An Introduction to Flow Meter Technologies

Walter Freeman
Neal Systems, Inc.

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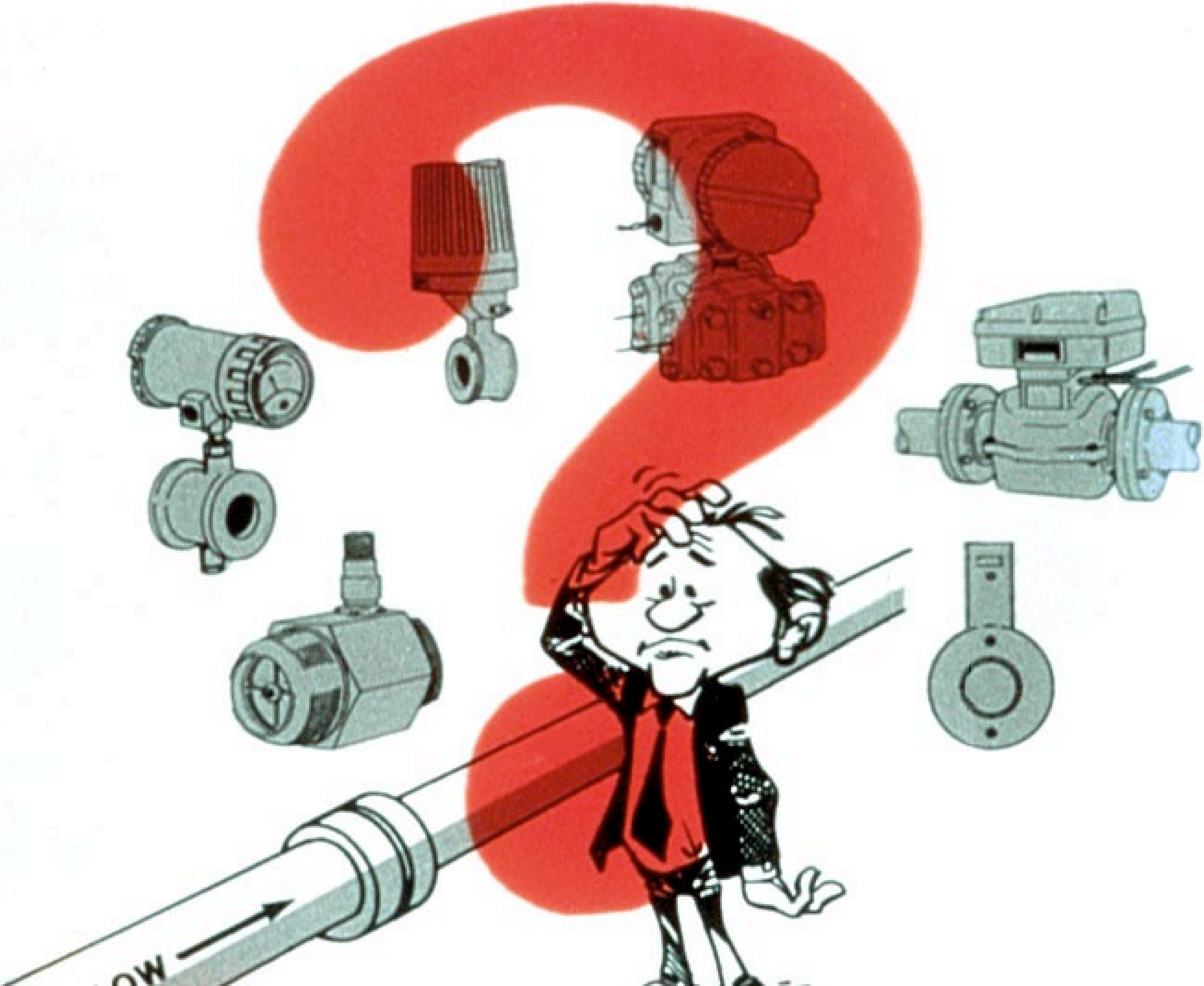
An Introduction to flowmeter technologies

The variety of choices facing anyone confronted with a flow measurement application are vast. This course will examine the most common flow meter choices providing understanding of measurement principles and the advantages/limitations of each type.

- Topics include: flow definitions, reasons for measuring flow, definition of volumetric, mass and standard volume units, accuracy, repeatability and rangeability.



Discussion Topics

LEARNING OBJECTIVES-In this course you will

Learn Flow Definitions

- *Reasons for flow measurements*
- *Difference between Total Flow and Flow Rate*
- *Understand Mass flow versus Volume flow*
- *Identify What is Standard Volume*
- *Understand Accuracy and Repeatability*
- *Calculate Percent of Rate vs Percent of Full Scale Accuracy*
- *Determine Rangeability*
- *Be knowledgeable of Flowmeter Technologies*
- *Identify Important organizations*

Glossary of Some Important Terms

- ***Accuracy – The degree of conformity of an indicated value to a recognized accepted value or ideal value.***
- ***Density – Mass per unit volume.***
- ***EMF – Electromotive Force is the driving force behind electron flow***
- ***Flowmeter – A device that measures the rate of fluid or quantity of a moving fluid in an open or closed conduit.***
- ***Fluid – Anything capable of flowing.***
- ***Laminar Flow – Flow in which a generally viscous slow-moving fluid separates into layers that do not mix.***
- ***Linear – A straight-line relationship between one variable and another.***
- ***Linearity – The Closeness to which a curve approximates a straight line.***
- ***Lower Range Value – The lowest value of the measured variable that a device is adjusted to measure.***
- ***Newtonian Fluid – A fluid wherein the the ratio of flow to force is constant.***
- ***Non-Newtonian Fluid – A fluid whose viscosity is not constant and, therefore, the pattern of its velocity is not predictable.***
- ***Nonlinear – The relationship between two or more variables cannot be described as a straight line.***

Glossary of Some Important Terms

- ***Pressure – Force exerted over a surface divided by its area.***
- ***Range – The region between the limits within which a quantity is measured, received or transmitted expressed by stating the lower and upper range values.***
- ***Rangeability – The ratio of maximum controllable flow of an instrument to minimum controllable flow (e.g., 3:1 or 10:1)***
- ***Specific Gravity – The quantification of relative density of a fluid. The ratio of the density of a liquid at a particular temperature to the density of water at a particular temperature.***
- ***Temperature – The change in the quantifiable degree of hotness or coldness of a system.***
- ***Upper Range Value – The highest value of the measured variable that a device is adjusted to measure.***
- ***Velocity Profile – A flow velocity pattern created in a pipe by the combined factors of fluid viscosity, pipe wall texture, and flow speed.***
- ***Viscosity – The resistance of a fluid to flow.***

What is a Flow Measurement ?

***Flow** is a measure of the **quantity** of fluid that passes through a conduit or a measure of the **rate** of fluid flow through the conduit.*

Sometimes <u>both</u> are needed from the same flow measurement device or flowmeter.

Total Flow and Flow Rate

*The **AMOUNT** of a fluid that has collected or passed through a pipe over a period of time is **TOTAL FLOW.***

***FLOW RATE** is the **SPEED** or **VELOCITY** of the fluid at any given instant in time.*

*Flowmeters are sized and specified based on **RATE!!***

Why do we measure flow?

- Quality control
- Health and safety
- Cost-efficiency

Some Reasons for Measuring Flow

- *Control a process*
- *Measure a process*
- *Custody transfer (billing)*
- *Blending of ingredients*
- *Mass/Energy balance / efficiency*

  Boiler / burner fuel & combustion air feed
- *Leak detection*

Steam

Dirty Liquids

Clean Liquids

Solvents

Cryogenic Service

Explosive

Water

Viscous Fluids

Corrosive Liquids

Area Class

Temperature

Abrasive Slurries

Inert Gas

Fibrous Slurries

Partially Filled Pipes

Open Channel Flows

Low Velocity Flows

Non-Newtonian Fluids

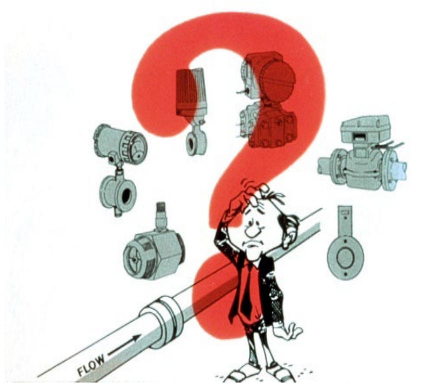
Conductive Fluid

Hydrocarbons

Multi-component

Pressure

Density

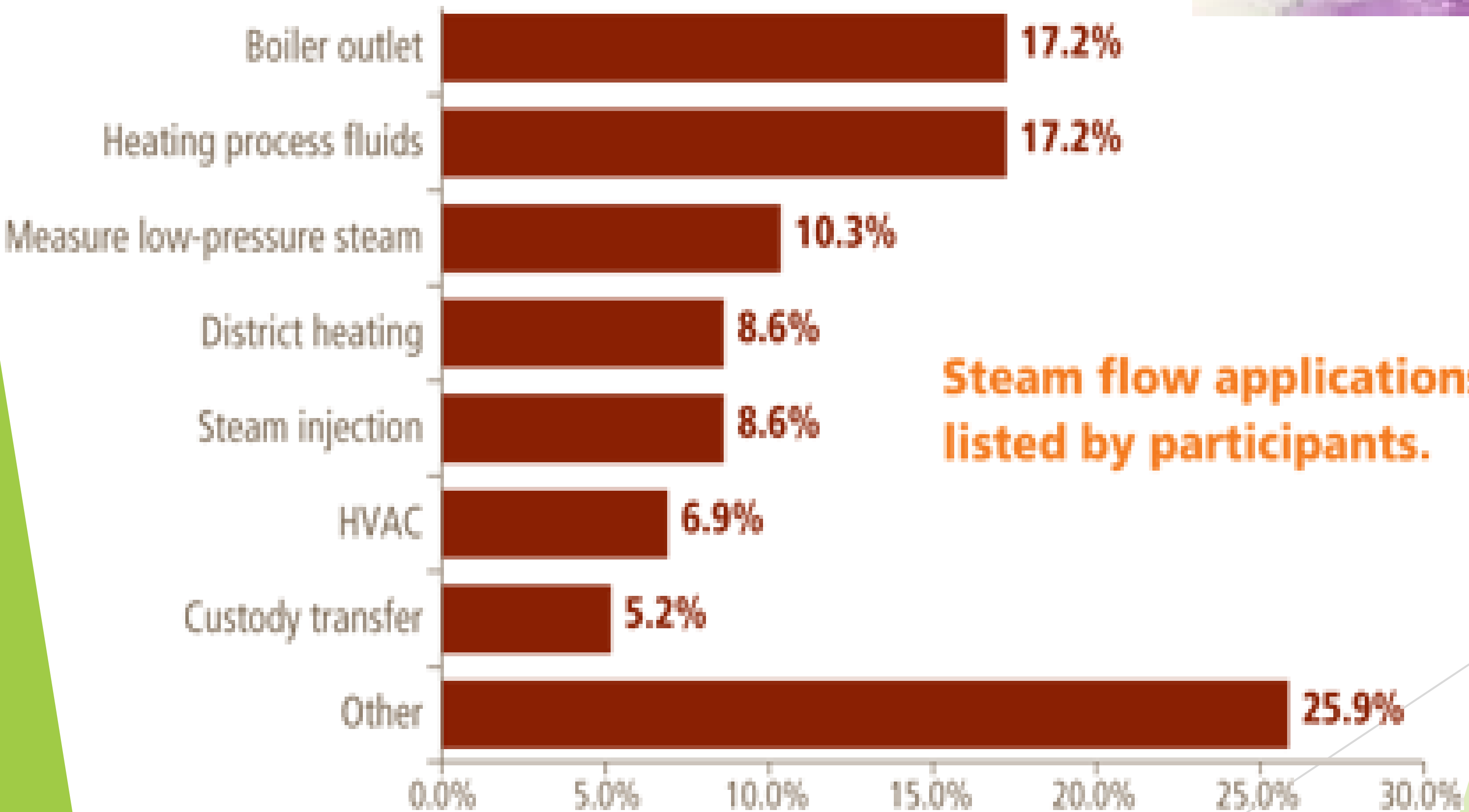


What is my application and process condition?

Commonly Measured Fluids

- Steam
- Water
- Air
- Natural gas
- Liquid fuel

Steam


Boiler outlet 17.2%
Heating process fluids 17.2%
Measure low-pressure steam 10.3%
District heating 8.6%
Steam injection 8.6%
HVAC 6.9%
Custody transfer 5.2%
Other 25.9%
0.0% 5.0% 10.0% 15.0% 20.0% 25.0% 30.0%
Steam flow applications listed by participants.

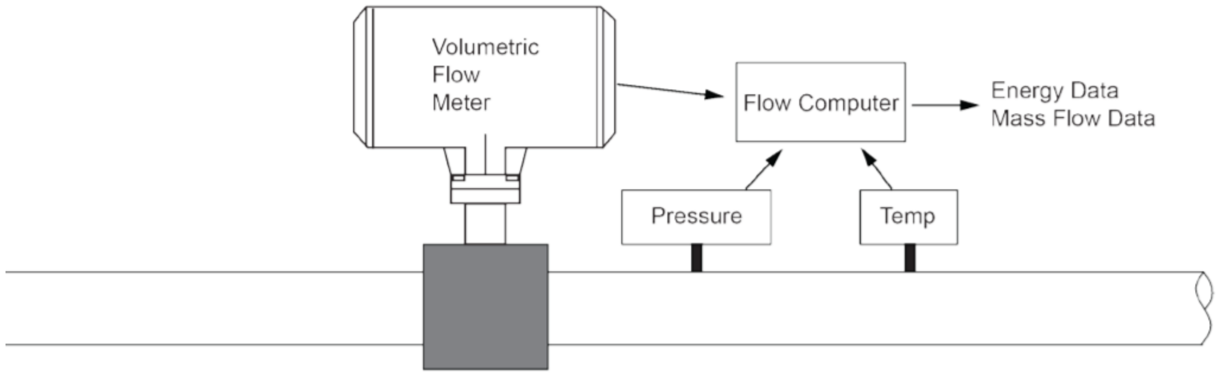
Saturated Steam

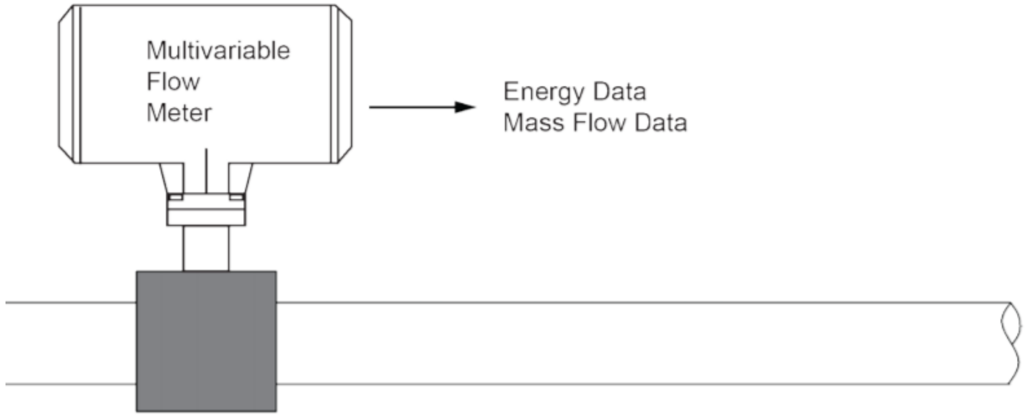
Steam at the saturation point meaning liquid (water) and vapor (steam) are coexisting. Typically for a given pressure, there is a unique temperature defined by the saturation line. Therefore, there is only the need to measure either temperature or pressure to determine density.

Note: Saturated steam is usually assumed to be dry but generally there can be some degree of liquid in the stream. High quality steam generally has less than 1 to 2 % liquid.

Superheated Steam

Steam above the saturation point meaning only the vapor phase is present.





Natural Gas

Hydrocarbon in gaseous form

Primarily Methane (CH4) with varied amounts of other hydrocarbons and some hydrocarbon constituents.

Liquids

Aqueous Solutions (H2O), Acids, Bases, Salts

Inert Gas

N2 / Ar

How do we measure flow?

Vortex

Turbine

Magnetic

Doppler / Transit Time

Orifice

Averaging Pitot

Target

Open Channel

Venturi

Positive Displacement

Thermal

Multi-variable Mass

Coriolis

What Flowmeter Technology should I use?

Flowmeter Selection Process

Flowmeter Selection Depends On:
The Application……

- ***Flow Rate***
- ***Fluid (liquid, gas, steam)***
- ***Process Conditions –Physical (pressure, temp, corrosiveness, clean, dirty, flow profile, Reynolds Number)***
- ***Process Conditions – Operational (line size, pipe geometry, materials compatibility)***
- ***Performance (accuracy, repeatability, rangeability, reliability)***
- ***Area classification and ambient conditions***
- ***Economics (performance / value advantages, installation, maintenance, parts, energy consumption, risk)***
- ***Piping arrangement***

Flow Conditions

Laminar Flow

Condition in which forces due to viscosity are more significant than forces due to inertia

Rp $< 2,000$

Transitional Flow

Flow between laminar and turbulent

Rp 2000 to 10,000

Turbulent Flow

Conditions in which forces due to inertia are more significant than forces due to viscosity. Particles are in random motion

Rp $> 10,000$

Reynold's Number

A dimensionless number that is accepted as a fluid parameter that combines the effects of viscosity, density and pipeline velocity. The ratio of inertia and viscous forces in a fluid defined by the formula

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

Density x Velocity x Dimension of the System

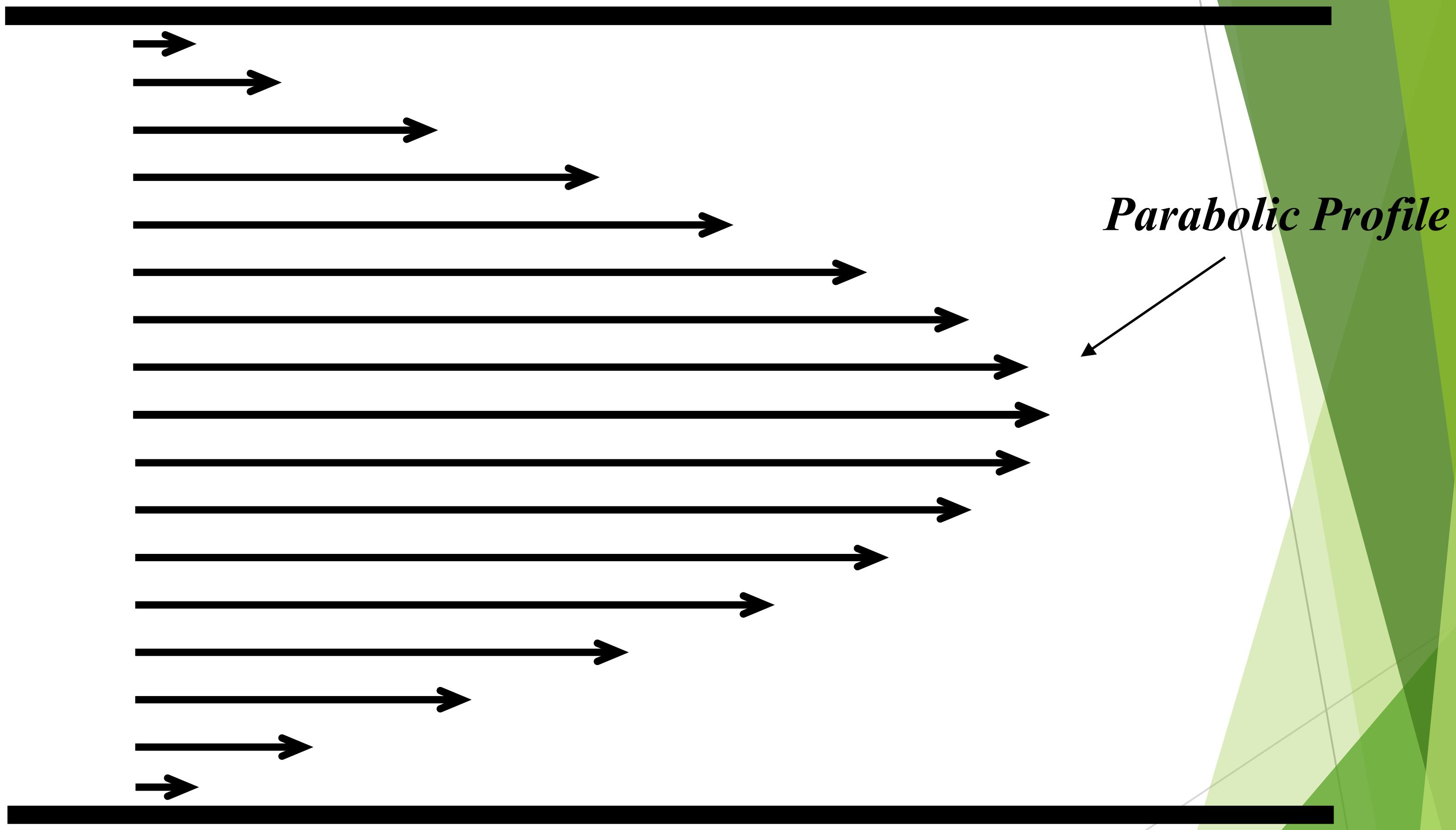
Viscosity

Reynold's Number, Rp

$$\frac{\textit{Flowrate}}{\textit{Viscosity}}$$

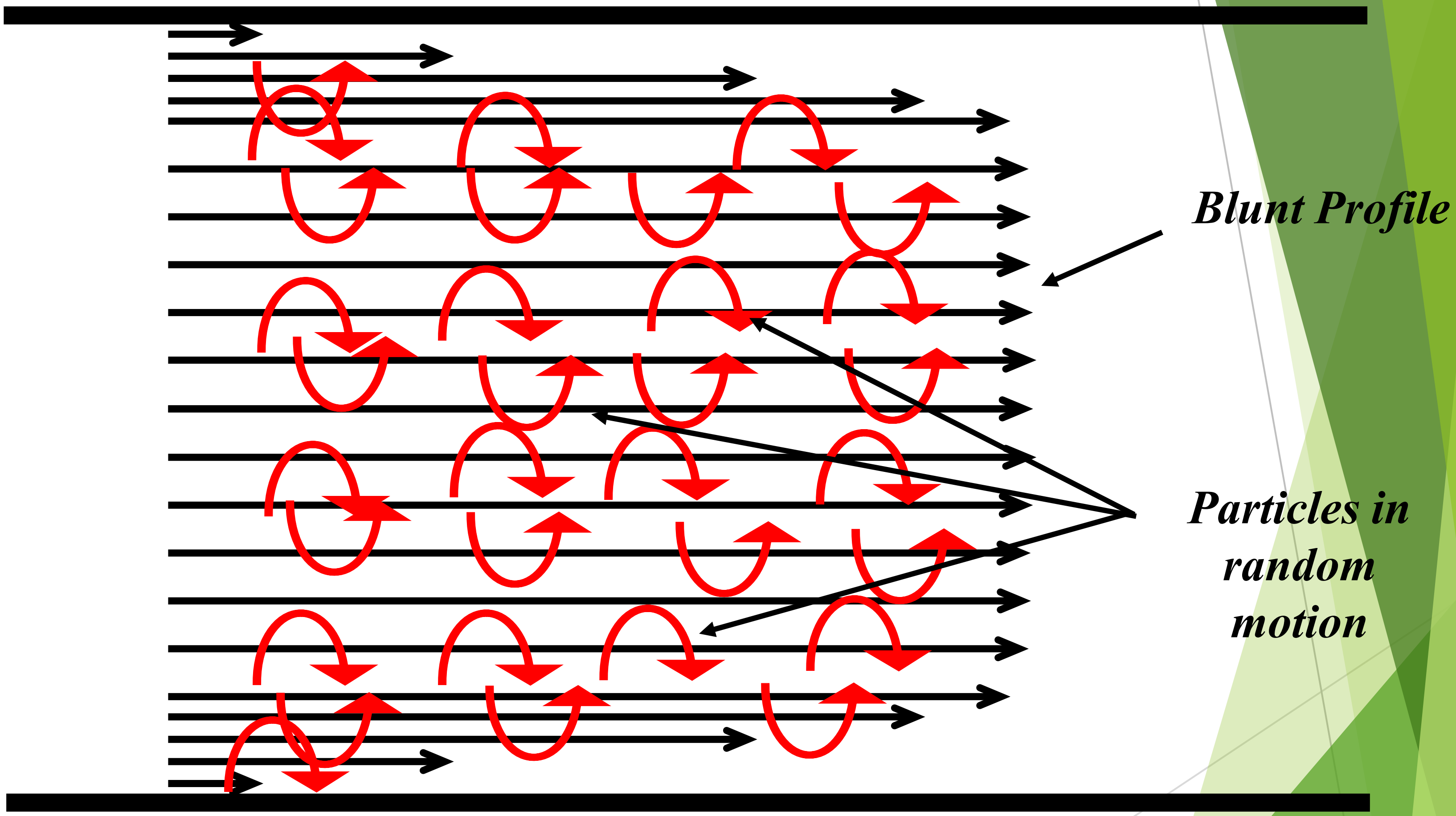
Note: ***At low velocities and for viscous fluids, viscous forces restrain fluid properties into parallel-layer motion. At higher velocities and for less viscous fluids, inertia forces overcome viscous forces and fluid properties move in a random turbulent motion. The flow coefficient for water at a specific Reynolds Number is the same for liquid, gas, steam and oil.***

Laminar Pipe Flow



Fully developed parabolic flow profile for a pipe with a Rp < 2000
Viscous forces are more significant that inertia forces

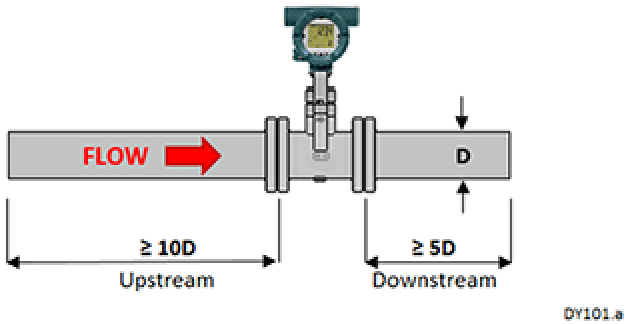
Turbulent Pipe Flow



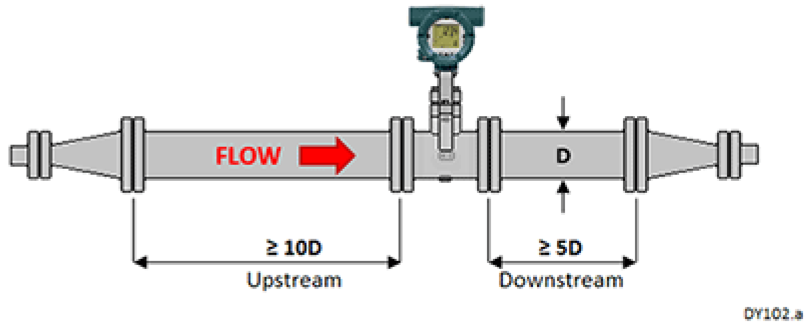
Parabolic flow geometry is altered. Rp > 10,000.
Inertia forces overcome viscous forces

Required Straight Pipe Length

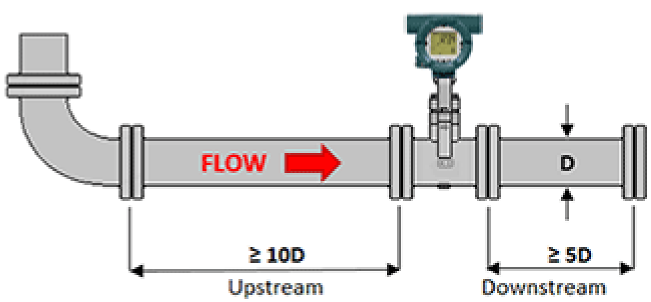
- Straight Pipe



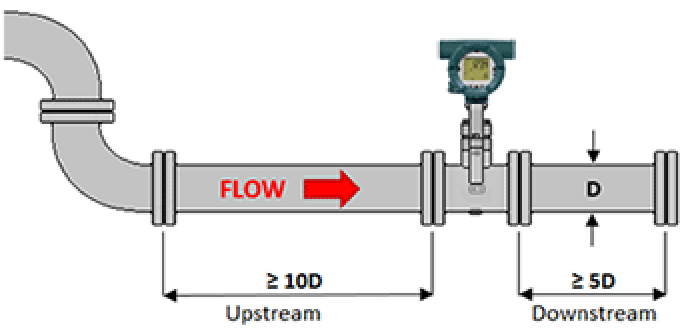
- Expander Pipe



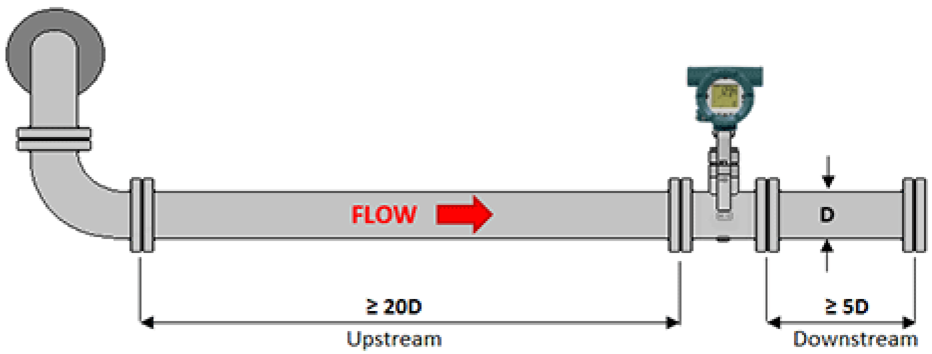
- Bent Pipe



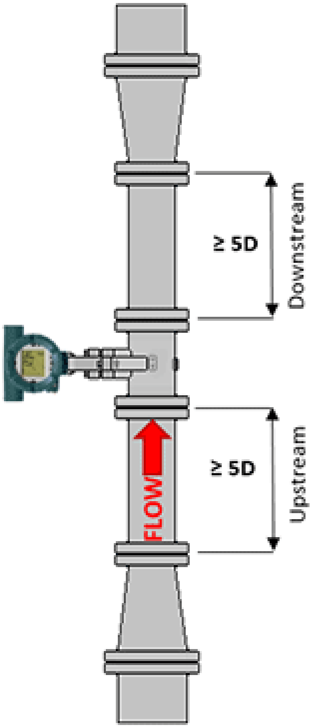
- Double Bent Pipe (Coplanar)



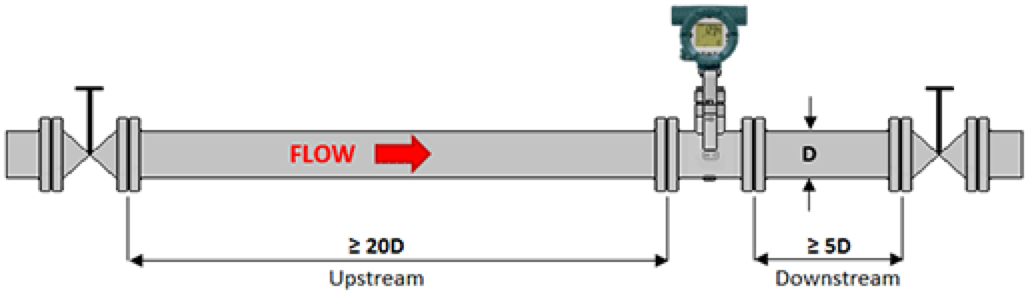
- Double Bent Pipe (Non-coplanar)

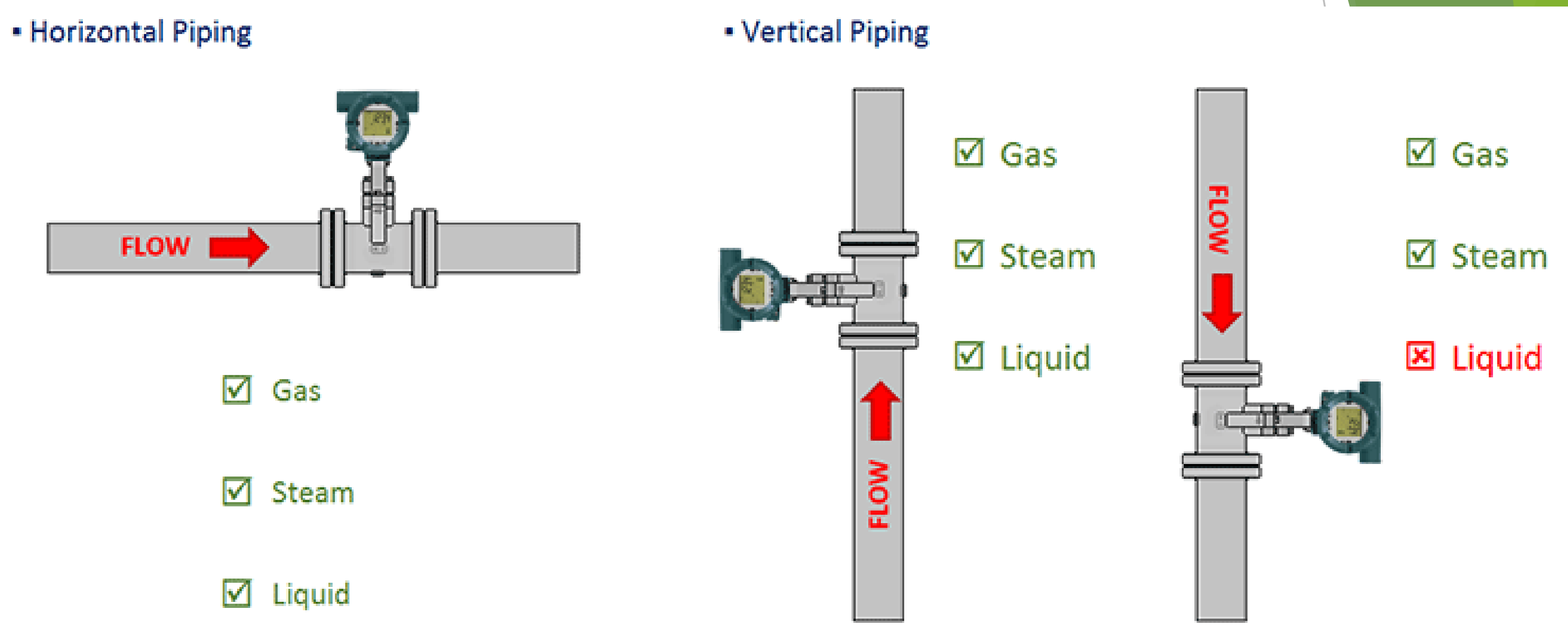


- Reducer Pipe



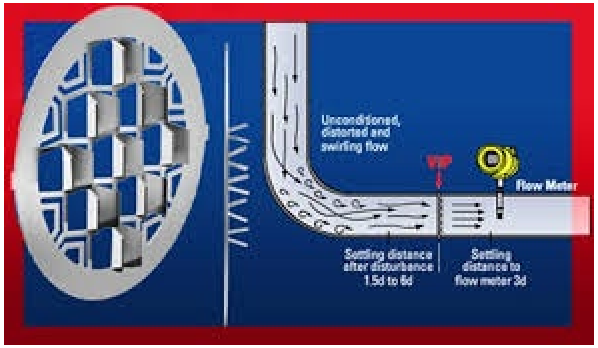
- Pipe with Valves





Horizontal Piping
FLOW
☑ Gas
☑ Steam
☑ Liquid
Vertical Piping
FLOW
☑ Gas
☑ Steam
☑ Liquid
FLOW
☑ Gas
☑ Steam
☒ Liquid

Flow straighteners



Mass Flow and Volumetric Flow

Mass Flow

The rate or total measured in units of mass (pounds, kilograms etc.)

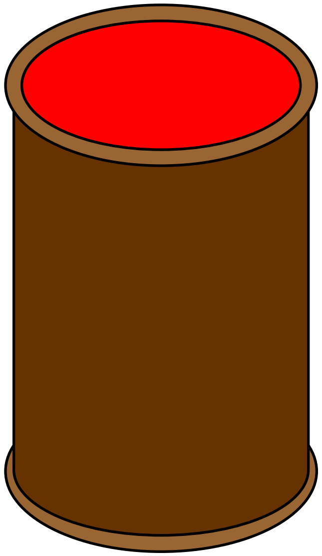
$\rho A V = Q_m$

Volumetric Flow

The rate or total measured in units of volume (gallons, liters, cubic ft.)

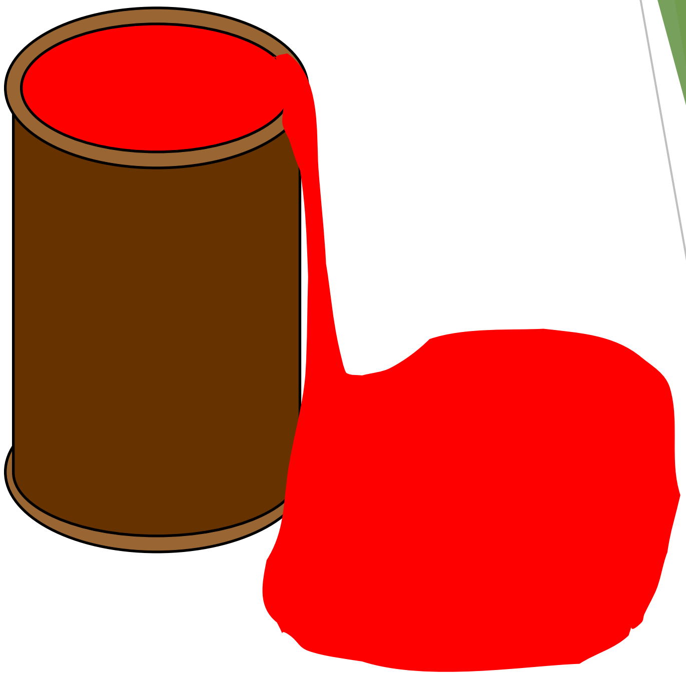
$A V = Q_v$

Mass and Volume



344 POUNDS OF GASOLINE
AT 20 DEG F

55 GALLONS



344 POUNDS OF GASOLINE
AT 60 DEG F

56.6 GALLONS

Standard Volumetric Flow

The volume flowrate of a fluid referenced back to standard or normal conditions of temperature and pressure (STP).

- ***Used for gases that ARE gases at reference and flowing conditions (typical).***
- ***Use for liquids (not common).***
- ***NOT used for vapors such as STEAM.***

Gas Equations

Ideal Gas – Conforms to Boyle's Law and has zero heat of expansion. At a constant temperature, the volume of a given quantity of gas varies inversely with pressure.

P V= n R T

P = Absolute pressure psia
V = Volume ft^3
n = number of moles = Mass/mol.wt
R = Universal gas constant
10.73151 (psia ft^3)/(lb mol deg R)
T = absolute temperature (degrees R)

Real Gas – PVT does not conform: Gases liquefy at low temp and high pressure

P V = n Z R T

Z = compressibility

Standard Volumetric Flow

Standard Volumetric Flow =

Actual Volumetric Flow x $\dfrac{\text{Density at Flowing Conditions}}{\text{Density at Ref Conditions}}$

For a real gas using temperature and pressure

Actual Volumetric Flow x $\dfrac{Z_{ref} \quad T_{abs\ ref} \quad P_{abs\ flowing}}{Z_{flowing}\ T_{abs\ flowing}\ P_{abs\ ref}}$

Standard Volume

Examples:

- ***Standard Cubic Feet (59F, 14.69595 psia), ISO 5024 for petroleum liquids***
- ***Standard Cubic Meter (60F, 14.69595 psia), API 2540***
- ***Normal Cubic Meter (32F, 14.69595 psia)***
- ***Standard Gallons***
- ***Normal Liters***

Accuracy and Repeatability

Often, We don’t need ACCURACY

We need ………

REPEATABILITY

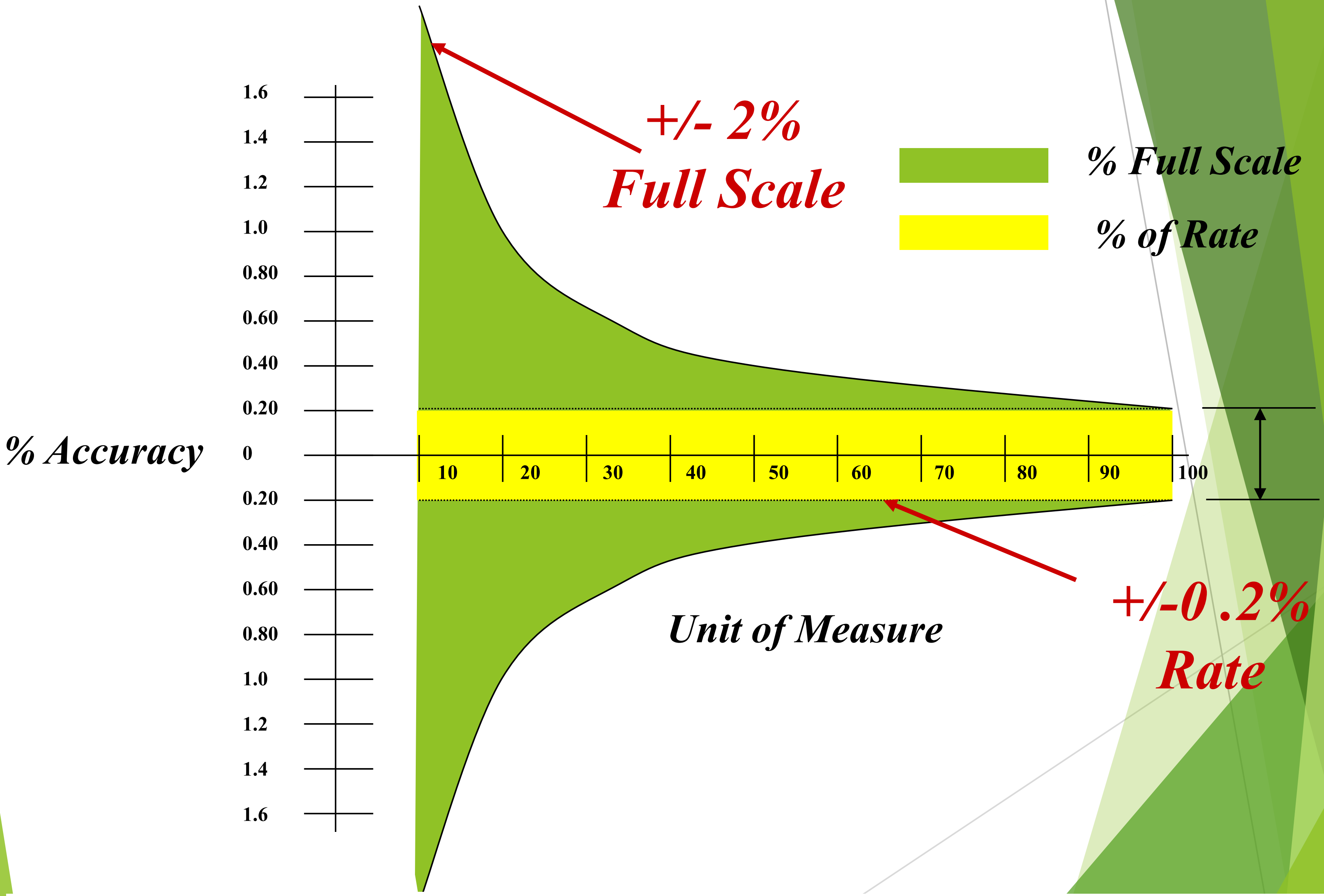
REPEATABILITY

The ability to reproduce the measured flow rate in the same direction, with identical process conditions on successive measurements

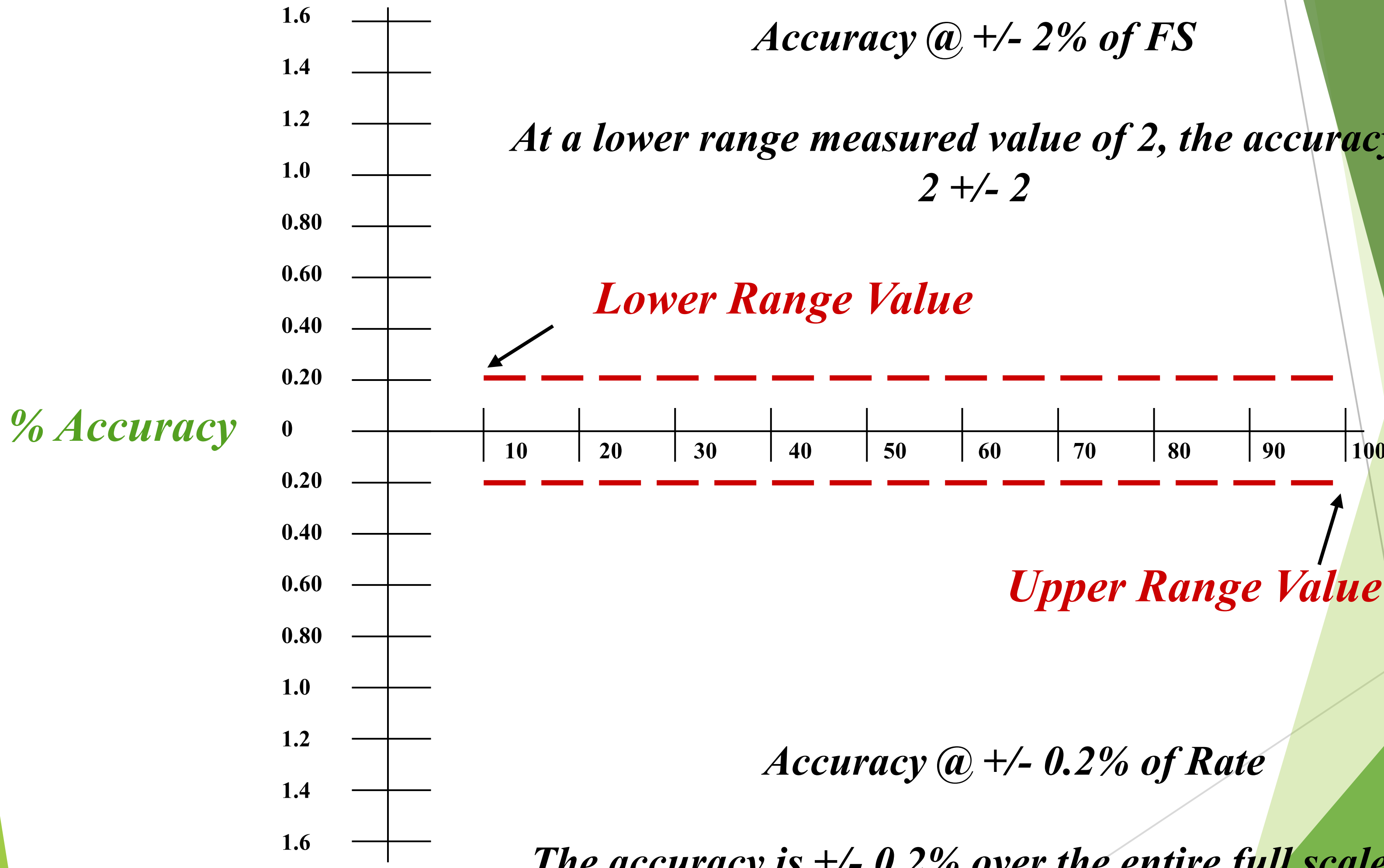
ACCURACY

The measured flow rate compared to the actual flow rate

% of Rate versus Full Scale Accuracy



% of Rate versus Full Scale Accuracy



Accuracy @ +/- 2% of FS

At a lower range measured value of 2, the accuracy is 2 +/- 2

Accuracy @ +/- 0.2% of Rate

The accuracy is +/- 0.2% over the entire full scale range

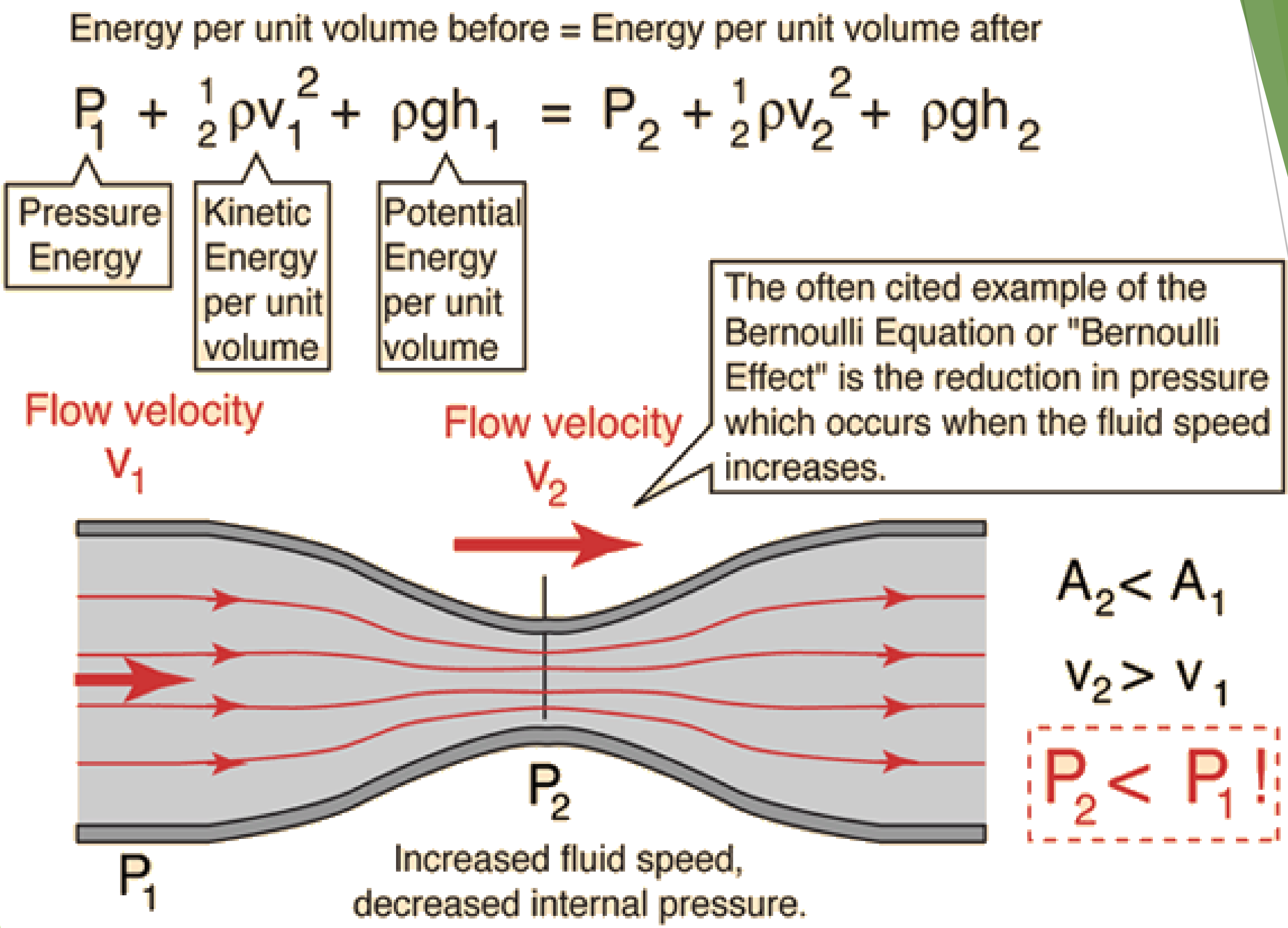
Linearity and Square Law

Linearity

The output of an instrument is proportional to the input. A straight line relationship between one variable and another.

Square Law

The output signal of an instrument is proportional to the square of the input. The relationship between two or more variables cannot be described as a straight line.


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
The often cited example of the Bernoulli Equation or "Bernoulli Effect" is the reduction in pressure which occurs when the fluid speed increases.
Flow velocity v_1
Flow velocity v_2
$A_2 < A_1$
$v_2 > v_1$
$P_2 < P_1$!
P_2
P_1
Increased fluid speed, decreased internal pressure.

Basic Square Law for all Differential Producing (Head Class) Flowmeters

Based on Bernoulli's Streamline Energy Equation:

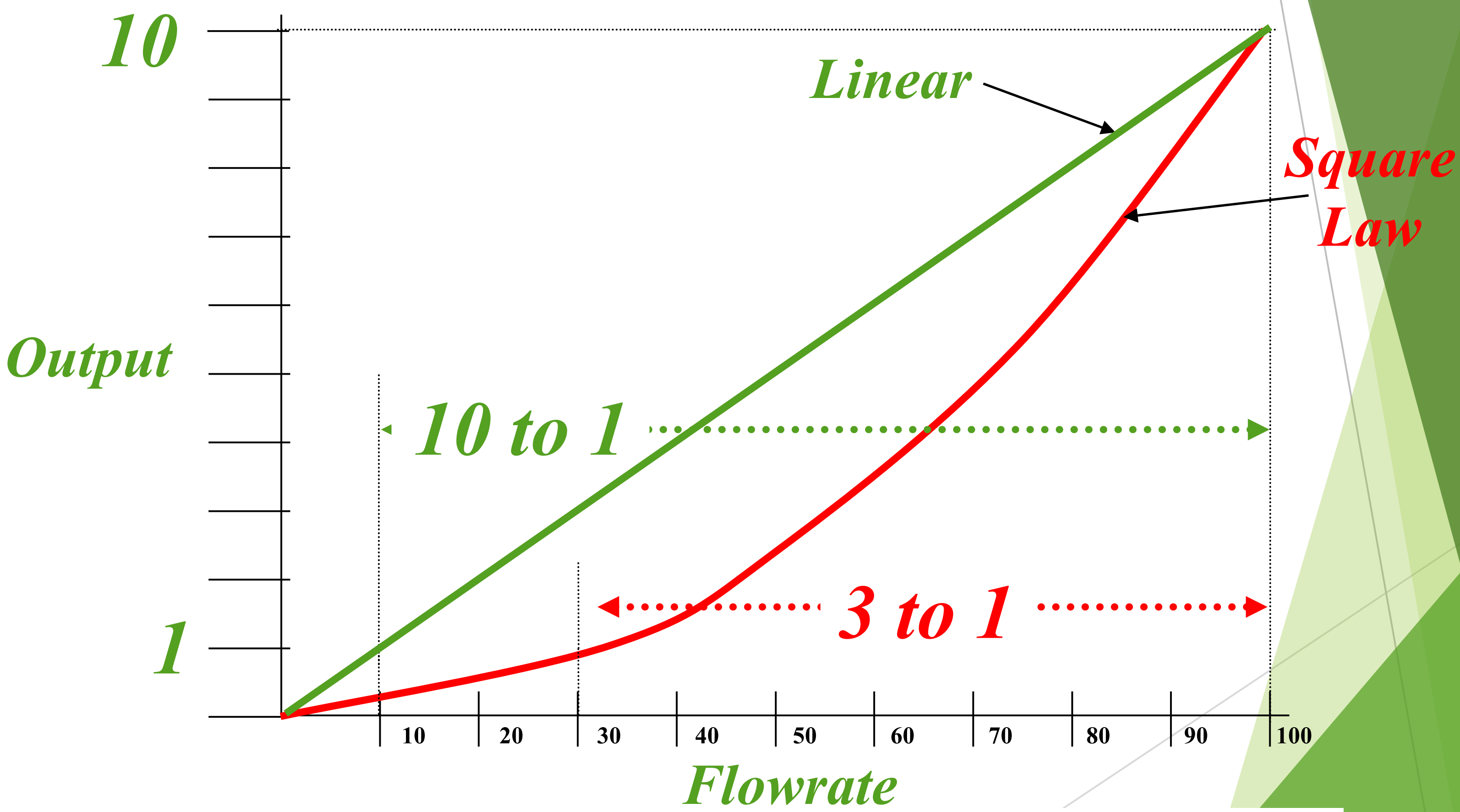
The square root relationship among measured differential Pressure (hw), density (pf) and flow rate (q) is written as:

$$q_{(cfs)} = F_{mc} \sqrt{\frac{hw}{pf}}$$

F_{mc} is the meter constant and corrects for dimensional units, discharge coefficients, pressure tap locations, velocity profile, etc ..

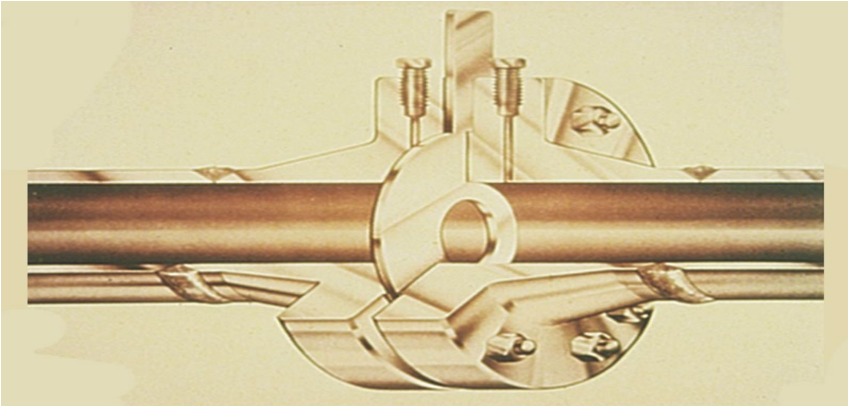
What do Linear Meters provide?

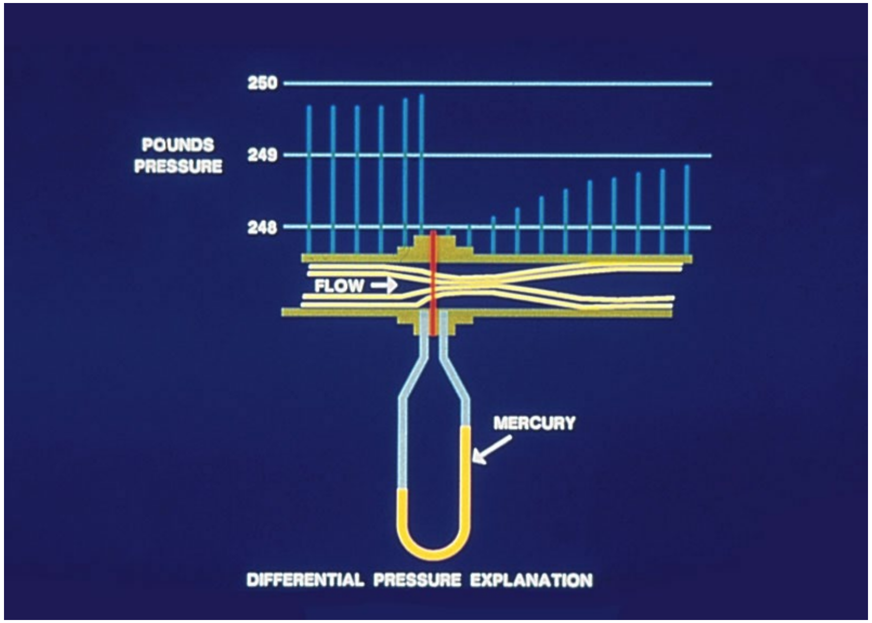
***Rangeability** – the ratio of the maximum controllable flow of an instrument to the minimum controllable flow*



Flowmeter Technologies

HEAD CLASS – Most Common (orifice, nozzle, venturi)





Pros

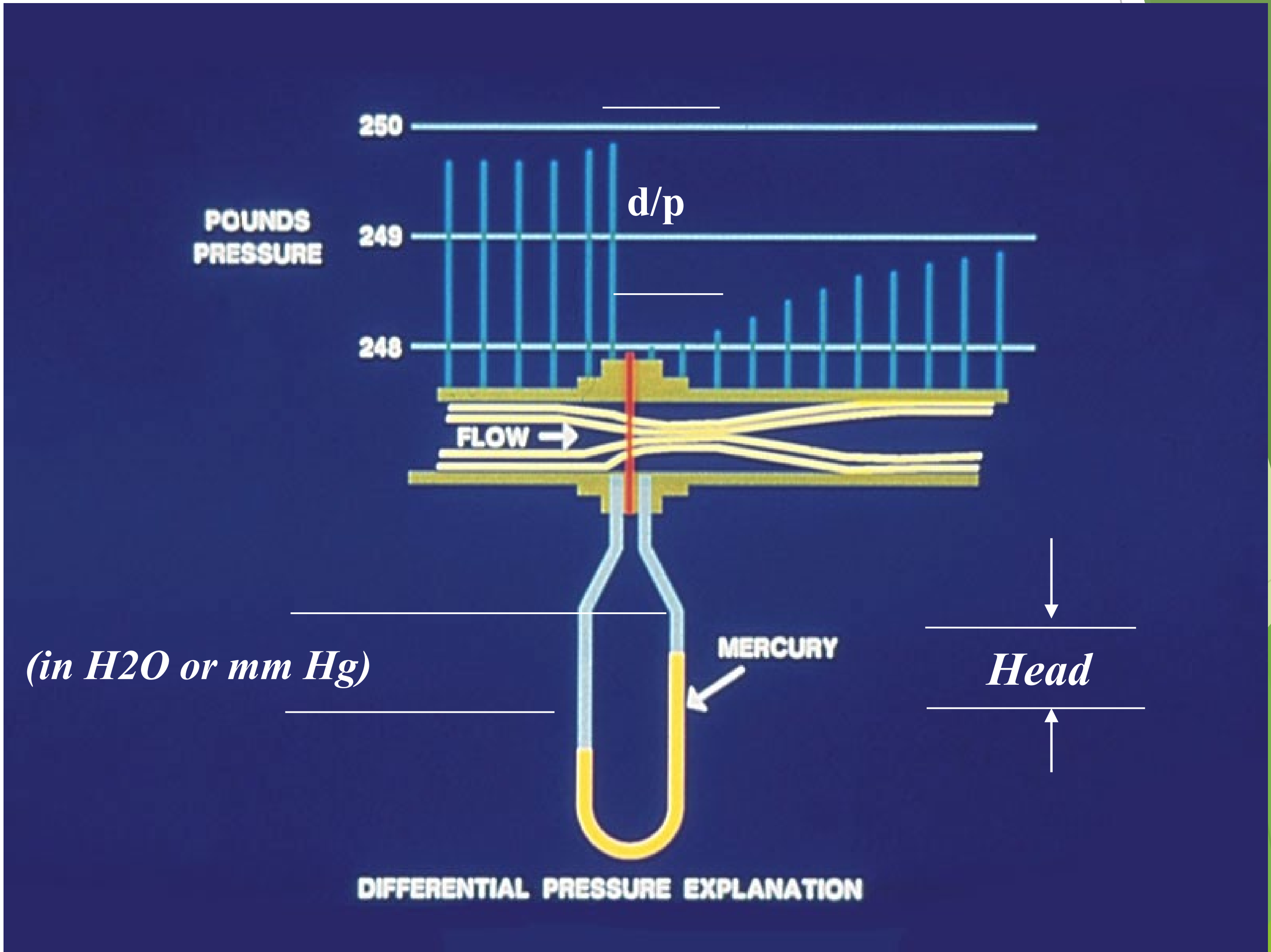
- ***Liquids, gases, vapors***
- ***Accepted by most industries***
- ***Tried and true***
- ***Low capital cost***
- ***Supported by standards***

Cons

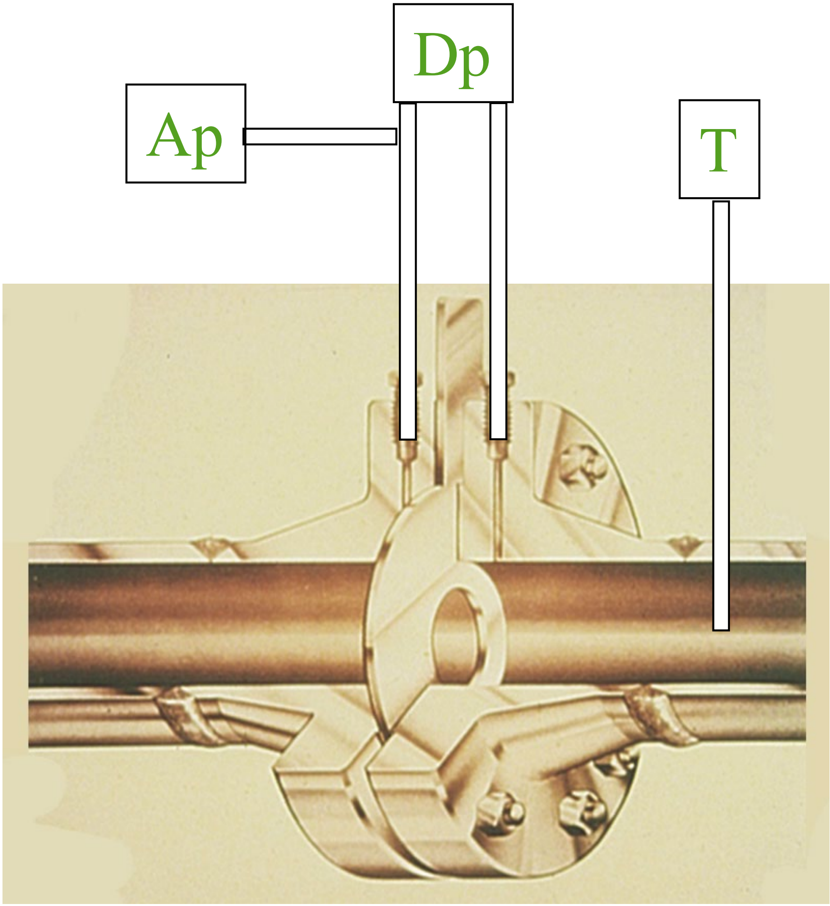
- ***Low Accuracy***
- ***Poor Rangeability (square law)***
- ***Requires compensation always***
- ***High sensitivity to wear***
- ***High cost of ownership***
- ***Plugging***

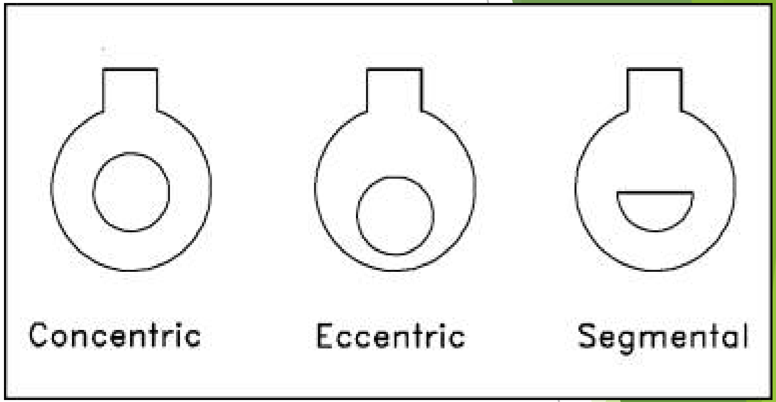
Flowmeter Technologies

HEAD CLASS – Most Common (orifice, nozzle, venturi)



Flowmeter Technologies - Orifice

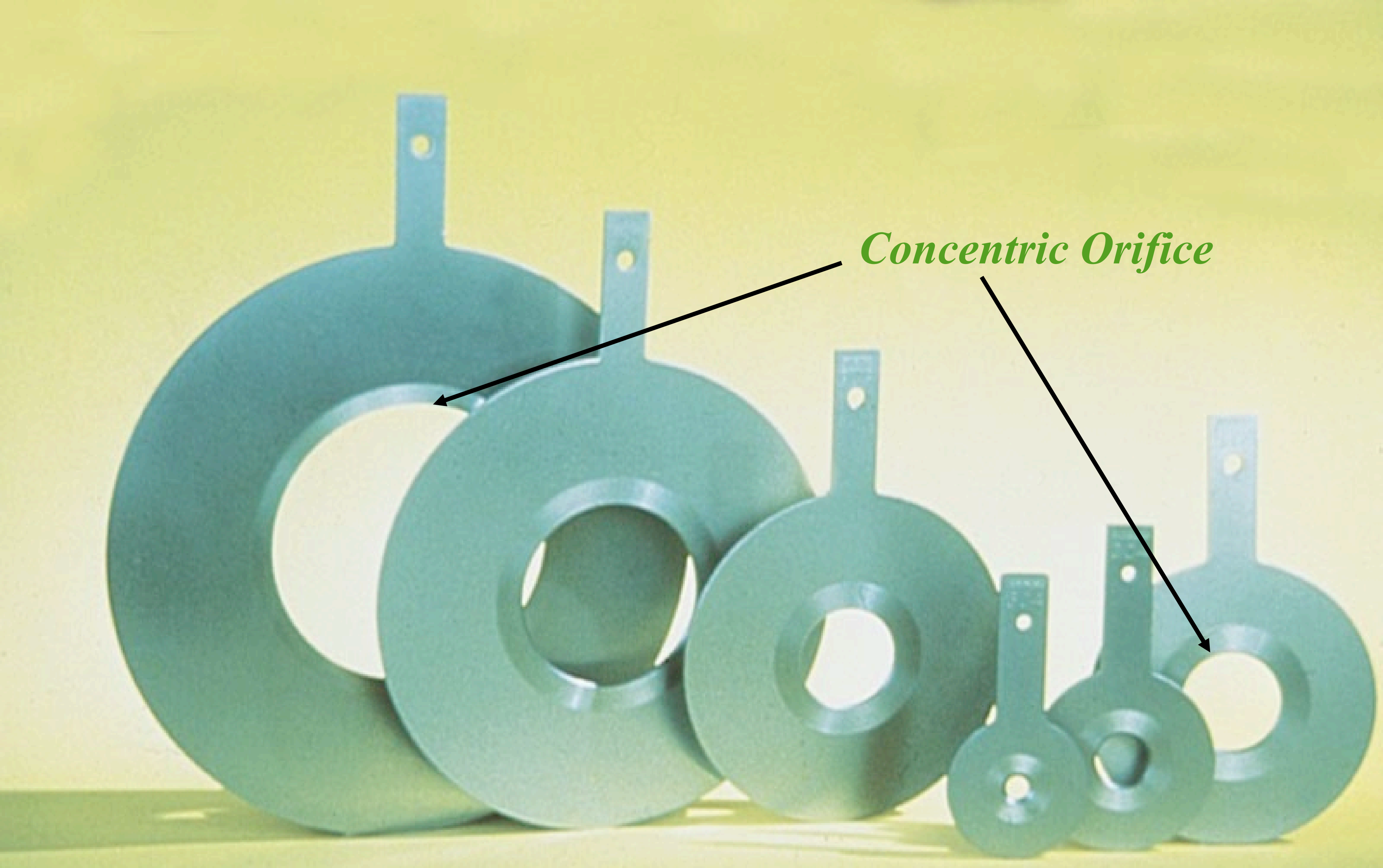




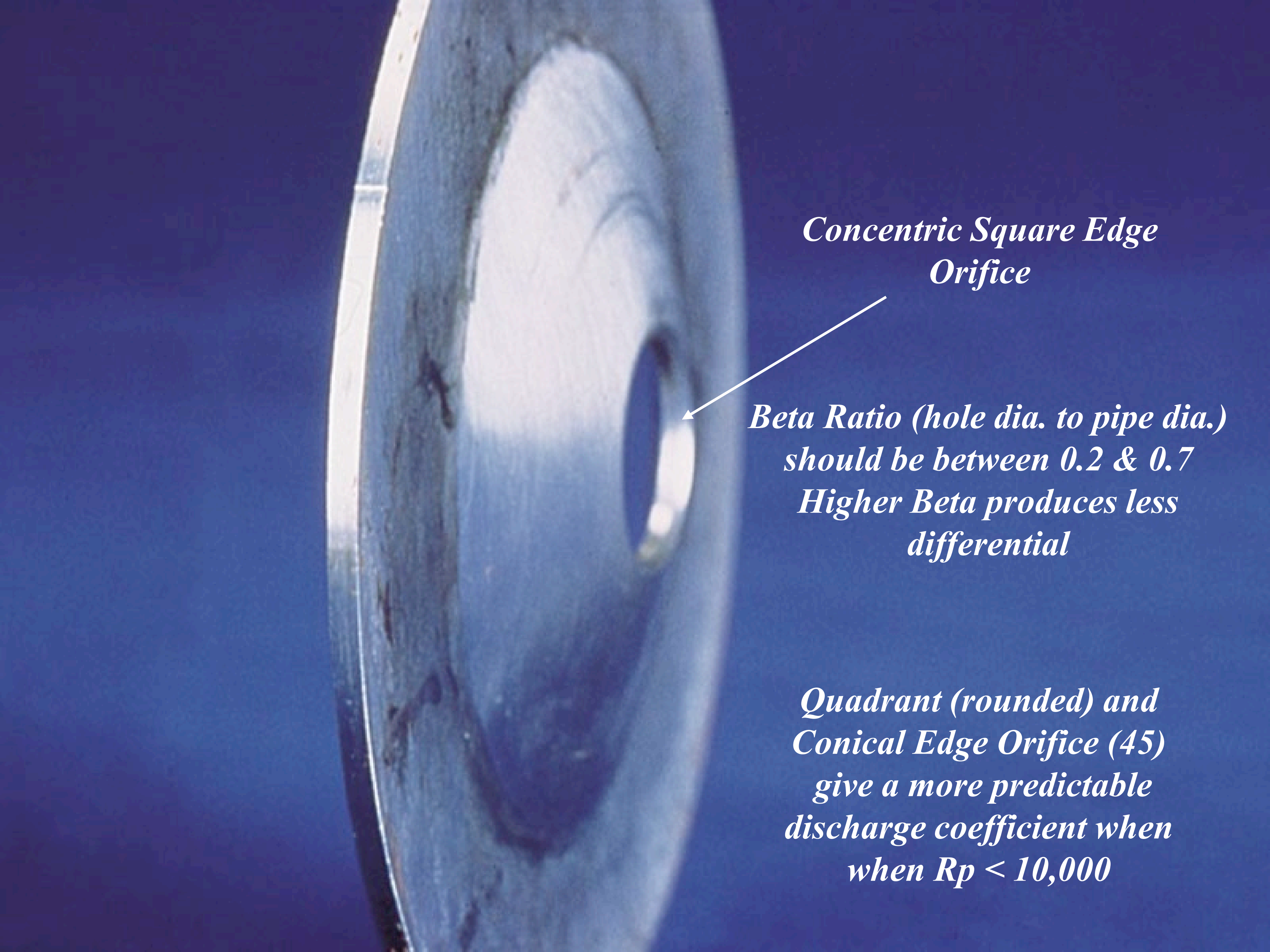
Concentric – Clean Liquids, Gases & Vapor

Eccentric – Hole orientation at the bottom for gases and at the top for liquids permits entrained water or air to flow

Segmental – Passage of dirty liquids and gas where particulate matter is present

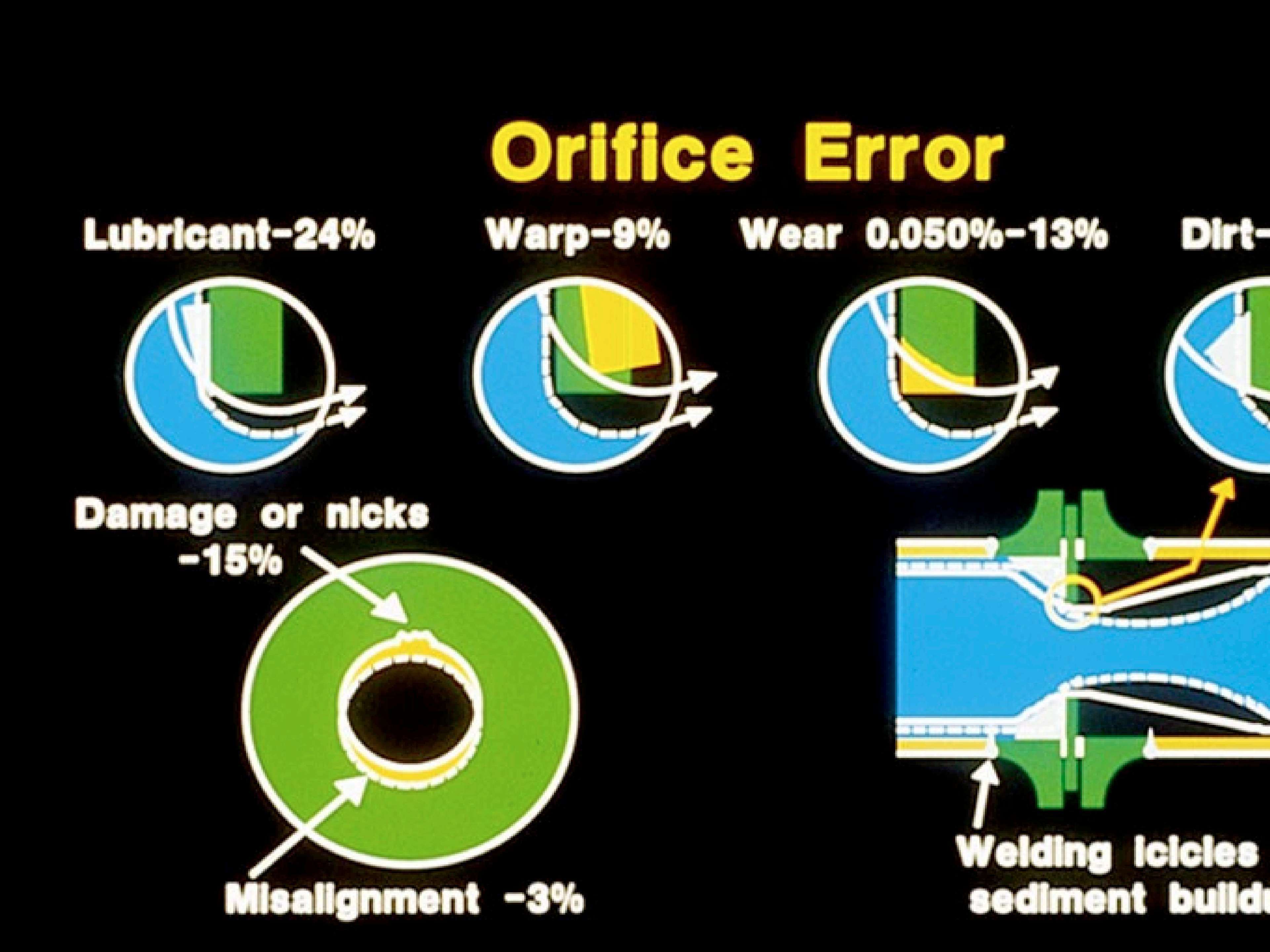


Most common for 2" and larger line sizes for clean liquids, gases and low velocity vapor (steam) flows.


Concentric Square Edge Orifice
Beta Ratio (hole dia. to pipe dia.) should be between 0.2 & 0.7 Higher Beta produces less differential
Quadrant (rounded) and Conical Edge Orifice (45) give a more predictable discharge coefficient when when Rp < 10,000

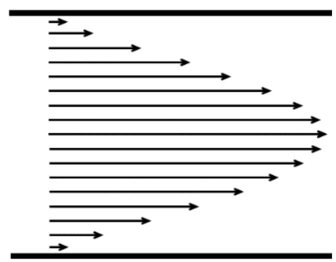
Contributors to Orifice Plate Accuracy

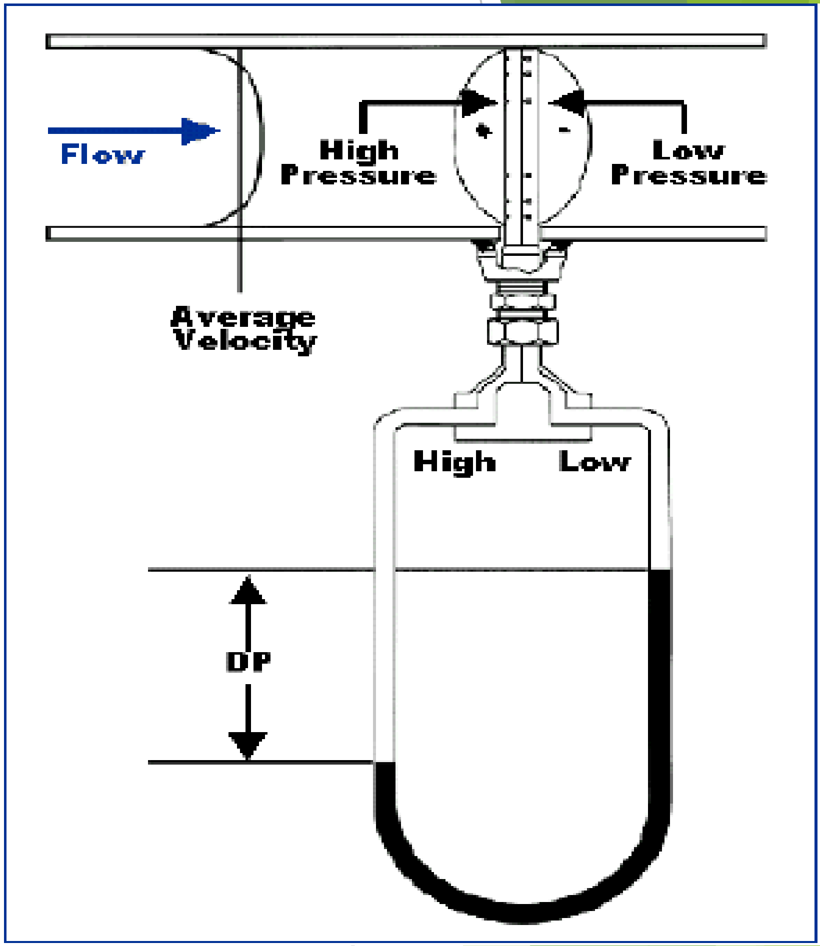
- Edge Shape
- Area and Orifice Type
- Pressure Tap Location and Shape
- Measurement of Differential Pressure
- Measurement of Density
  (density changes with temperature & pressure)
- Fluid, thermal expansion and plate discharge coefficients
- Calculations (gas / vapor & liquid equations)
- Upstream Velocity Profile
- Build-up at the Upstream Face of the Orifice.


Orifice Error
Lubricant-24%
Warp-9%
Wear 0.050%-13%
Dirt-
Damage or nicks
-15%
Misalignment -3%
Welding icicles
sediment build

Flowmeter Technologies

AVERAGING PITOT





$$\text{Total Pressure} = P_{static} + \tfrac{1}{2}\rho V^2$$

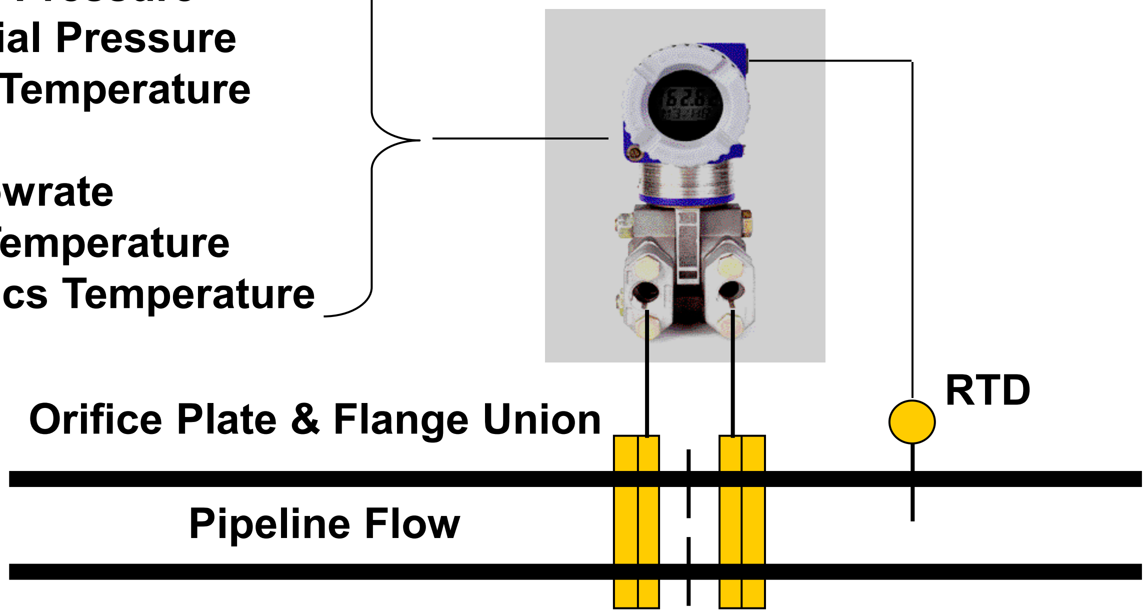
$$\sqrt{\frac{\text{Total Pressure} - P_{static}}{\rho}} \propto V \propto Q_v$$

Flowmeter Technologies

MULTIVARIABLE TRANSMITTER

Outputs Available:

- **Absolute Pressure**
- **Differential Pressure**
- **Process Temperature**
- **Density**
- **Mass Flowrate**
- **Sensor Temperature**
- **Electronics Temperature**



Schematic Illustration of Multivariable Flow Transmitter Application

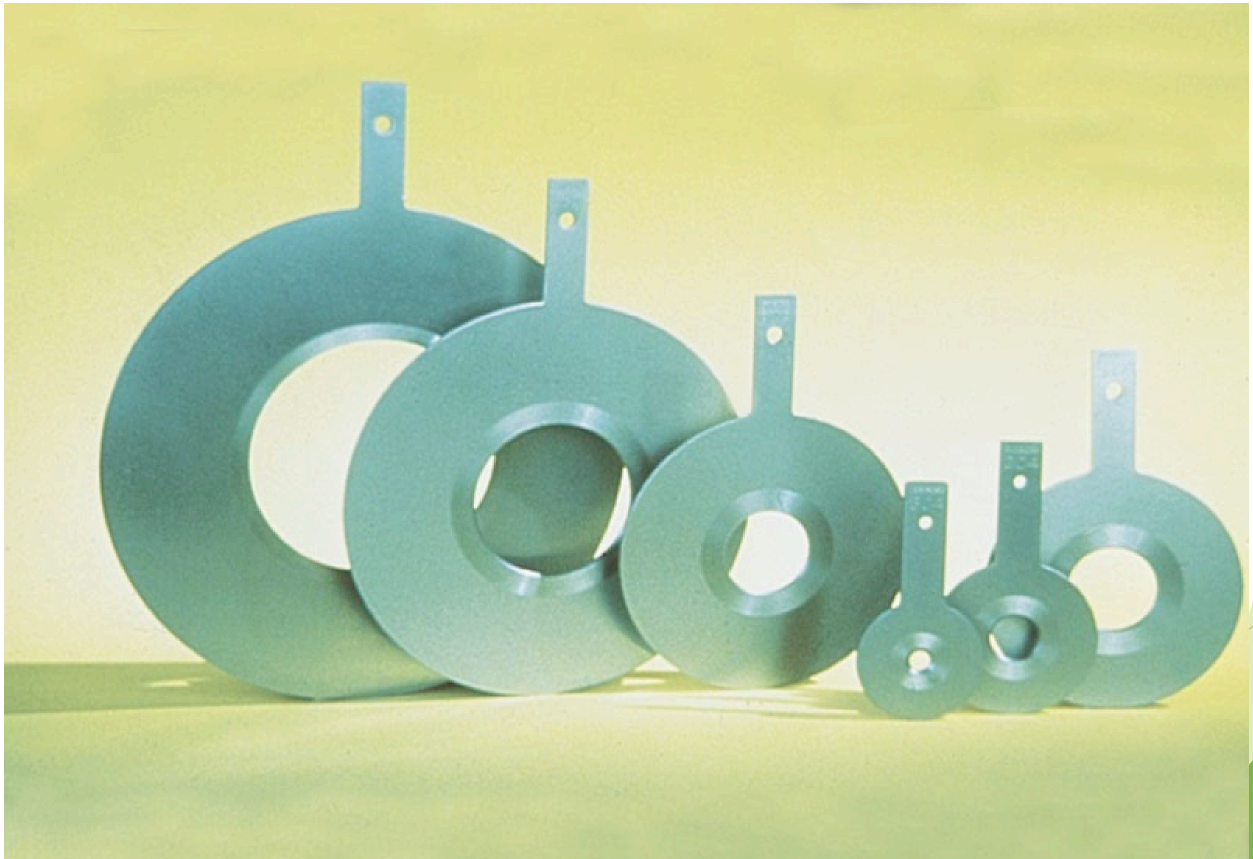
Most Common Flowmeter

Other Flowmeters are selected because:

- *Wider Rangeability and Linearity*
- *Better Accuracy*
- *Obstructionless*
- *No Line Plugging*
- *Fluid condition is abrasive, dirty or multi-component*

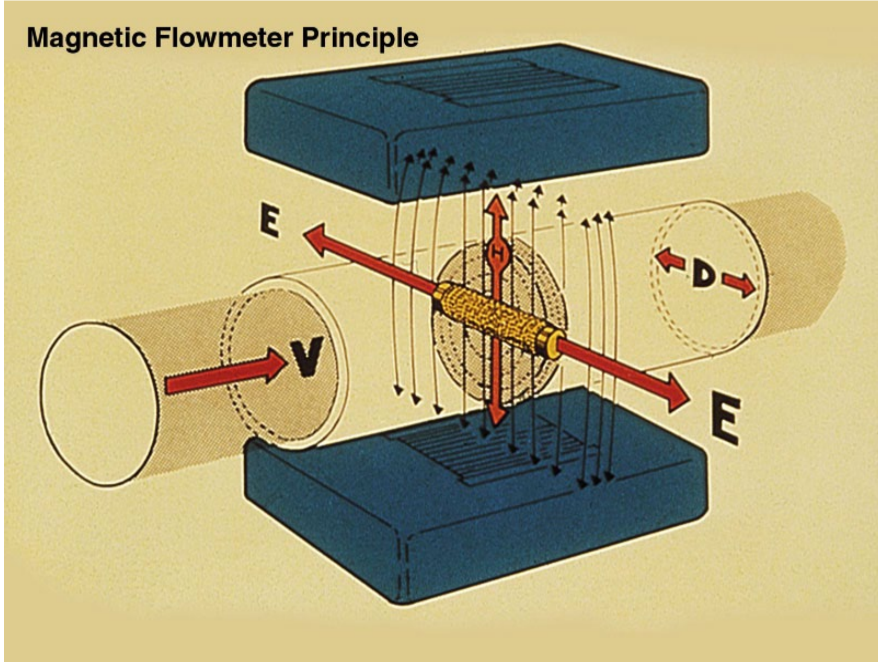
IMPORTANT CONSIDERATION:

FLOW IS A CALCULATED MEASUREMENT WHEN USING A HEAD-TYPE METER



Flowmeter Technologies

MAGNETIC



Applications

- Clean Fluids, Slurries
- Sludges
- Corrosive Fluids
- Abrasive Fluids
- Viscous Fluids
- Low Flow Rates
  0-0.07 GPM
- High Flow Rates
  0-77,000 GPM
- Industrial & Sanitary

BASED UPON FARADAY'S LAW OF MAGNETIC INDUCTION:

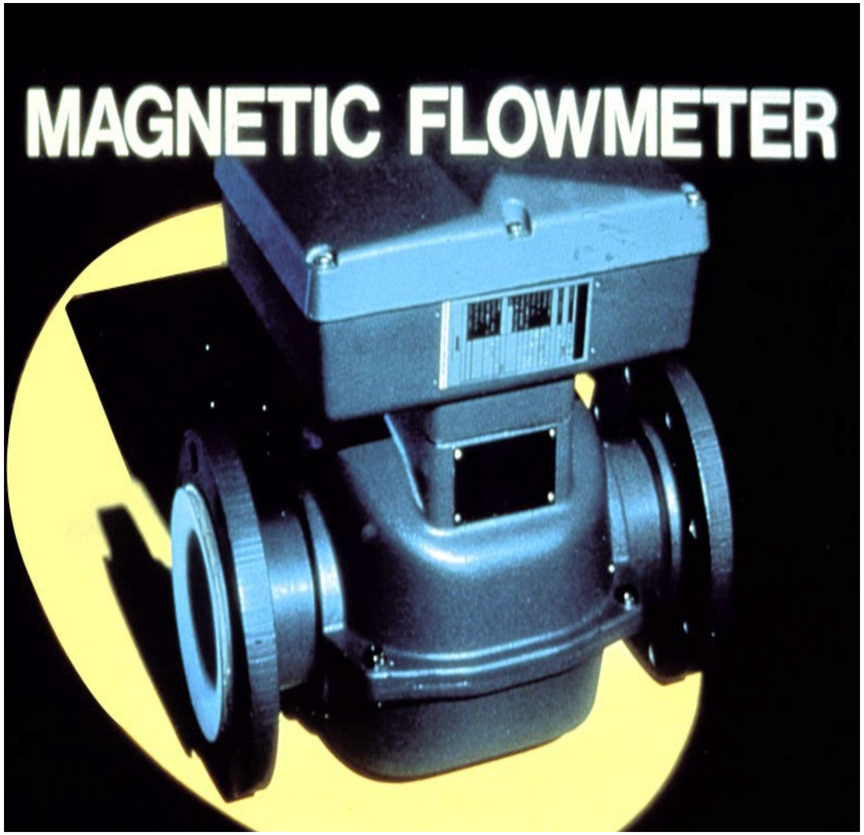
The EMF induced in a coil is proportional to the rate of change of the magnetic flux enclosed by the coil.

EMF, proportional to the speed of a conductive fluid in the mag field is due to ions giving up their charge to the electrodes

Flowmeter Technologies

MAGNETIC

Pros



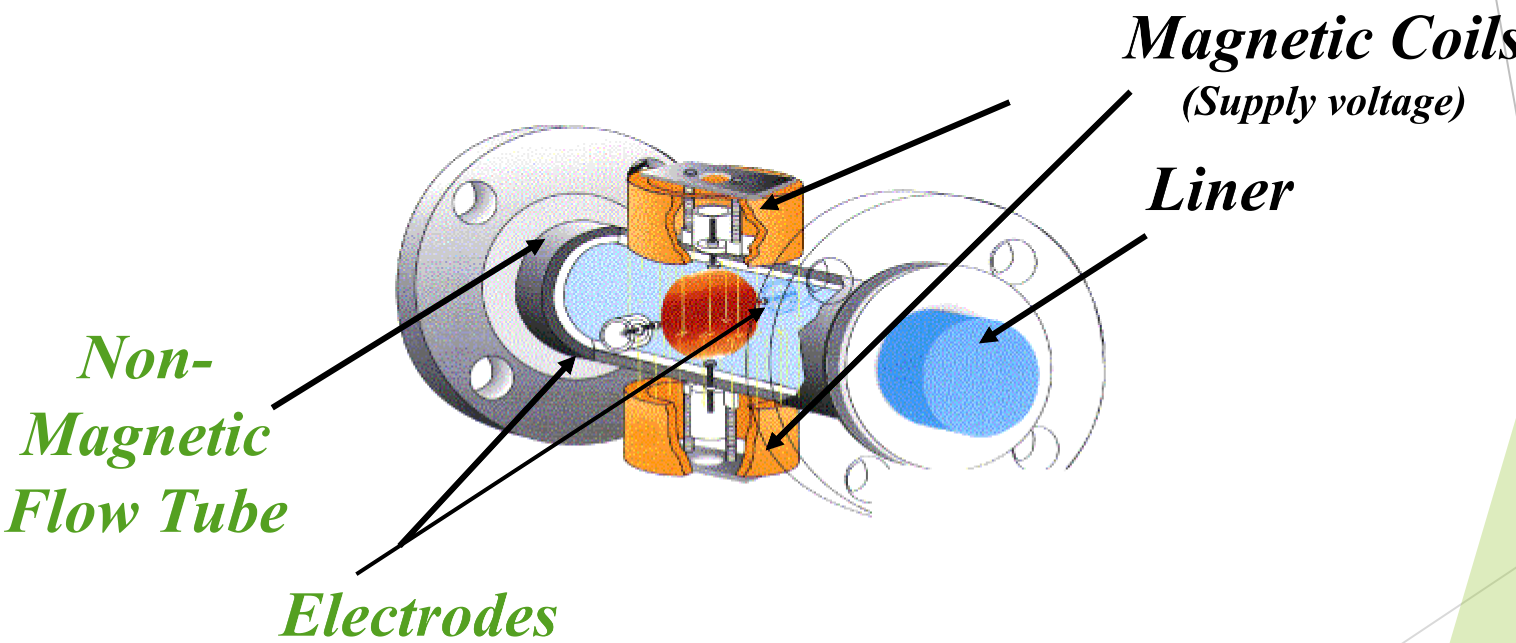
- ***High Accuracy***
- ***Wide Rangeability***
- ***Obstructionless (no head loss)***
- ***No moving Parts***
- ***Bi-directional***
- ***Linear and volumetric***
- ***Available in very large lines***
- ***High Temp & Pressure***
- ***Durability & Low Maint***

Cons

- ***Requires conductive liquids (3-5 uS minimum)***
- ***Higher initial cost***

FLOWMETER TECHNOLOGIES

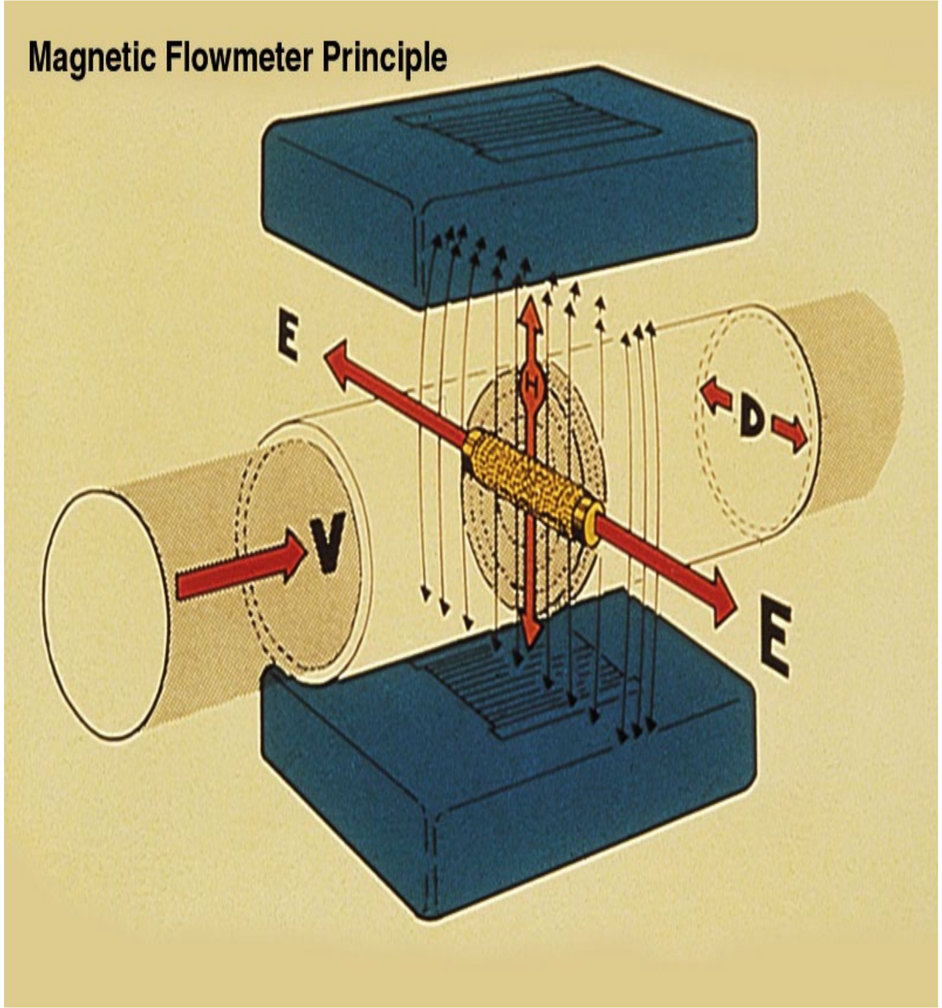
MAGNETIC FLOW TUBE



Supply voltage produced by ac (50 or 60 Hz) excitation, pulsed dc excitation or eX pulse.

Flowmeter Technologies

MAGNETIC



For a circular pipe the volumetric flowrate can be expressed as:

$$q_{vel} = \frac{\pi}{4} k_1 D \frac{e_s}{B_f}$$

where:

- *k is the calibration constant*
- *D is the distance between electrodes*
- *e_s is the signal voltage*
- *B_f is the Mag Flux Density*

or

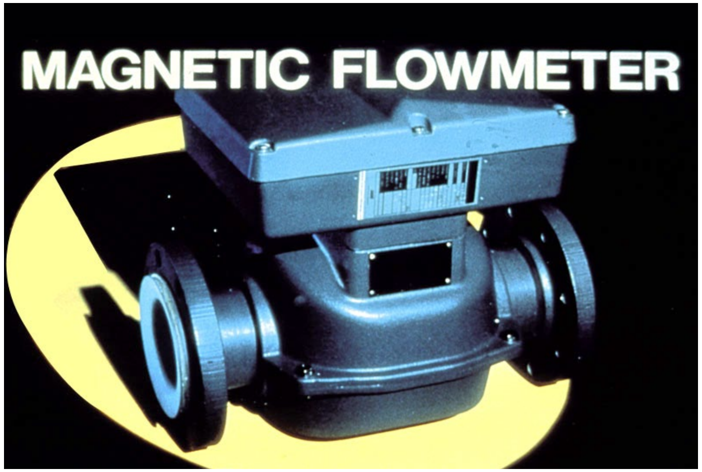
$$e = BDV$$

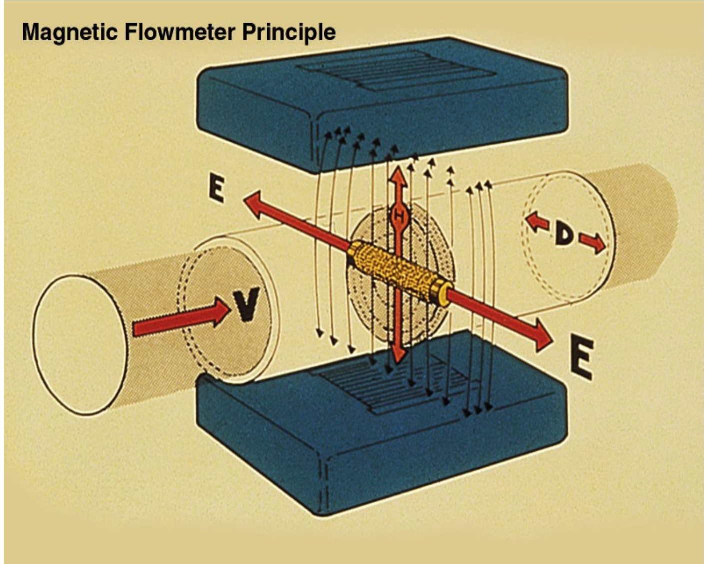
where

Voltage = Mag field Strength x Dia x Vel

Flowmeter Technologies

MAGNETIC





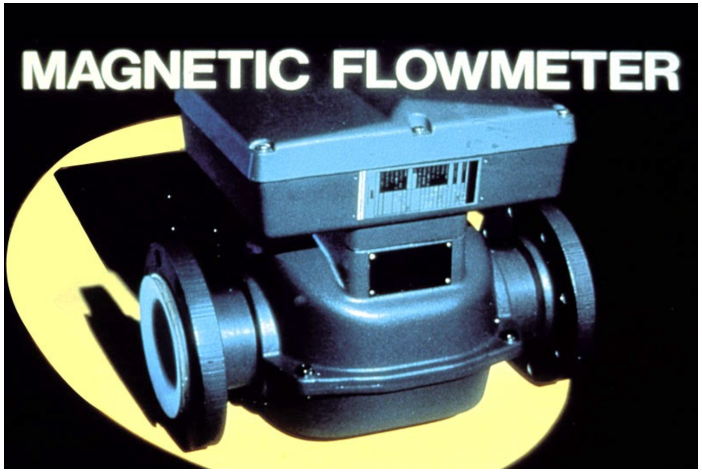
ADVANTAGES OVER ORIFICE (d/p)

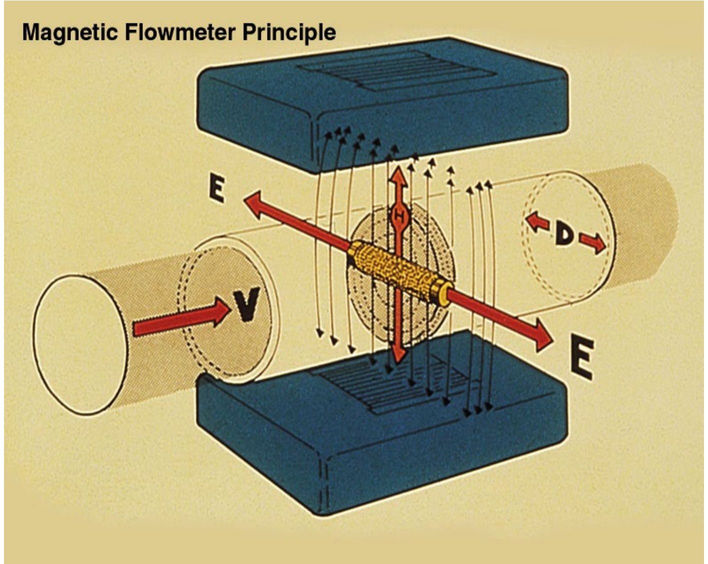
Minimal wear and performance degradation.

- ***Structurally sound nonmagnetic body with selectable non-conductive liners***
- ***Wider Rangeability (~10:1)***
- ***Linear Output (analog or pulse)***
- ***Higher Performance***
- ***Simple to install (no impulse lines)***
- ***Cost Competitive***

Flowmeter Technologies

MAGNETIC



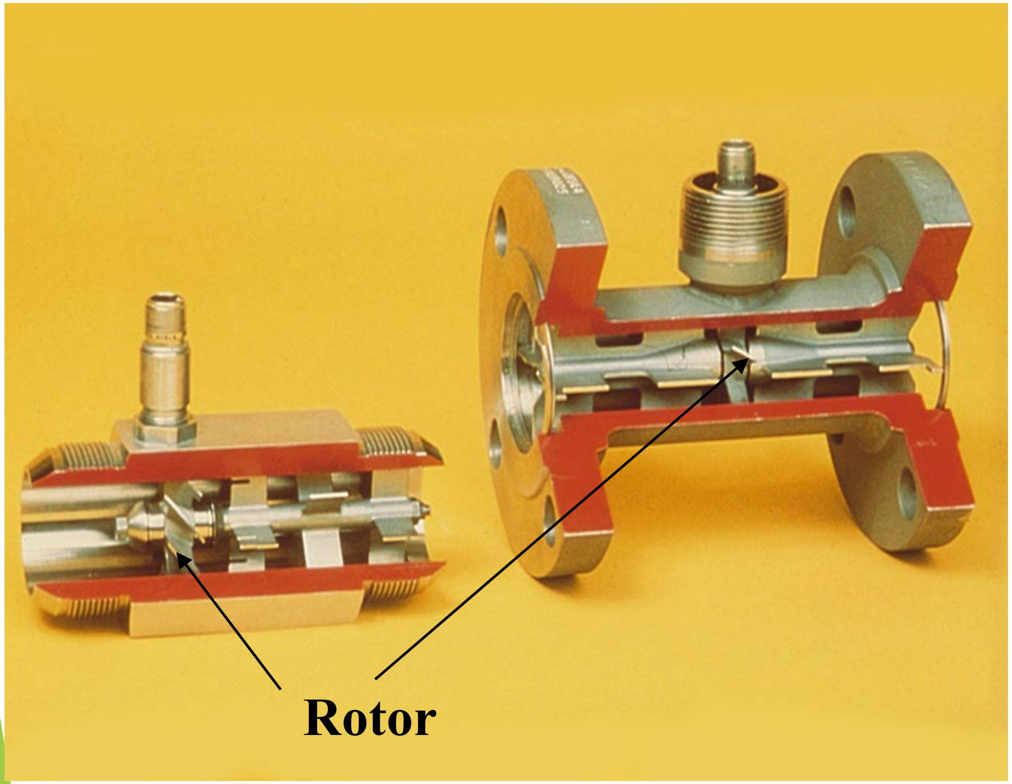


ADVANTAGES OVER TURBINE

- *Minimal wear and performance degradation*
- *Handle Dirty Fluids*
- *Wider Rangeability*
- *Linear Output (analog or pulse)*
- *Higher Performance*
- *Simple to install (no moving parts)*
- *Cost Competitive*

Flowmeter Technologies

TURBINE



Pros

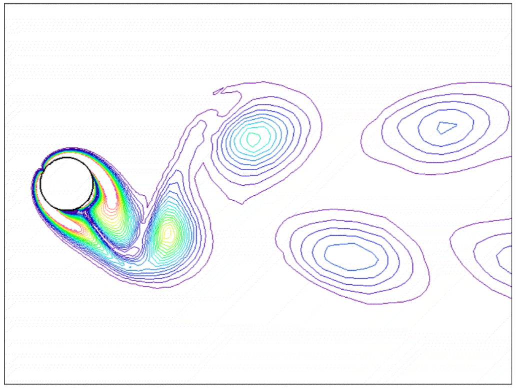
- Linear with flow
- Easy to install
- Principle readily accepted
- High accuracy
- Wide Rangeability (10:1 / 20:1)
- Liquids, gases, vapors
- Approved by AGA

Cons

- Moving parts/ bearings
- Not suited for dirty fluids
- High maintenance costs

Frequency ∝ to flowrate – The speed of the rotor increases linearly with flow velocity. Measurement is by non-contacting magnetic detector.

VORTEX FLOWMETER



IDEAL FLOWMETER FOR:

LIQUID, GAS & STEAM

Principles of Operation

The Karman vortex frequency "f" is proportional to the velocity "v". Therefore, it is possible to obtain the flow rate by measuring the Karman vortex frequency:

$$f = St\ (v/d)$$

where: f = Karman vortex frequency

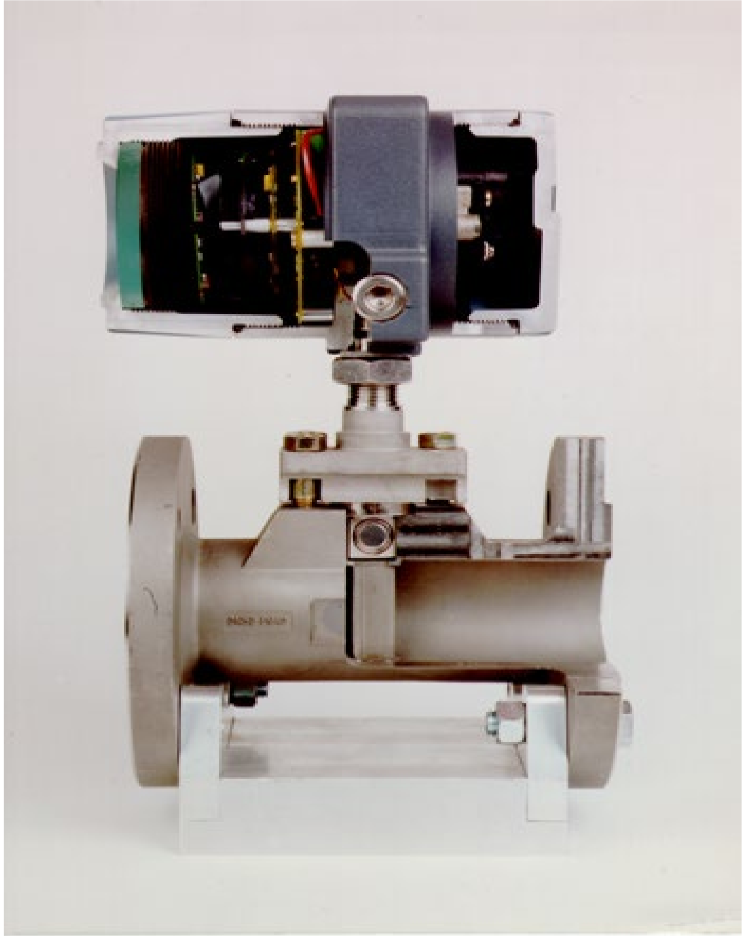
St = Strouhal number (constant)

v = Velocity

d = Width of vortex shedder (constant)

Flowmeter Technologies

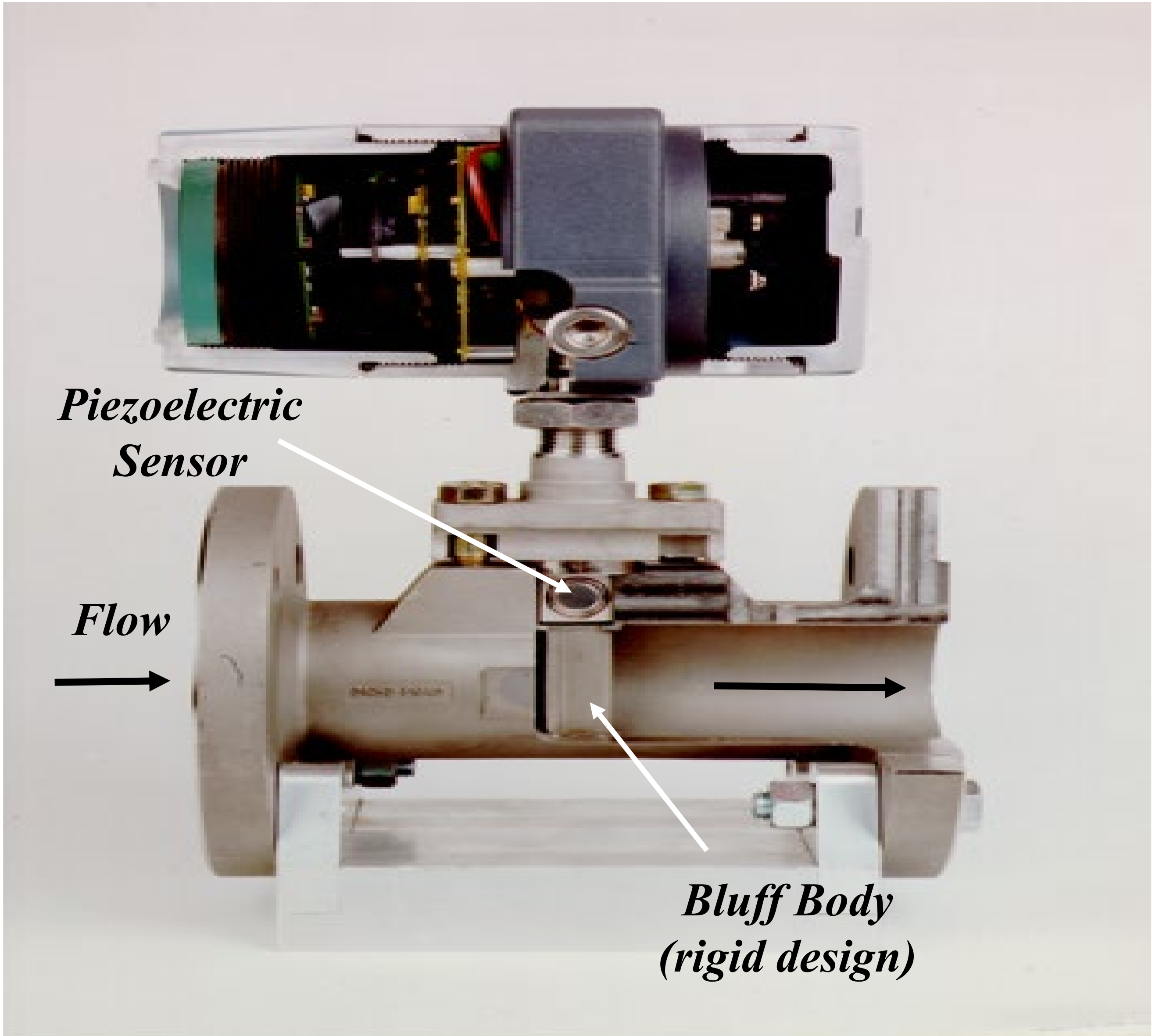
VORTEX



MAJOR FEATURES

- ***Liquid, Gas, Steam***
- ***High Accuracy***
- ***Wide Rangeability***
- ***Dirty Fluids***
- ***Linear***
- ***Volumetric***
- ***Few or No Moving Parts***
- ***Protected Electronics***
- ***Easy to Install (no external piping)***

Flowmeter Technologies



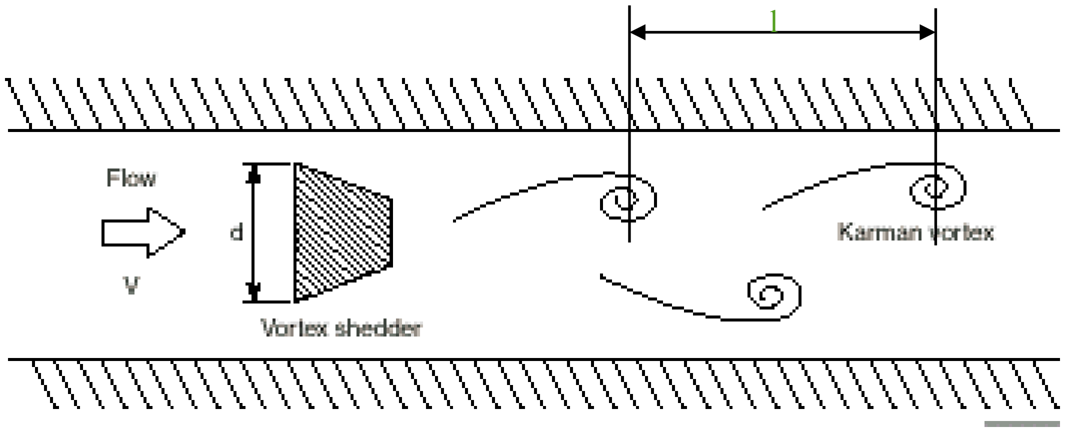
VORTEX

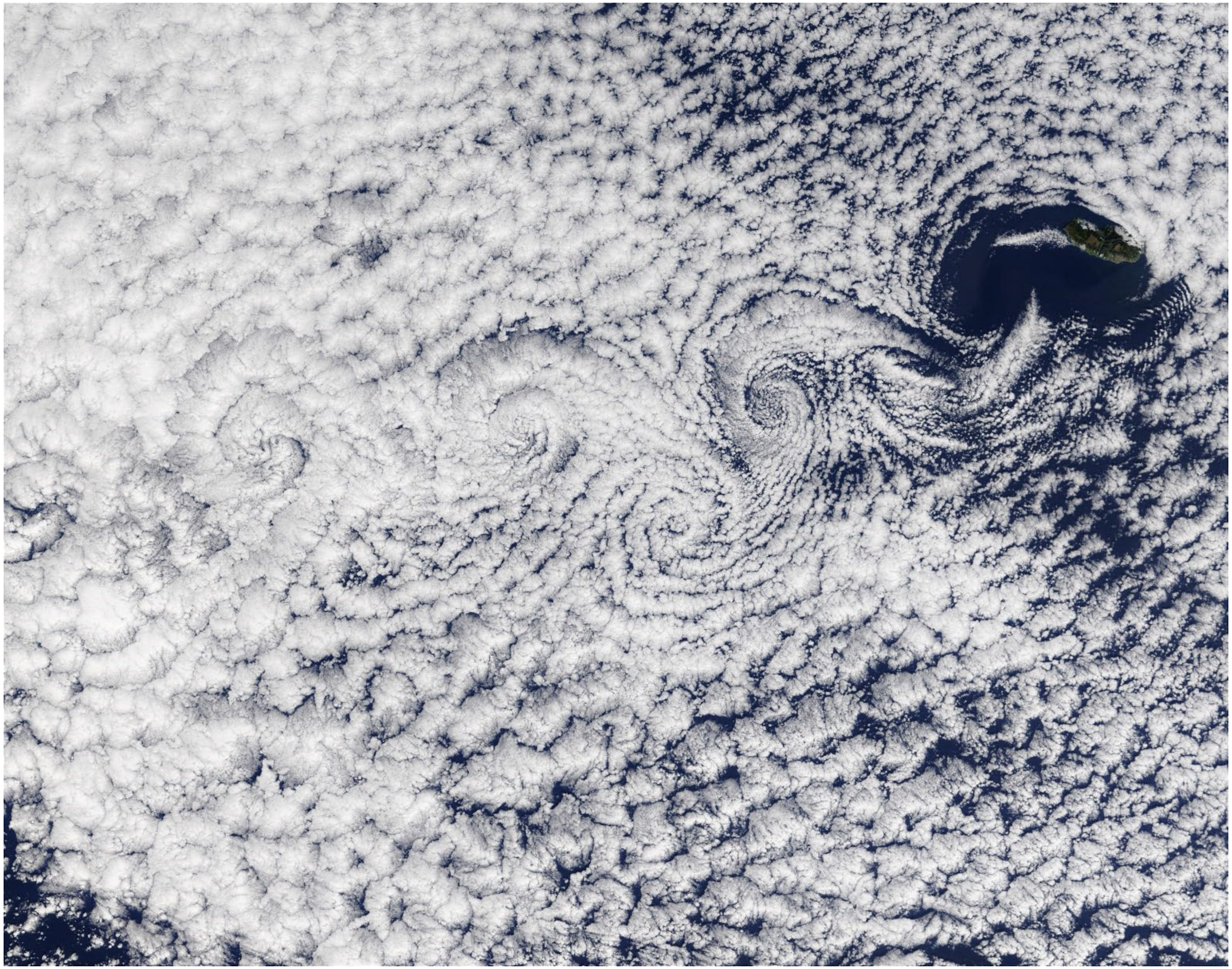
What is Strouhal Number?

• The Strouhal number is the ratio between the vortex interval and the shedder bar width

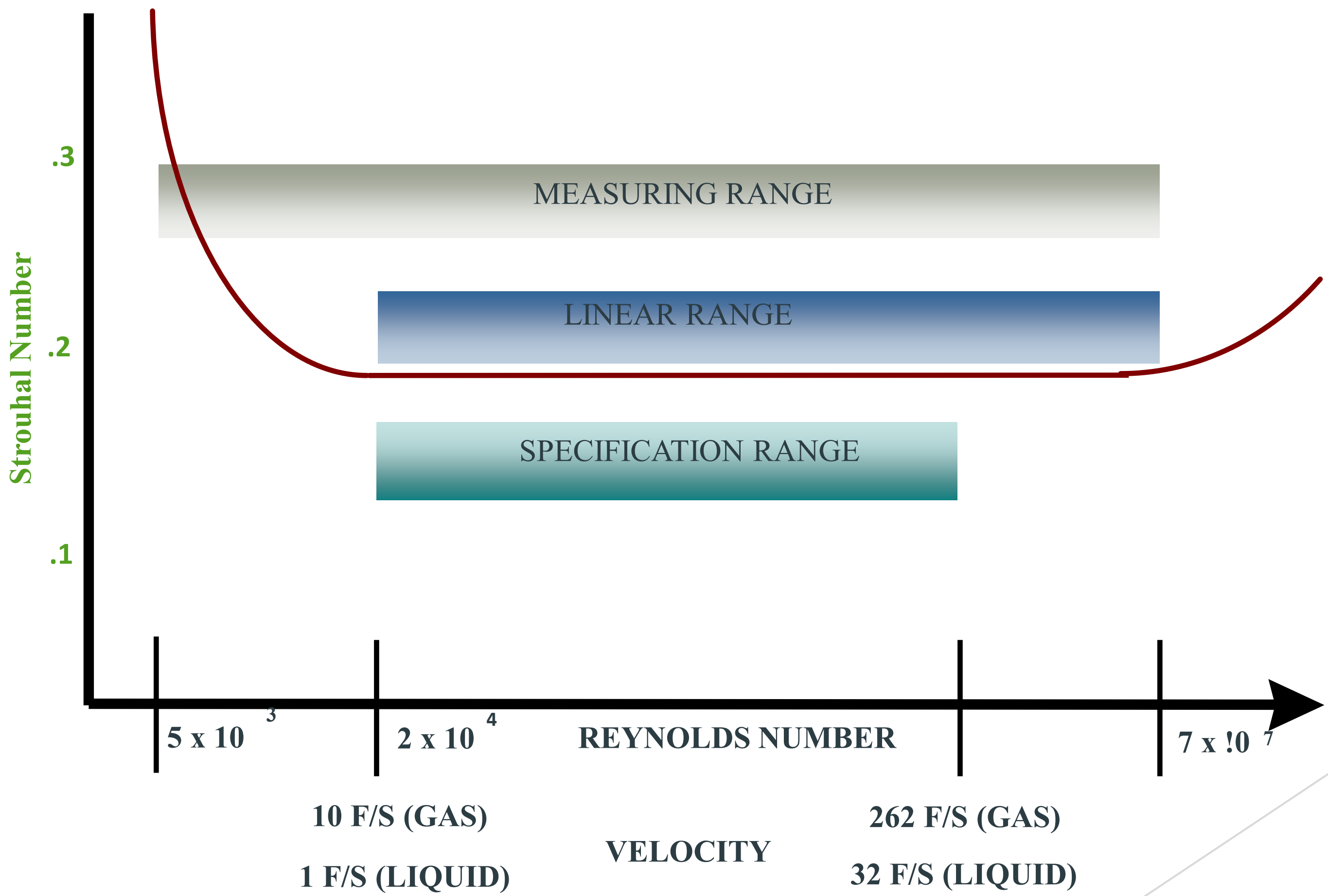
• Usually the vortex interval (l) is about 6 times the shedder bar width (d), while the Strouhal number is the reciprocal value (~0.17)

• When the Strouhal number is fixed, the velocity can be measured by counting the number of vortices

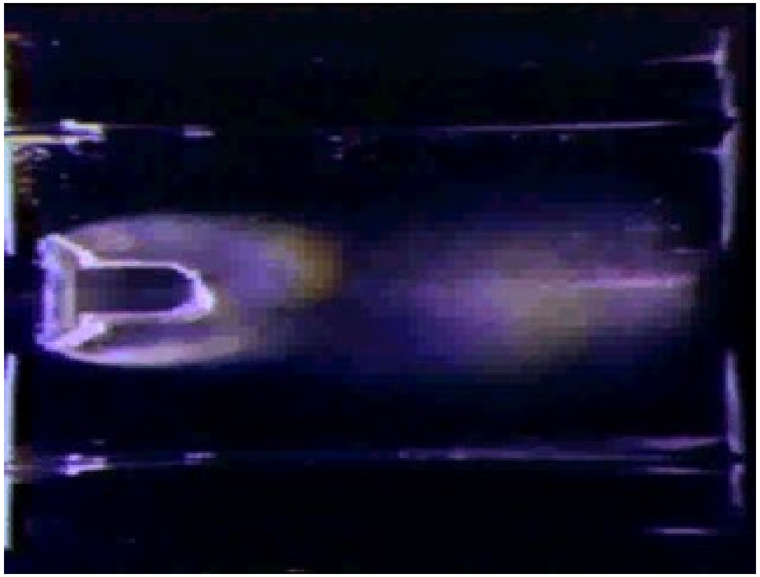


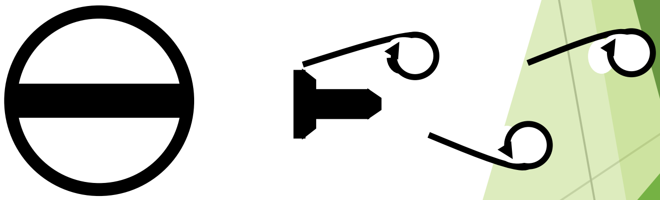


Relationship Between Strouhal Number, Reynolds Number and Velocity



Vortex Shedding



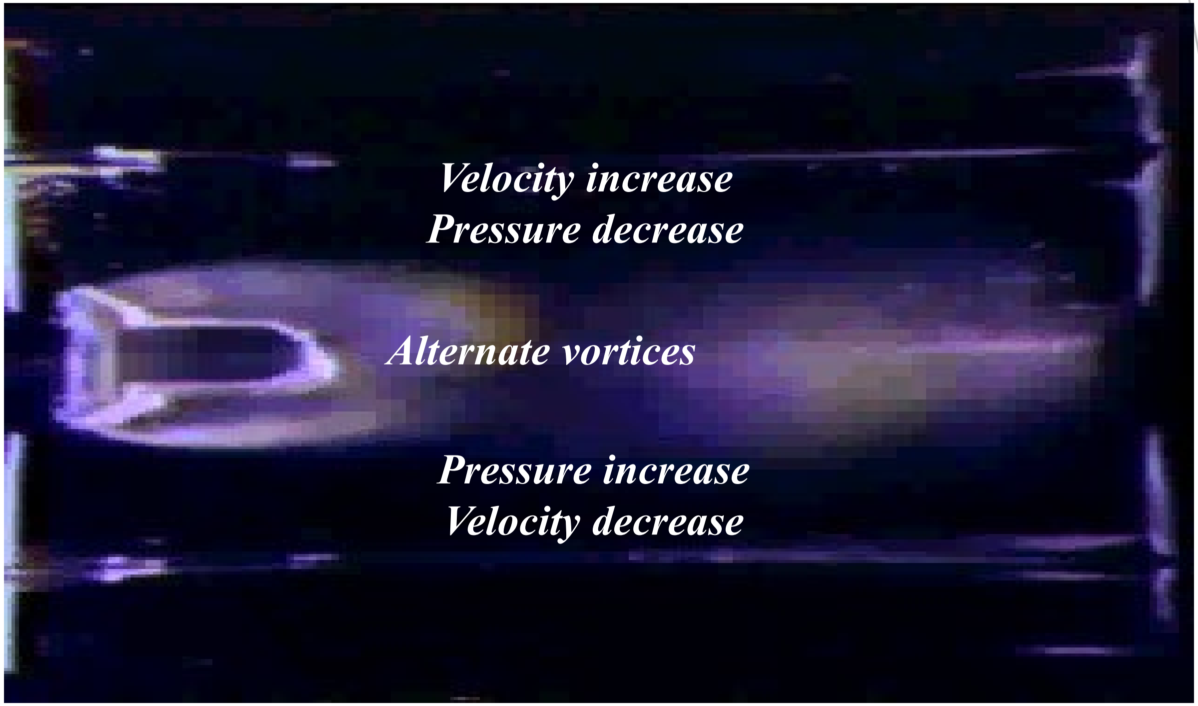


Flowmeter Technologies

Vortex Formation Process

Flow >

High velocity, low viscosity fluid



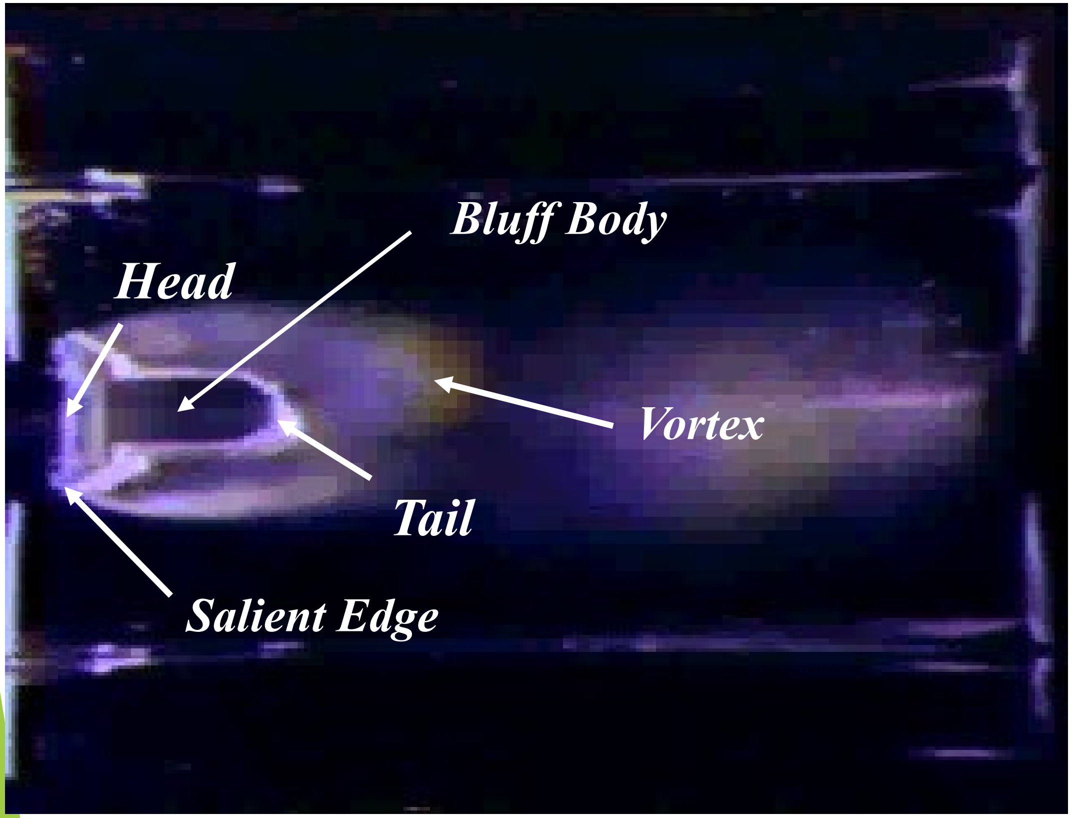
The vortex formation process causes a local velocity increase and a pressure decrease on the vortex formation side of a bluff body. The pressure increase on the opposite side inhibits simultaneous vortex formation.

$$V = (f \times d) / S_t$$

Where: V = velocity, f is the shedding freq, d is the width and S_t is the experimentally determined Strouhal # for the meter

Flowmeter Technologies

VORTEX

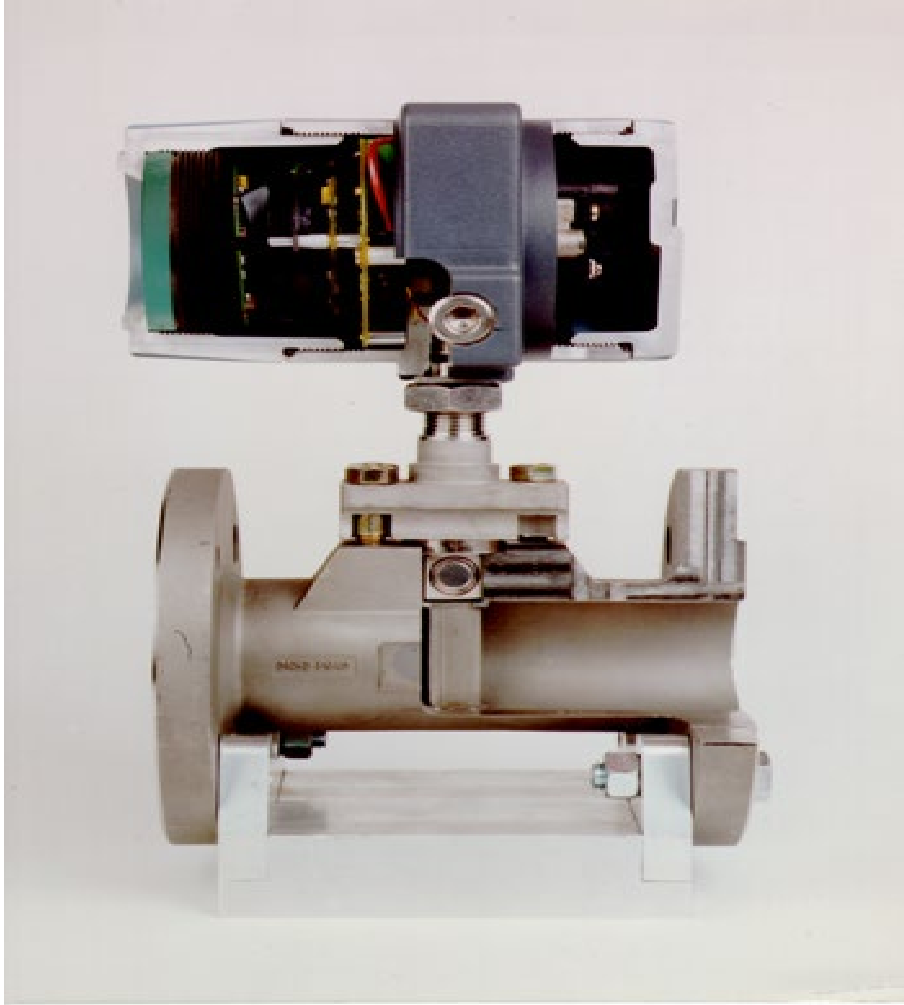


VORTEX FORMATION REQUIRES

- ***The bluff body must have salient edges on the upstream face for flow separation regardless of flow to achieve a desired performance.***
- ***The bluff body must have a width that is a specific fraction of the pipe diameter so the entire flow participates in the shedding process.***
- ***The bluff body length in the direction of flow must be a certain multiple of the bluff body width.***

Flowmeter Technologies

VORTEX



Pros

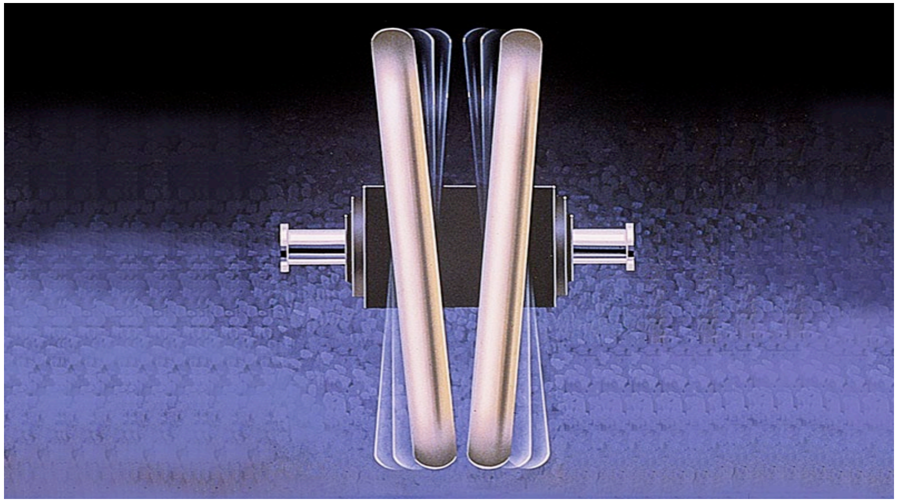
- ***Linear & % of Rate Meter***
- ***Shedding frequency output is linearly proportional to fluid vel***
- ***No moving parts***
- ***High accuracy***
- ***Wide rangeability (~ 20:1, pipe dia and process dependent)***
- ***Relatively low cost***
- ***Ideal for clean low viscosity liquids (<8 cp), gases, vapors***

Cons

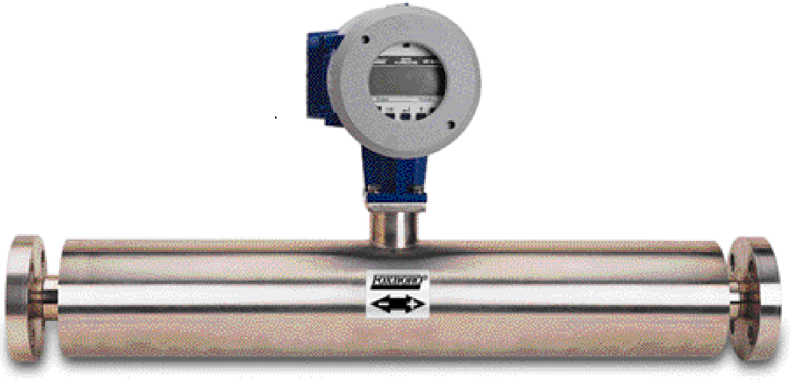
- ***Not suited for high viscosity (>30 cp), low velocity fluids or slurries***
- ***Doesn't go to zero flow***
- ***Accuracy requires Reynold's Numbers > 10,000 although 3,000 is measurable but nonlinear.***

Flowmeter Technologies

CORIOLIS



Bent Tube Design



Straight Tube Design

What is the Coriolis Effect ?

The acceleration of a particle moving in a relative coordinate system.

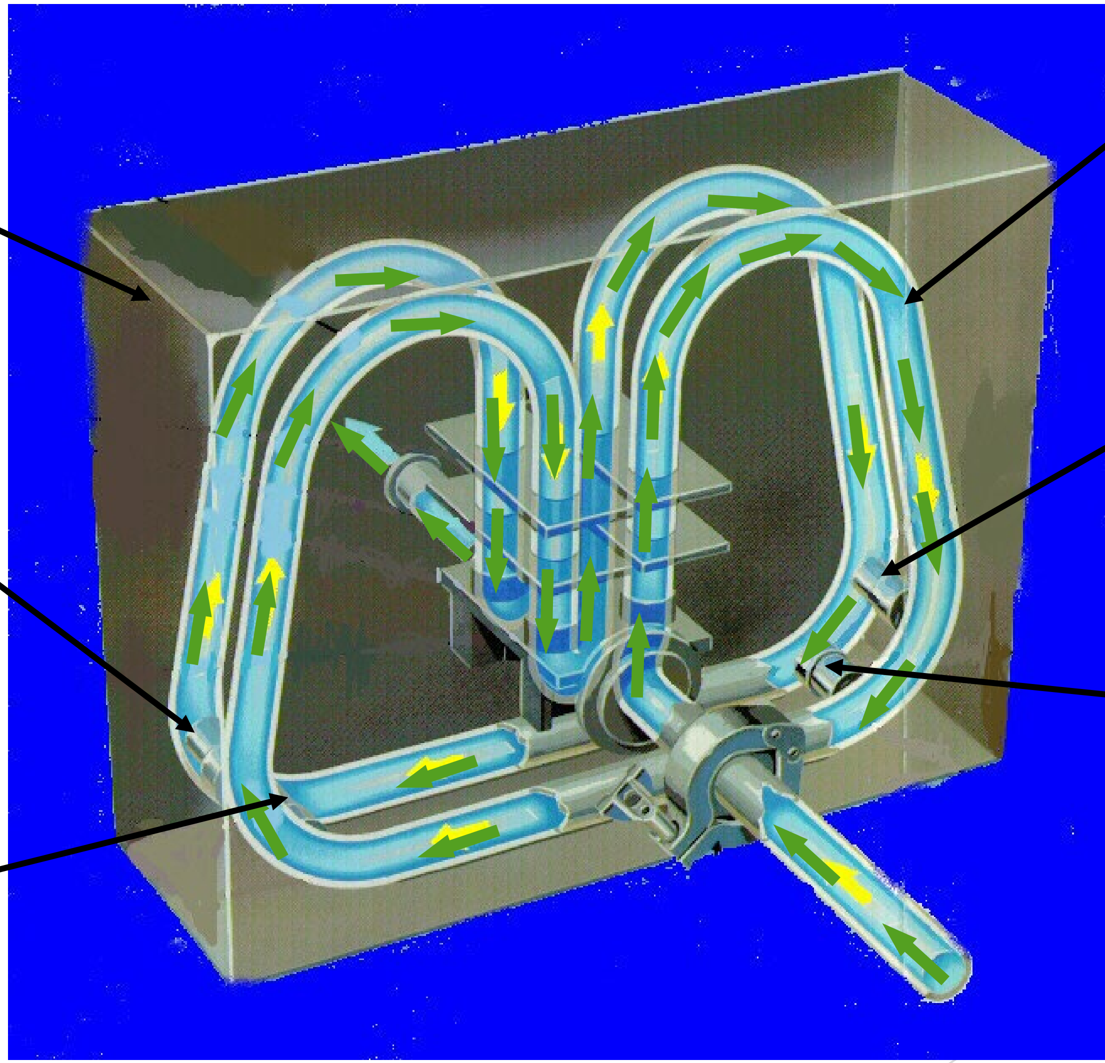
As applied to Newton's Law, Coriolis Acceleration and the acceleration of the relative system must be treated as force

$$F = MA$$

Physically: ***Coriolis Acceleration is due to the conservation of momentum in a body not moving parallel to the axis of rotation of a relative system.***

Mathematically: ***Coriolis Acceleration comes from the difference between the angular velocity and the absolute velocity of a particle.***

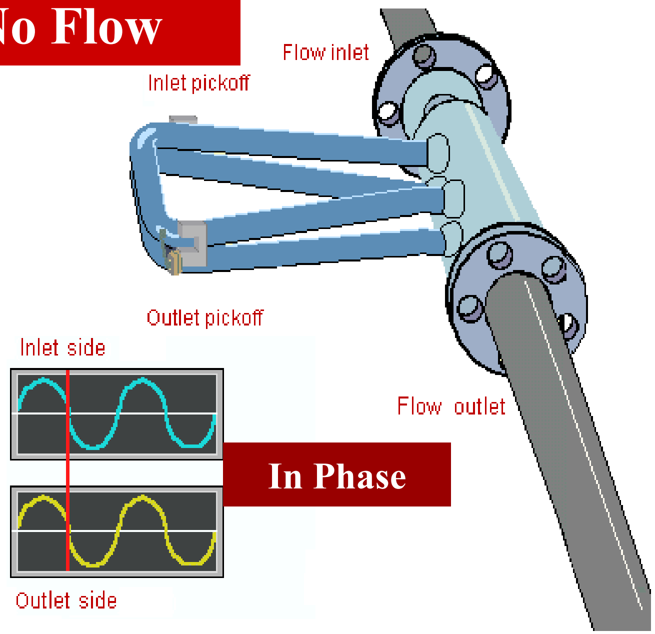
Flowmeter Technologies



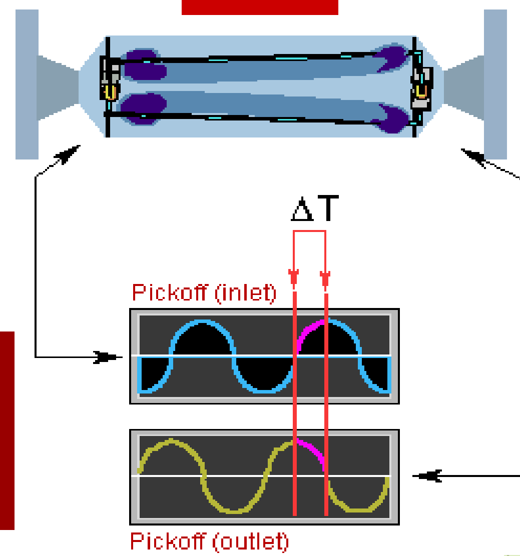
Coriolis Single Flow Path Design

Coriolis Measurement Principle

No Flow

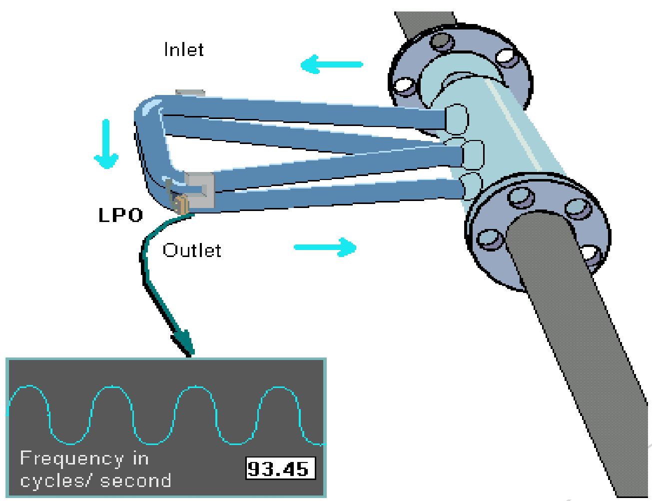


Flow



Phase Shift

Flow rate dependent



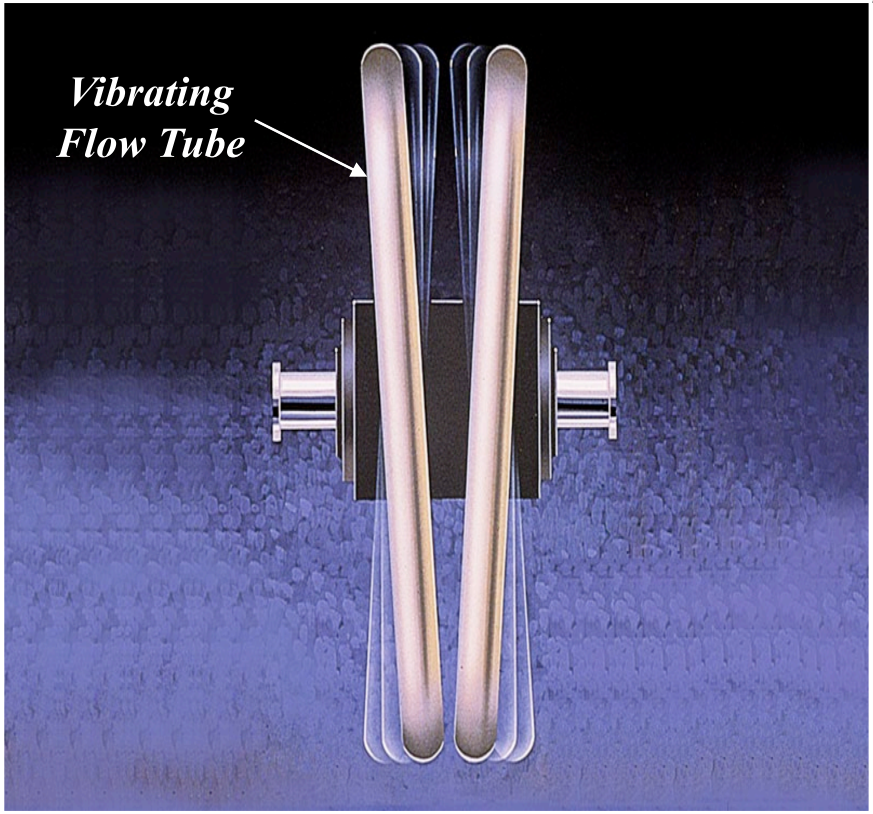
Phase Shift is directly proportional to Mass Flow

Frequency of vibration gives Density

Normal Frequency of vibration ~90 Hz

Flowmeter Technologies

CORIOLIS

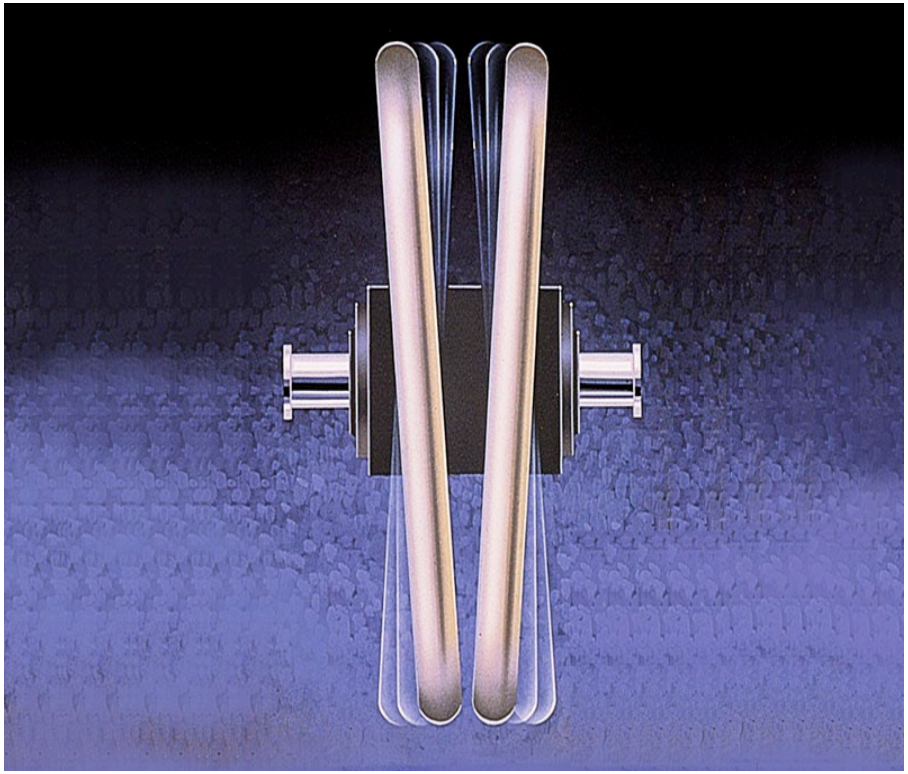


MEASUREMENT CAPABILITY

- Mass Flow
- Volumetric Flow
- Density
- % Solids
- Temperature
- Custom Units (brix)

Flowmeter Technologies

CORIOLIS



WHY USE CORIOLIS ?

- ***Density Varies***
- ***Expensive Process Fluids***
- ***Two Phase Flow ******* (New Patented Digital Technology)***
- ***High Accuracy***
- ***Wide Rangeability***
- ***Multiple Fluids in the same line***

Flowmeter Technologies

DIGITAL CORIOLIS
"Two Phase Flow"

Pros

- ***Direct precise mass and density measurements***
- ***Highest accuracy***
- ***Widest rangeability***
- ***Ideal for most liquids and gases***
- ***Ideal for high viscosity fluids***
- ***Non-Newtonian Fluid measurements***
- ***Unaffected by pipe geometry and changes in fluid conditions***
- ***Non-Intrusive***
- ***No stalling or interruptions due to entrained air (digital)***
- ***Fast Response for Batching Apps***

Cons

- ***Relatively expensive***
- ***Size limitations***

Flowmeter Technologies

ULTRASONIC

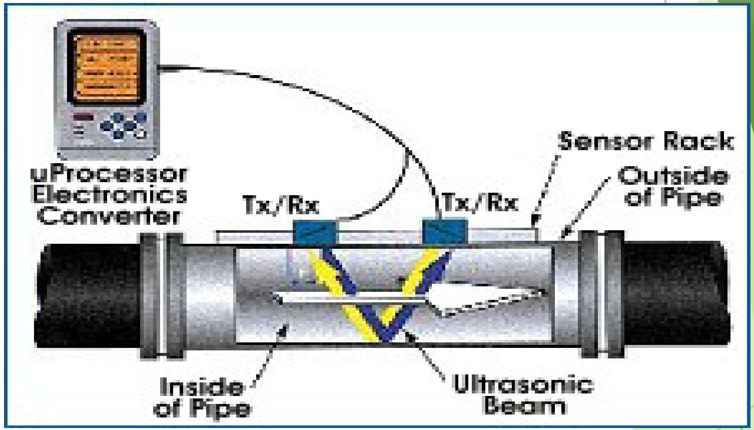
Doppler / Transit Time

- *Clamp on technologies*
- *Liquid service*
- *Gas applications (Transit Time)*
- *Single and Multi-beam applications*
- *Cost independent of pipe diameter*

Flowmeter Technologies

- *For relatively "clean" liquids*
- *Can also be used for gas*
- *Uses two transducers- each sends and receives a given frequency through the pipe*
- *The meter is actually making a time measurement- the difference in the upstream and downstream times is proportional to the flow velocity.*
- *Once known, a simple area velocity equation is made to calculate flow rate.*

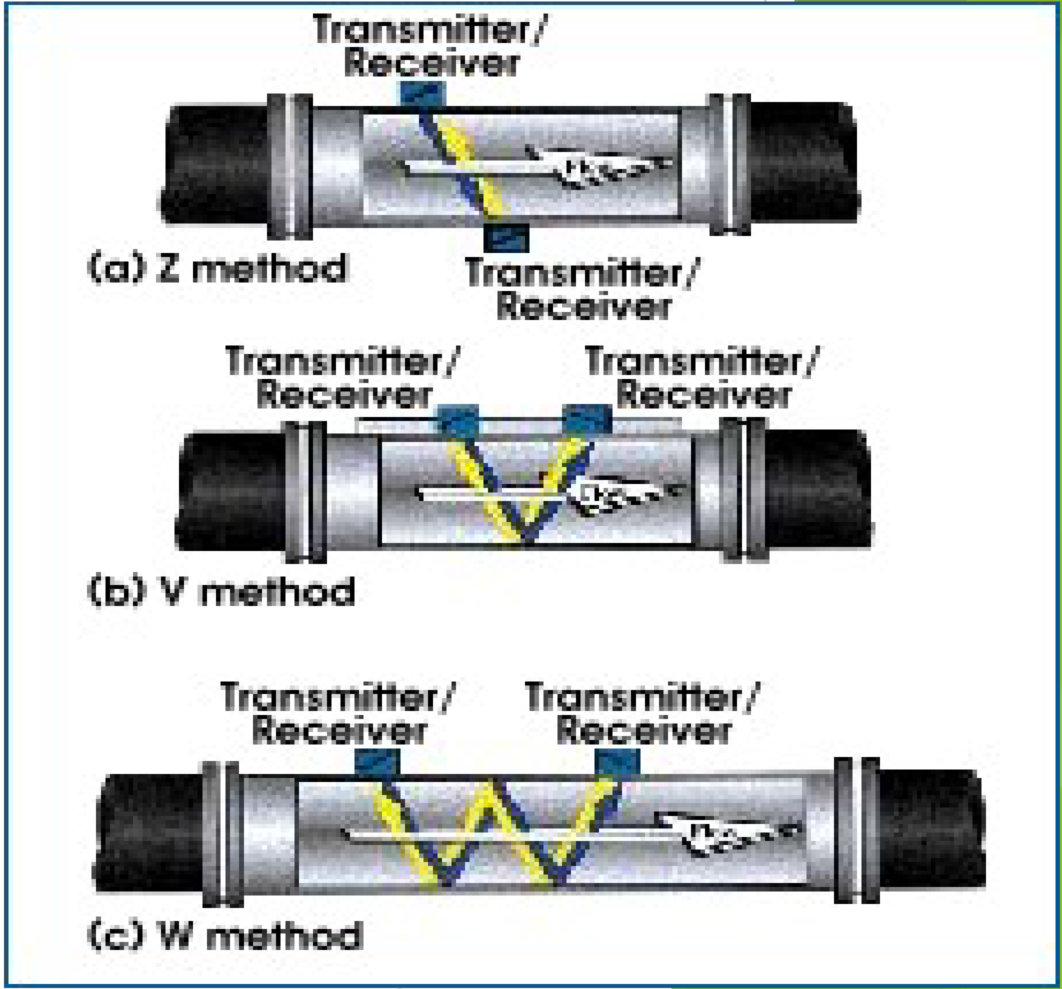
Ultrasonic Flow-Transit Time



Flowmeter Technologies

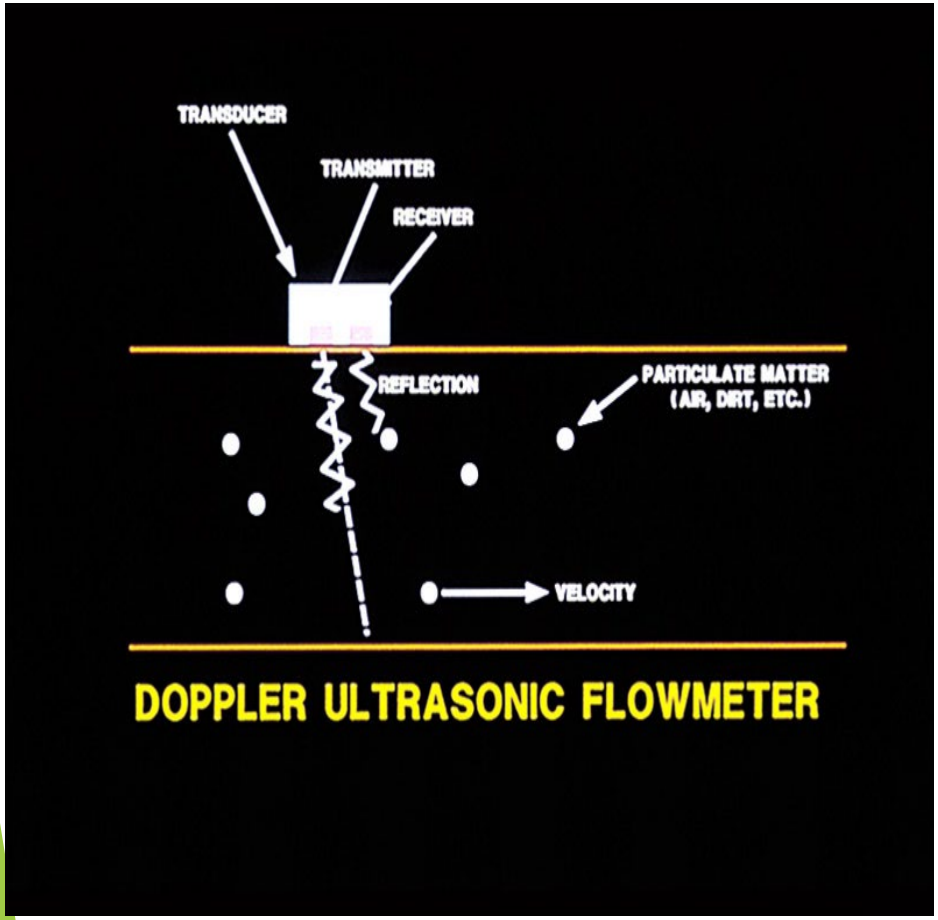
Ultrasonic Flow-Transit Time

- *Various transducer mounting methods are used depending on pipe size, material in pipe and condition of flow.*
- *Other uses for Transit Time Technology:*
  - *Density calculations*
  - *Product identification using Sonic Velocity*



Flowmeter Technologies

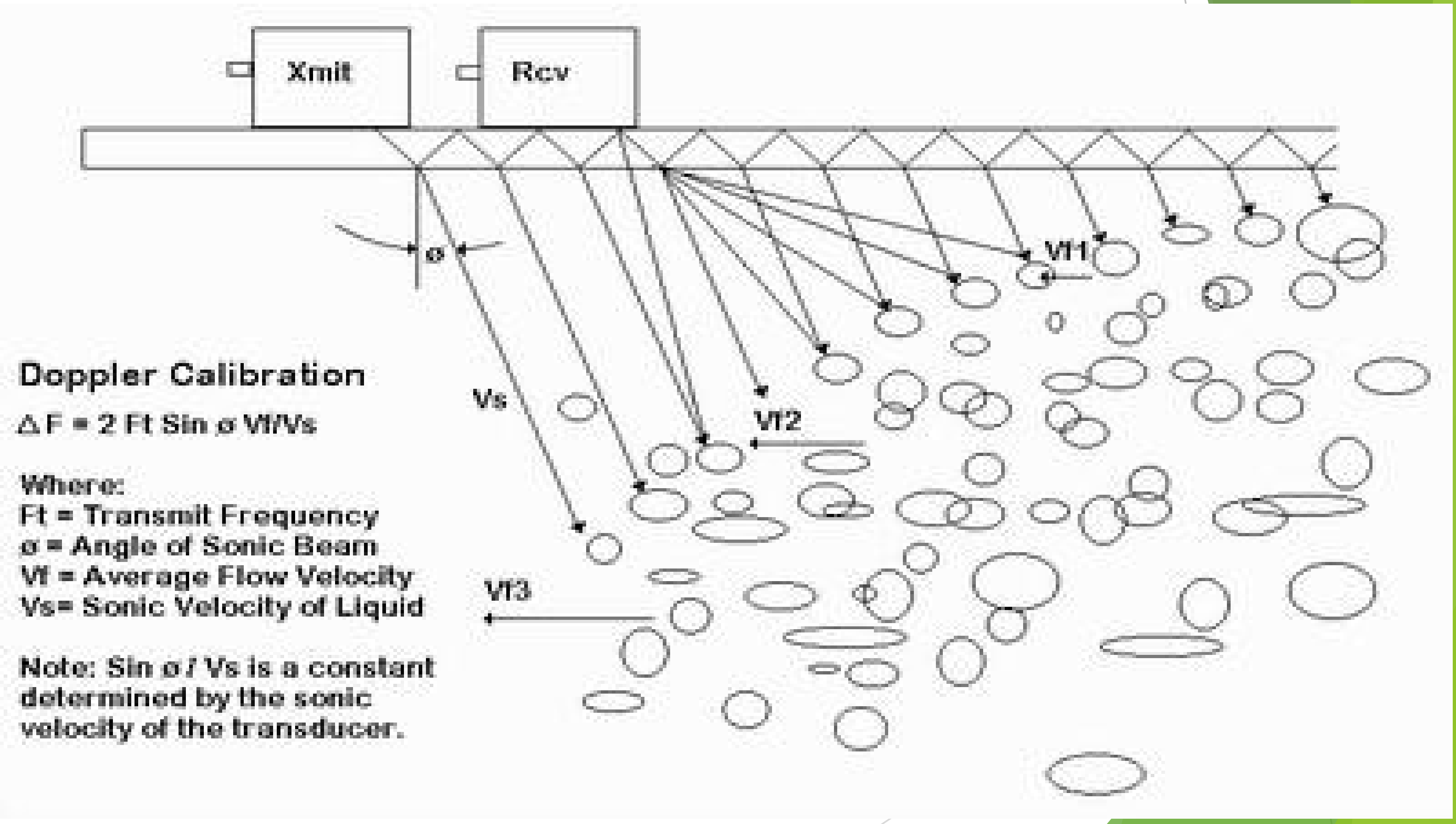
DOPPLER



- ***Requires Suspended solids (dirty fluids)***
- ***Accuracy depends on velocity profile, particle concentration and distribution***
- ***Repeatability dependent on particle concentration and beam penetration***
- ***More of a flow indicator than a meter***

Flowmeter Technologies

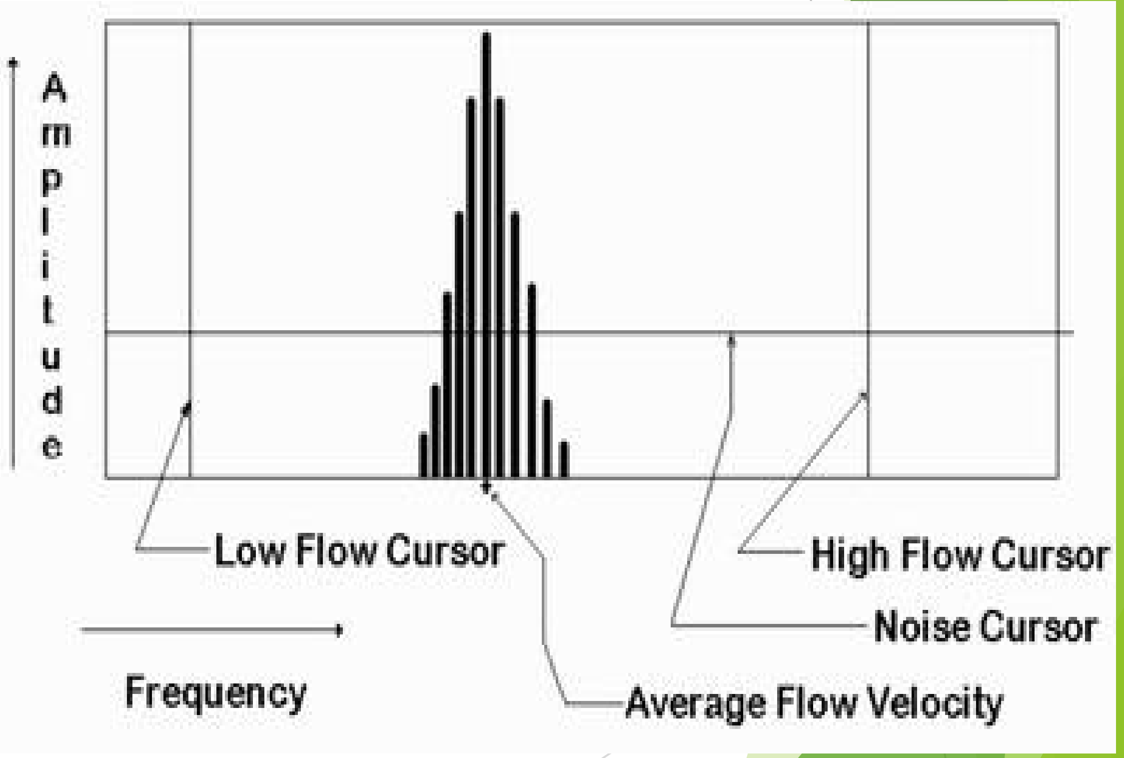
Ultrasonic Flow-Doppler



Flowmeter Technologies

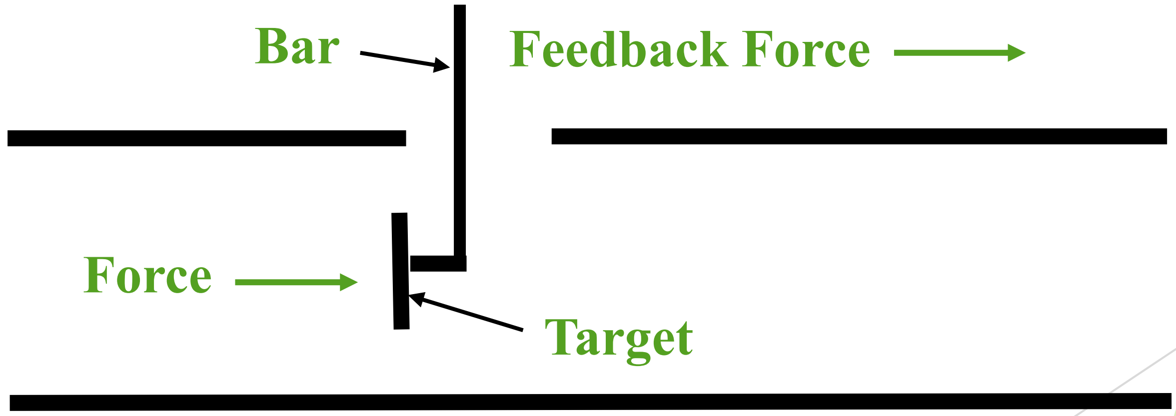
Ultrasonic Flow-Doppler

- Graphical profile of return frequencies
- Software filtering is used to separate noise from actual velocity frequencies
- Doppler should not be used when highly accurate flow information is required



Flowmeter Technologies

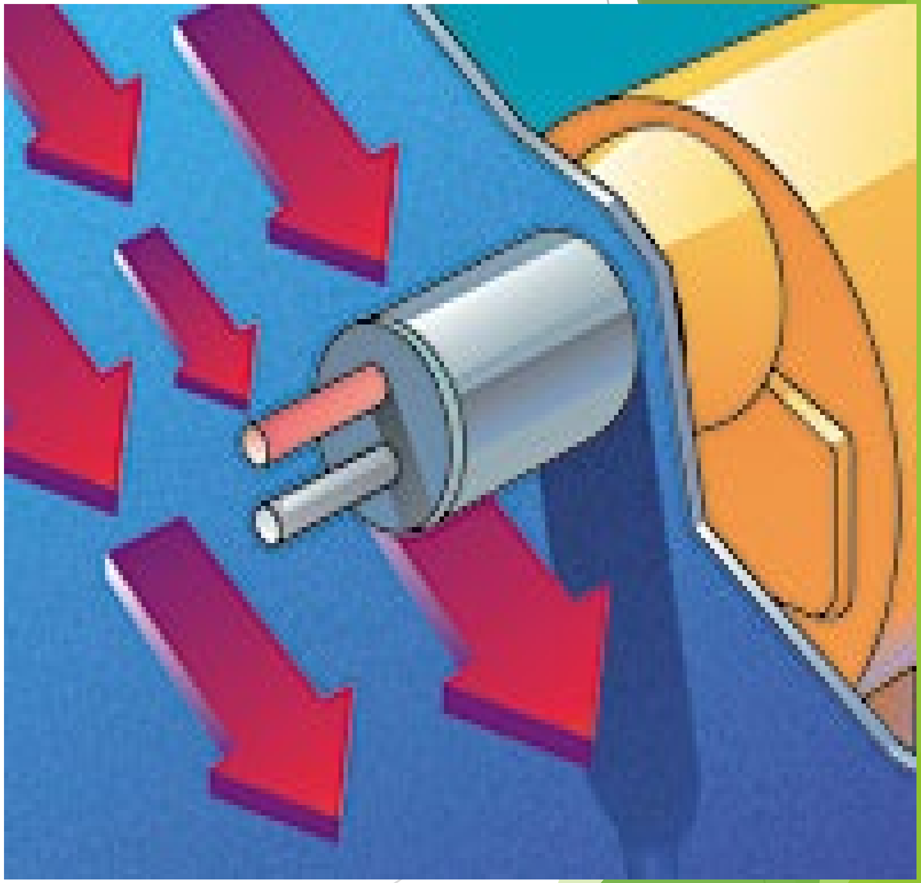
TARGET – ***Primary element consist of a sharp-leading-edge-disk (target) fastened to a bar. The differential pressure produced by the reduced annular area creates a disk drag force. The force is transmitted through the bar to a force measuring device and the flow rate is calculated as a square law function.***



Flowmeter Technologies

Thermal Mass Flow

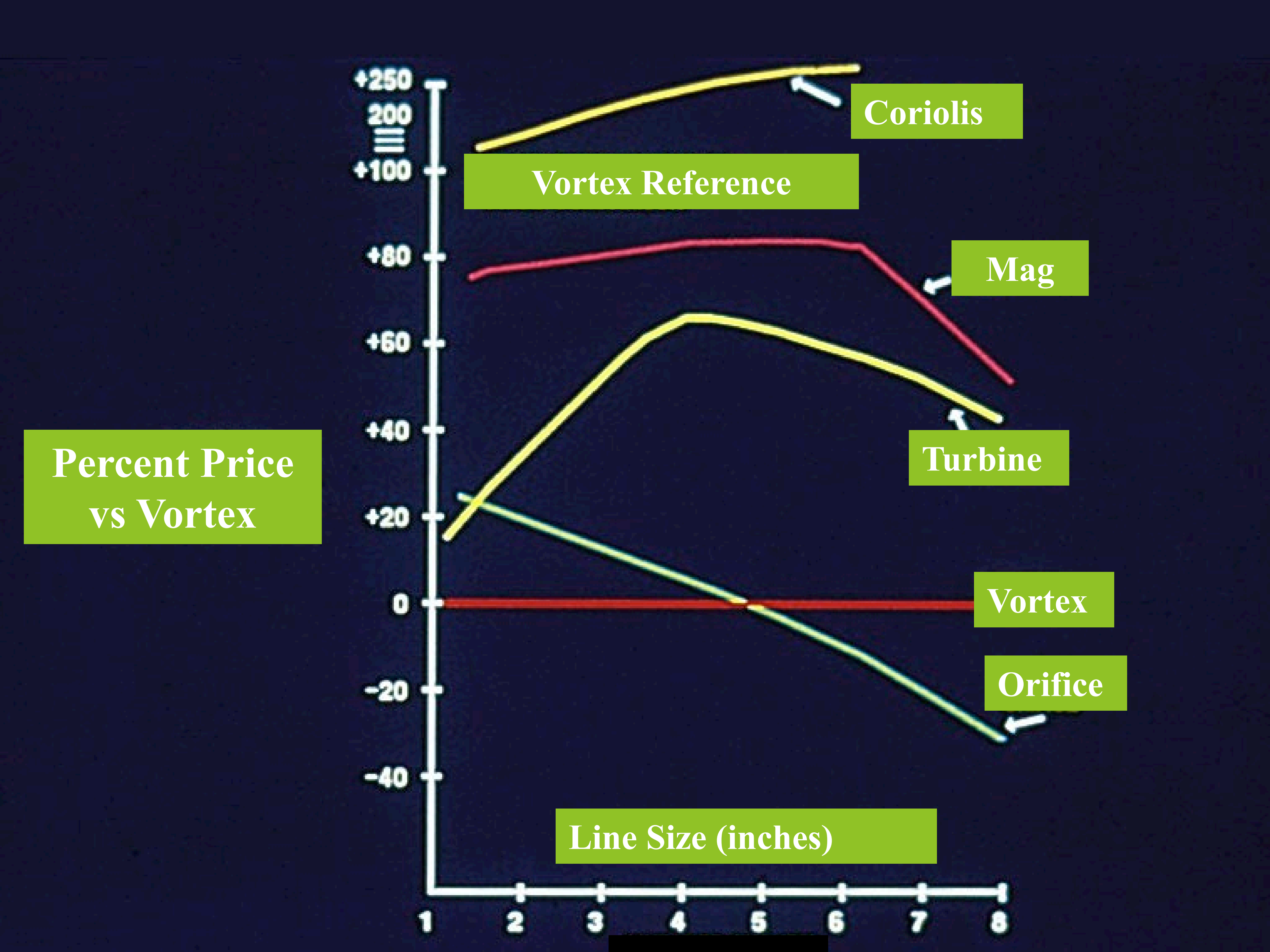
- *Use HEAT to arrive at flow measurement*
- *Actually heat dissipation is measured with temperature sensors*
- *Two methods of measuring:*
  - *Heated sensor is kept at a constant temperature and measures the amount of current necessary to keep it at that temperature*
  - *Measure the difference in temperature of the heated sensor and the temperature of the flowstream*



FLOWMETER TECHNOLOGIES

Thermal Mass Flow

- ***Either method works on the idea that higher velocity flows result in greater cooling of the heated sensor.***
- ***Both measure the effects of this cooling and use that result to compute mass flow.***
- ***Only used for gases***
- ***Low cost when compared to other mass flow devices***
- ***Low Flow Sensitivity***
- ***High Accuracy***



Percent Price vs Vortex
Coriolis
Vortex Reference
Mag
Turbine
Vortex
Orifice
Line Size (inches)
+250
200
+100
+80
+60
+40
+20
0
-20
-40
1
2
3
4
5
6
7
8

Some Important US Organizations

- ***American Gas Association (AGA)***
- ***American Petroleum Institute (API)***
- ***American National Standards Institute (ANSI)***
- ***American Society of Mechanical Engineers (ASME)***
- ***Instrument Society if America (ISA)***
- ***International Standards Organization (ISO)***

NOTE: The proper use of any flowmeter assumes that the appropriate Organization standards and recommendations of the manufacturer have been adhered to in order to achieve reference accuracy.

Recommended Reading: Miller, Richard W., Bristol Fellow of The Foxboro Company. Flow Measurement Engineering Handbook, McGraw Hill, Third Edition, 1996 - Digital Version $30.00 Hardcover $100.00

Recommended Reading: Foxboro. Flowmeter Selection Guide

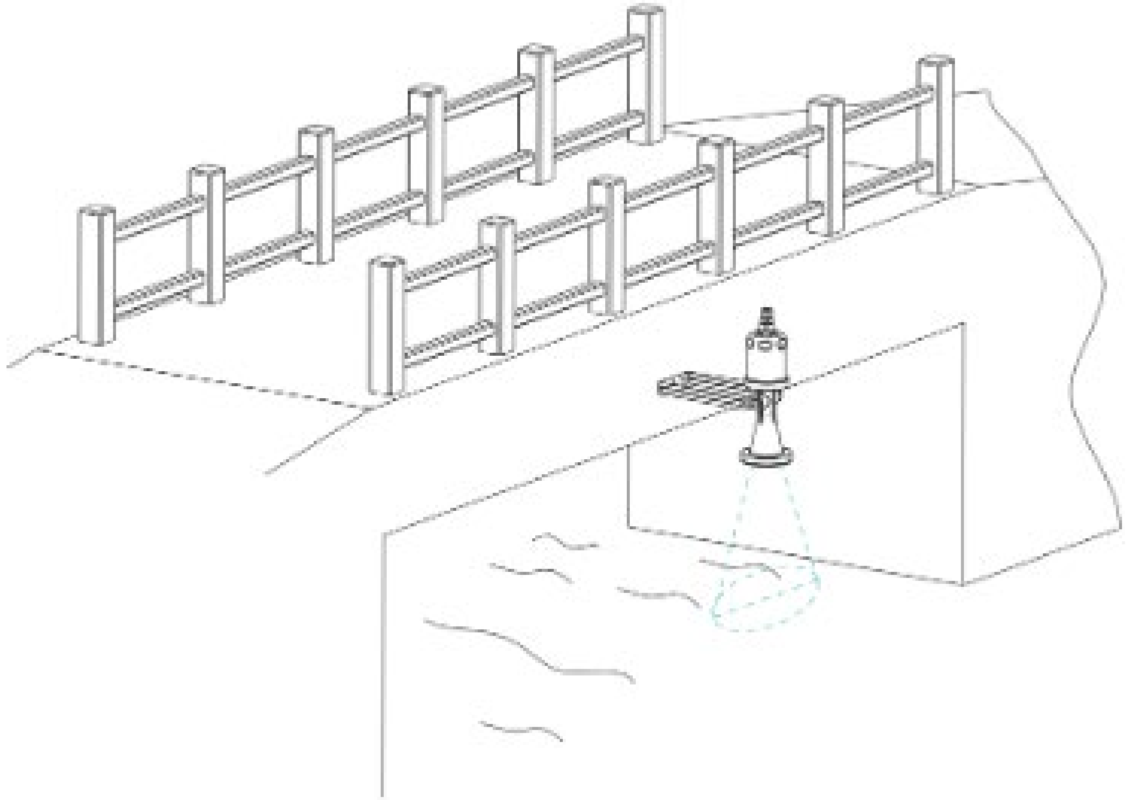
Recommended Reading: DeCarlo, Joseph P., The Foxboro Company. Fundamentals of Flow Measurement, ISA Learning Module, 1984

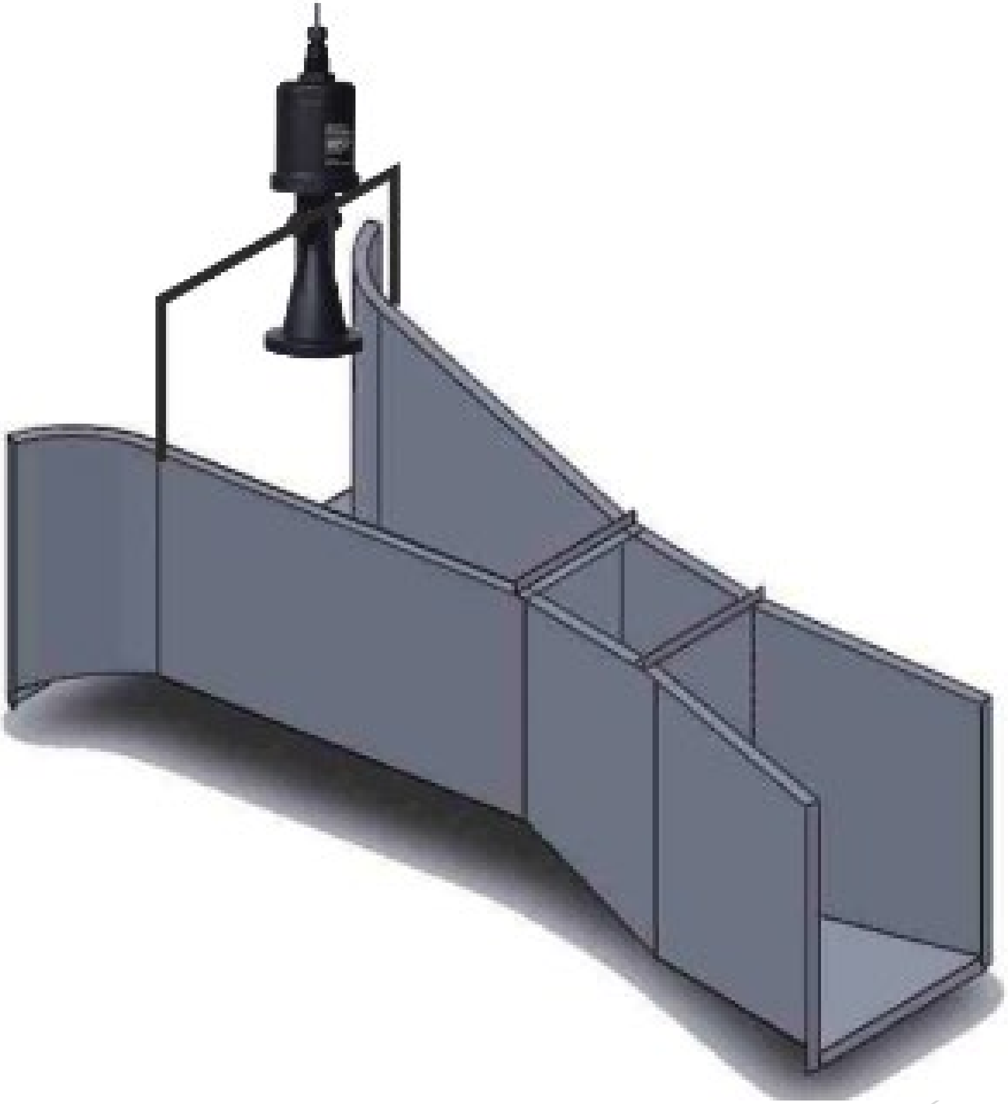
ISBN 13: 9780876646274

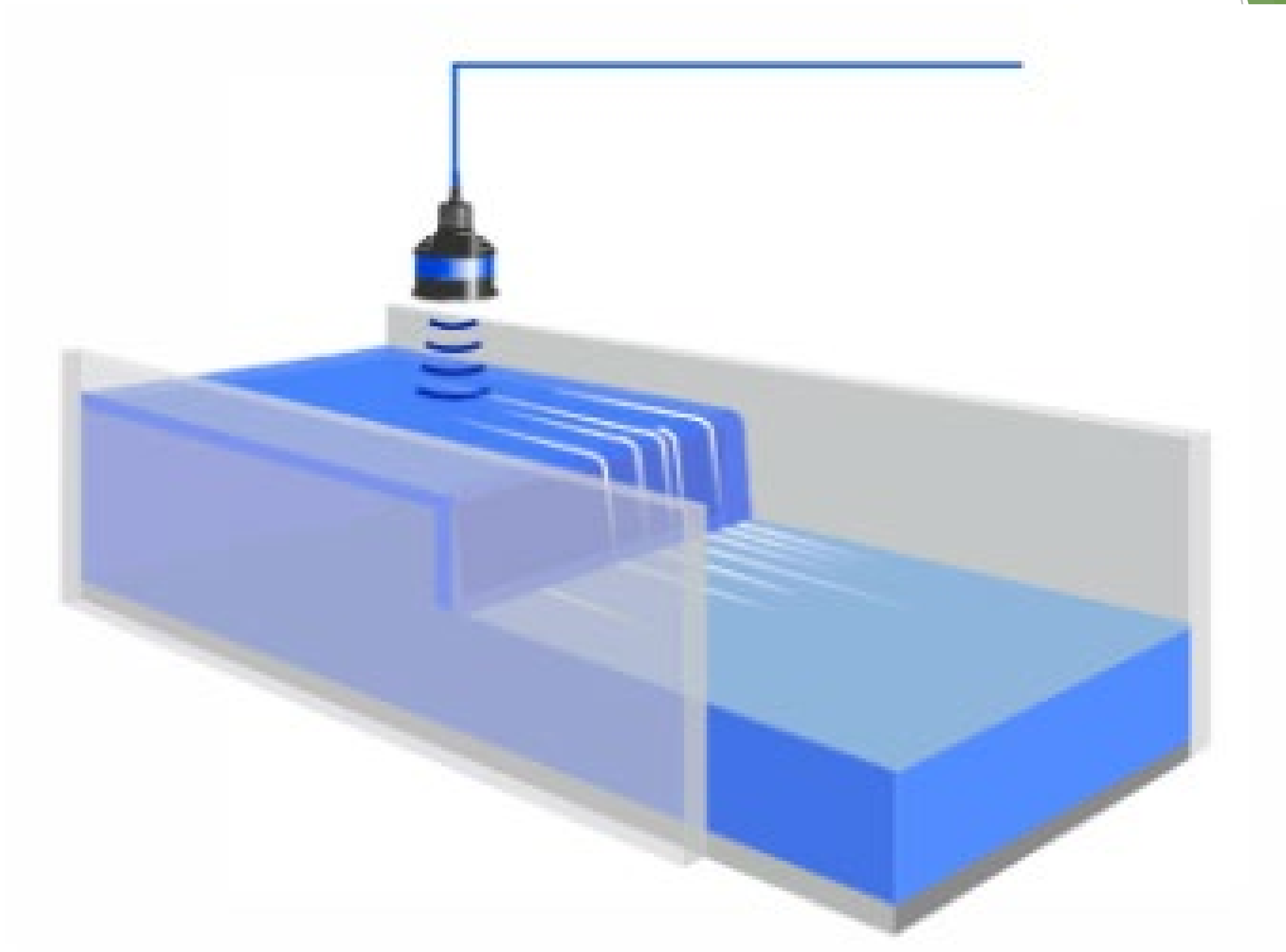
Sizing Program: http://www.flowexpertpro.com/

Fluids flowing under the influence of gravity alone:

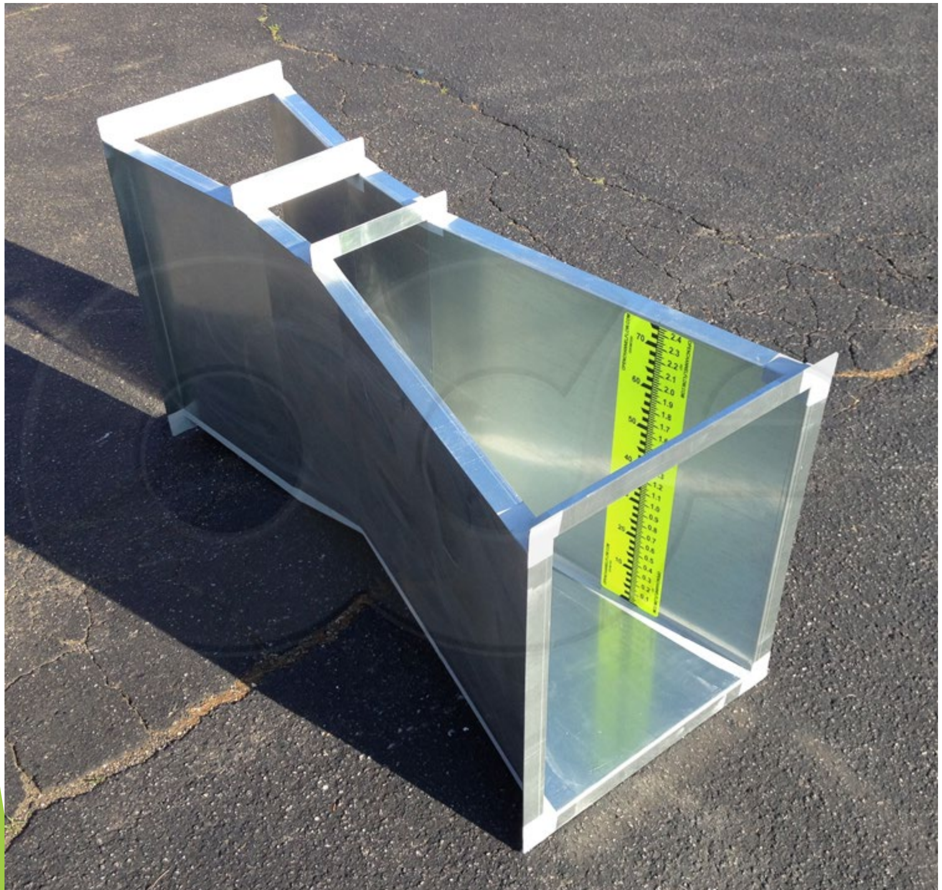
- Applications
- Manning equation will be used in partially filled pipe.
- Weirs, Flumes, Nozzles - *Isco Open Channel Flow Measurement Handbook* - for purchase $5-$70.







9” Galvanized Parshall Flume with level gauge Fiberglass and concrete are also typical construction materials – Throat, Neck and Tail way.



Summary

- ***Flowmeter Selection Process***
- ***Flow definition and reasons for a measurement***
- ***Total Flow and Flow Rate***
- ***Mass flow versus volumetric flow***
- ***Accuracy, Repeatability and Rangeability, Linearity, Square Law***
- ***Flowmeter Technologies***
  Principles of Operation, Applications, Pros & Cons
- ***Important organizations***
- ***Price Comparisons***
- ***Recommended Reading***

Conclusion-Assessment of Learning

Flowmeter Selection Thought Process:

- ***Why is Application (measurement or control) important***
- ***How does Measurement (mass, volume, rate) affect decision***
- ***Why Process Conditions (fluid, pressure, temp, range, corrosiveness, clean, dirty, composition, single or two phase, flow profile, Rp, line size, materials compatibility, area classification and ambient conditions) are important***
- ***What Flowmeter Technology is best for Steam Flow***
- ***Which one Performance factor (accuracy, repeatability, rangeability, reliability) is priority***
- ***Economics (performance / value advantages, installation, maintenance, parts, energy consumption, risk)***

Questions

THE END