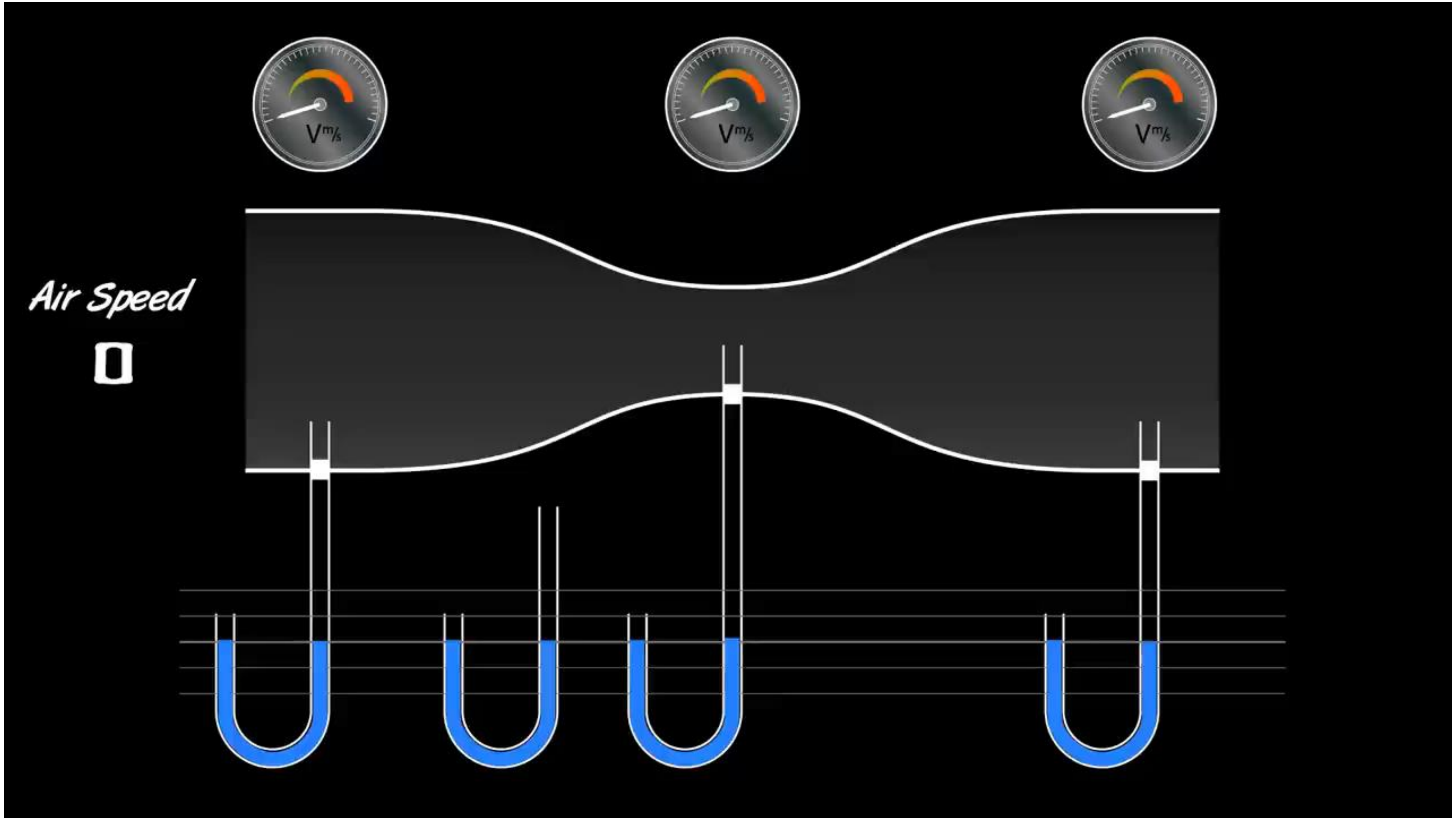
$$Q = 0.218m^3/s$$

Venturi tube Flowmeters

The **Venturi tube** is a type of flow meter that is used to measure the flow rate of fluid in a pipe. The principle behind a Venturi tube flowmeter is based on Bernoulli's Equation and the Continuity Equation, which are fundamental principles of fluid dynamics.



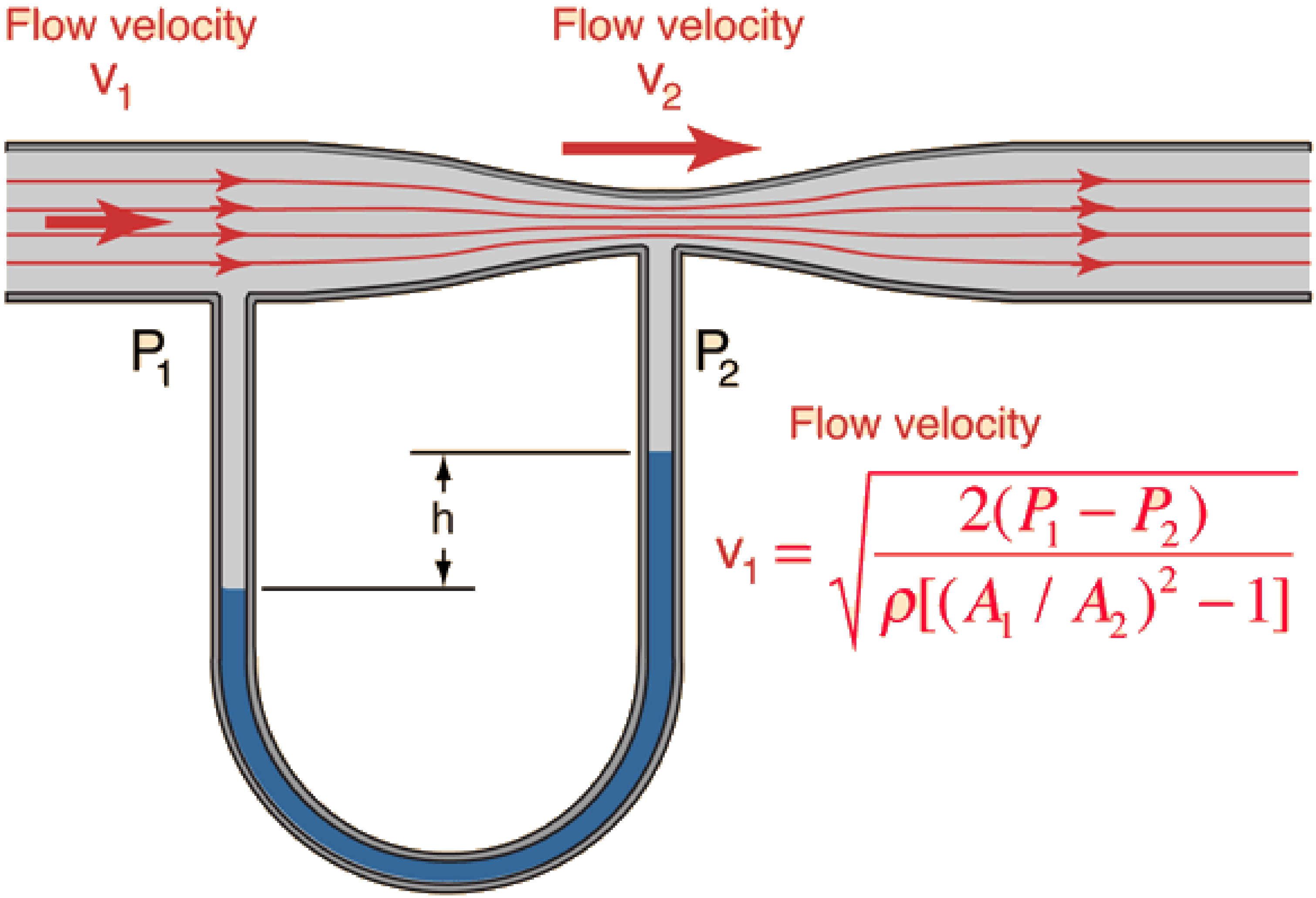
Venturi tube Flowmeters



Video link: https://youtu.be/WvFNqEPNPOc

The mathematical equation used to calculate the flow rate (*Q*) using an Venturi tube flowmeter

Incompressible Fluids



$$v_1 = \sqrt{\frac{2(P_1 - P_2)}{\rho[(A_1 / A_2)^2 - 1]}}$$

Exemple

- Assume you have the following parameters:
- Upstream pipe diameter (D_1): 300 mm
- Throat diameter (D_2): 150 mm
- Differential pressure (ΔP): 50 kPa
- Fluid density (ρ): 1000 kg/m³ (density of water)

$$v_1 = \sqrt{\frac{2(P_1 - P_2)}{\rho[(A_1 / A_2)^2 - 1]}}$$

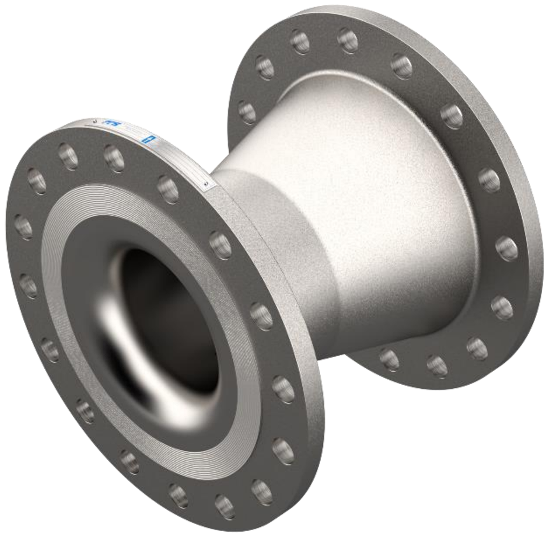
Calculate the Flow Q_1?

$$A_1 = \pi \times \left(\frac{D_1}{2}\right)^2 = \pi \times \left(\frac{0.3}{2}\right)^2 \approx 0.0707 \text{ m}^2$$

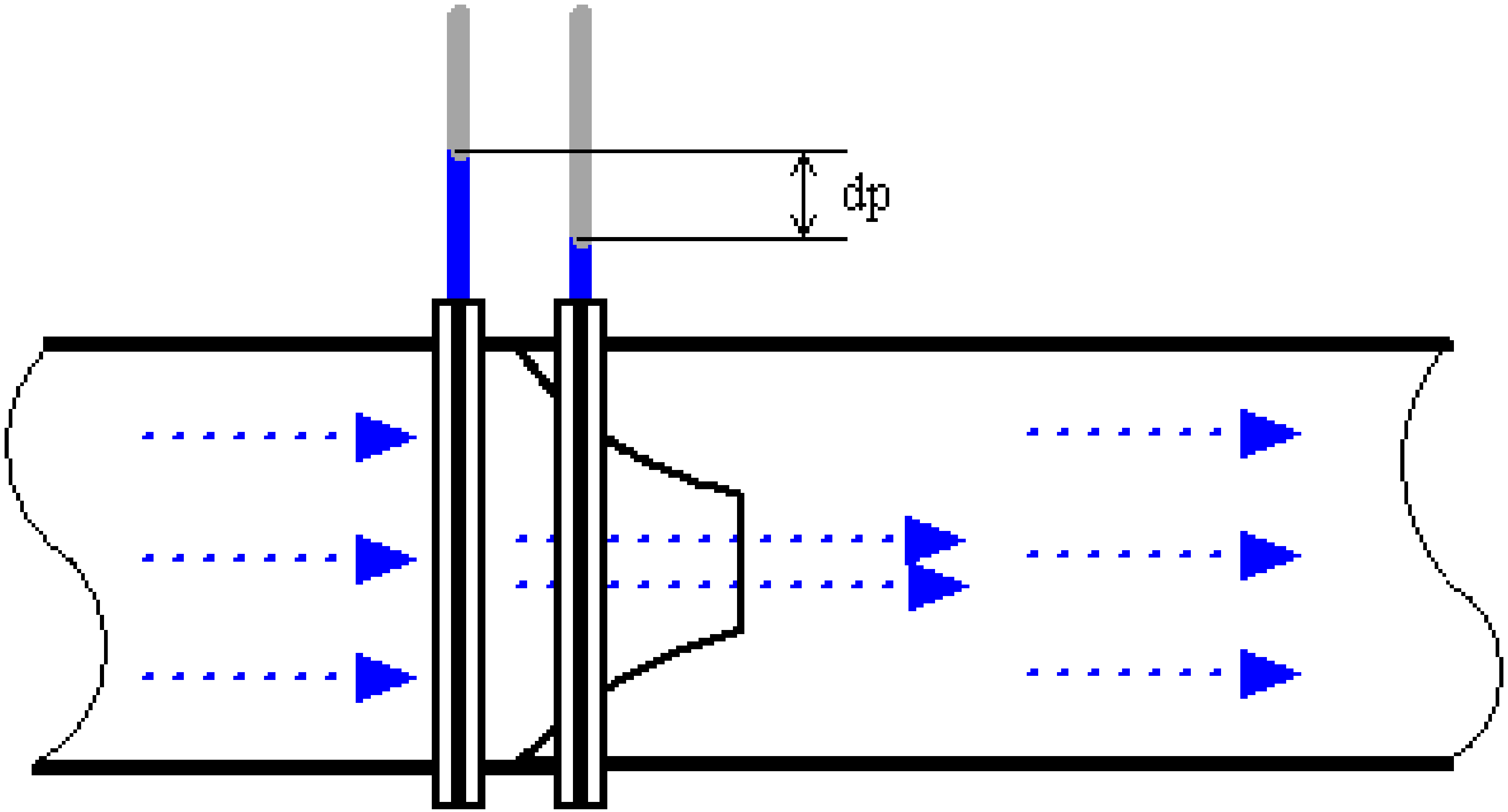
$$A_2 = \pi \times \left(\frac{D_2}{2}\right)^2 = \pi \times \left(\frac{0.15}{2}\right)^2 \approx 0.0177 \text{ m}^2$$

Mozzle Flowmeters

- The flow measurement principle using nozzle flowmeters is quite similar to other differential pressure flowmeters like orifice plates and Venturi tubes.
- The nozzle flowmeter, specifically, operates on the same fundamental principles of fluid dynamics, primarily **Bernoulli's principle** and the **Continuity equation**, to determine the flow rate of fluid through a pipe.



Mozzle Flowmeters



Video link: https://youtu.be/GXDJvva1g9A

Differential Pressure (DP) flowmeters

Advantages / Disadvantages

Advantages

- ✓ **Versatility**: Can be used for liquids, gases, and steam.
- ✓ **Well-established Technology**: Established standards and practices (Well known).
- ✓ **Economical**: Especially orifice plates, which are simple and inexpensive to produce and maintain.

Disadvantages

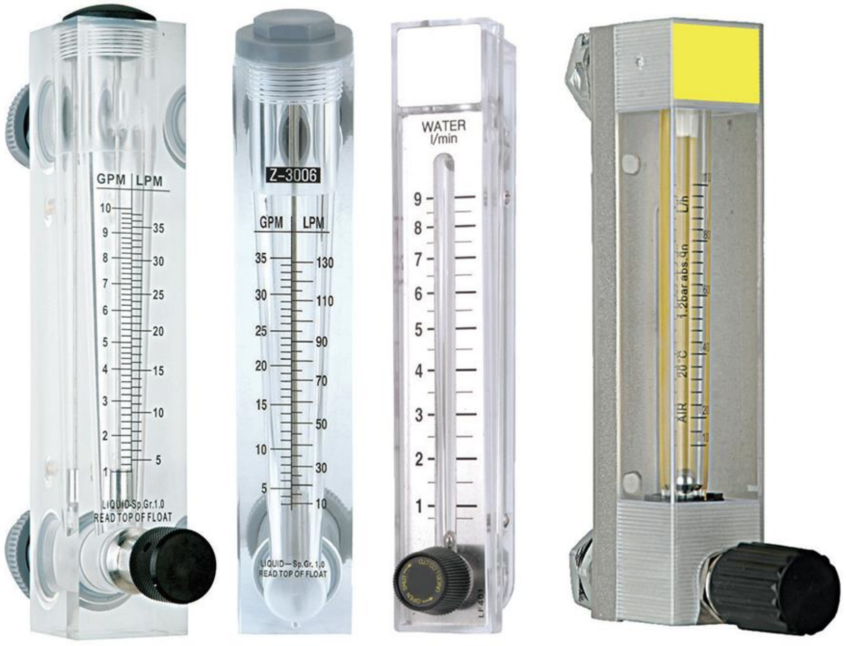
- ✓ **Pressure Loss:** They inherently reduce pressure in the process, which can be a drawback in systems where maintaining pressure is crucial.
- ✓ **Sensitivity to Installation Conditions:** Incorrect installation or piping conditions can significantly affect accuracy.
- ✓ **Requirement for Clean Fluids:** Particulates or bubbles in the fluid can affect the pressure drop and, thus, the accuracy of the flow measurement.

VARIABLE-AREA FLOWMETERS

VARIABLE-AREA FLOWMETERS

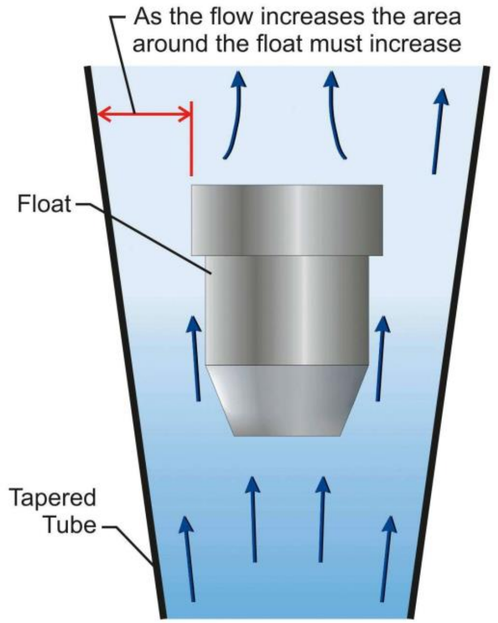
Rotameters

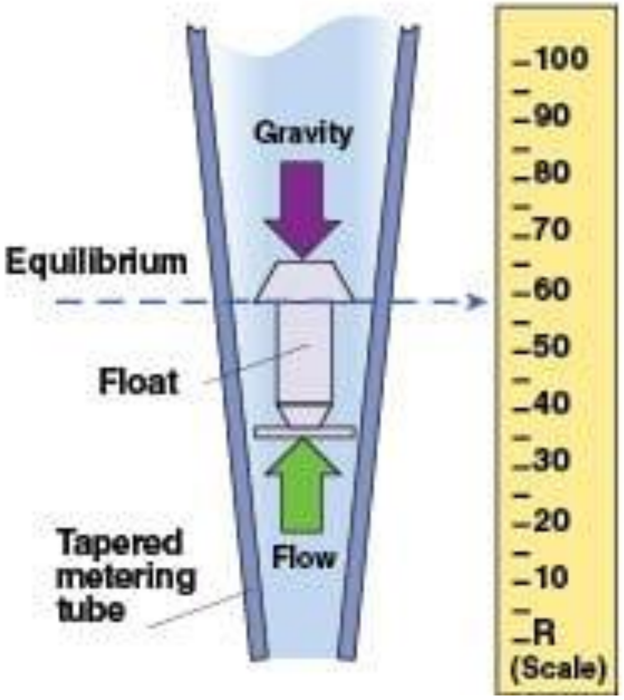
Variable-area flowmeters, often referred to as **rotameters**, are a type of flow meter used to measure the volumetric flow rate of a fluid in a closed tube. They are widely used in various applications due to their simplicity, low maintenance, and versatility.



Rotameters: Working principle

The operation of a rotameter is based on the variable area principle. That is, the flow of a liquid raises the float inside a tapered tube, increasing the area through which the liquid can pass. The larger the flow, the higher the float will be raised.





Video link: https://youtu.be/hzJ-_cfM03w

Video link: https://youtu.be/TCBHD8gL26g

Positive-displacement flowmeter

Positive-displacement flowmeter

positive-displacement flowmeter: A flowmeter that admits fluid into a chamber of known volume and then discharges it.

Nutating Disc

Video link: https://youtu.be/TYX884HI6kw

Rotating-Impeller

Video link: https://www.youtube.com/shorts/6zE7KN1FiCE?feature=share

Turbine Flowmeters

Turbine meters

Turbine meter: A flowmeter consisting of turbine blades mounted on a wheel that measures the velocity of a liquid stream by counting the pulses produced by the blades as they pass an electro magnetic pickup.

Video link: https://youtu.be/KWkrt-hPZh4

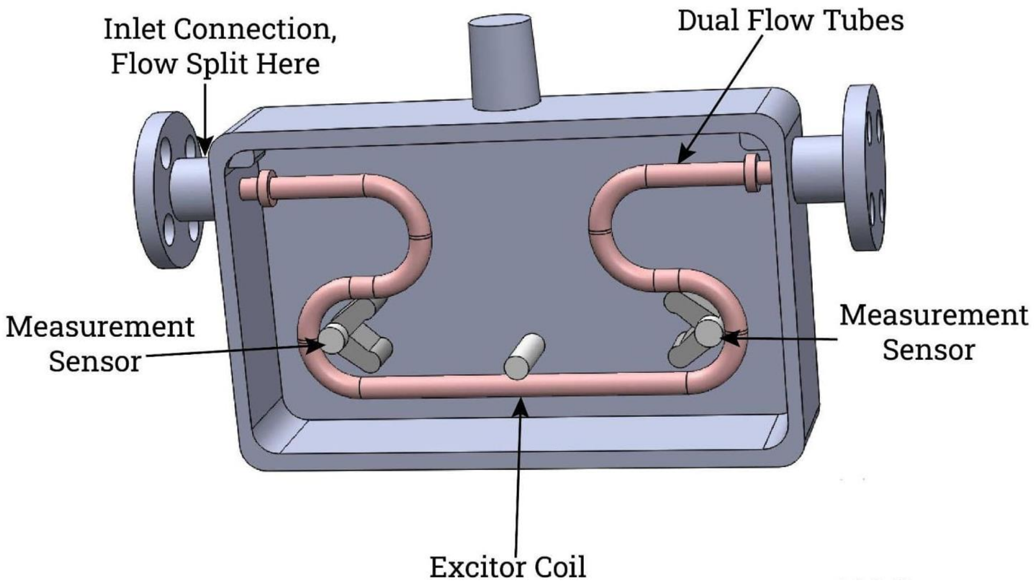
Coriolis Flowmeters

Coriolis Flowmeters

•**Principle**: Utilizes the Coriolis effect, where vibrating tubes twist due to mass flow.

•**Accuracy**: Very high, suitable for direct mass flow measurement.

•**Applications**: Widely used in chemical and food processing industries for precise measurements.



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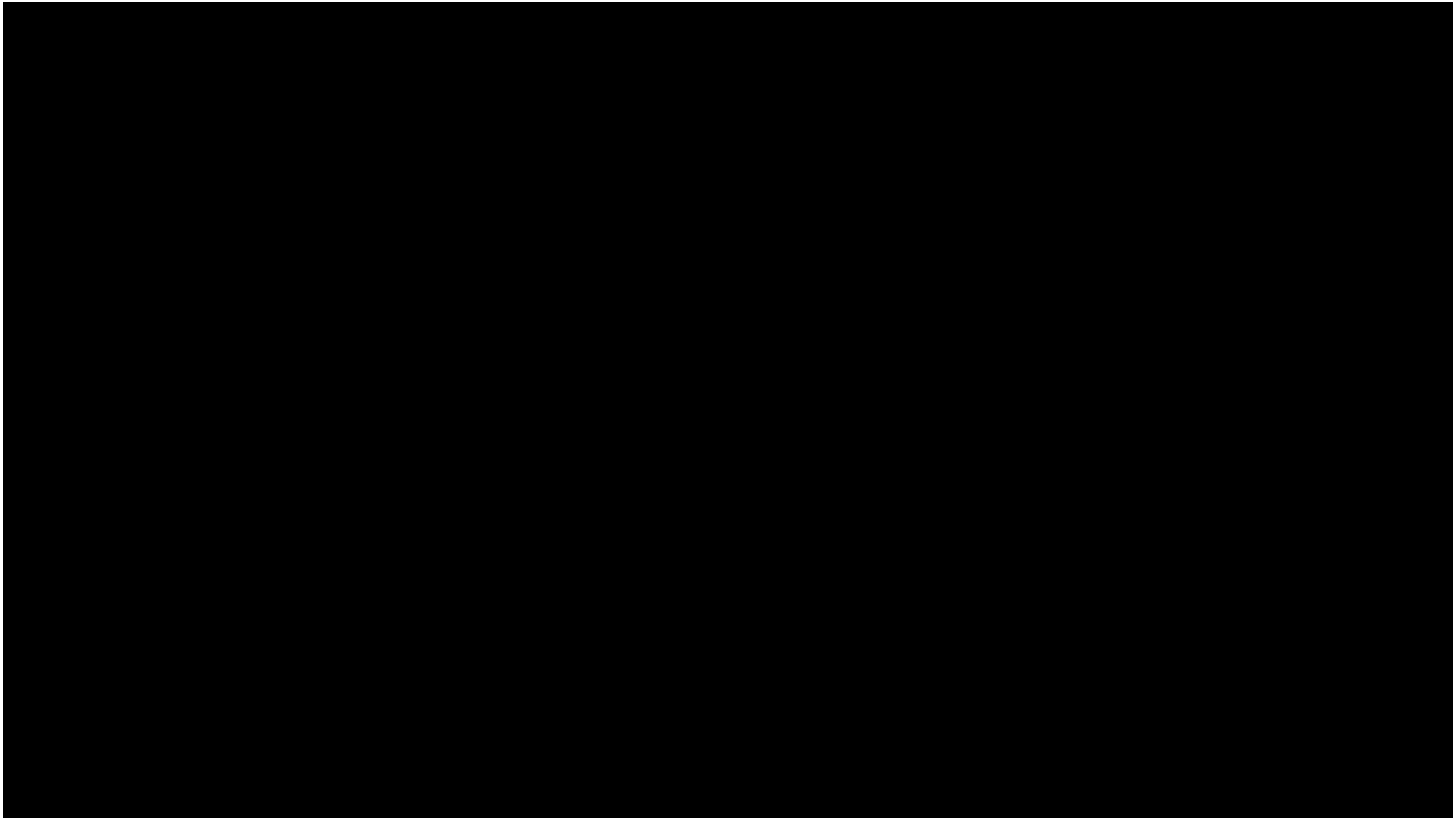


Video link: https://youtu.be/XIIViaNITIw

MCQ questions

MCQ questions

1/ Bernoulli’s Equation is a mathematical expression of :

a) The ratio of kinetic to viscous force in a flow stream

b) Friction loss as fluid moves through a rough pipe

c) Potential and Kinetic energies in a flow stream

d) Vertical height and Pressure for a static fluid

MCQ questions

2/ As a compressible fluid moves through a restriction,

a) Velocity decreases and Pressure increases

b) Velocity increases and Pressure increases

c) Velocity increases and Pressure remain the same

d) Velocity increases and Pressure decreases

MCQ questions

3/ Which of the following instruments used to measure flow on the application of Bernoulli's theorem?

a) Venturi meter

b) Orifice

c) Nozzle

d) All of the above

MCQ questions

4/ Which of the following are the basic equation of compressible flow?

1.Continuity equation

2.Bernoulli's equation

3.Momentum equation

4.All of the above

Explanation:

$$\frac{P}{\rho g} + \frac{v^2}{2g} + Z = Constant$$

$$\mathbf{F} = \frac{\mathbf{d(mv)}}{\mathbf{dt}}$$

$$\rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

MCQ questions

5/When an orifice for flow measurement in a pipe is replaced by a venturimeter, the pressure drop for the same flow is expected to

1.remain same

2.increase

3.decrease

4.None of these

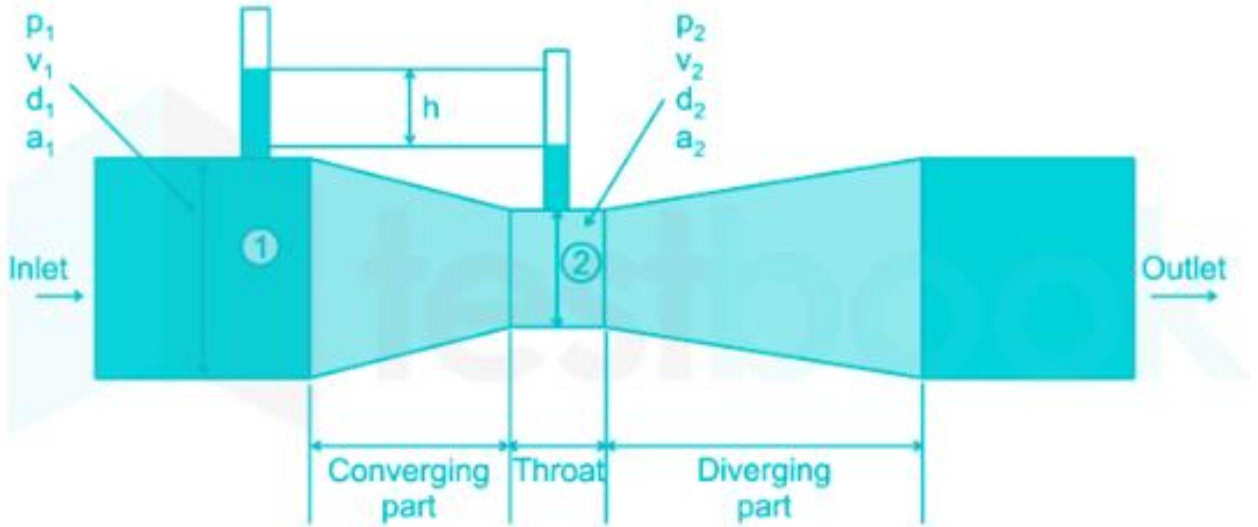
Explanation:

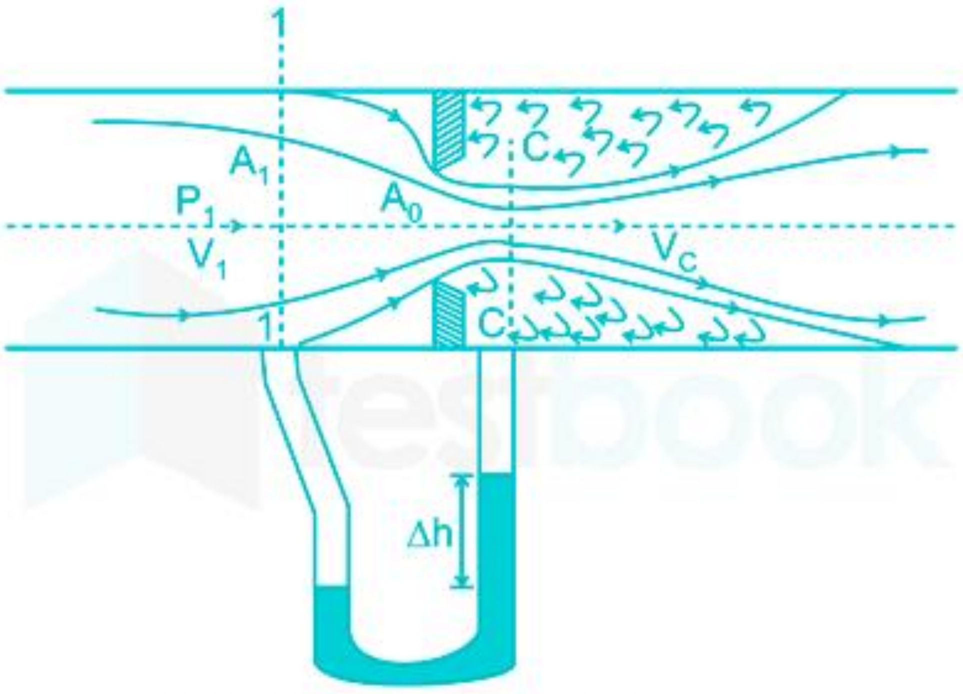
$$Pressure\ drop\ (\Delta P) \propto \frac{1}{Coefficient\ of\ discharge\ (C_d)}$$

$\because (C_d)_{venturimeter} > (C_d)_{orifice\ meter}$

$\therefore (\Delta P)_{venturimeter} < (\Delta P)_{orific\ meter}$

Venturimeter is more efficient than the **Orifice meter**. Hence the coefficient of discharge is higher for Venturimeter than for Orifice meter.





Flow through an Orificemeter

MCQ questions

6/A venturi meter is preferable to orifice meter because

1.it is cheaper

2.it is more convenient

3.energy loss is less

4.it is easy to assemble

Explanation:

Orifice meter	**Venturimeter**
The orifice meter is used for measuring the rates of flow in incompressible fluid only.	Venturimeter is used for measuring rates of flow in both incompressible and compressible fluids.
Simple in construction	Relatively complex in construction
Relatively cheap	Expensive
Head losses are more	Head losses are insignificant
Energy loss is more	**Energy loss is less**
Coefficient of discharge is about 0.61	Coefficient of discharge is 0.98
Low space requirement	Occupies more space

MCQ questions

7/A fluid flows through an orifice of an area 0.4 m^2 with an actual discharge of 400 l/s. If the theoretical velocity of flow through the orifice is 2 m/s, what is the coefficient of discharge?

1. 0,71
2. 0,68
3. 0,50
4. 0,56

Explanation:

The **coefficient of discharge** (C_d) is the ratio of the actual discharge (Flow) (Q_a) to theoretical discharge (Flow) (Q_{th}) .

V_{th} = 2 m/s; A = 0.4 m^2

Q_{th} = 0.4 × 2 = 0.8 m^3/s or 800 l/s

C_d = 400/800

C_d = 0.5

MCQ questions

8/An orifice meter, having an orifice of diameter ‘d’ is fitted in a pipe of diameter D. For this orifice meter, what is the coefficient of discharge C_d?

1.A function of Reynolds number only

2.A function of d/D only

3.A function of d/D and Reynolds number

4.Independent of d/D and Reynolds number

Explanation:

For the orifice meter, the coefficient of discharge C_d depends on the shape of the nozzle, the ratio of pipe to nozzle diameter and the Reynolds number of the flow.

MCQ questions

9/Coefficient of discharge (C_d) in the orifice meter usually ranges between:

1. 0.72 band 0.76
2. 0.83 and 0.87
3. 0.61 and 0.65
4. 0.95 an 0.99

Explanation:

Coefficient of discharge for various devices are:

⇒ **Venturimeter – 0.95 to 0.98**

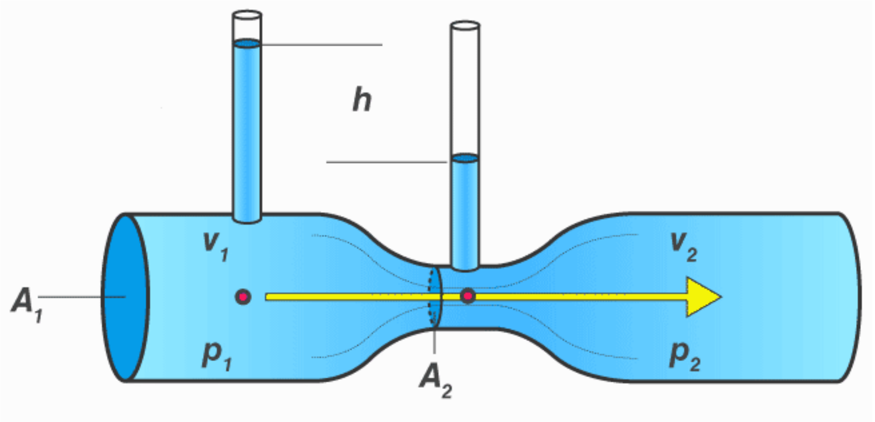
⇒ **Orifice meter – 0.62 to 0.65**

⇒ Nozzle – 0.93 to 0.98

MCQ questions

10/A horizontal venturimeter with inlet and throat areas A_1=10 cm² and A_2=5 cm² respectively is used to measure the flow of water. The reading of differential manometer connected to the inlet and the throat is h=61,2 cm of water. The rate of flow is:

1. 0,2 L/s
2. 2 L/s
3. 4 L/s
4. 4,5 L/s



Explanation:

$$v_1 = \sqrt{\frac{2(P_1 - P_2)}{\rho[(A_1 / A_2)^2 - 1]}} \rightarrow V_1 = \sqrt{\frac{2gh}{(A_1/A_2)^2 - 1}} \rightarrow V_1 = 2 \text{ m/s}$$

$Q=V_1 * A_1 = 2*10*10^{-4} = 0{,}002 \text{ m}^3/\text{s} = 2 \text{ L/s}$