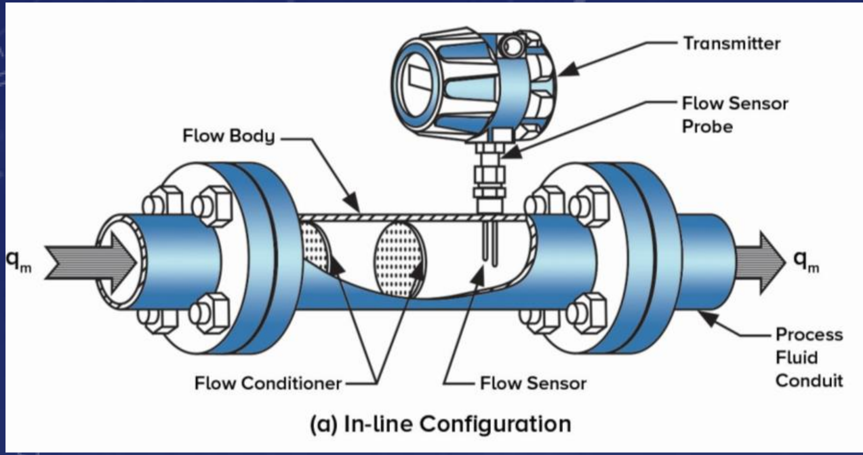

RNG GAS METERING: ACCURACY MATTERS

NW SWANA REGIONAL SYMPOSIUM

MCMENAMINS EDGEFIELD

TROUTDALE, OR

OCTOBER 28,2021

TENT ENGINEERING

TENT ENGINEERING- WHO WE ARE

- Located in Bend, OR
- Process/Mechanical/Electrical Engineers
- Biogas Experts
  - Renewable Natural Gas
  - Power Generation
  - Gas Treatment Systems
  - LFG Collection and Control
- System Integrators

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All Your Biogas Expertise Under One Tent

THE PROBLEM

- Accurate Gas Metering has always been difficult in the landfill and digester gas industries
- Issues
  - Wet gas
  - Contaminants (H_2S, Siloxanes, VOCs)
  - Widely varying flows and gas concentration
  - Calibration/Maintenance

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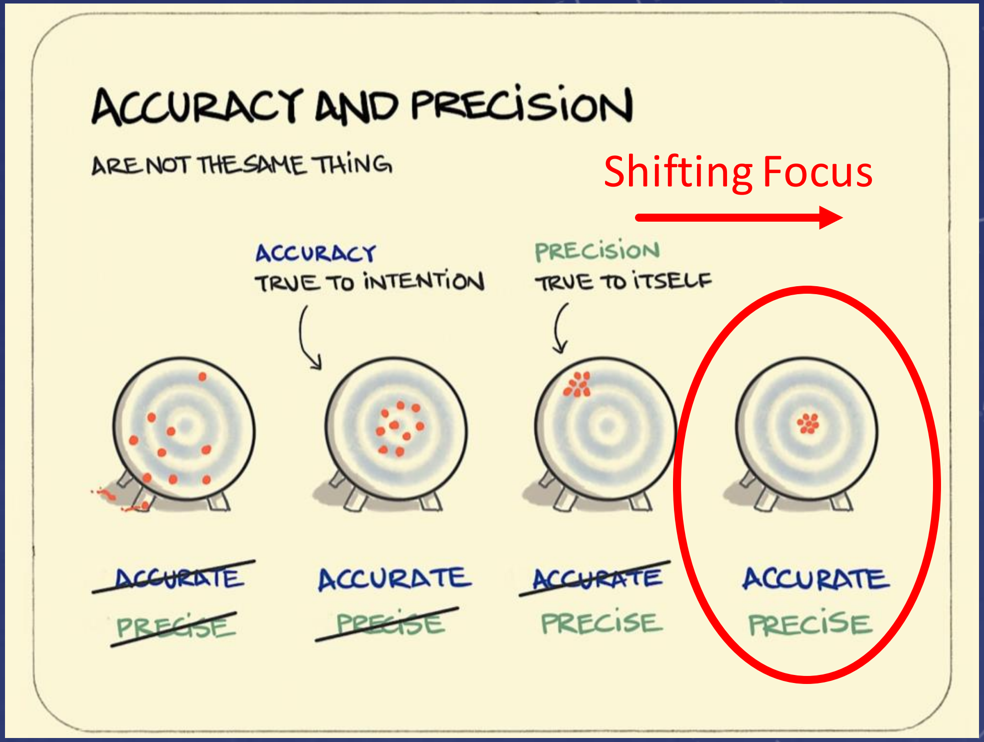
THE PROBLEM

- History of Gas Metering/Progression
  - Operations/Performance Monitoring
  - Environmental Compliance
  - Gas Sales Agreements
  - Renewable Natural Gas Production
- Focus up to this point has been Precision
- Now there is a target → Utility meter



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THE PROBLEM

- LCFS Fugitive Emissions are shining a spotlight on the problem

$$Fugitive\ Emissions = BTU_{in} - BTU_{utility}$$

- Findings have implications for more than just LCFS projects: landfill gas sales agreements, environmental reporting, RINs, etc.

>2% directly affects CI score

Biogas CI Example for Dairy RNG

Manure Handling	0	User control
Grid electricity for upgrading	10	User control
Utility source NG for biogas production and upgrading	20	User control
Biomethane flaring	0	User Control
Fugitive Emissions	10	Almost fixed
Transmission	12	Proportional to distance, almost fixed
Compression*	3	Fixed
Tailpipe*	61	Fixed
Avoided emissions credits	-316	Dependent on baseline vs. project volume
Total	-200	

*Set Values

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THE PROBLEM

<u>Tent Observation</u>

Many RNG facilities are operating at >10% fugitive emissions

Some are as high as 30%!!!

$$1{,}000scfm \times \pm 10\% = \pm 100scfm$$

Lost Revenue can be significant

\$1/MMBTU @100scfm error= ~\$27,000/yr

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GAS METERING BASICS

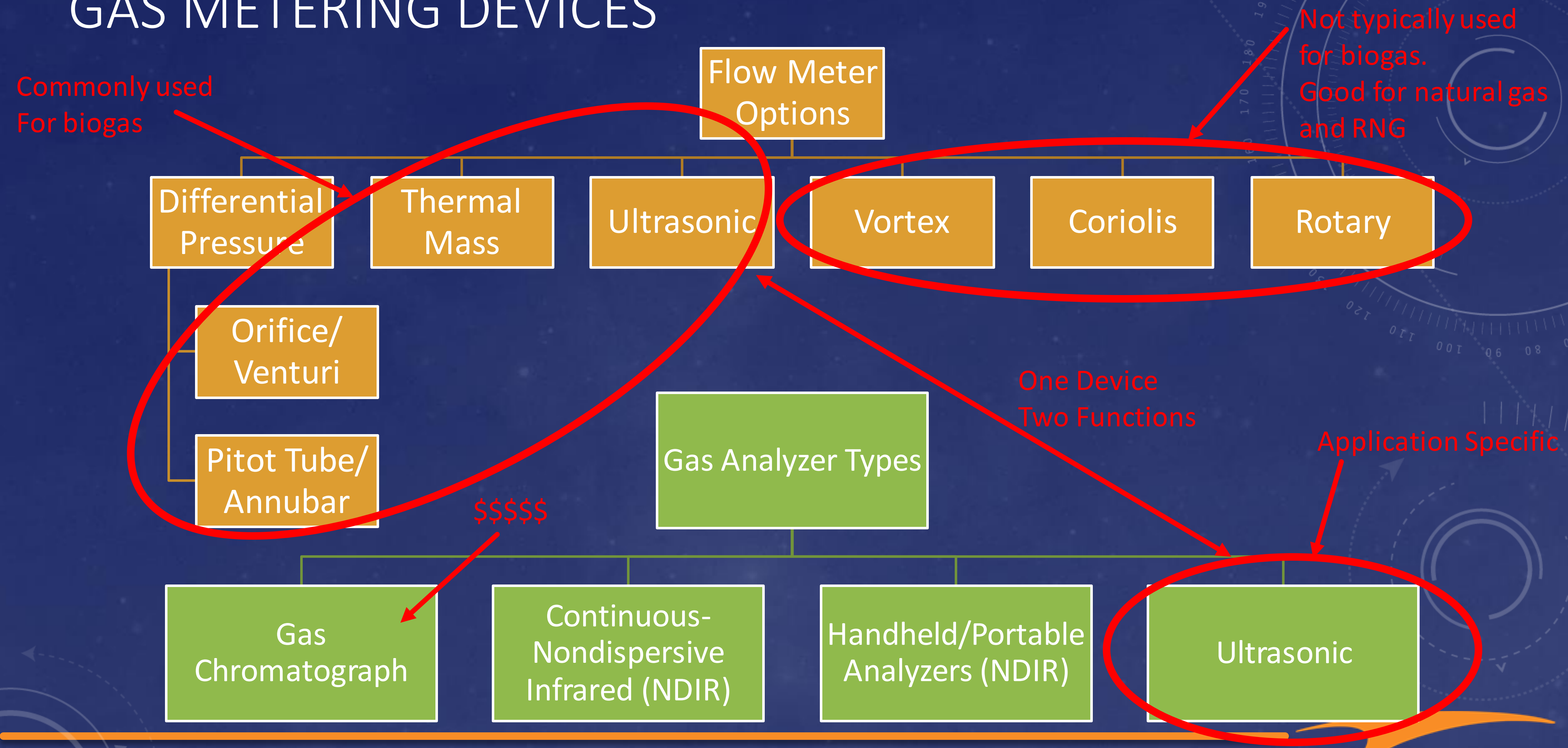
Flow Meter

- Two Key Aspects of Gas Metering
  - Flow (scfm)
  - Gas Composition (primarily CH4%)
- SCFM + CH4% → BTU

Energy Flow (BTUs)

Gas Analyzer

GAS METERING DEVICES



GAS METERING- SOURCES OF ERROR

1. Inherent Device Accuracy
2. Compounding Error- Multiple Devices
3. Initial Device Calibration
4. Proper Installation (Sizing, Location, Orientation)
5. Device Maintenance & Recalibration
6. Improper Application

#1- INHERENT DEVICE ACCURACY

- Typical Wet Biogas Devices
  - Flow Meters- ±0.7% to 5%
  - Analyzers- ±0.5% to 2% vol
- Based on ideal lab calibration conditions
- Read the fine print!

Flow accuracy (SCFM at laboratory conditions)
± (1% of reading +20 SFPM)

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#2- COMPOUNDING ERROR- MULTIPLE DEVICES

- Compounding Error Example
  - Flow Meter- ±1% inherent accuracy
  - Gas Analyzer- ±1% volume inherent accuracy

$$1{,}000scfm \times 1\% = \pm 10scfm$$

$$55\%\ CH_4 \rightarrow \pm 1\%\ CH_4$$

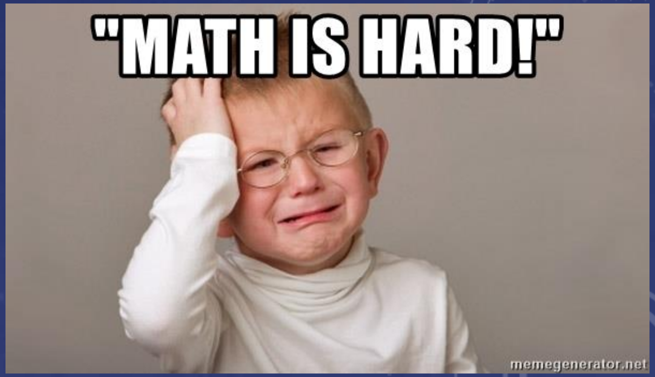
$$High = 572{,}000\ BTU/min$$

$$Low = 541{,}000\ BTU/min$$

$$Range = \pm 31{,}000\ BTU/min$$

5.5% Compounded Error!!!!

1+1 does not equal 2!

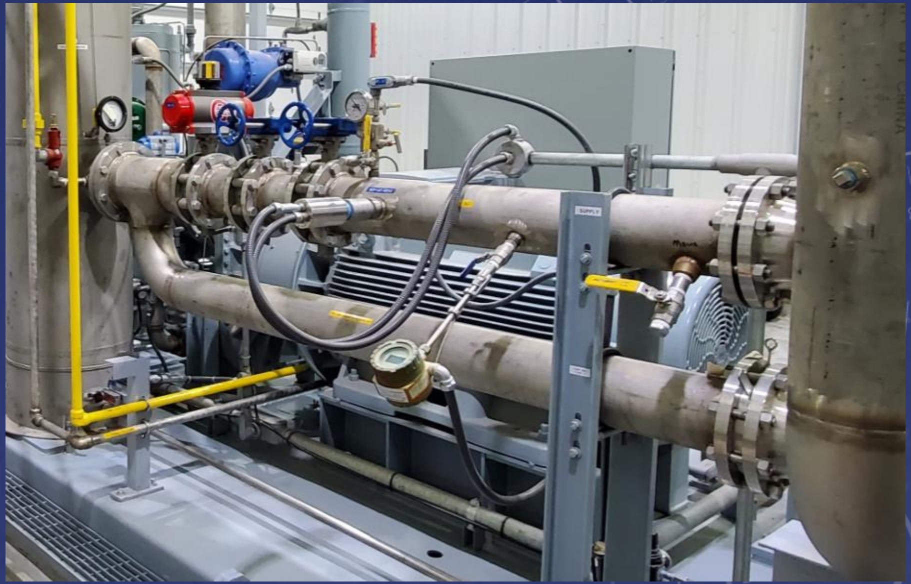


#3- INITIAL DEVICE CALIBRATION

- Flow Meters
  - Gas Composition and Specs by Customer
  - Factory Lab Testing
  - Typically does not include water vapor (5-7% for most biogas)
- Gas Analyzers
  - Calibration Gas
  - Proper Procedures Needed

#3- INITIAL DEVICE CALIBRATION

- Real Example- Thermal Mass Flow Meter
- 2,300scfm, 10" pipe
- Instances of Error from Factory Calibration
  - Water Vapor- 4% Error
  - Pipe Schedule- 15% Error
    - Sch40 vs Sch10
  - Different STP Condition- 4% Error
  - CH_4/CO_2 Ratio- 20% Error
    - 60/40 vs 50/50



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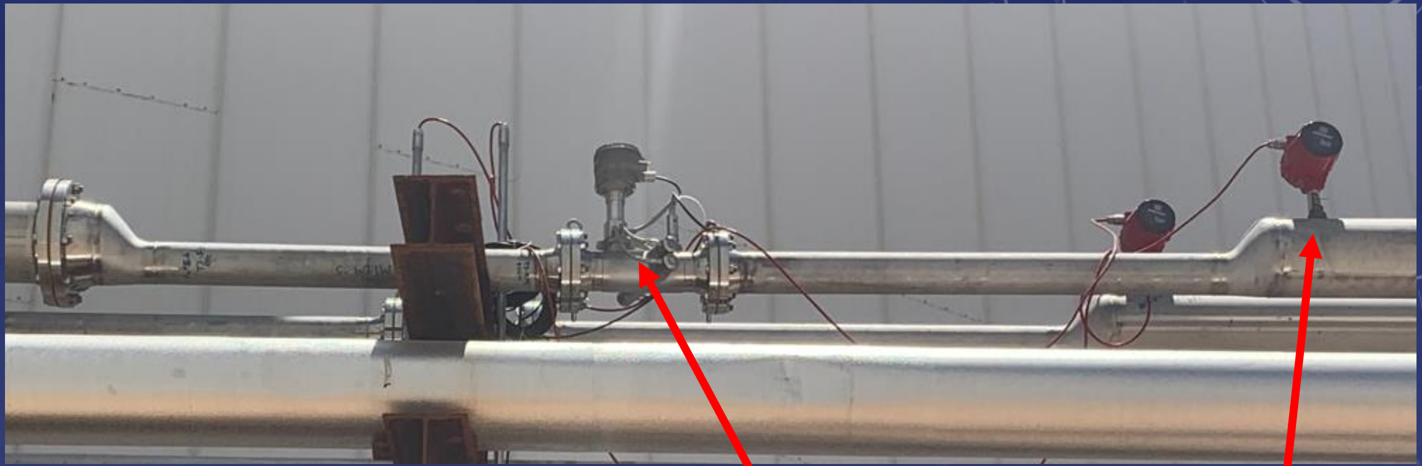
#4- PROPER INSTALLATION

- Flow Meters
  - Size (pipe, turndown)
  - Proper Upstream/ Downstream Requirements for Laminar Flow
  - Water Considerations



Ultrasonic Meter

Thermal Mass Meter

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#4- PROPER INSTALLATION

- Gas Analyzers
  - Sampling System- Pump, Lag Rate
  - Gas Conditioning
    - Water
    - H2S
    - VOCs/Siloxanes/Etc
    - Note: Will gas conditioning effect BTU calculations?
- Best ability is availability
- Can you avoid Gas Conditioning?

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#5- DEVICE MAINTENANCE AND RECALIBRATION

- Analyzers and Flow Meters Drift
- Continual Maintenance and Calibration Programs are needed
- Continually Revisit Base Conditions
  - Flow
  - Composition
  - Pressure/Temperature

#6- IMPROPER APPLICATION

- Some devices just don’t work for a given application
- Be flexible enough to abandon ship

GAS METERING- LESSONS LEARNED

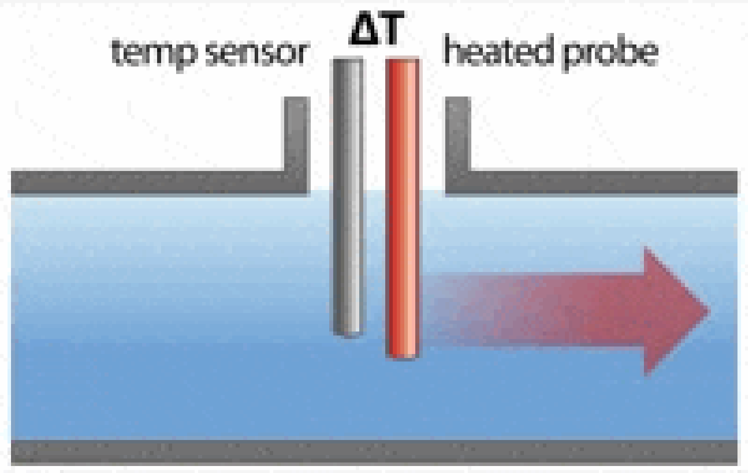
1. Properly Engineered Solutions are critical
2. "Don't optimize something that shouldn't exist"- Elon Musk
3. Significant improvements are possible
   - i.e. 15% fugitive emissions reduced to less than 3%

GAS METERING- LESSONS LEARNED

4. Specify the right devices with the right conditions
5. Accuracy requires adapting to changing gas concentration in real time
6. Consolidate to as few devices as possible
7. Best ability is availability- reduce maintenance requirements

QUESTIONS????


Orifice/Averaging Pitot Tube Meters



Thermal Mass Meter

Ultrasonic Meter

Coriolis Meters

Gas Chromatograph

NDIR- Cabinet Analyzer

NDIR- In-Situ Analyzer

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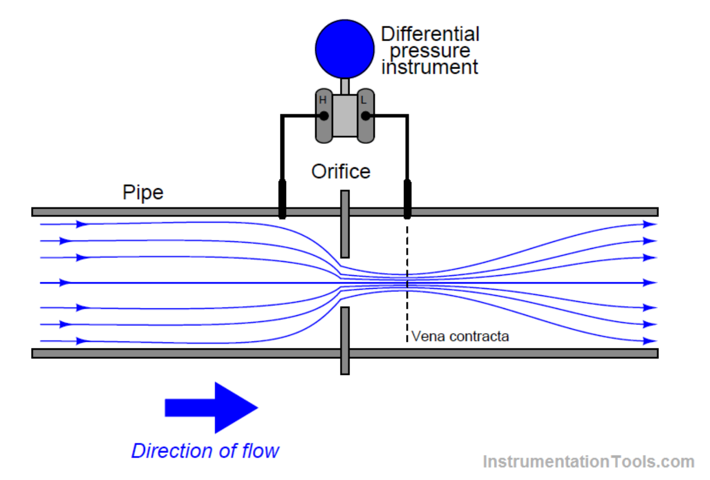
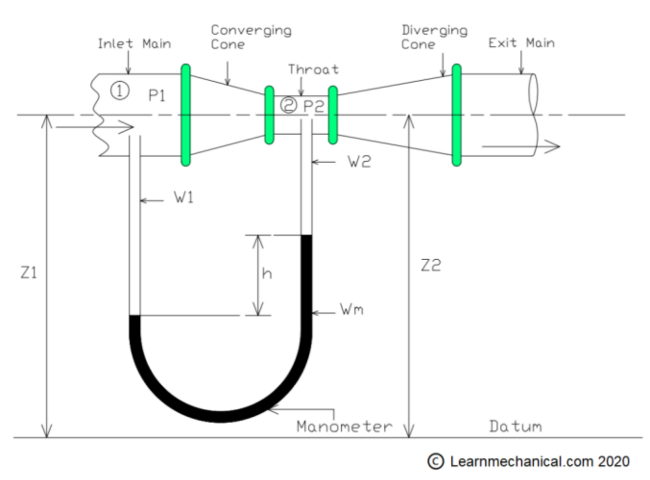
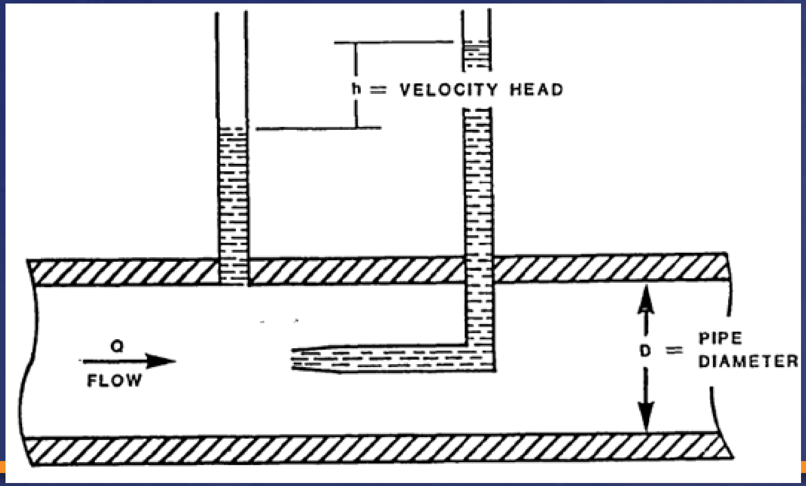
DIFFERENTIAL PRESSURE METERS



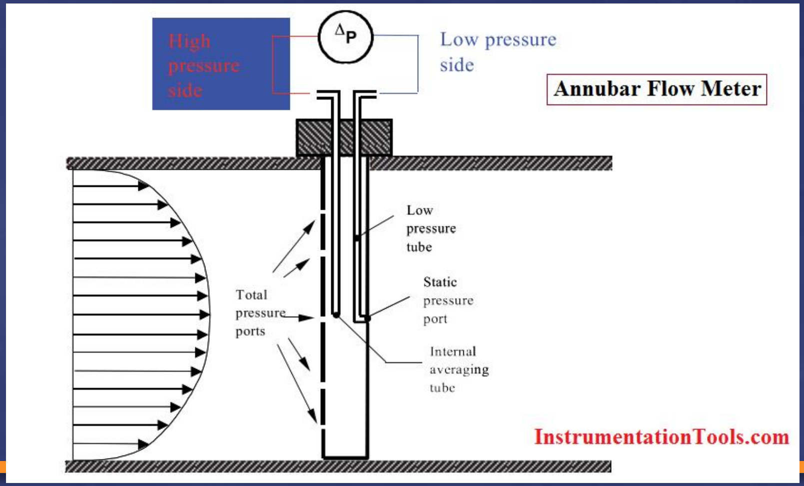
Orifice Plate



Venturi



Pitot Tube



Averaging Pitot Tube (Annubar, Verabar, etc)

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DIFFERENTIAL PRESSURE METERS

Typical DP Meter Equation

$$Q_v = 218.527 C_d E Y_2 d^2 \left(\frac{T_b}{P_b}\right) \sqrt{\left(\frac{P_{f1} * Z_b * h_w}{G_r * Z_{f1} * T_f}\right)}$$

Where

C_d = Orifice plate coefficient of discharge

d = Orifice plate bore diameter calculated at flowing temperature (T_f) (mm or inches)

G_r = Real gas relative density (specify gravity)

h_w = Differential pressure (kPa or inches of water at +60°F)

E = Velocity of approach factor

P_b = Base pressure (bara or psia)

P_{f1} = Flowing pressure (upstream tap) (bara or psia)

Q_v = Standard volume flow rate (Nm^3/hr or SCF/hr)

T_b = Base temperature (°R)

T_f = Flowing temperature (°R)

Y_2 = Expansion factor (downstream tap)

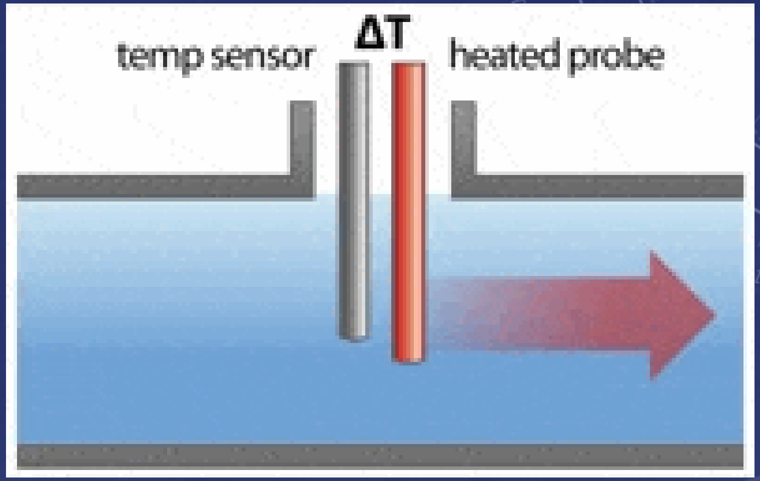
Z_b = Compressibility at base conditions (P_b, T_b)

Z_{f1} = Compressibility (upstream flowing conditions - P_{f1}, T_f)

Changes w/ gas composition. Introduces significant error to flow calculation

THERMAL MASS FLOW METER

- Very commonly used
- Calculates mass flow based on thermal dissipation and converts to volume flow
- Water beads up and introduces error
- Very difficult to maintain accuracy in changing conditions



$$(4)\quad Q = \frac{KA}{d}\left[B + C\left(\frac{\rho V_d}{\mu}\right)^m\right](T_s - T_\infty)$$

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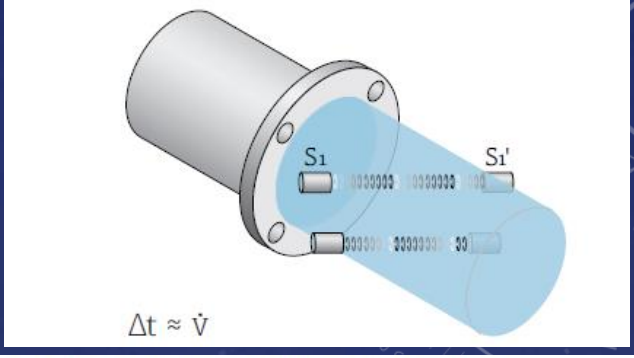
ULTRASONIC FLOW METER

- Uses acoustics and ultrasonic sensors to determine transmit time of sound through a medium
- Two functions in same device
  - Flow- Flow velocity from transmit time dT combined with cross section area
  - Gas Analyzing- Sound velocity, temperature, pressure, and composition are dependent on each other
- Application Specific
  - Pressure/temperature compensation
  - Constant assumptions for certain gas components



Transit time difference in upstream direction is given by:

$$t_U = \frac{L}{c - v_B \cos\phi}$$

Transit time difference in downstream direction is given by

$$t_D = \frac{L}{c + v_B \cos\phi}$$

Bulk velocity is given by:

$$V_B = \frac{L}{2\cos\phi}\left(\frac{1}{t_D} - \frac{1}{t_U}\right)$$

Speed of light c is given by:

$$c = \frac{L}{2}\frac{(t_U + t_D)}{t_U * t_D}$$

www.instrumentationtoolbox.com

Flow Rate of gas or flowing medium is now given by:

$$Q = A \times V_B$$

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