MECE 3320 – Measurements & Instrumentation

Flow Measurements

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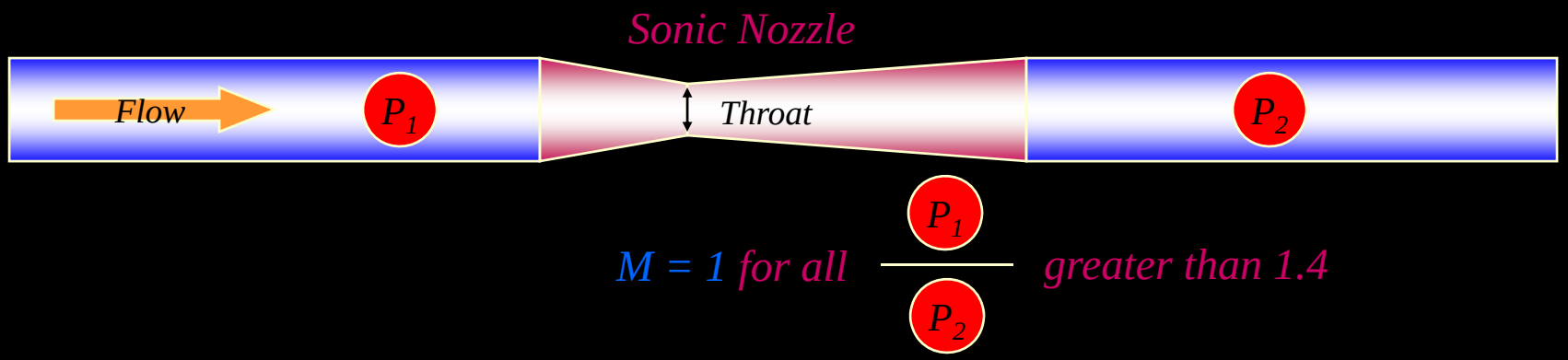
Sonic Nozzles

- Also called *critical flow nozzle* or *critical flow venturi*



- $M = 1$ represents choked condition, i.e. *condition of maximum mass flow rate*.
- Flow conditions downstream do not affect the mass flow rate.
- Mass flow rate through the sonic nozzle is given by:

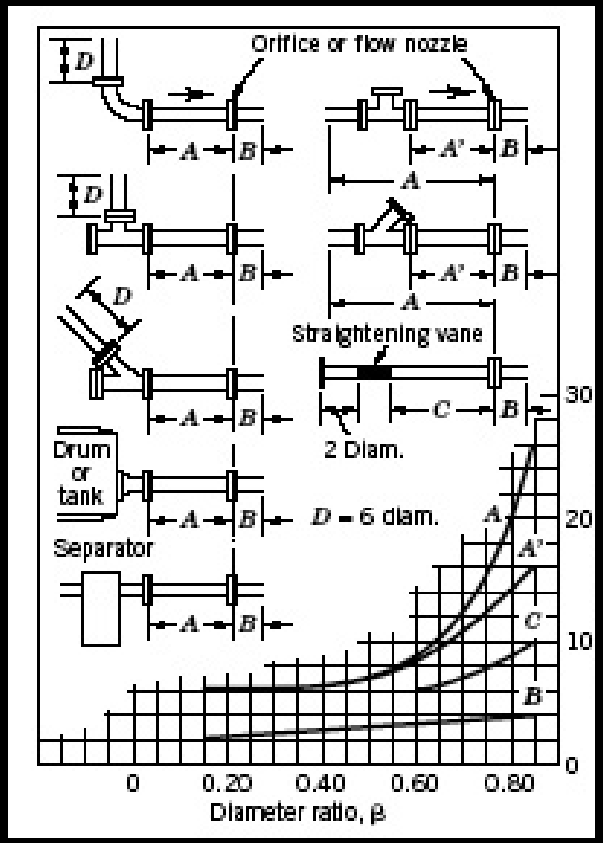
$$\dot{m}_{max} = \rho_1 A \sqrt{2RT_1} \sqrt{\frac{k}{k+1}\left(\frac{2}{k+1}\right)^{2/(k+1)}}$$

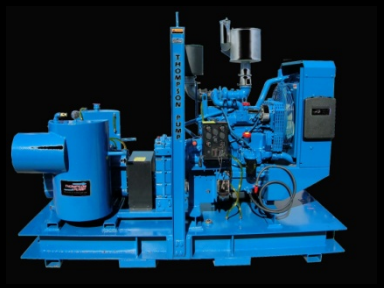
Sonic Nozzles

- Consider a straight hose of inner diameter 2 inches connected to a fire extinguisher that discharges a gas which has a specific heat ratio of 1.3. If the discharge pressure is 22.5 psia, calculate the mass flow rate through the hose.

- Flow through a straight pipe is always a choked flow as long as the pressure ratio is greater than 1.4.

Obstruction Meter Selection





- Power required to overcome pressure loss

$$\dot{W} = Q\frac{\Delta p_{loss}}{\eta}$$

- Assume the pump is being used at a rate of 6000 hrs./year with the cost of electricity being 80 cents/kW-h. If the efficiency of the pump is 60% and the pressure loss is 50 cm of Hg for a flow rate of 0.55m^3/s, estimate the **annual cost of electricity required**.

Insertion Volume Flow Meters

Vortex Shedding Meters

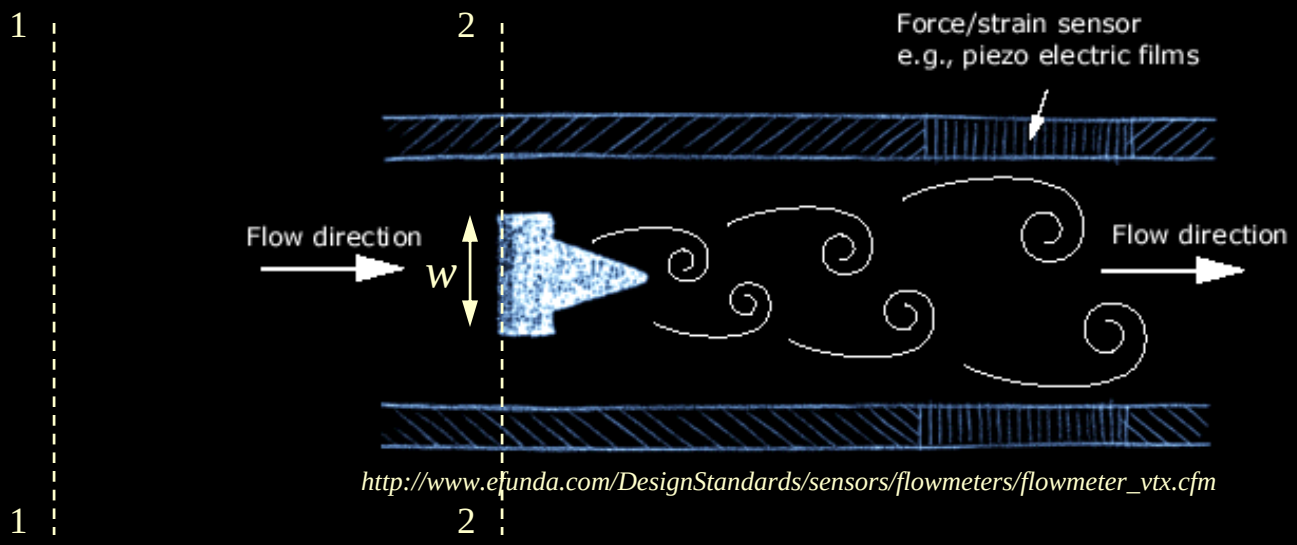
http://www.efunda.com/DesignStandards/sensors/flowmeters/flowmeter_vtx.cfm

- The vortex shedding frequency is related to the flow velocity.

$$St = \frac{fd}{U}$$

- The Strouhal number is constant for flow Reynolds numbers of $10^2 \sim 10^7$ (0.18 for a cylinder).

Vortex Shedding Meters



http://www.efunda.com/DesignStandards/sensors/flowmeters/flowmeter_vtx.cfm

$$V_1 A_1 = V_2 A_2 \Rightarrow \frac{V_1}{V_2} = \frac{A_2}{A_1} = \frac{\frac{\pi d^2}{4} - wd}{\frac{\pi d^2}{4}} = 1 - \frac{4w}{\pi d}$$

$$Q = V_1 A_1 \qquad St = \frac{fd}{V_2}$$

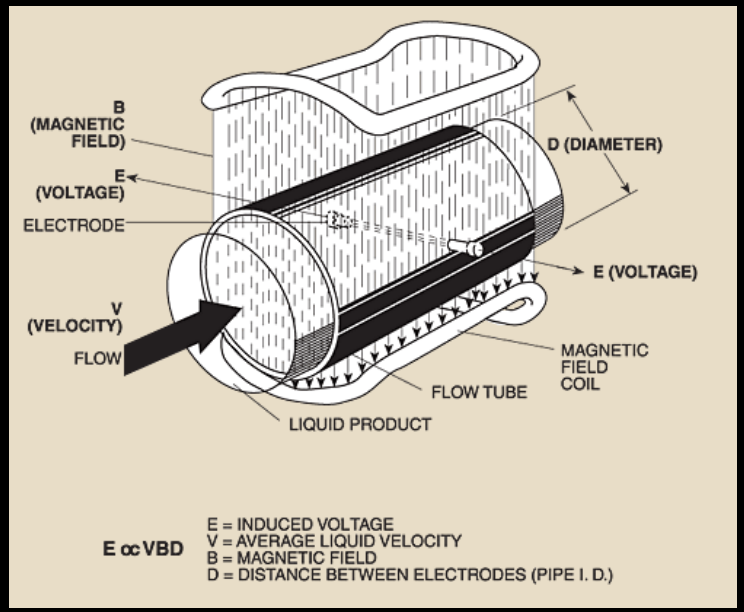
$$Q = \frac{f \pi d^3}{4St}\left(\frac{w}{d}\right)\left(1 - \frac{4Kw}{\pi d}\right)$$

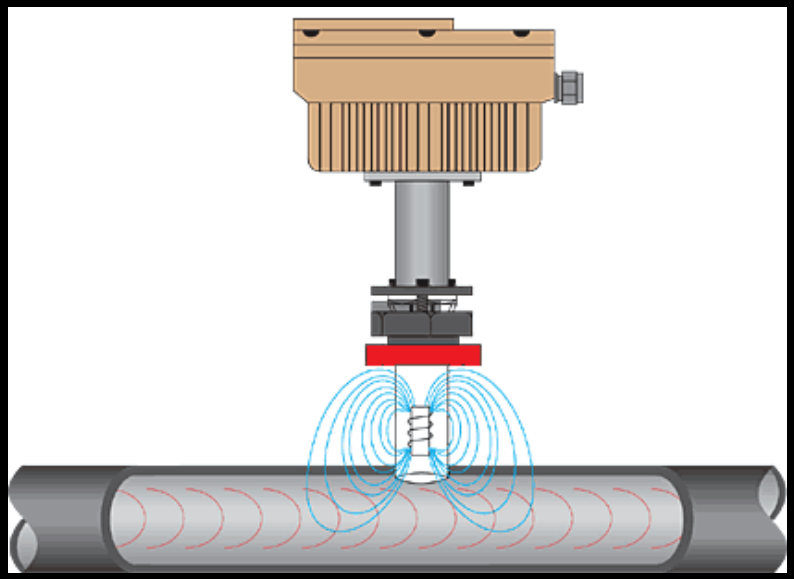
Electromagnetic Flow Meters

- Does not have any moving parts.
- Ideal for conductive liquids.
- Ideal for applications where low pressure drop and low maintenance are required.

Principle of Operation

- Based on Faraday's law





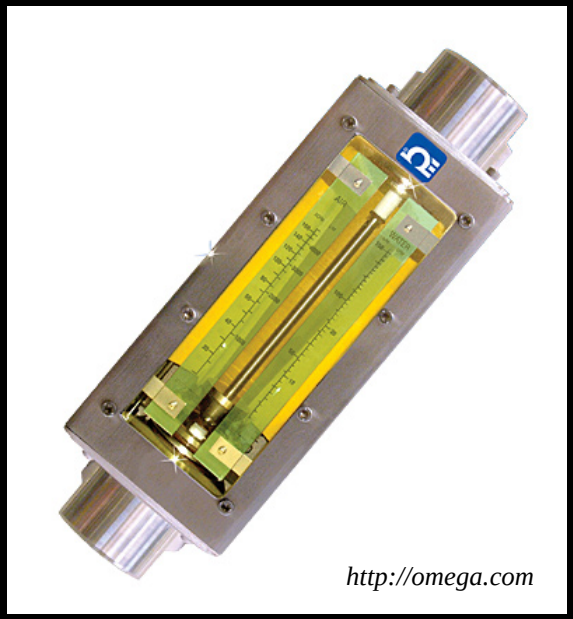
http://omega.com

Rotameters

- It is a flowmeter used to measure the flowrate of liquids and gases.
- Rotameter consists of a tube and float.
- Float response to flowrate changes is linear.
- Has a linear scale, a relatively long measurement range, low pressure drop, simple to install and maintain.

Principle of Operation

- Based on variable area principle



- Fluid flow raises a float in a tapered tube, increasing the area for passage of the fluid.
- Greater the flow, the higher the float is raised. The height of the float is directly proportional to the flowrate.
- With liquids, the float is raised by a combination of the buoyancy of the liquid and the velocity head of the fluid.
- With gases, buoyancy is negligible, and the float responds to the velocity head alone.

Other common types of Flow meters

- Turbine Meters: Rotational speed of rotor is proportional to flow rate (based on angular momentum principles).

- Ultrasonic Flow Meters: Travel time of sound waves proportional to flow rate.

- Positive displacement Meters: Based on movement of diaphragm.

- Coriolis Flow Meter: Measures mass flow rate by inducing Coriolis acceleration on the flowing fluid.