Flow Meters

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What Are Flow Meters?

- Designed to measure the discharge of a fluid.

- Four major types used:
  - Differential Pressure
  - Positive Displacement
  - Open Channel
  - Electromagnetic

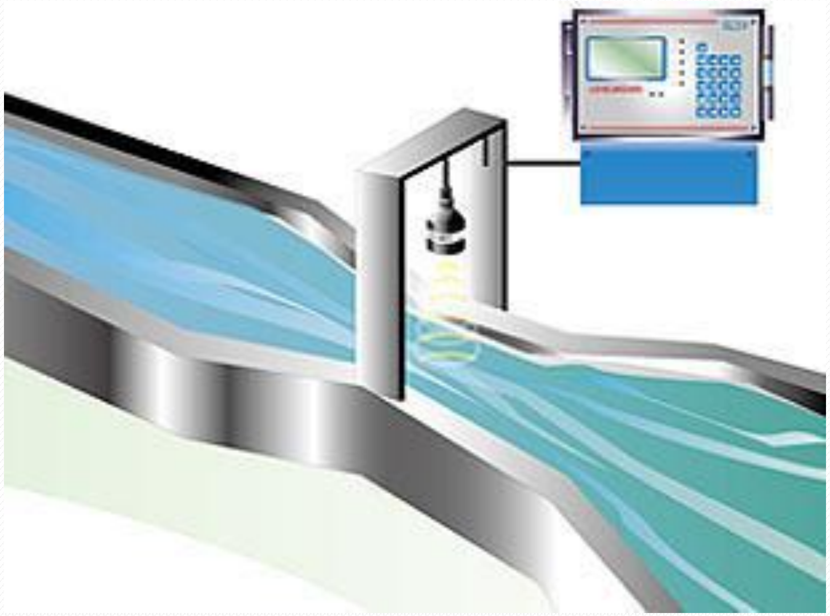


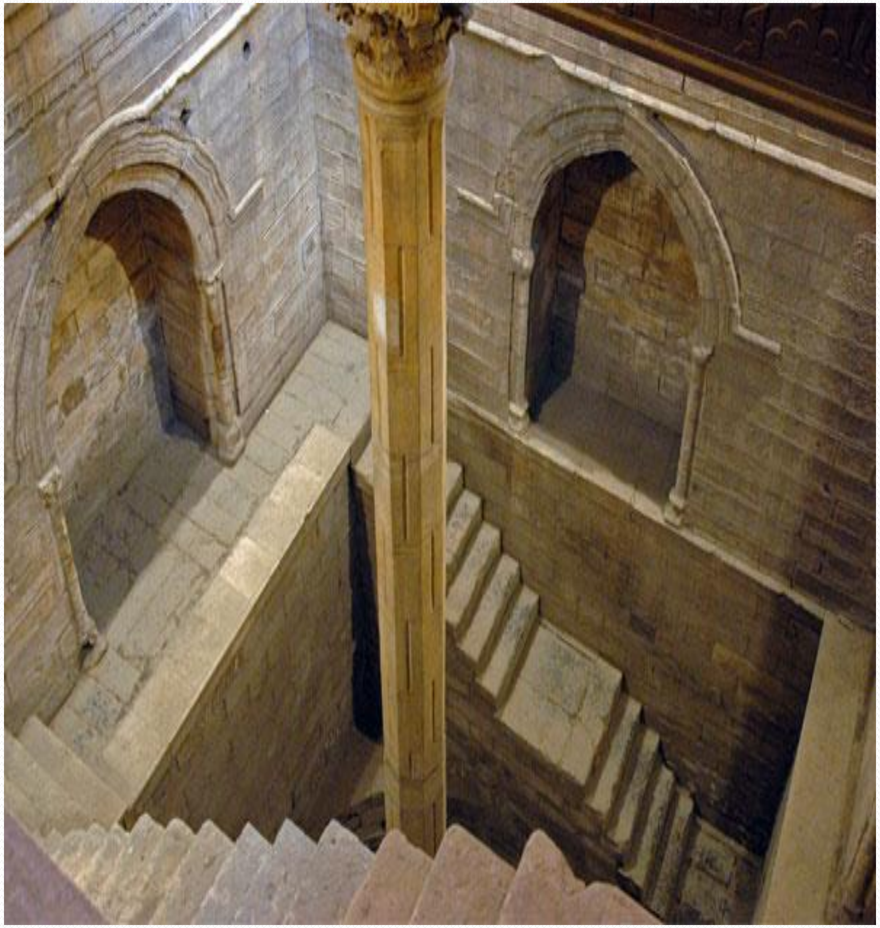
Image Courtesy of Encyclopedia of Chemical Engineering Equipment

History of Flow Meters

- Flow meters have been used since early civilizations to measure flows of rivers
- Ancient Egypt:
  - Measured Nile River flows to predict the quality of harvests
- Ancient Rome:
  - Used orifice flow to measure discharge in drainage pipes
- Ancient China:
  - Weirs were used to monitor and control natural waterways for irrigation purposes

Nilometer

- Used monitor the Nile river in Ancient Egypt
- Water would fill the Nilometer, and set water levels would represent the quality of the upcoming harvest.
- High levels indicated great harvests and very low levels indicated drought



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Scientific Advancements

- Key Scienfitic discoveries lead to the advancement of flow meters into what we have today.
- Bournoulli's Principal -> Differential Pressure Flow Meters
- Faraday's Law -> Electromagnetic Flow Meters
- Reynold -> Open Channel Flow Meters

Bernoulli's Principle

- In 1738, Daniel Bernoulli found that the velocity, potential energy, and pressure of a fluid body are related:

$$\frac{P_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{v_2^2}{2g} + z_2$$

- For horizontal flow, an increase in a fluid's velocity must result in a decrease in pressure.
- Therefore, the velocity or discharge of a fluid system can be determined by measuring the change in pressure.

Electromagnetic to measure flow

- In 1831, Michael Faraday an English scientist discovered that electromagnetic fields can be used to measure flow rate.

$$e = N\frac{d\Phi}{dt}$$

Where,

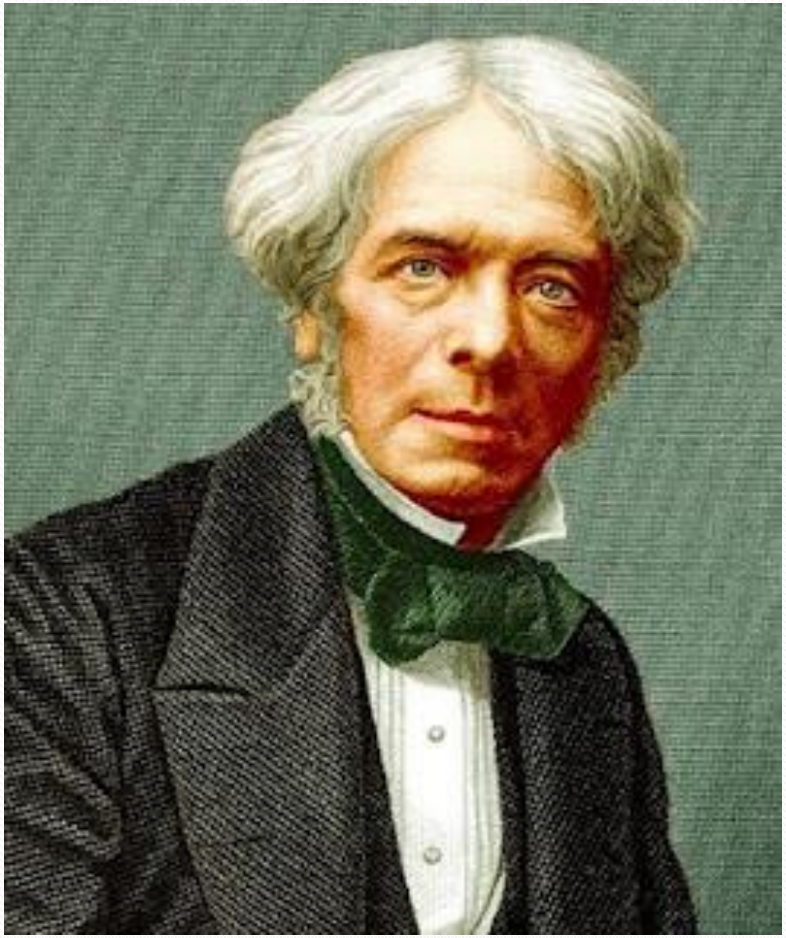
$e =$ (Instantaneous) induced voltage in volts

$N =$ Number of turns in wire coil (straight wire = 1)

$\Phi =$ Magnetic flux in Webers

$t =$ Time in seconds

Image courtesy of Lessons In Electric Circuits



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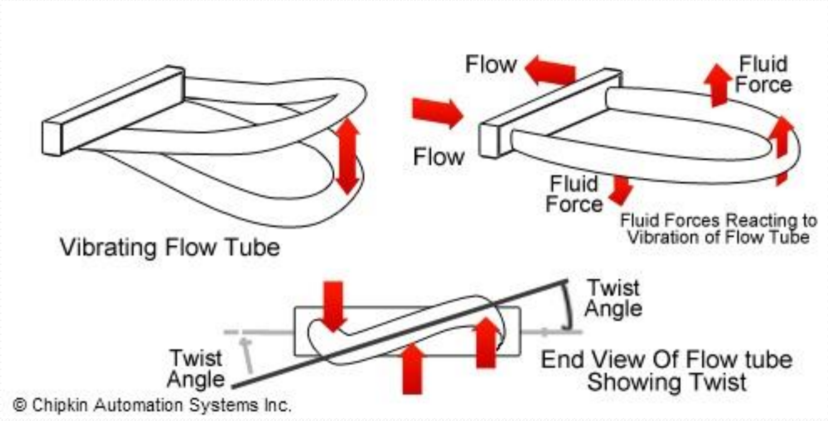
Coriollis Flow Meter

- Designed by aeronautical engineer Theodore von Karman in 1970.
- Measures mass of fluid moving inside of a pipe.
- Using the fluid's density, the volume of fluid per time can be determined.



Laminar and Turbulent Flows

- 1883, Osborne Reynold a British scientist and engineer discovered a mathematical relationship to determine if the flow of a fluid is turbulent or laminar.

$$Re = \rho VD/\mu$$

Re=Reynolds Number
ρ = density of the fluid
V = velocity
D = pipe diameter
μ = fluid viscosity

How to choose flow meter type?

Consider the following factors when choosing which flow meter type best fits your purpose

1- Type of fluid
2- Fluid temperature and viscosity
3- Pressure drop
4- Type of flow
5- Maximum and minimum flow rate

Positive Displacement Flow Meters - Theory

- Unique in that they directly measure the volume of the fluid passing through
  - They do this by temporarily trapping the fluid
- Similar to recording the time it takes to fill a bucket of known volume
- *Discharge= Volume/Time*

Image Courtesy of 7 Million 7 Years

Positive Displacement Flow Meters - Applications

- Provide a high level of accuracy at a reasonable price
- Not ideal for fluids with large particles
- Best in smaller lines or where flow rates are relatively low
- Often used in oil and gas, water and wastewater, and chemical industry

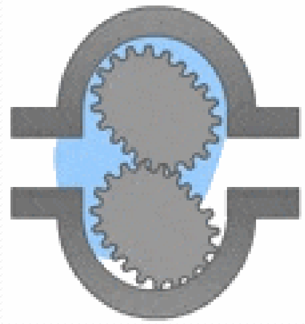


Image Courtesy of Universal Flow Monitors

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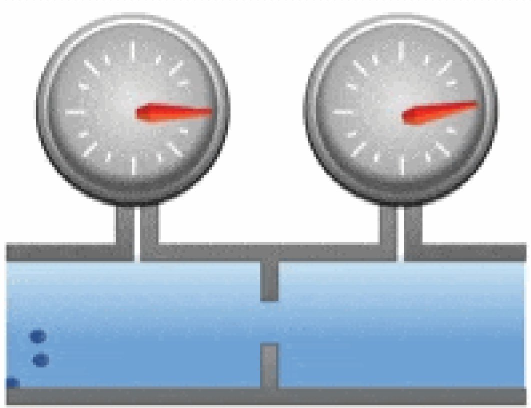
Differential Pressure Flow Meters - Theory

- Based on Bernoulli's Equation
- Measure pressure drop over a constriction and use the pressures to calculate the flow
- Approximately 21% of the flow meters used are differential pressure flow meters



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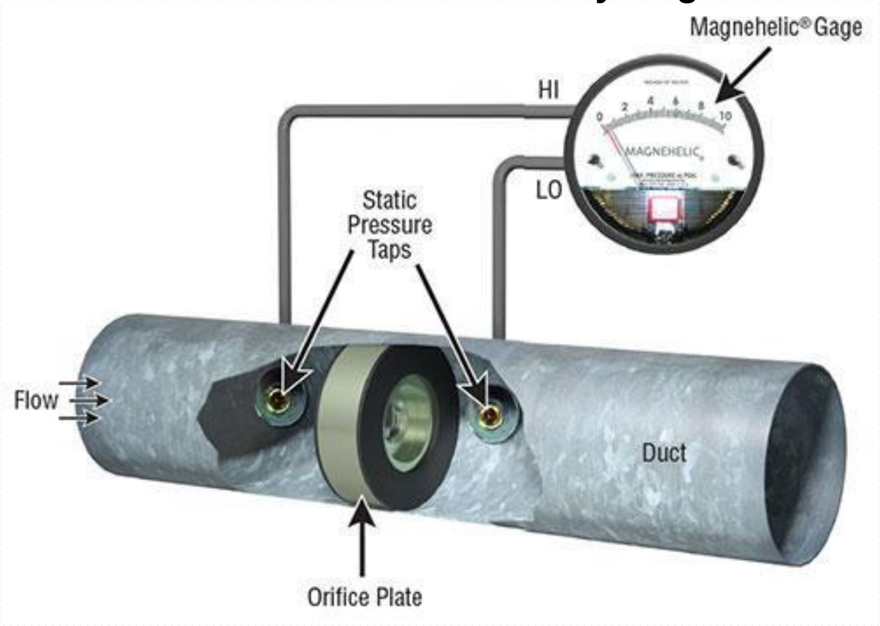
Differential Pressure Flow Meters - Applications

- Low cost, however, accuracy can be poor or variable
- Not ideal for fluids with high viscosity
- Commonly used in oil and gas, chemical, and power applications
- There are many different types including the orifice plate, venturi tube, and flow nozzle

Orifice Plate Air Velocity Gage



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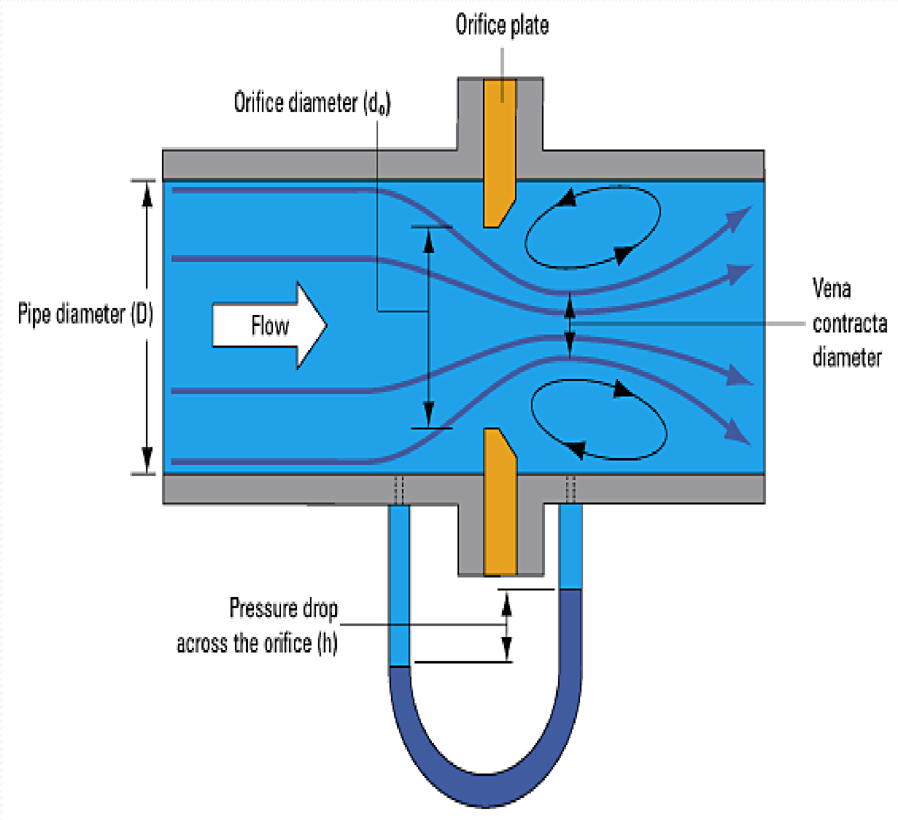
Orifice Plate

- Orifice plates are the most common type of differential flow meter.
- A fluid is passed through a plate with a small opening.
- The pressure drop can be measured to find the discharge, similar to Venturi Tube.
- Commonly used in pipe systems



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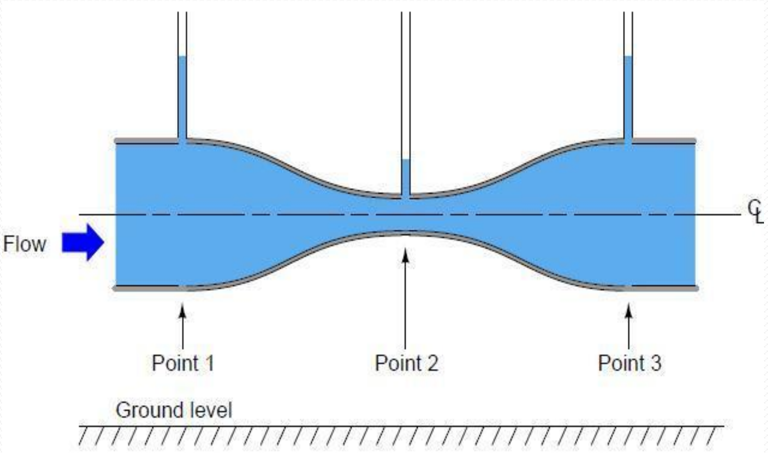
Venturi Tube

- Venturi Tube are a direct application of Bernoulli's Principle.
- This tube forces an increase in a fluid's velocity.
- Manometers allow the pressure head to be directly measured.
- Using Bernoulli's equation, the discharge can easily be found.



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Open Channel Flow Meters - Theory

- Open channel flow velocities are most commonly measured with weirs or flumes
- These measurements are based on measuring the height of the flow before the weir or in the flume

$$Q=KH^n$$

Where, Q is volumetric flow rate
K is a units coefficient
H is the measured height at the flume or weir
n is the specific coefficient of the type of flume or weir

- Similar to devices and theories used by the Egyptians to calculate the flow of the Nile river

Open Channel Flow Meters - Applications

- Often used for irrigation, streams, wastewater, and stormwater measurements
- Have moved from manual readings to more automated systems
- Weirs are relatively inexpensive and easy to build but can require frequent cleaning
- Flumes are more expensive and slightly more complicated to build but rarely require maintenance

Parshall Flume

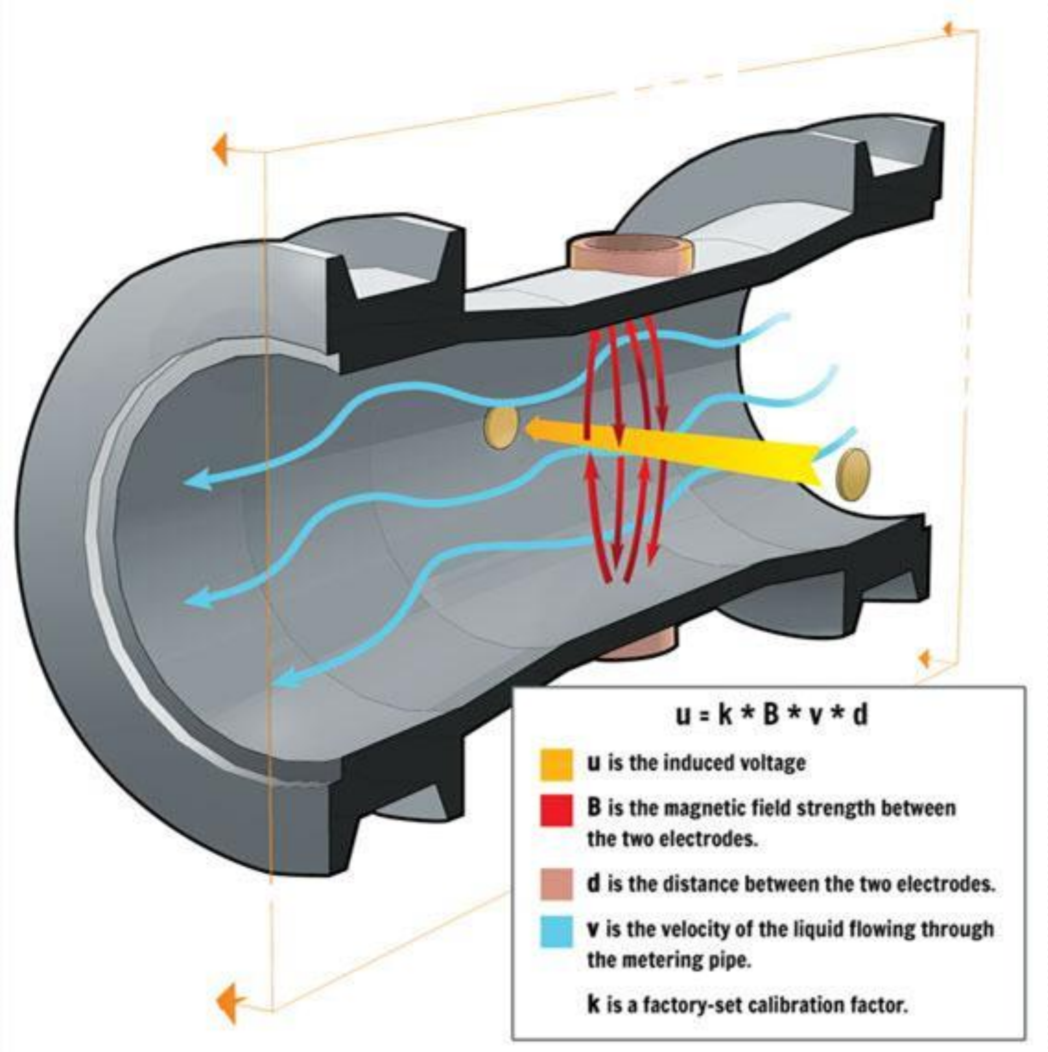
Image Courtesy of TRACOM Fiberglass

Weir

Image Courtesy of Dwyer Instruments, Inc.

Electromagnetic Flow Meters - Theory

- Based on Faraday's law of electromagnetic induction
- Requires the fluid to be conductive
- The flow of the fluid creates an induced voltage which is proportional to the flow velocity



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Electromagnetic Flow Meters - Applications

- Require the fluid to completely fill the pipe
- Very accurate
- Not recommended for fluids with high, very low, or variable conductivity
- Can be used on a wide range of pipe sizes
- Used in many industries including water and wastewater, mining, and utilities

Image Courtesy of ABB

Image Courtesy of Flomotion Systems

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