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GSA

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Metering All Things Not Electric

Presented by
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Presentation objectives

To explain

- Why measure flow?
- Flow measurement fundamentals
- Meter selection criteria
- Different meter types & principles of operation

Why measure flow?

"When you can measure what you are speaking about, you know something about it;

but when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind."

Statement by Lord Kelvin

…..or put another way

You cannot manage what you cannot measure!

William Thomson (Lord Kelvin)

Why measure flow?

- 2005 Energy Policy Act
- Verify and reduce energy/utility use and costs
- Benchmark building or process energy use
- Verify energy saving project performance
- Costing and custody transfer (billing)
- Diagnose equipment & systems operations

Fluid flow in pipes

All fluids have a unique set of characteristics:

- Density (ρ) - a fluid's mass per unit volume (lb/ft^3)
- Specific Volume (ν) - a fluid's volume per unit mass (ft^3/lb)
- Dynamic viscosity (μ) - the molecular friction within a fluid or the temporary resistance to flow of a fluid (cP)
- Velocity, viscosity, density & pipe friction all affect the flow of a fluid in a pipe

Fluid flow in pipes

These factors combined, express the flow characteristics in a dimensionless value: Reynolds Number (R_e)

$$R_e = \frac{\rho V_d D}{\mu}$$

Where:

ρ = density

V_d = mean velocity in the pipe

D = Internal pipe diameter

μ = Dynamic viscosity

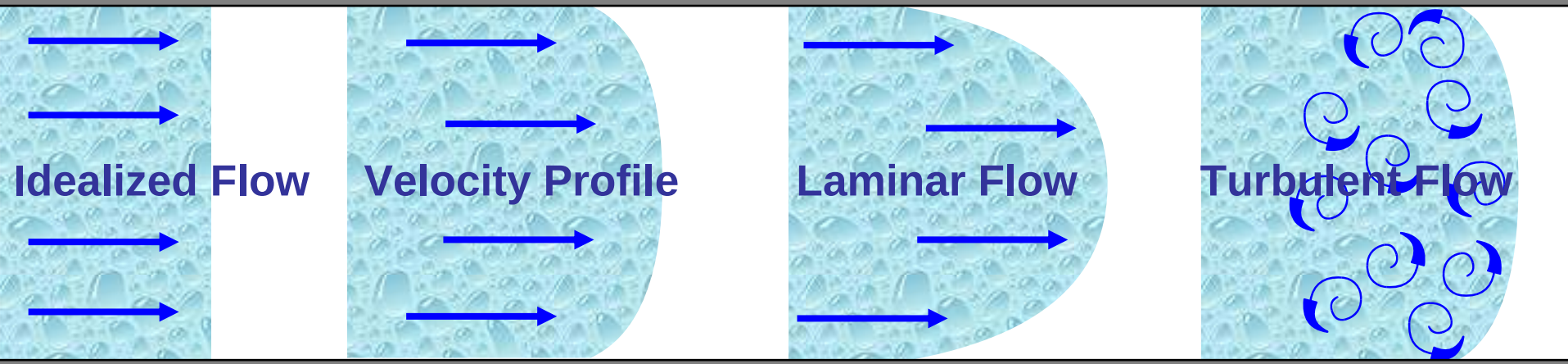
Fluid flow in pipes

Another way of describing Reynolds Number is: $\frac{\text{Dynamic Force}}{\text{Viscous Force}}$

High velocity & low viscosity (i.e.steam) gives a high R_e

Low velocity & high viscosity (i.e. molasses) gives a low R_e

Velocity profile



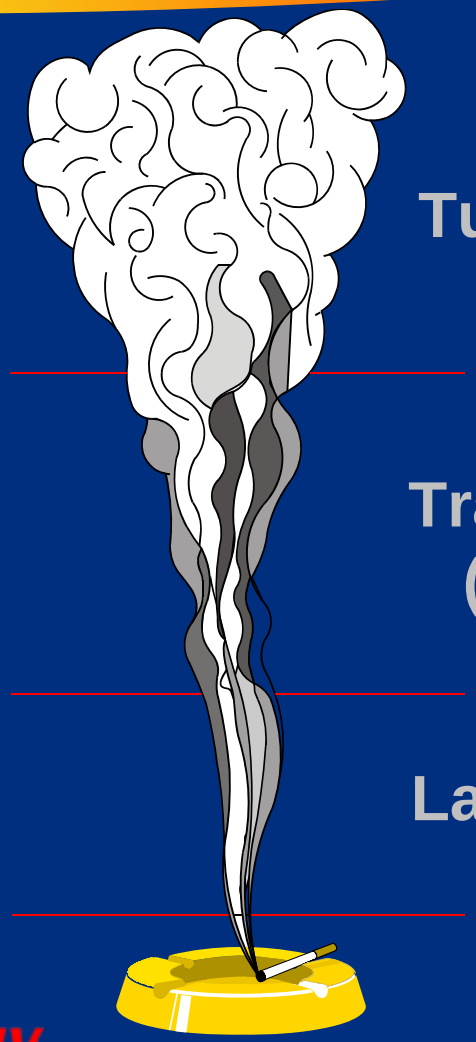
Idealized flow ignores the effects of viscosity and pipe friction

Viscosity and pipe friction decrease the fluid flowrate near the pipe wall

At R_e <2,300 flow is “laminar” where all motion is along the axis of the pipe

As velocity increases to a R_e >10,000 flow is completely turbulent

R_e visualization

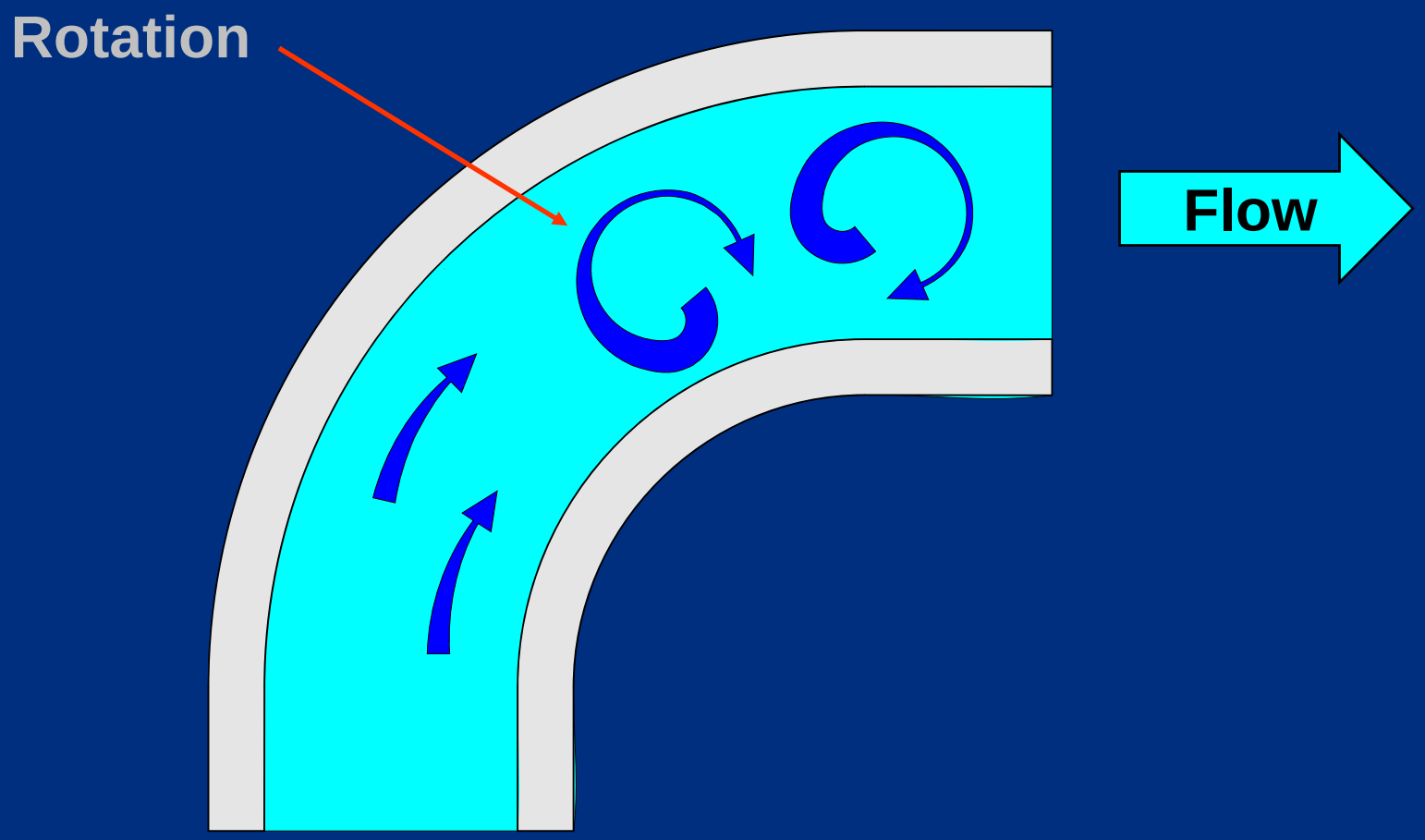


Turbulent flow region
(R_e above 10,000)

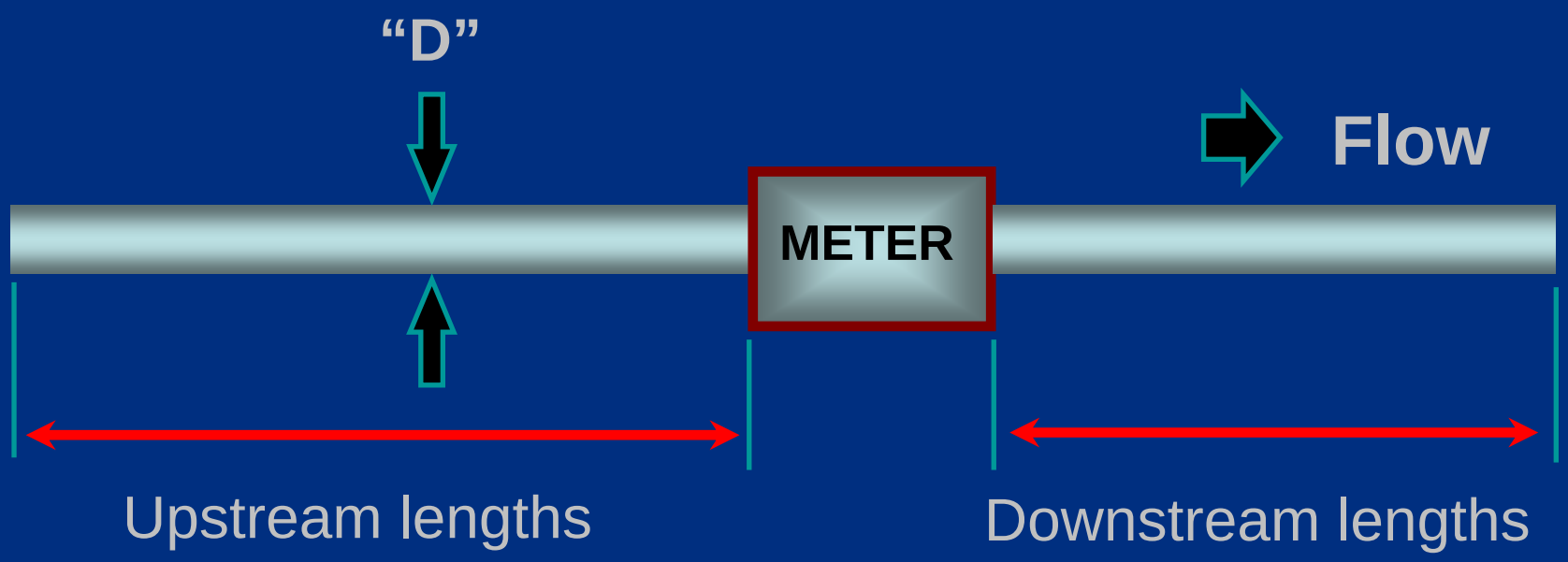
Transition flow region
(R_e 2,300 – 10,000)

Laminar flow region
(R_e 100 - 2,300)

Swirl

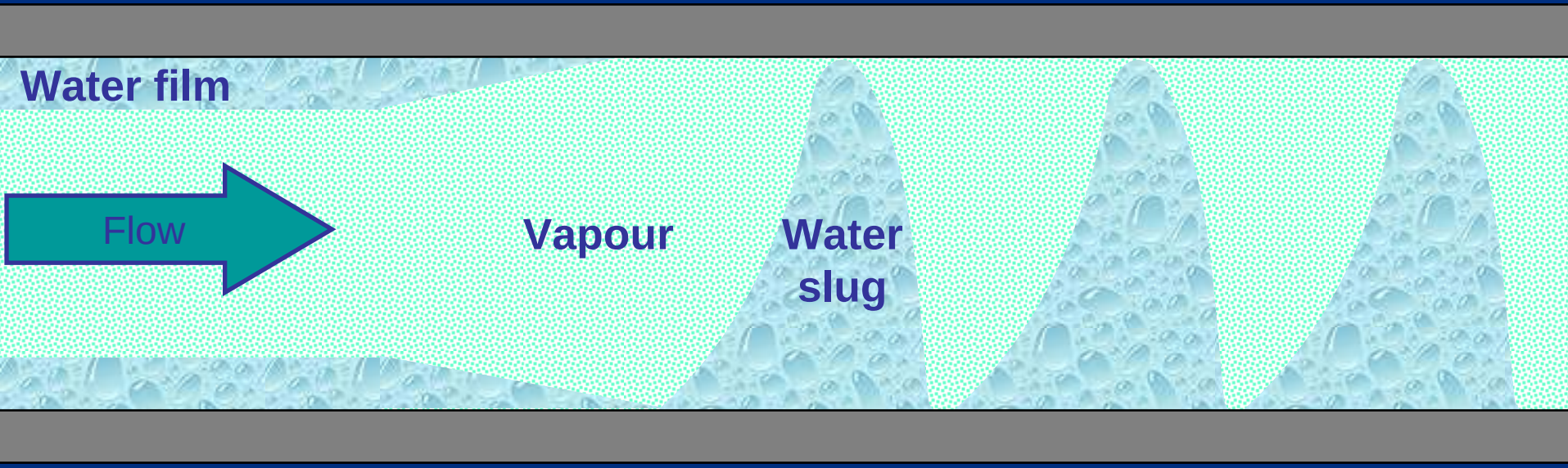


Up and downstream piping

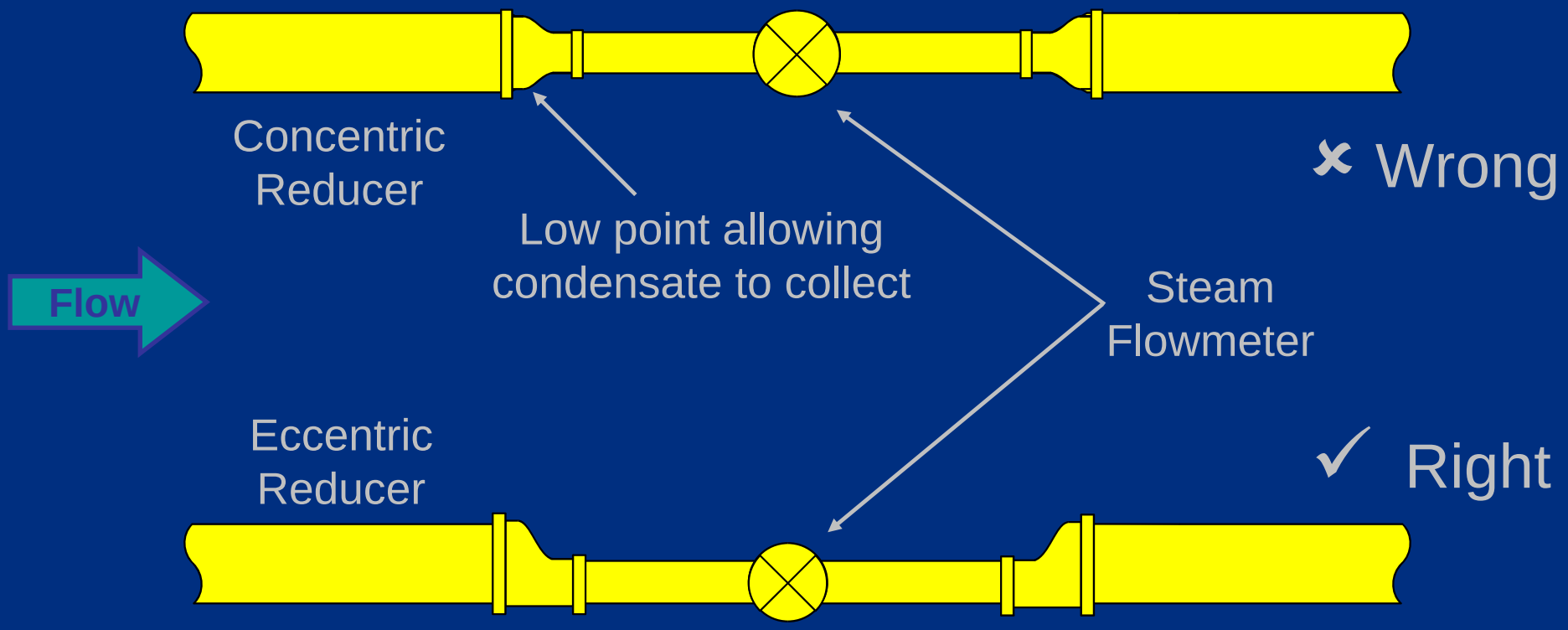


Flow straighteners can reduce up and down pipe requirements

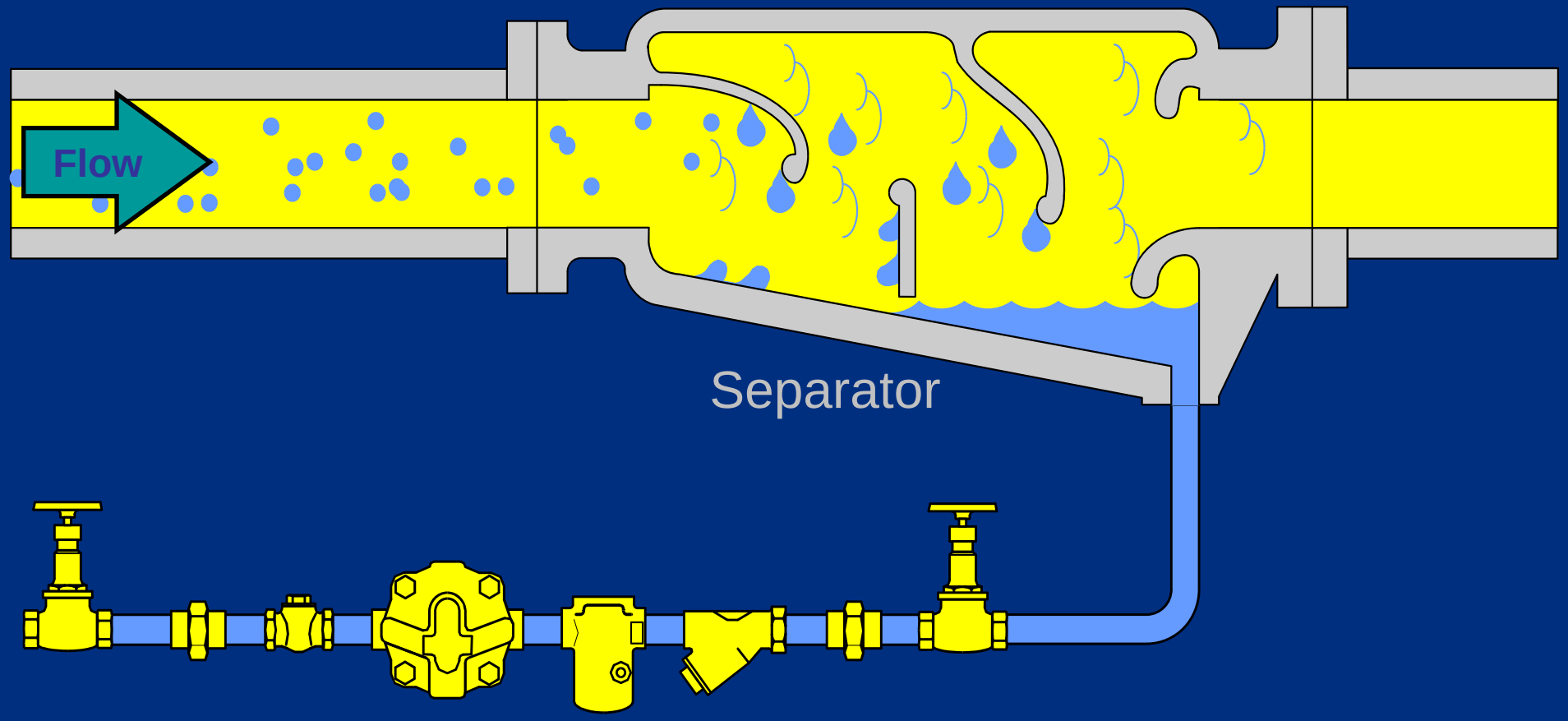
Annular & slug flow in steam



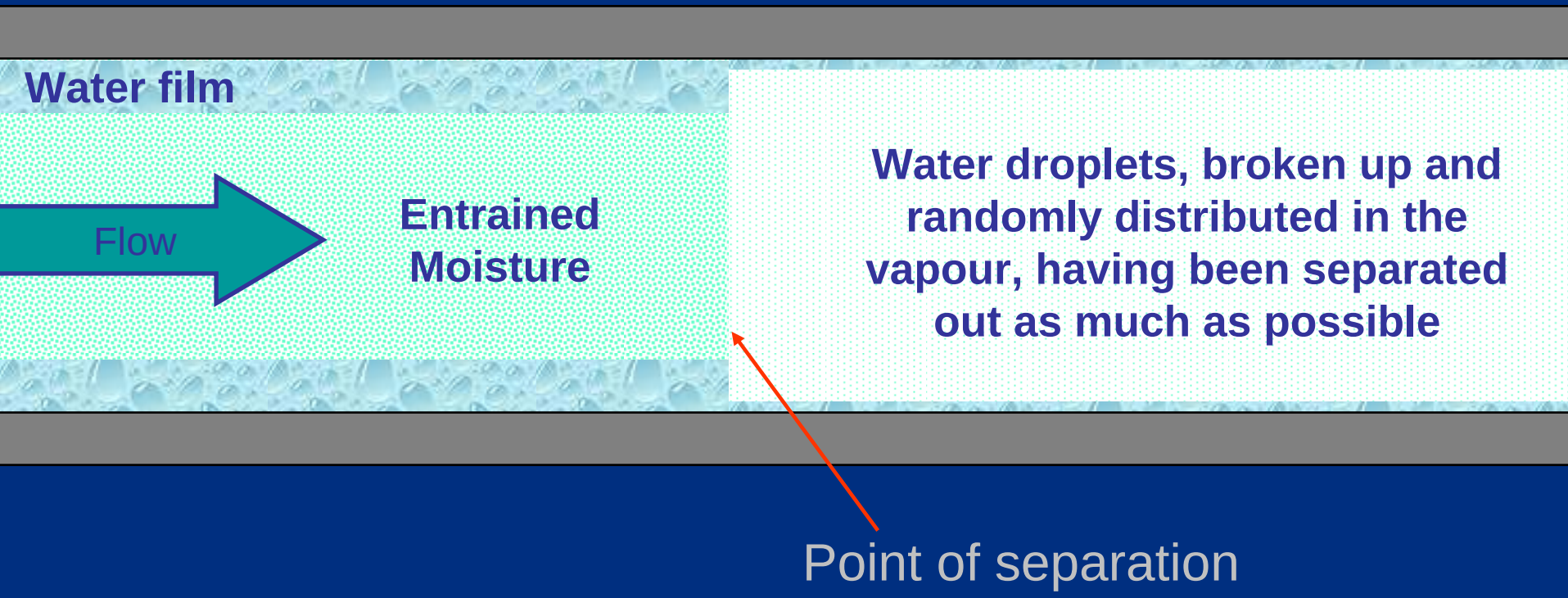
Pipe size reduction



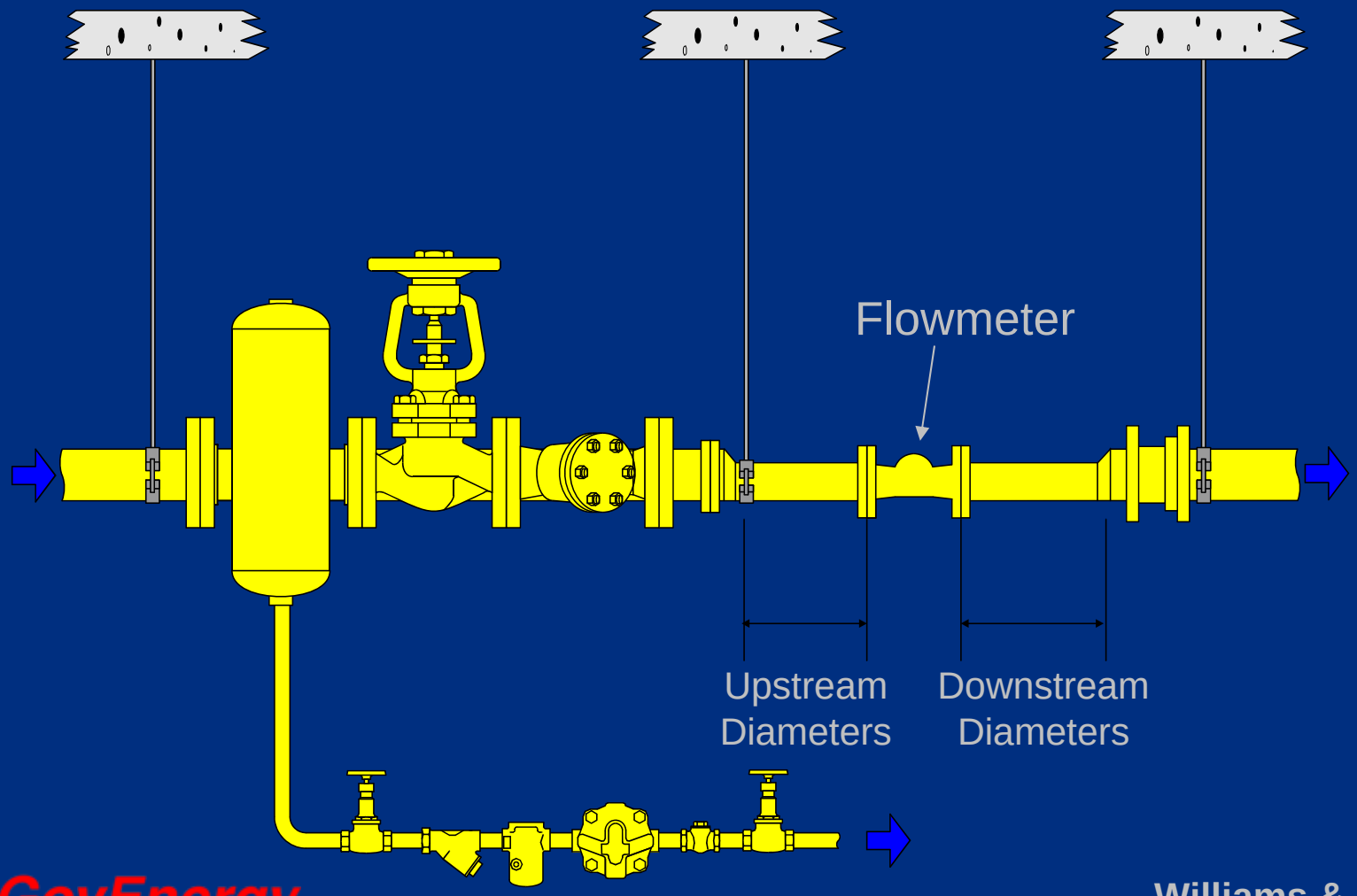
Steam quality



Annular & annular dispersed



Steam conditioning station



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Flowmeter types

Differential Pressure

- Orifice Plate
- Flow Nozzles
- Venturi Tubes

Positive Displacement

- Diaphragm
- Rotary
- Reciprocating Piston
- Helical Rotor Meter
- Oval Gear

Other Differential Pressure

- Target
- Pitot
- Averaging Pitot
- Bypass
- Rotameters
- Spring loaded variable area (Gilflo, ILVA, DIVA)
- V-Cone
- Accelabar

Flowmeter types

Rotary Meters
- Turbine
- Propeller
- Pelton Wheel
- Anemometers

Ultrasonic
- Transit Time
- Doppler

Oscillatory
- Vortex Shedding
- Fluidic Oscillator

Other
- Electromagnetic
- Coriolis
- Thermal Mass

Selecting a flowmeter

- Performance
  - Accuracy (or Uncertainty)
  - Repeatability
  - Turndown
  - Density compensated (Multivariable)
  - Display options
  - Ability to interface (comms)
  - Response time
  - Pressure drop

Selecting a flowmeter

- Material
  - Pressure, temperature, corrosion compatibility
- Installation issues
  - Inline or insertion (hot tap?)
  - Up and downstream piping requirements
  - Horizontal or vertical
  - Environmental: inside/outside, NEMA, I.S. etc.
  - Power requirements

Selecting a flowmeter

- Reliability
  - Moving parts
  - Ruggedness (vibration,shock,humidity, temp)
  - Calibration needs
- Cost
  - Meter
  - Associated equipment
  - Installation
  - Ownership

Selecting a flowmeter

- Maintenance
  - Ease of maintenance & spare parts availability
- Reputation and support of manufacturer
  - Technical support
  - After sales service
  - Warranty
  - Quality of literature and information provided

Selecting a flowmeter

Accuracy

- A measure of a meter's performance or uncertainty in indicating a correct flowrate value against a 'true' value obtained by extensive calibration procedures.

Two methods used to express accuracy:

- As a percentage of reading
- As a percentage of full scale deflection (FSD)

Accuracy....+/- 3%

+/- 3% of Reading

- At true flow of 1,000lb/h meter displays: 1,030-970 lb/h
- At true flow of 100 lb/h meter displays: 103-97 lb/h

+/- 3% of FSD

- At true flow of 1,000lb/h meter displays: 1,030-970 lb/h
- At true flow of 100 lb/h meter displays: 130-70 lb/h

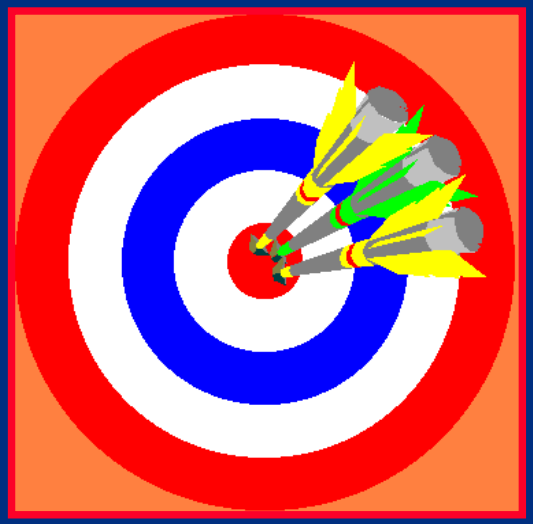
i.e. +/- 30% ERROR!!!

Selecting a flowmeter

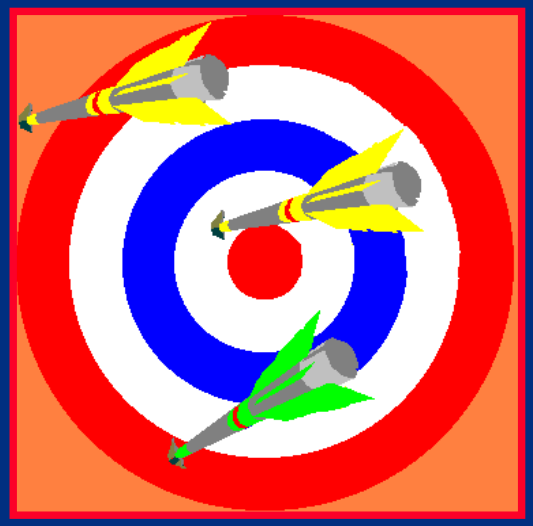
Repeatability

- A flowmeter's ability to indicate the same value for an identical flowrate on more than one occasion.
- Repeatability should not be confused with accuracy.
- Good repeatability is important because many flowmeter users are more interested in observing trends than absolute and minute accuracy.

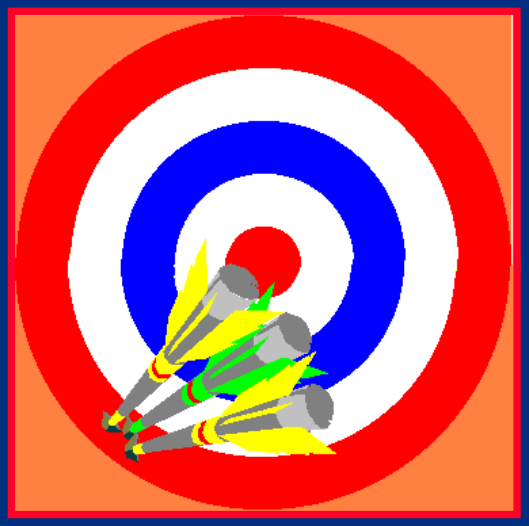
Repeatability



Accurate and therefore repeatable



Not repeatable and therefore not accurate



Repeatable <u>but</u> not accurate

Selecting a flowmeter

Turndown

- The Turndown of a flowmeter is the ratio of the maximum to minimum flowrate over which it will operate within it's specified accuracy and repeatability tolerances

Maximum Flowrate = 1,000 lb/h

Minimum Flowrate = 100 lb/h

Turndown = 1,000 ÷ 100 = 10:1

The BIGGER the Better!

Density compensation

The pressure in steam systems is rarely constant i.e. its density varies and must be accounted for...

Example: Consider a simple vortex meter specified to operate at 75 psig but actually operating at only 50 psig. Without density compensation the error can be calculated as follows:

Flow error = ((75 psi density ÷ 50 psi density) -1) x 100

= ((0.2043 ÷ 0.1503) -1) x 100

= 35.928

The meter over reads by almost 36%!

Reference Terms

- Flow Measurement Accuracy

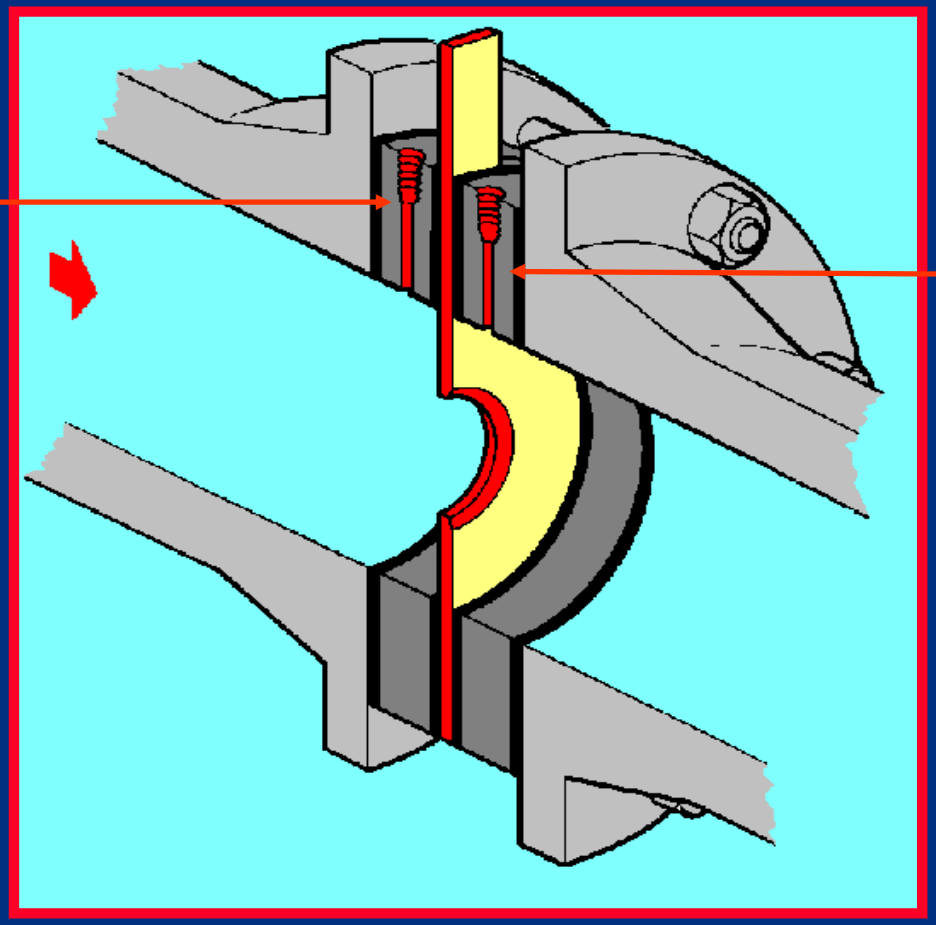
  Average = 1-2% of flow rate
- Turndown (Max. flow/Min. flow)

  Typical = 10 to 1
- Straight run Requirements

  Typical = 10 upstream and 5 downstream

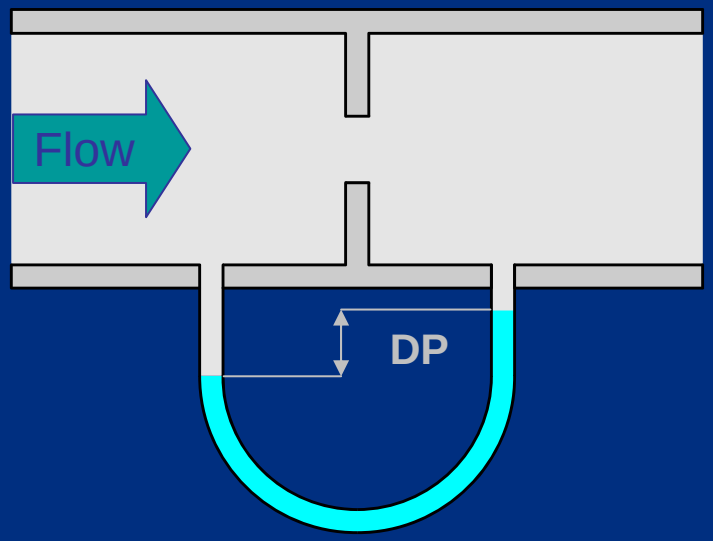
Orifice Plate

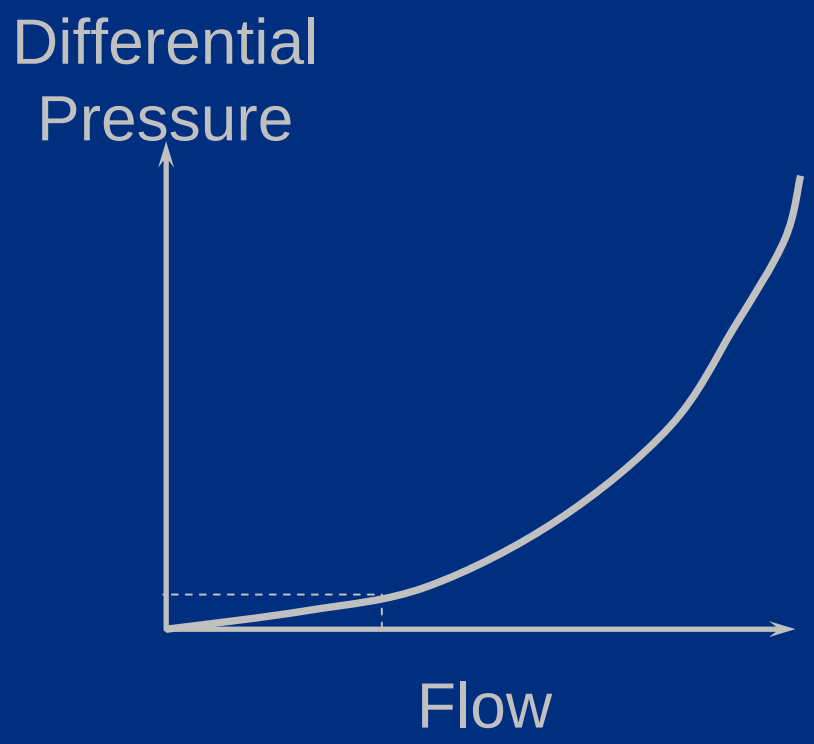
Upstream Pressure Tapping



Downstream Pressure Tapping

Orifice Plate





Orifice Plate

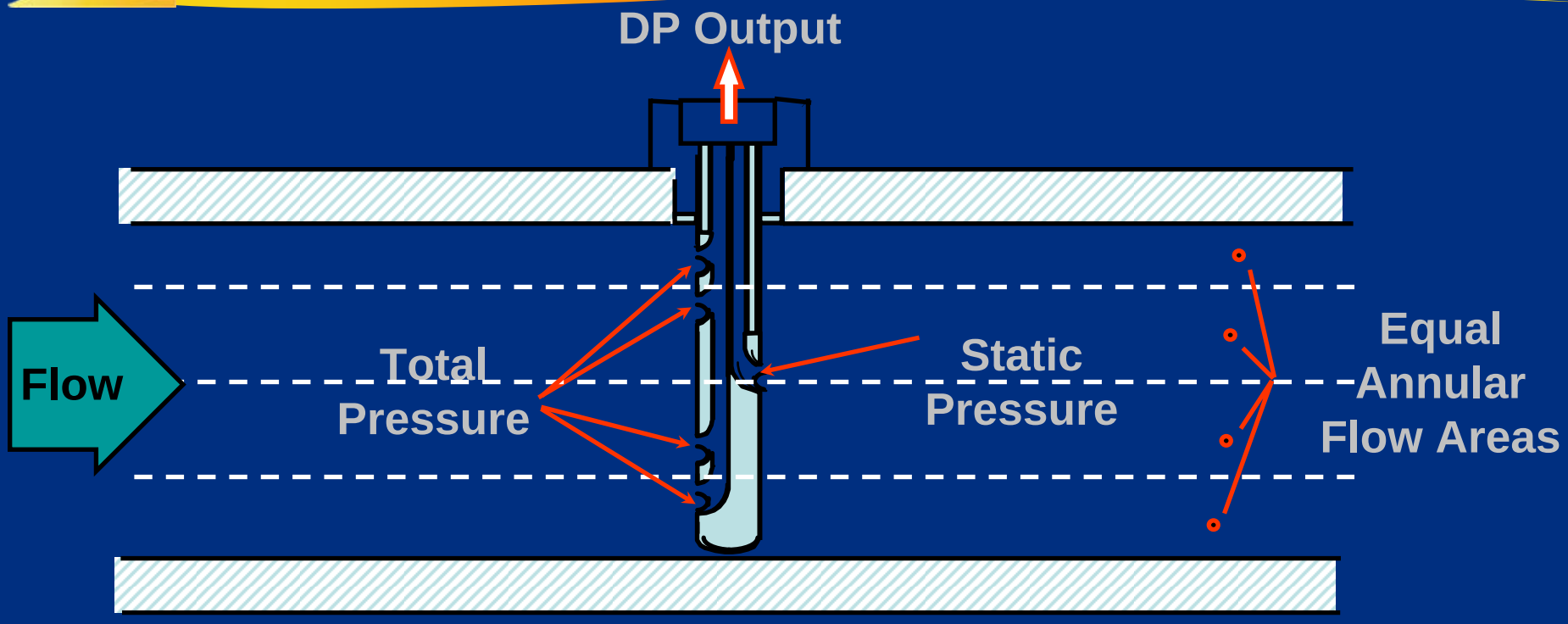
Advantages

- Simple and rugged
- Average to low accuracy
- Low cost

Disadvantages

- Low Turndown 4 or 5:1
- Can buckle due to waterhammer & liable to silt up
- Regular inspection required
- Typical to Long Straight run requirements

Averaging Pitot Tube



Averaging Pitot Tube

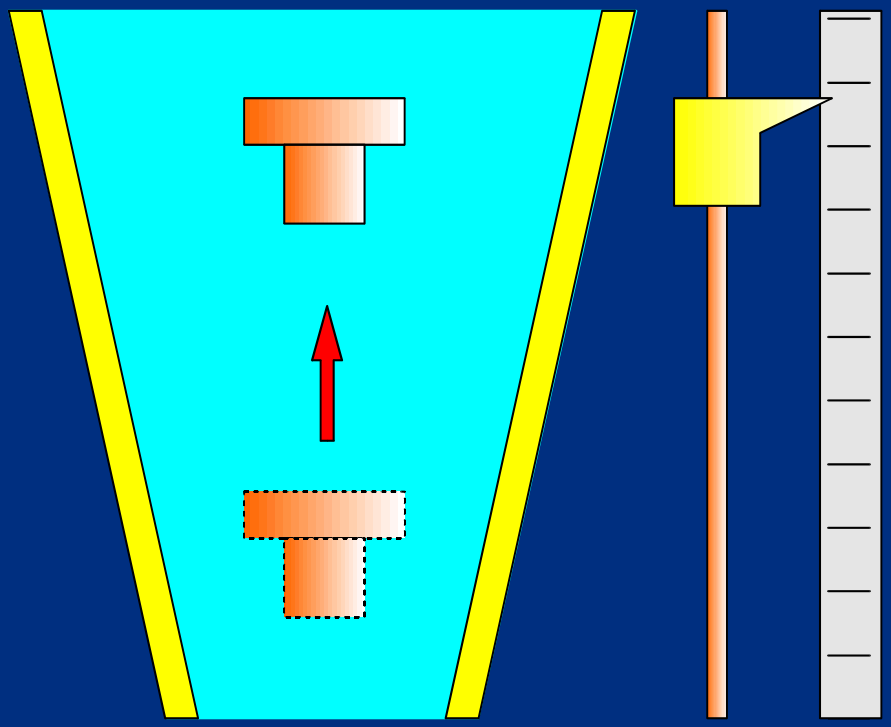
Advantages

- Low cost (especially for large pipes)
- No moving parts
- Low pressure drop
- Average accuracy

Disadvantages

- Typical Turndown (10:1)
- Subject to blockage
- Typical to Long straight run requirements

Simple Variable Area



Float Position According to Flow Rate

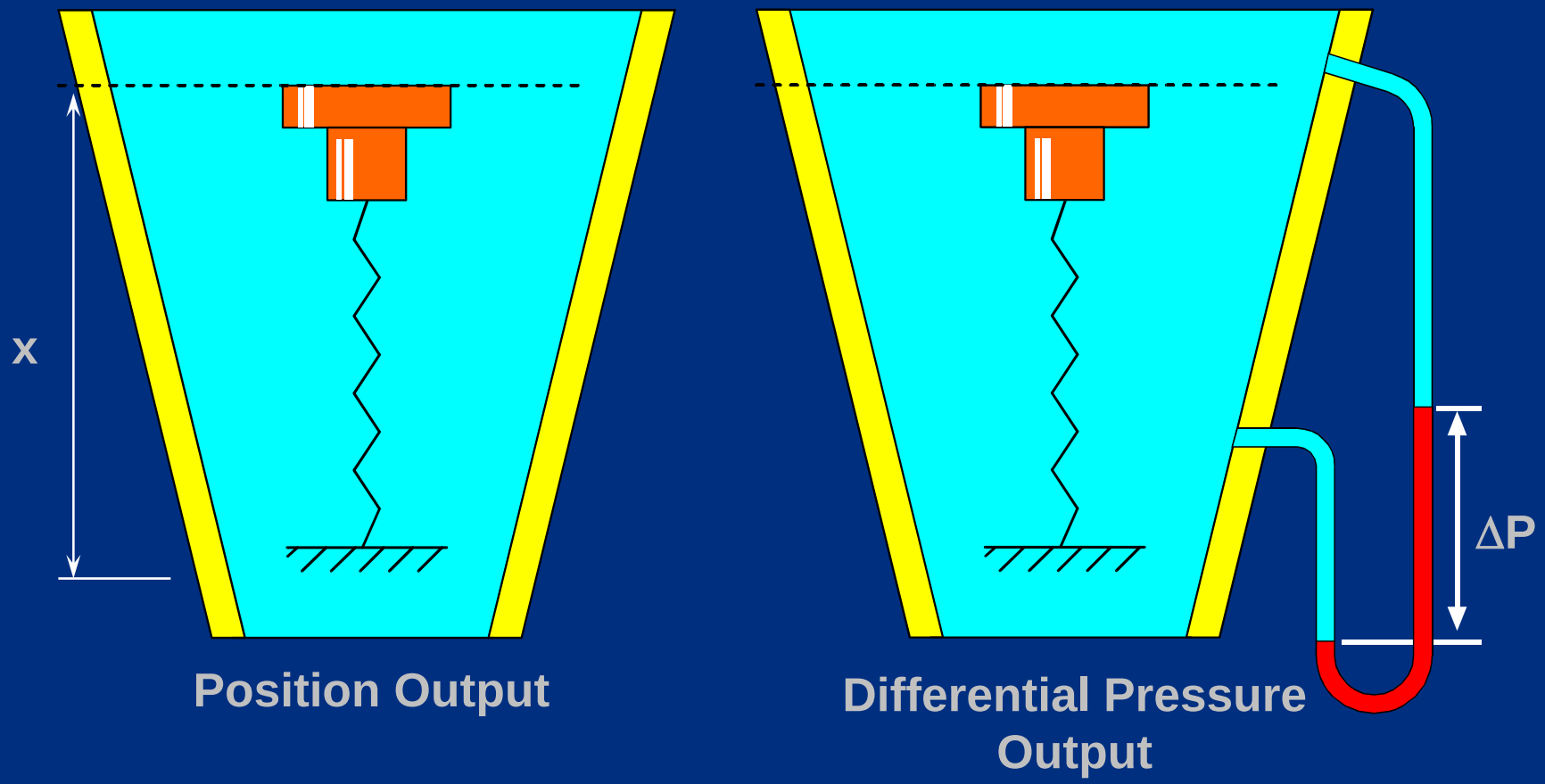
Advantages

- Linear output
- Simple to use & install
- No straight run

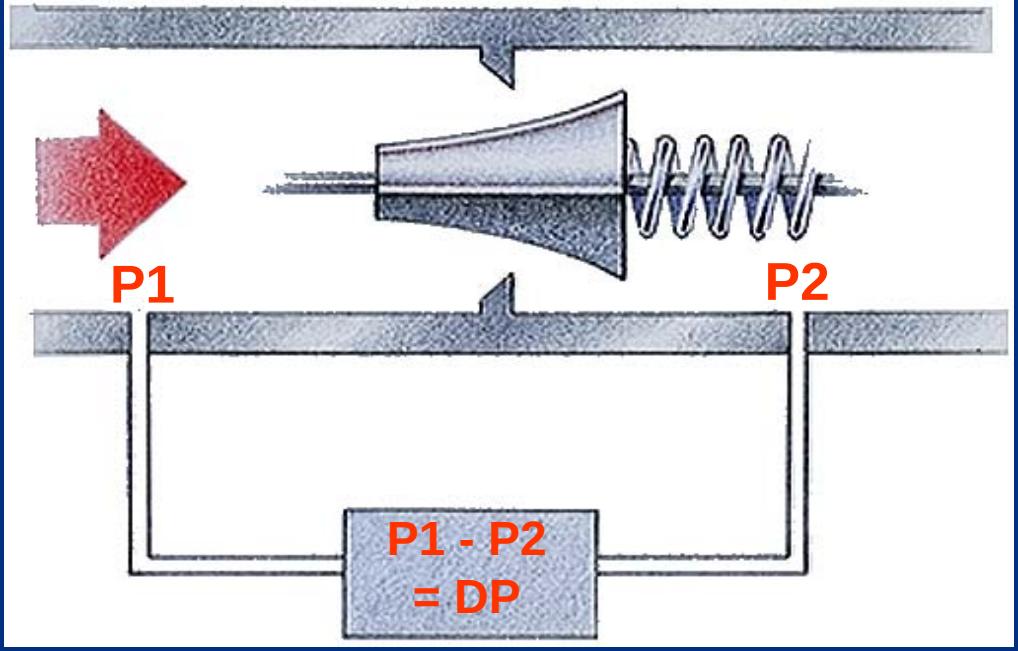
Disadvantages

- Must mount vertically
- Low accuracy
- Limited applications (P & T)
- Difficult to read remotely
- Density sensitive

Spring Loaded Variable Area

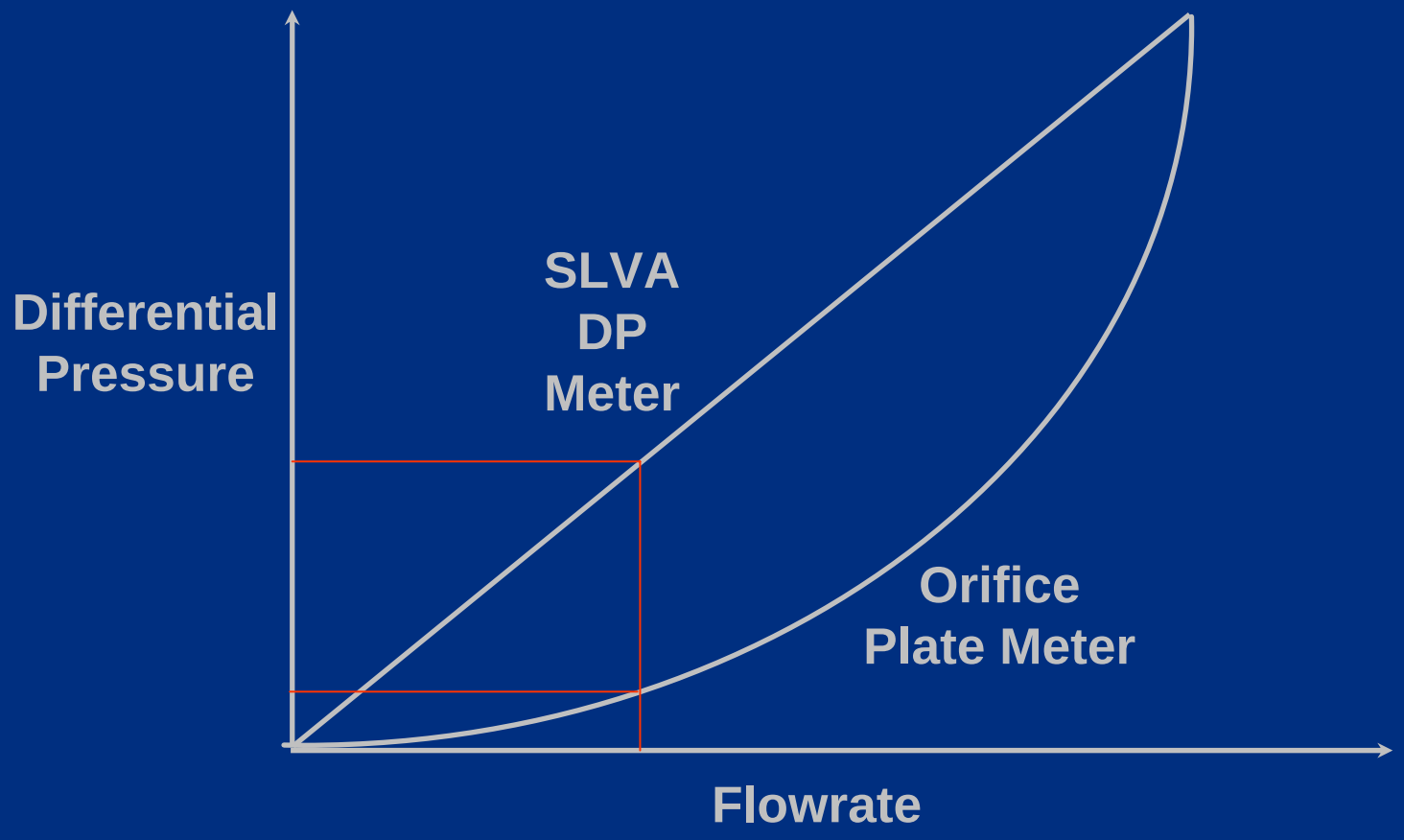


SLVA – DP Output



- Area of annular orifice is varied by movement of profiled cone against spring
- Differential pressure is measured by DP transmitter

SLVA – DP Output



SLVA – DP Output

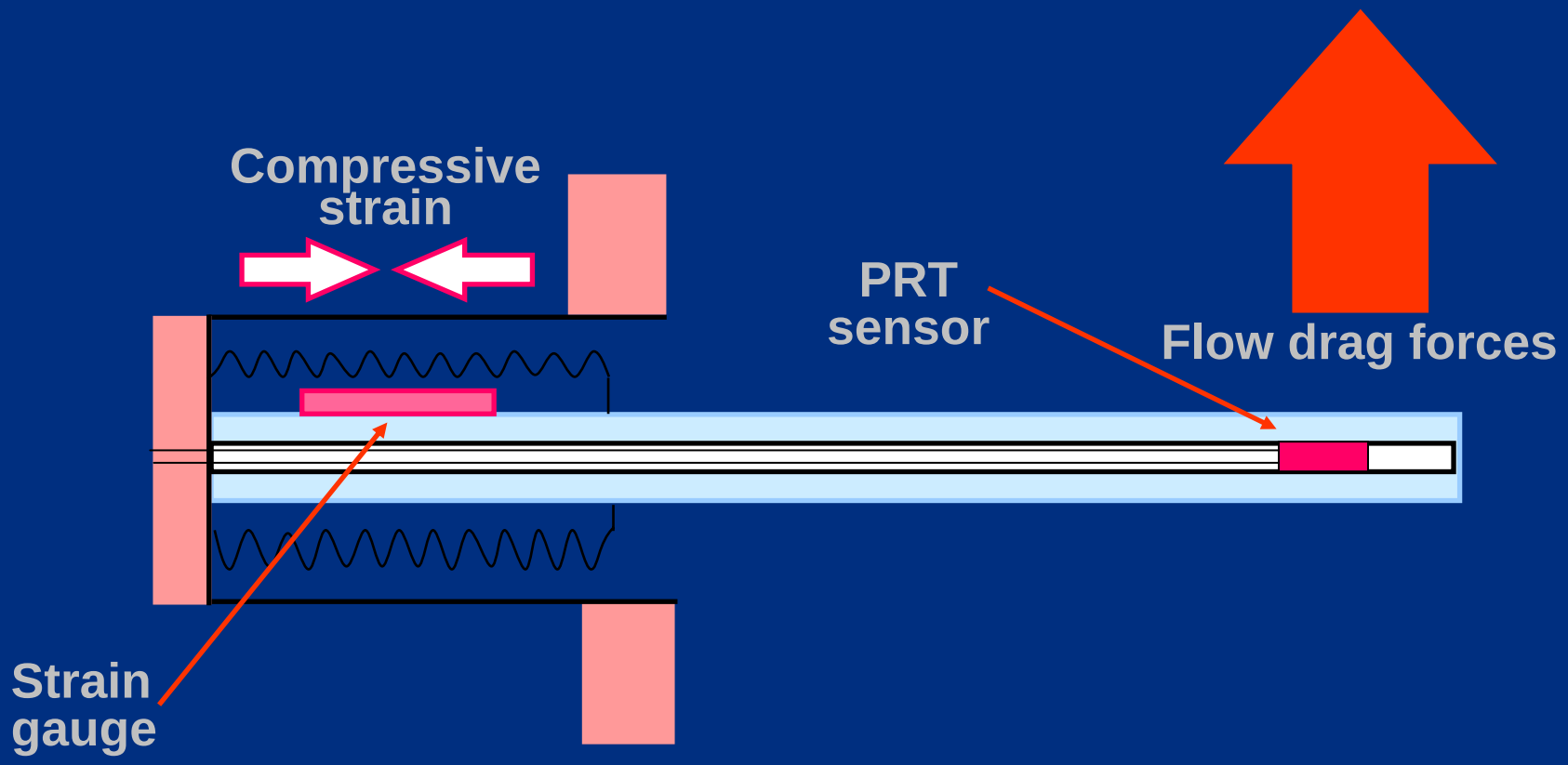
Advantages

- Very high turndown (100:1)
- Average accuracy
- Short straight run requirements (6 & 3D)

Disadvantages

- Moving parts
- Average pressure drop

SLVA – Position Output



DIVA uses 1 compressive strain gauge whose resistance changes under compression. Output is 1 millivolt per 1000 microstrains

SLVA – Position Output

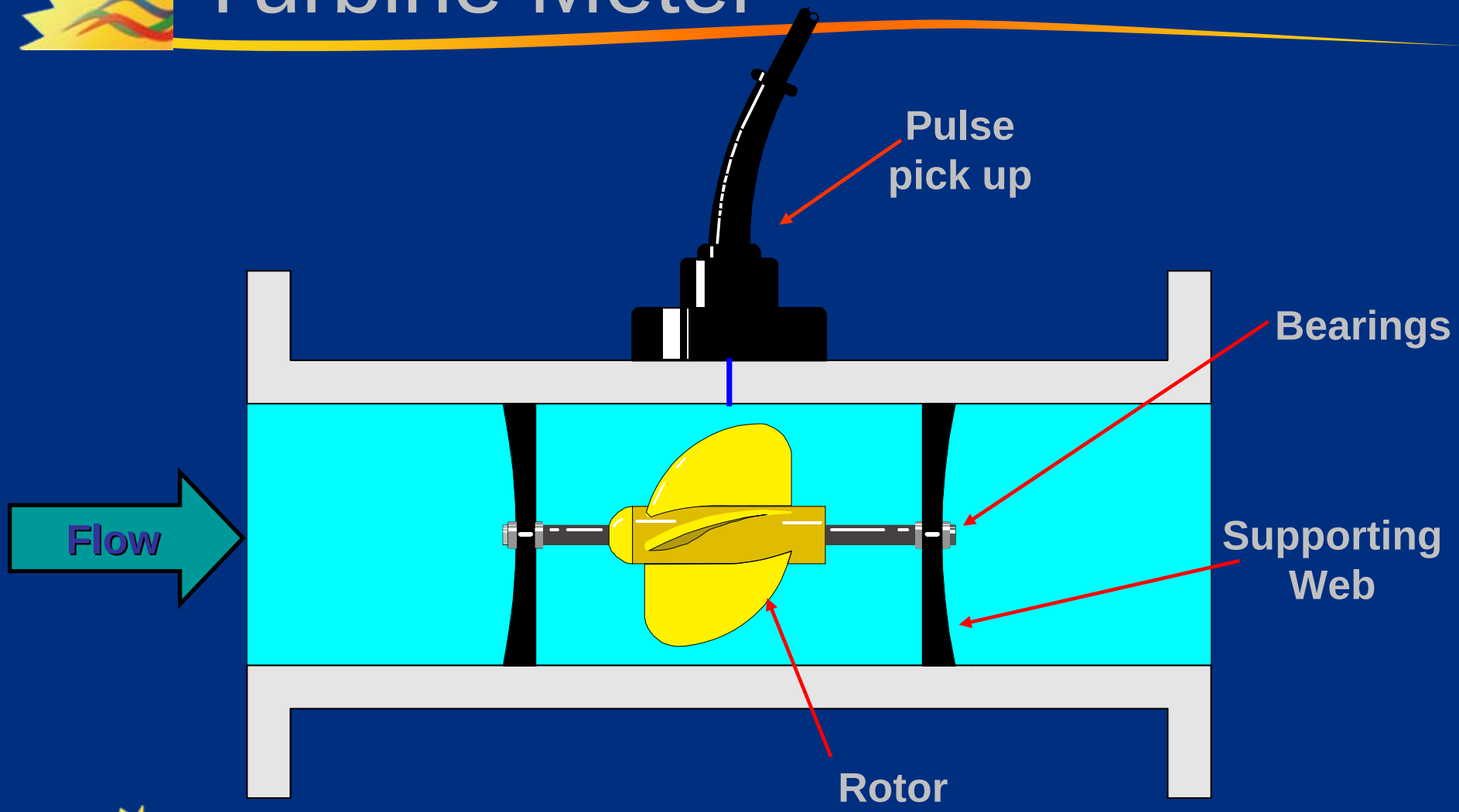
Advantages

- High turndown (50:1)
- Density compensated for saturated steam
- Typical “system” accuracy
- Short straight run requirements (6 up & 3 down)

Disadvantages

- Moving parts
- Relatively high pressure drop
- Saturated steam only

Turbine Meter



Turbine Meter

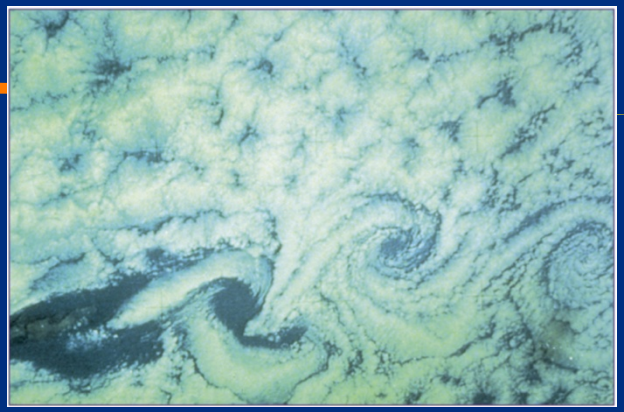
Advantages

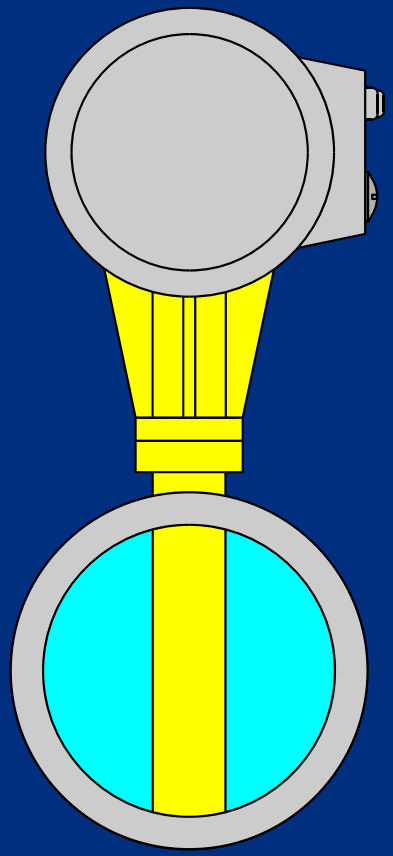
- High to Poor accuracy
- Average to high turndown
- Insertion type economic solution for large pipes
- Typical straight run requirements

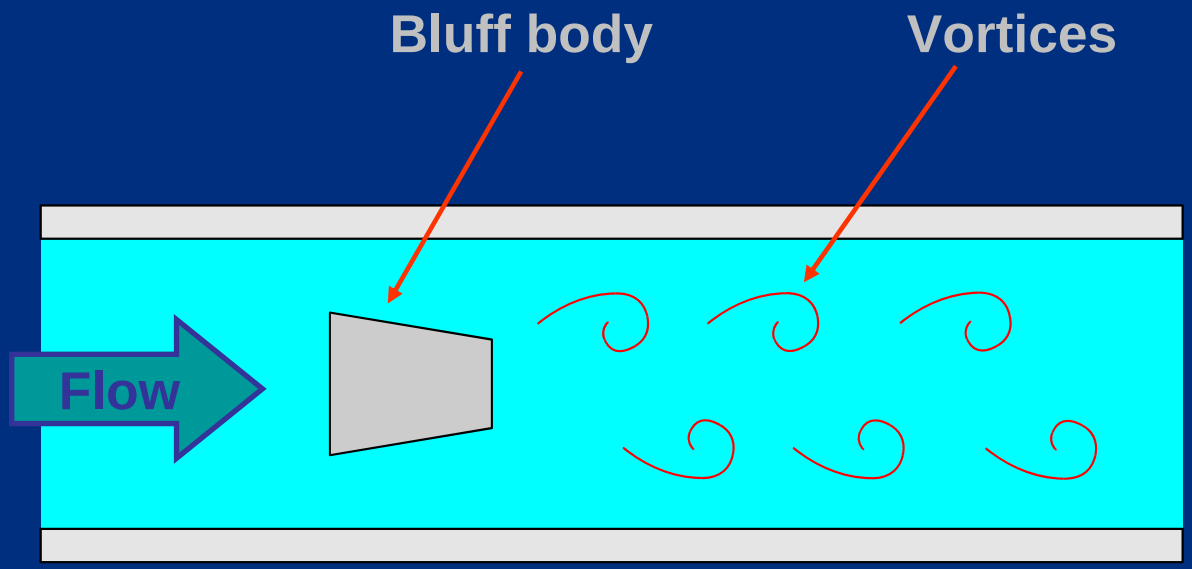
Disadvantages

- Moving parts
- Wear or fouling of rotor surfaces causes inaccuracies requiring replacement or recalibration
- Rotor bearing susceptible to wear

Vortex Shedding







Vortex Shedding

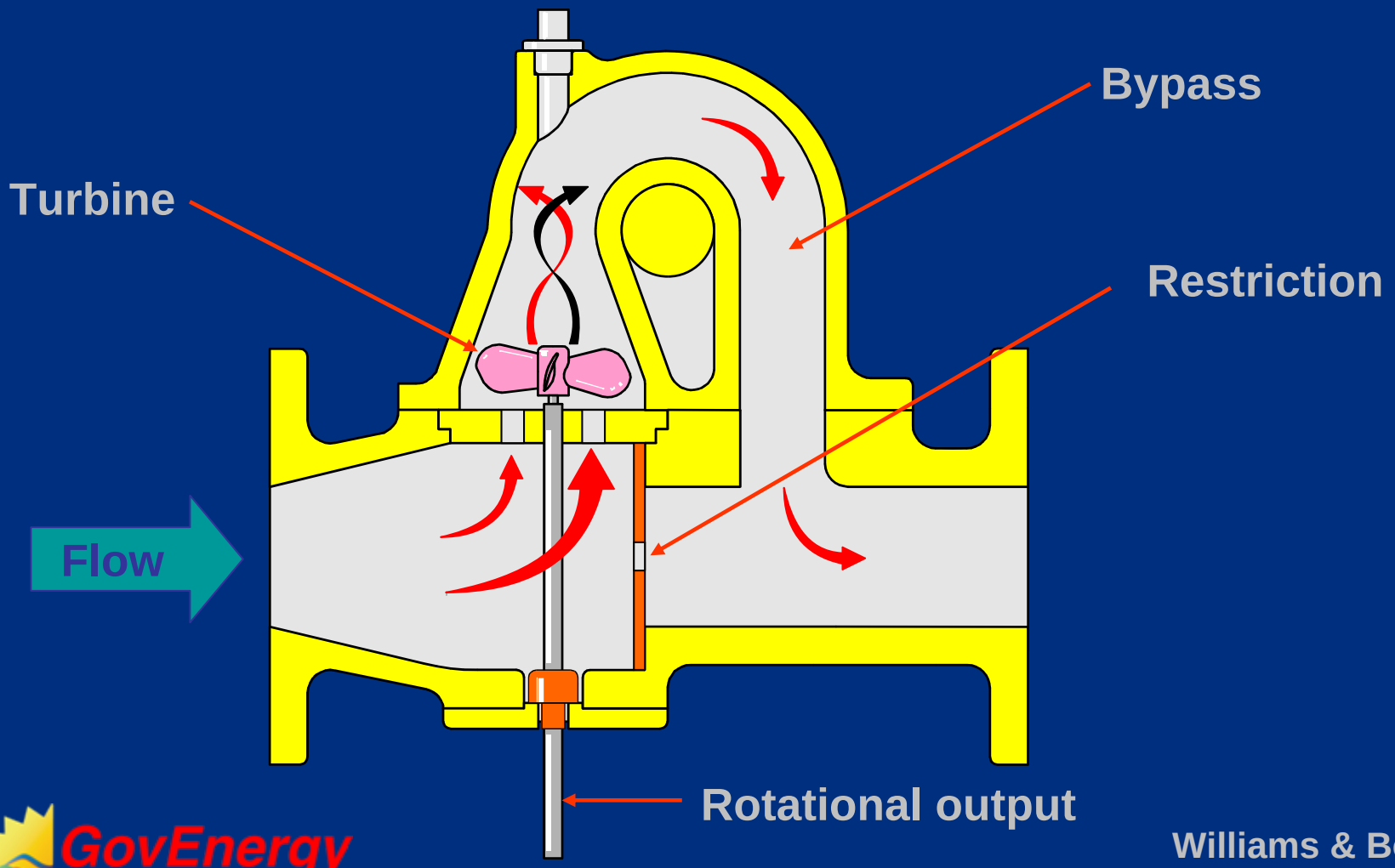
Advantages

- High turndown (20:1)
- No moving parts
- Low Pressure Drop
- Insertion type economic solution for large pipes
- High to Typical Accuracy

Disadvantages

- Vortices no longer shed at low flows
- Vibration can produce false readings
- Typical to Short Straight run requirements

Bypass or Shunt



Bypass or Shunt

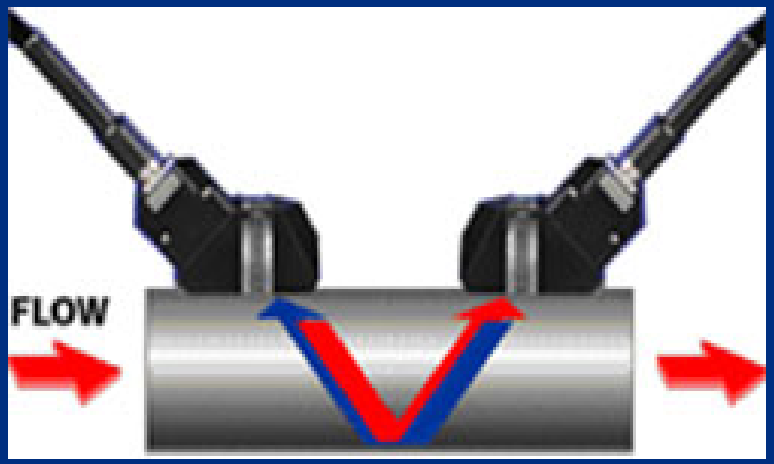
Advantages

- Relatively low cost
- Well proven on steam
- Visual indication of total
- Typical or short straight run requirements

Disadvantages

- Low turndown
- Flow rate indication not usually available
- Moving parts
- Affected by density changes

Ultrasonic – Transit-Time



Ultrasonic (high frequency) sound waves are transmitted simultaneously from each transducer – one travels in the direction of flow, the other travels in the opposite direction against flow

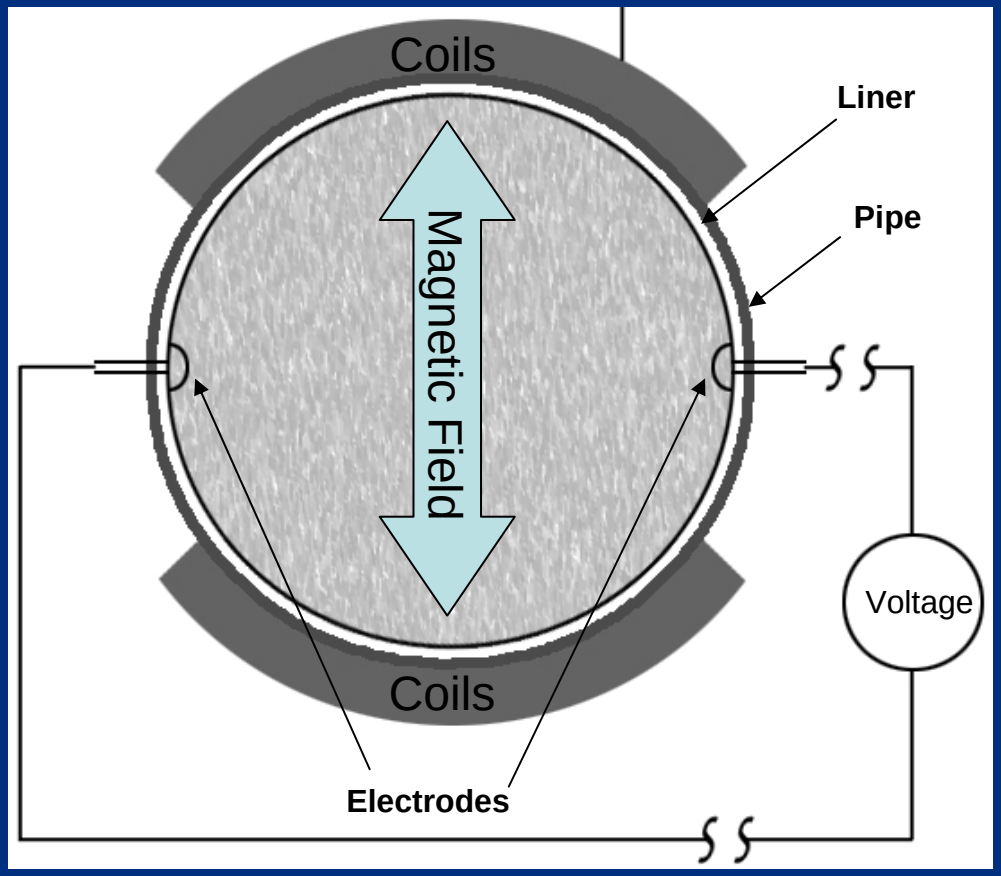
No flow – the travel time of each signal between the two transducers is the same

Flow – the signal moving with the flow travels faster than the signal moving against the flow

Ultrasonic – Transit-Time

- Advantages
  - Low to high accuracy
  - High turn-down
  - No Moving Parts
  - Typical straight run requirements
  - Easy installation for strap-on meters
- Disadvantages
  - Corrosion, pitting or coating inside pipe can cause loss of signal
  - Density variations can cause inaccuracies

Electromagnetic



Faraday's Law

$V_{gen} = K*B*v*D$

V_{gen}= Voltage Generated (µ)

K=Constant

B= Magnetic Flux Density

v= velocity

D= Distance Between Electrodes

V_{gen}, K, B, D are known, velocity is the only variable

Electromagnetic

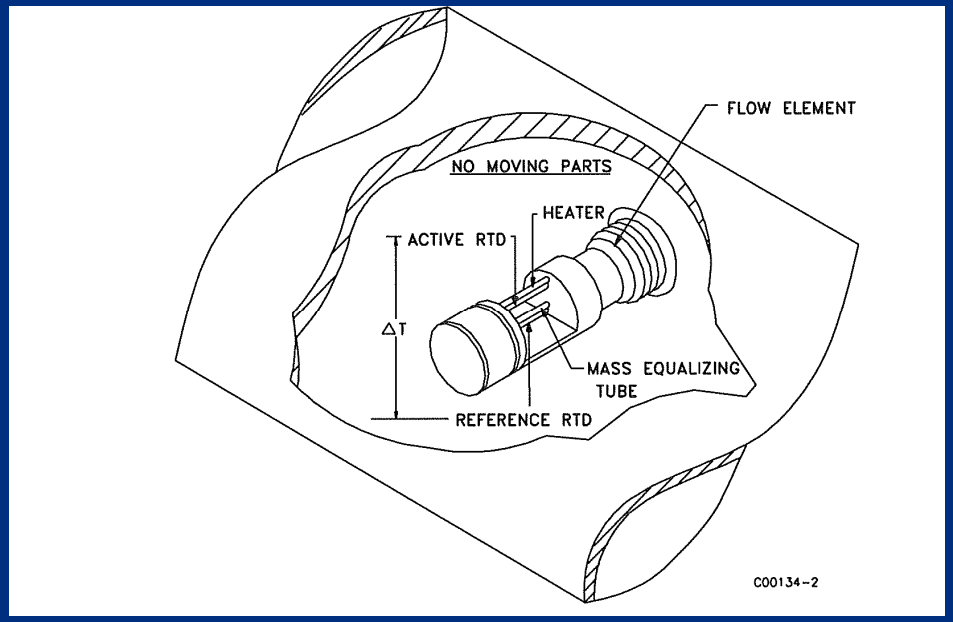
Advantages

- High to average accuracy
- High turndown (40/50:1)
- No moving parts
- No pressure loss
- Bi-directional

Disadvantages

- Liquids must be conductive
- Typically pipes should be full
- Liners can fail, electrodes can coat

Thermal Mass



Thermal Mass

Advantages

- Measure mass flow directly
- No moving parts
- Average to Low accuracy
- Low pressure loss
- Good for very low flows
- High turndown

Disadvantages

- Moderate meter & installation costs
- Condensation/moisture on sensor causes errors
- Typical to long straight runs required

For More Information

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