Coriolis Meter Overview

Seth Harris
O&G Manager – Northern Rockies

What is a Coriolis Meter?

A. A volume meter
B. A mass meter
C. A densitometer
D. A process diagnostic tool
E. A highly accurate,
low/no maintenance meter
F. All of the above

Coriolis Theory of Operation

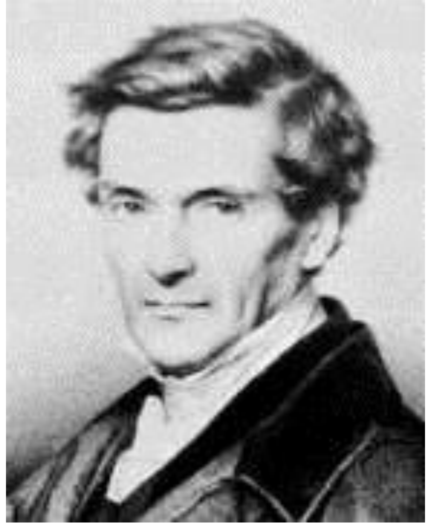
Micro Motion:
The Birthplace of Coriolis

- Founded in 1977
- Invented first practical Coriolis flow and density meter
- Valued for its precision
  - Direct mass measurement
  - Multivariable capabilities
    - Mass Flow
    - Volume Flow
    - Density
    - Temperature

First Micro Motion Sensor

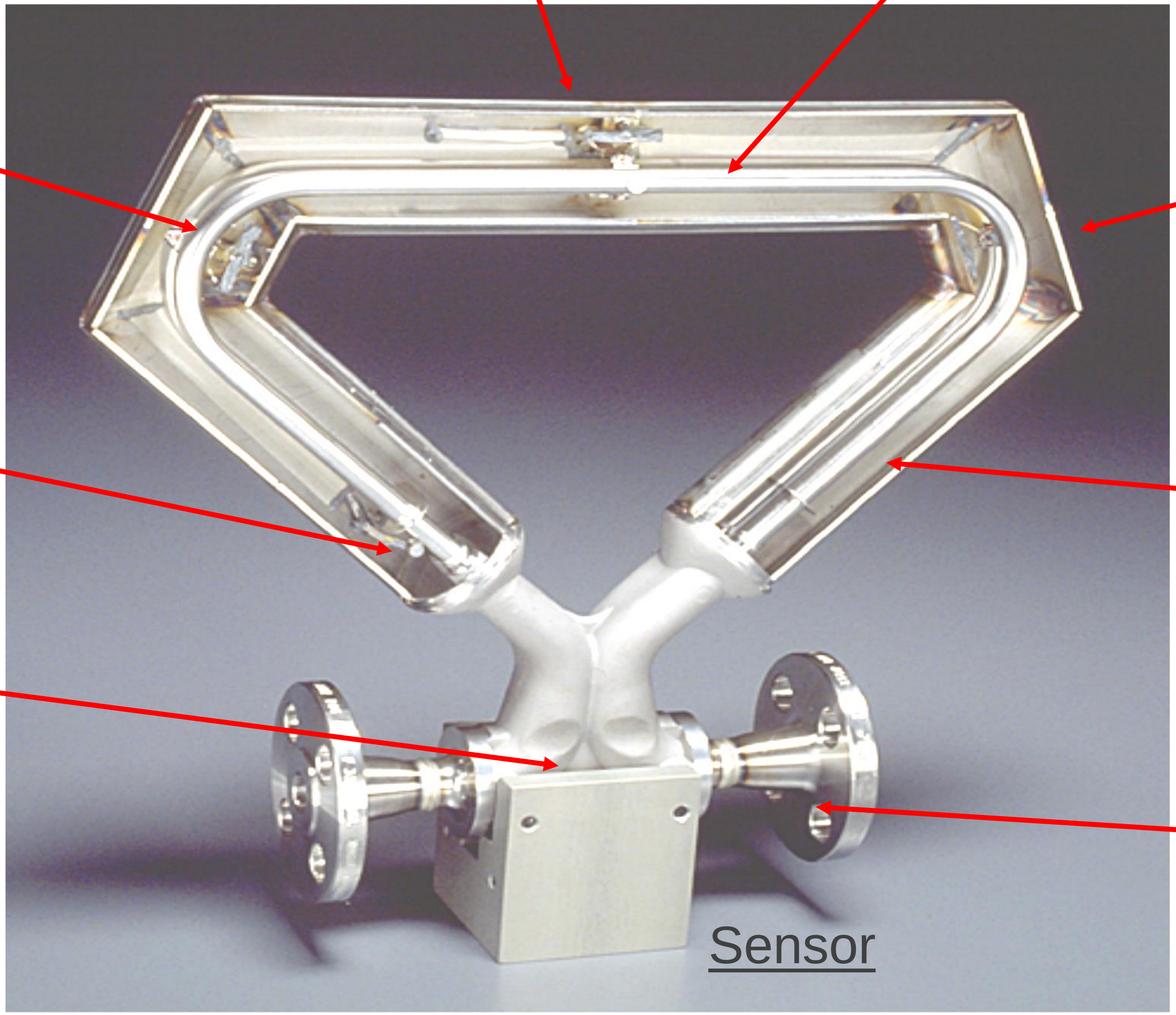
Original Micro Motion Manufacturing

1,000,000th Micro Motion Sensor Manufactured by year end 2014



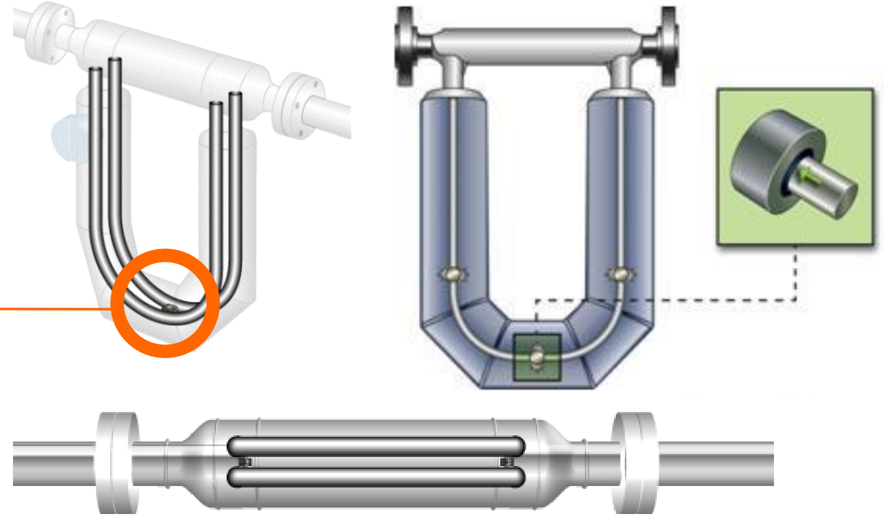
Gaspard-Gustave CORIOLIS (1792 – 1843)

Coriolis Sensor Components

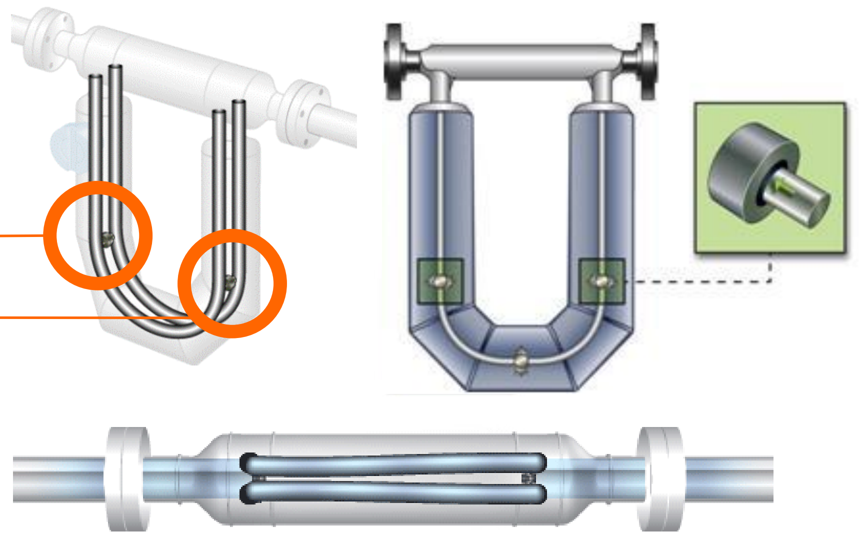


Theory of Operation — Mass Flow

Process fluid enters the sensor and flow is split with half the flow through each tube. The sensor flow tubes are vibrated in opposition to each other by energizing a drive coil. Tubes are oscillated at their natural frequency.



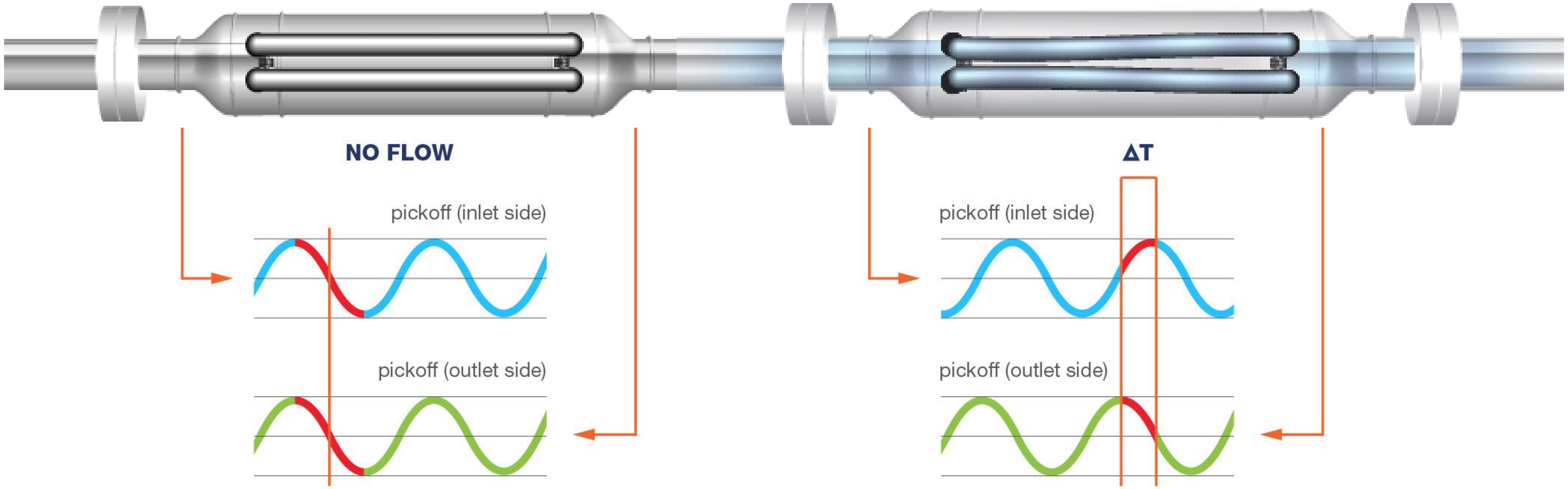
Magnet and coil assemblies, called pick-offs, are mounted to the flow tubes. As each coil moves through the uniform magnetic field of the adjacent magnet it creates a voltage in the form of a sine wave.



Theory of Operation — Mass Flow

During a no flow condition, there is no Coriolis effect and the sine waves are in phase with each other.

When fluid is moving through the sensor's tubes, Coriolis forces are induced, causing the flow tubes to twist in opposition to each other. The time difference between the sine waves is measured and is called Delta-T, which is directly proportional to the mass flow rate.

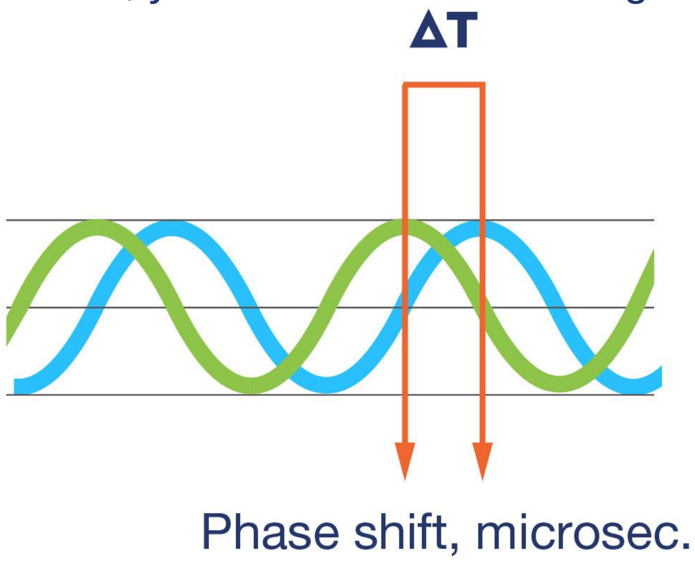


Theory of Operation — Mass Flow

The Flow Calibration Factor consists of
10 characters, including two decimal points.

4.2745 4.74

The first five digits are the flow calibration factor. This calibration factor, multiplied by a given Delta-T, yields mass flow rate in grams/sec.

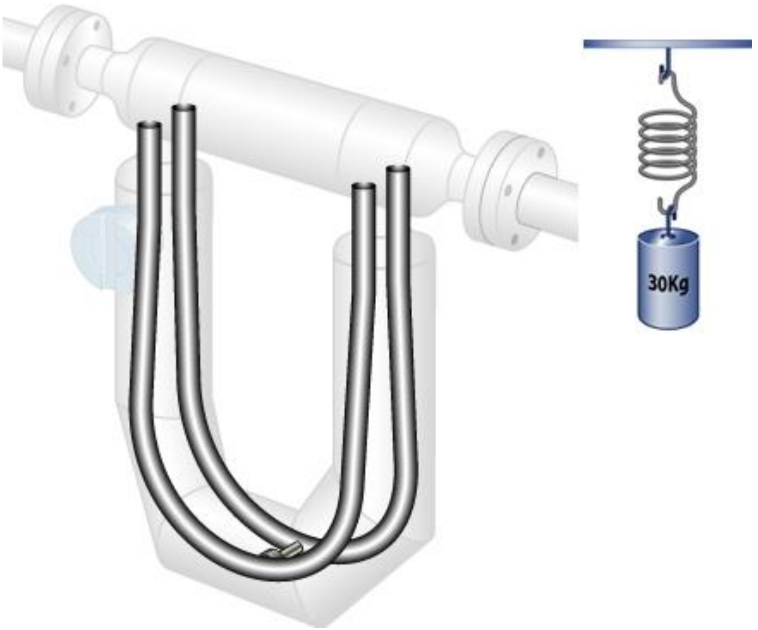


The last three digits are a temperature coefficient for the sensor tube material. This coefficient compensates for the effect of temperature on tube rigidity (% change in rigidity per 100°C).

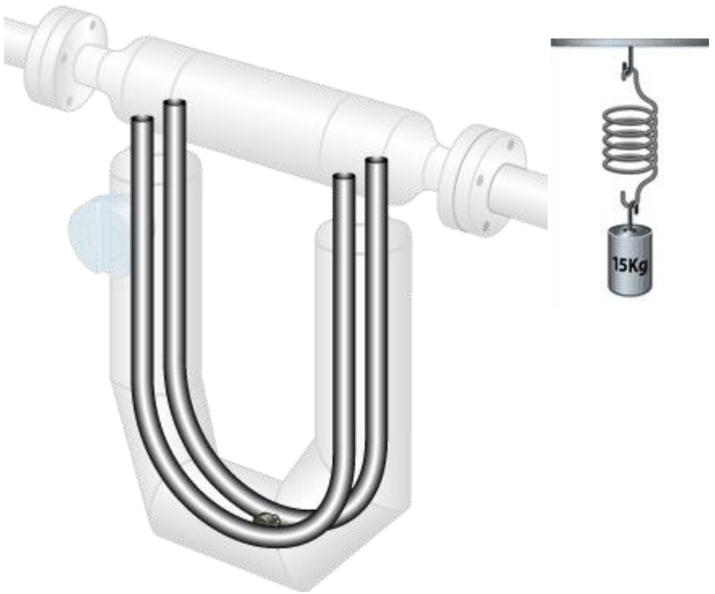
The Flow Calibration Factor applies to liquid and gas, and is linear throughout the entire range of the meter

Theory of Operation — Density

Density measurement is based on the natural frequency of the system including the flow tubes and the process fluid.

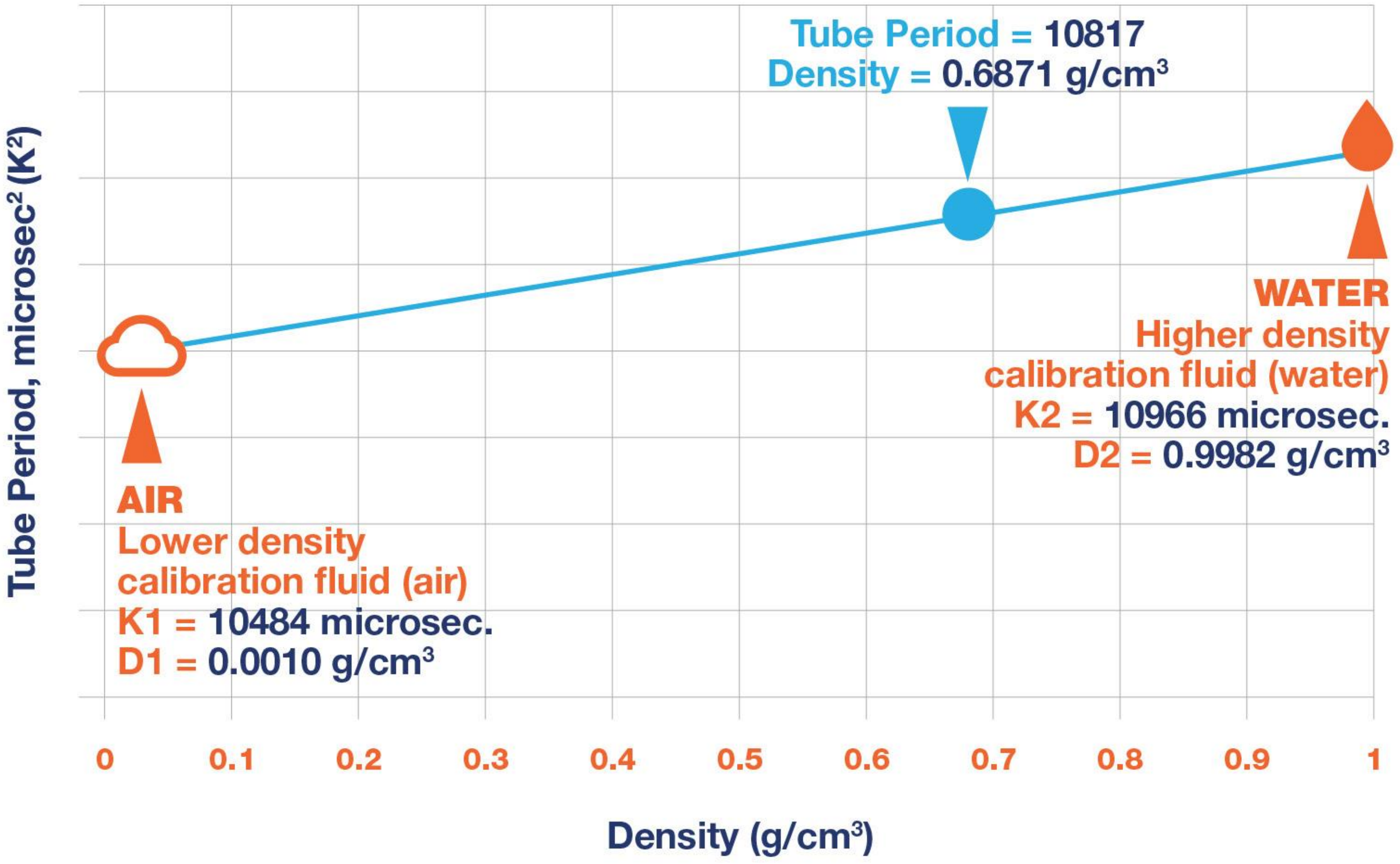


As the mass **increases**, the natural frequency of the system **decreases**.



As the mass **decreases**, the natural frequency of the system **increases**.

Theory of Operation — Density



Theory of Operation — Volume (indirect or calculated)

Coriolis 101

- Volumetric Flow is a calculated variable
- Volume can be referenced to standard temperature using the temperature input
- Coriolis meters are preferred for volume measurements
  - Low pressure drop
  - Wide turndown
  - High accuracy
  - High degree of linearity

Volume Flow Rate

- Liquids – Measured Density

$$\boxed{\text{Volume Flow} = \frac{\text{Mass Flow}}{\text{Density}}}$$

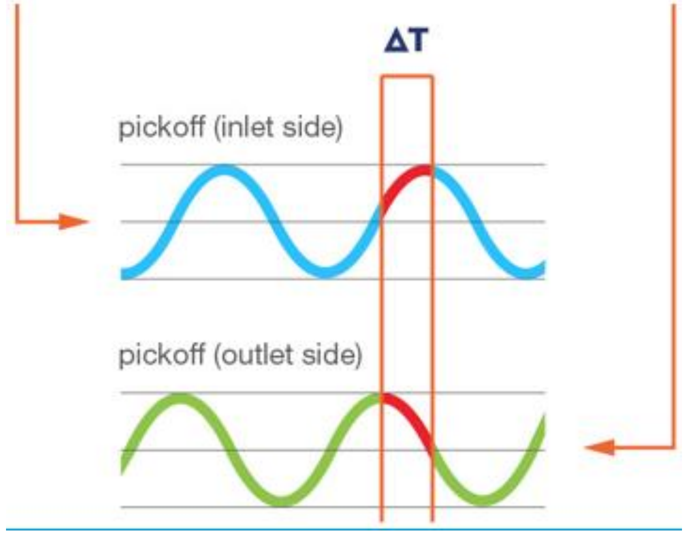
- Gas – User Provided Base Density

$$\boxed{\text{Volume Flow} = \frac{\text{Mass Flow}}{\cancel{\text{Density}}}} = 0$$

Review - 3 Basic Measurements

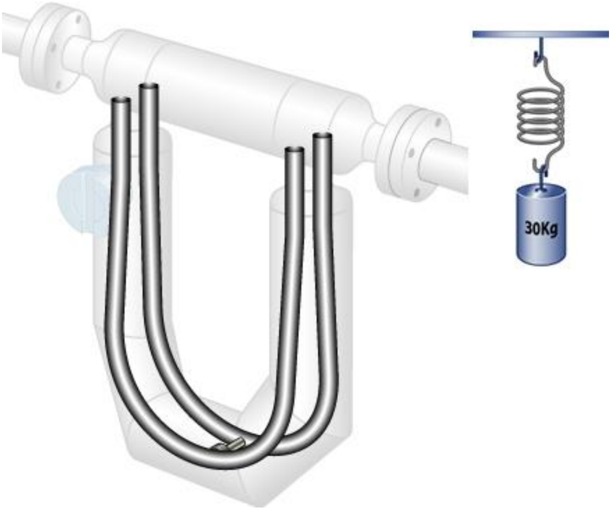
Mass Flow Rate - Twist

- Higher the mass flow rate – more twist
  - ΔT = Time delay



Density - Frequency

- Lighter the fluid → Higher Frequency
- Heavier the fluid → Lower Frequency



Temperature - RTD

- Compensate for Tube Stiffness changes
- Not for custody transfer of liquids

Product Overview & Recent Advancements

ELITE Coriolis Portfolio Combines Premium Meter Performance, Electronics and Software Offering

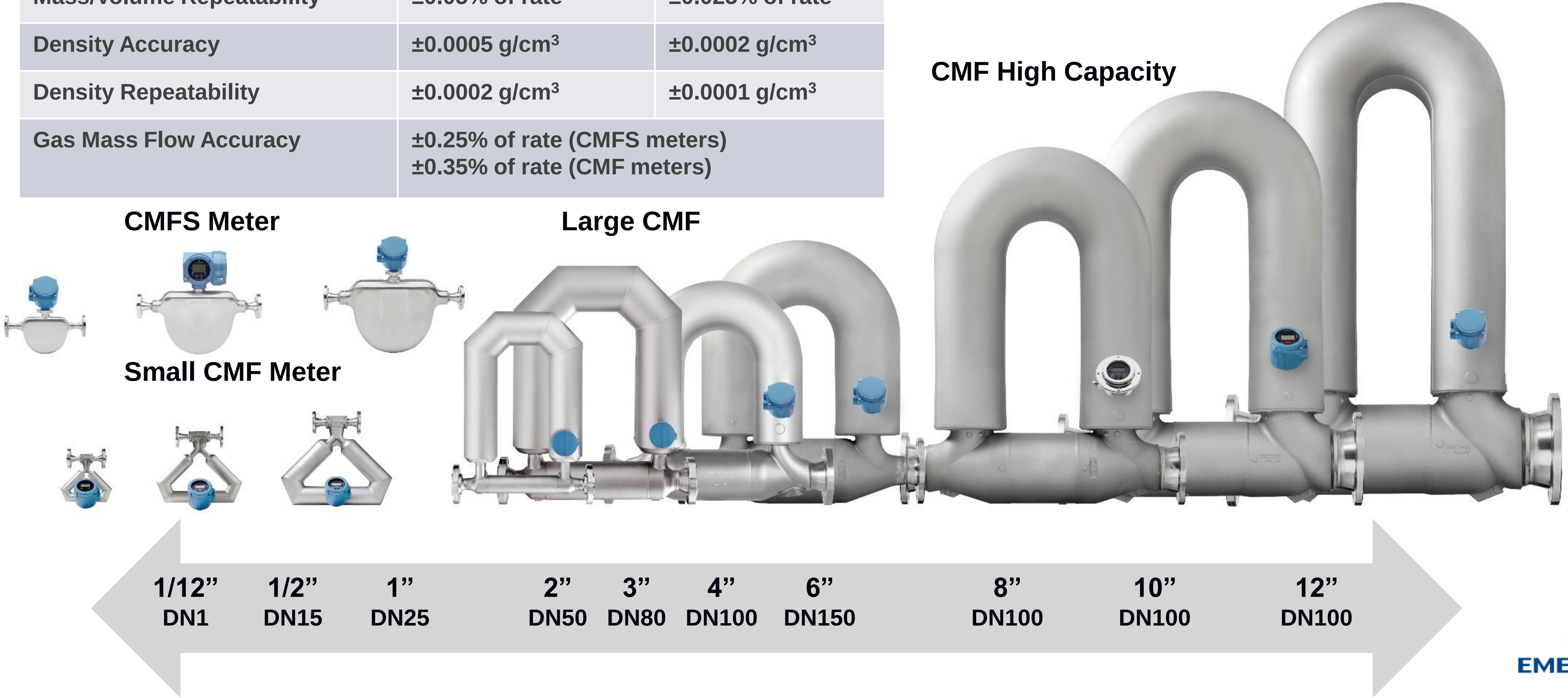
±0.4 – 0.5% Mass Flow	✓
±0.003 g/cm^3 Density	✓
±0.5% Volume Flow	✓
Sensor Sizes 025-200	✓
Limited Transmitter Capabilities	✓

Improvements	
±0.1 – 0.2% Mass Flow	✓✓
±0.0005 – 0.002 g/cm^3 Density	✓✓
Sensor Sizes 025-300	✓✓
Turndown	✓✓
Improved Sensitivity	✓✓
Reduced T & P effects	✓✓
Smart Meter Verification	✓✓
Transmitter Flexibility	✓✓

Improvements	
±0.05% - 0.1% Mass Flow	✓✓✓
±0.0002 – 0.0005 g/cm^3 Density	✓✓✓
Sensor Sizes 1/12-12inch (DN1-DN300)	✓✓✓
0.25% Gas accuracy	✓✓✓
Widest Turndown	✓✓✓
Best Sensitivity	✓✓✓
Low/No T & P effects	✓✓✓
Entrained Gas Performance	✓✓✓
Smart Meter Verification	✓✓✓
Transmitter and Software Offering	✓✓✓

From Chemical Injection to Large Transport Pipelines…….

Performance Specification	Standard	Optional
Mass/Volume Accuracy	±0.1% of rate	±0.05% of rate
Mass/Volume Repeatability	±0.05% of rate	±0.025% of rate
Density Accuracy	±0.0005 g/cm³	±0.0002 g/cm³
Density Repeatability	±0.0002 g/cm³	±0.0001 g/cm³
Gas Mass Flow Accuracy	±0.25% of rate (CMFS meters) ±0.35% of rate (CMF meters)	



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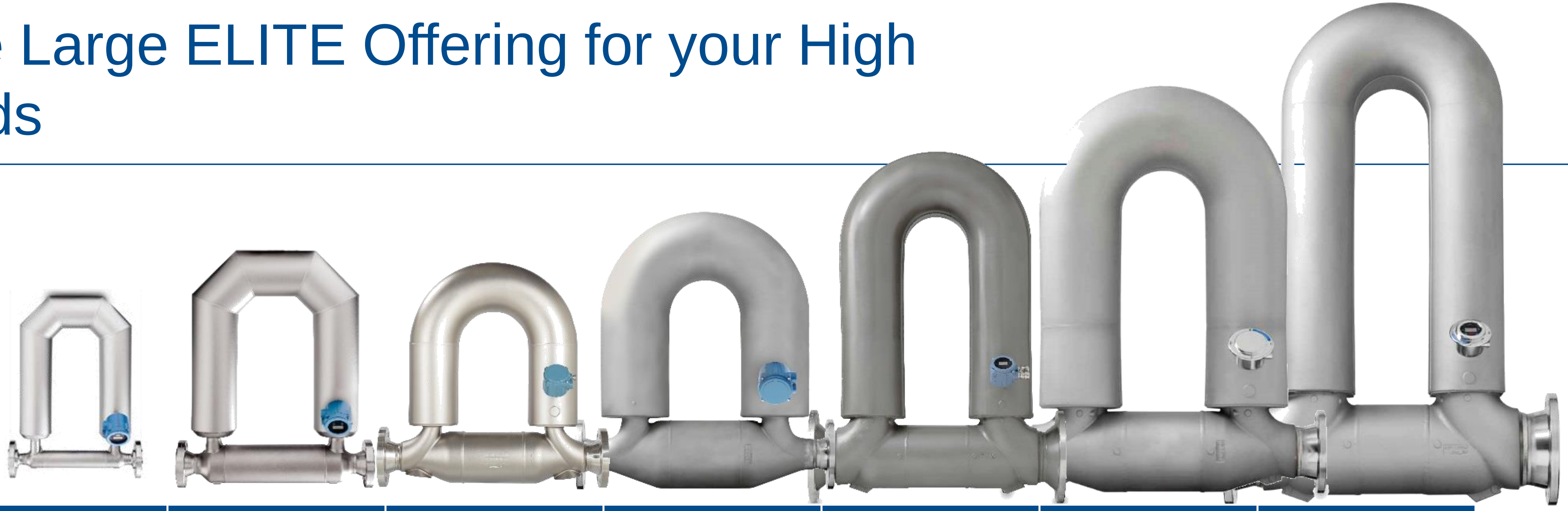
Comprehensive Large ELITE Offering for your High Flow Rate Needs



	CMF200	CMF300	CMF350	CMF400	CMFHC2	CMFHC3	CMFHC4
Line Size	2inch (DN50)	3inch (DN80)	4inch (DN100)	6inch (DN150)	8inch (DN200)	10inch (DN250)	12inch (DN300)
Nominal Flow Rate (lb/min / bbls/hr – Oil @ 0.75 g/cm^3)	1,760 403	5,840 1340	10,700 2455	15,200 3490	28,900 6632	49,000 11245	75,000 17210
Liquid Mass Flow Accuracy (% of rate)	±0.1% (±0.05%)	±0.1% (±0.05%)	±0.1% (±0.05%)	±0.1% (±0.05%)	±0.1%	±0.1%	±0.1%
Liquid Mass Flow Repeatability (% of rate)	±0.05% (±0.025%)	±0.05% (±0.025%)	±0.05% (±0.025%)	±0.05% (±0.025%)	±0.05%	±0.05%	±0.05%
Density Accuracy (g/cm^3)	±0.0002	±0.0002	±0.0002	±0.0002	±0.0002	±0.0002	±0.0002
Density Repeatability	±0.0001	±0.0001	±0.0001	±0.0001	±0.0001	±0.0001	±0.0001
Gas Mass Flow Accuracy (% of rate)	±0.35%	±0.35%	±0.35%	±0.35%	±0.35%	±0.35%	±0.35%

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Micro Motion 2000 Series Transmitters

- **2500 DIN Rail Transmitter**
  - Two 4-20mA output, one frequency, RS – 485
  - Digital options: HART and Modbus
  - Remote mount & DC power only

- **2700 Transmitter**
  - 2700 Configurable I/O, two 4-20mA outputs, one frequency
  - Digital options: HART, Foundation Fieldbus, Profibus PA
  - Modbus with Analog version only
  - Available with stainless steel housing
  - Self-switching AC and DC power

- **9739 MVD**
  - Two analog (mA) outputs
  - Frequency output
  - HART and Modbus

5700 Transmitter

- Five output channels
- Three analog (mA) output option
- Frequency pulse output
- Digital protocols: Modbus and HART

Special Features / Options

- Fully configurable through display
- Smart Meter Verification
- Discrete batch control
- Concentration measurement
- Petroleum measurement and API correction option
- Zero verification
- Historian feature

SMART METER VERIFICATION

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Transmitter Improvements that Can Have a Big Impact on Your Operations

Five Output Channels

- Industry Leading Output Selection
- Two linked Pulse outputs + One independent Pulse for maximum flexibility in applications like proving

Channels	A	B	C	D	E
	mA HART	mA	mA	mA-Input	RS-485
		FO	FO	FO	
		DO	DO	DO	
			DI	DI	

Variables Available for Outputs	
Mass Flow	External Pressure
Volume Flow	Velocity
Density	Drive Gain
Temperature	Two Phase Indication
External Temperature	Application Specific (% Fill)

Main Design Drivers

- Ease of Use
  - Improve productivity
  - Eliminate need for special service tools
  - Minimize time in the field
- Measurement Confidence
  - Absolute trust in the output from your meter
  - Diagnostics and tools to resolve uncertainty
- Process Insight
  - Enable the ability to “go back in time” to understand a process event
  - Open a window into your process for informed optimization

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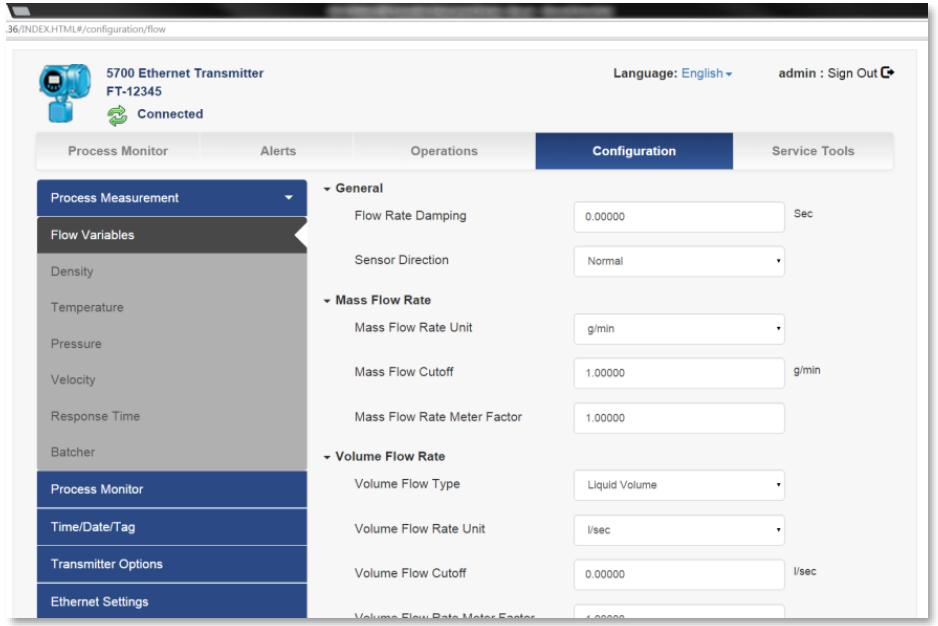
5700 with Ethernet!

- Expansion of the popular 5700 Coriolis transmitter platform to include an Ethernet output version
- Native Ethernet architecture and connections, no extra converters or adapters needed
- Multiple protocol choices including EtherNet/IP, Modbus TCP and PROFINET
- On-board Web server for easy configuration
- Simplified PLC integration



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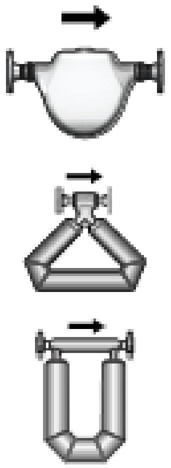
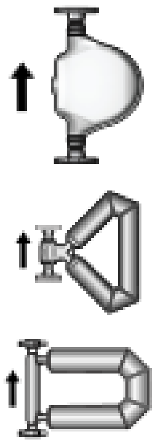
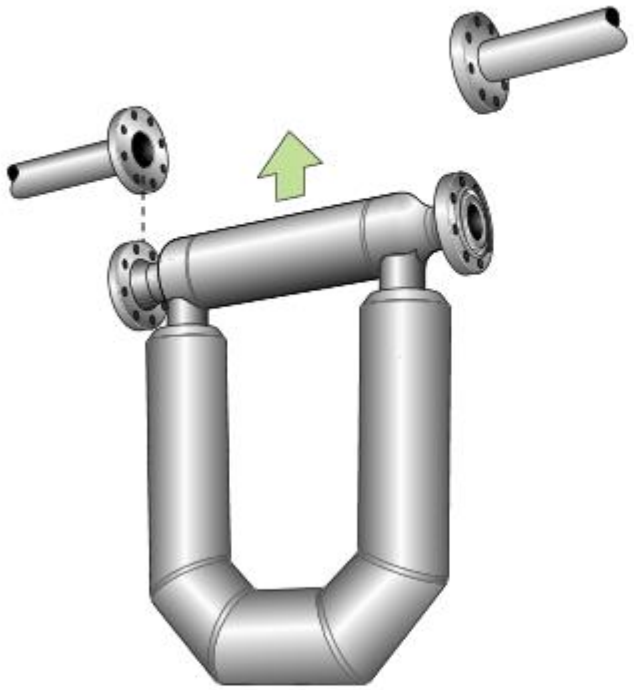
Liquid Coriolis Measurement & O&G Industry Guidelines

Mounting Considerations for Liquid Service

Liquids			



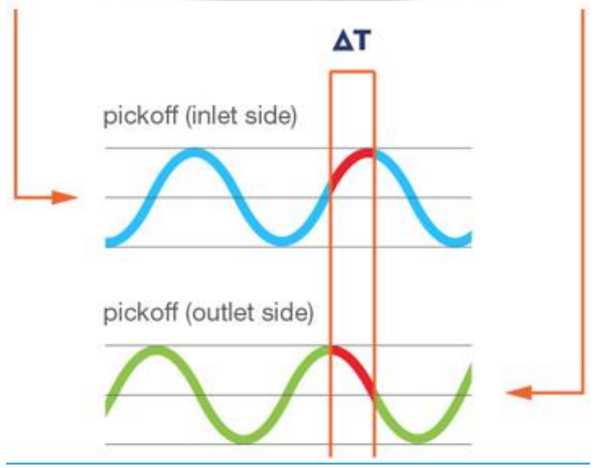
Use your common piping practices to minimize:

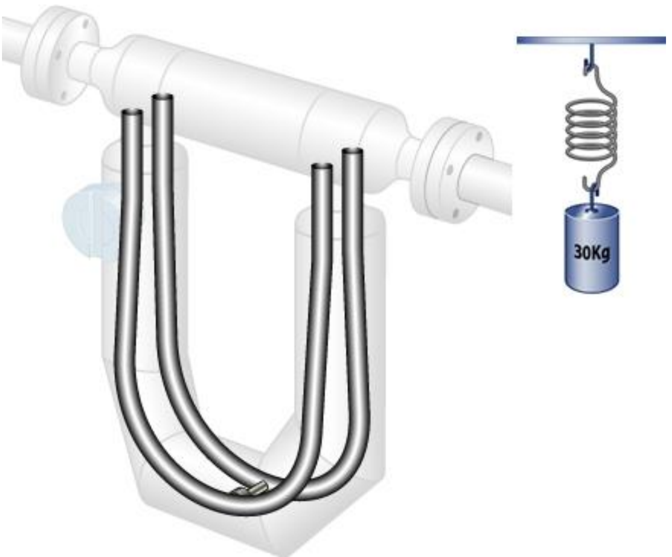
- Do NOT use the sensor to support the piping
- The sensor does not require external supports.

Liquid Volume Measurement Basics

Volumetric Flow is a Calculated Variable

$$\text{Volume Flow} = \frac{\text{Mass Flow}}{\text{Density}}$$



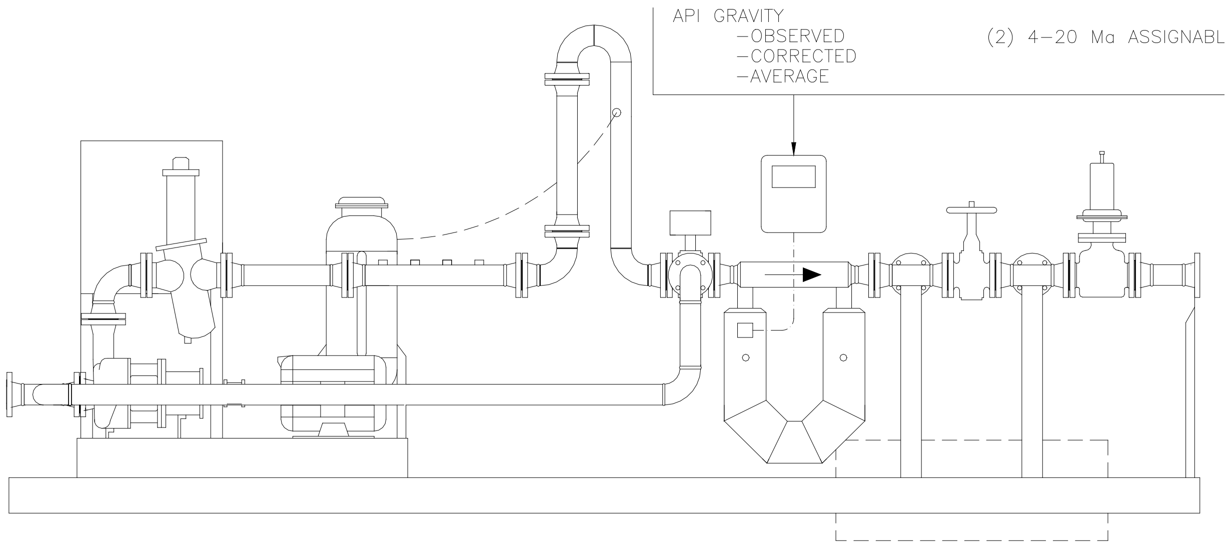


$$\frac{\cancel{\text{Lbs}}/\text{HR}}{\cancel{\text{Lbs}}/\text{BBL}} =$$

BBLs/HR

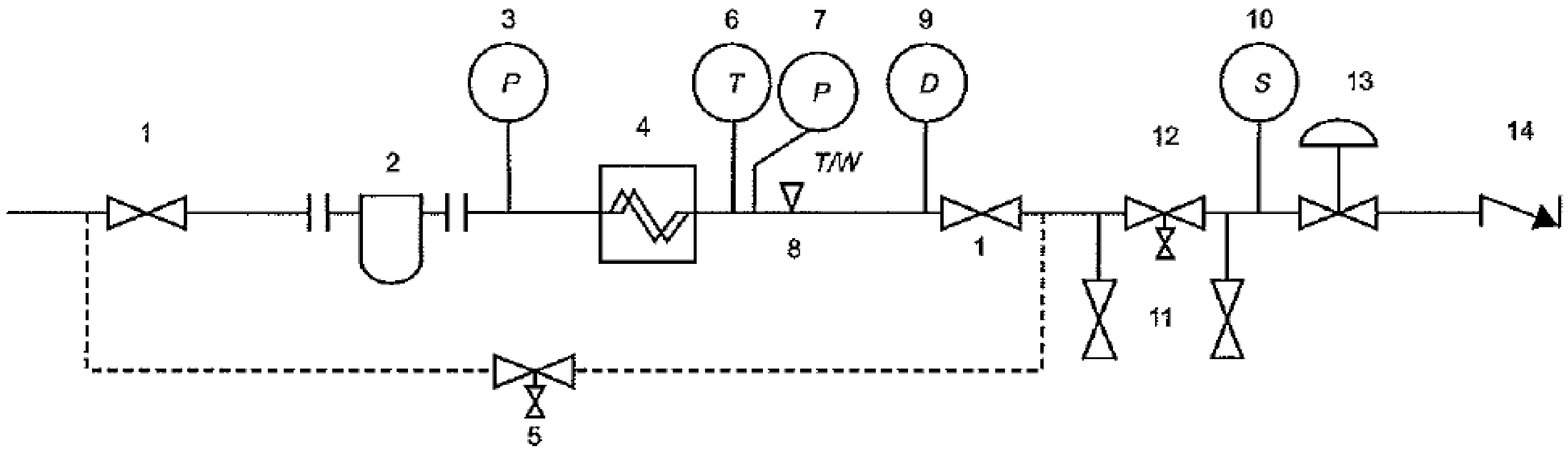
Oil Custody Transfer

- Generics of Crude Oil
  - Contracts are the rule of law
  - 3rd Party Influences…..
- American Petroleum Institute Guidelines (API)
  - Various Existing Standards for Reference including but not limited to:
    - 18.1 – Measurement Procedures for Crude Oil Gathered from Small Tanks by Truck
    - 5 – Metering
    - 6.1 – Generic LACT
    - 7 – Various Temperature Measurements
    - 3 – Tank Gauging (Various)
    - Etc., etc.
  - Not Requirements…..unless?



Requirements vs. Guidelines

API MPMS Chapter 5.6



1. Block valve
2. Strainer/air eliminator (optional)
3. Pressure indicating device (optional)
4. Coriolis meter
5. Meter bypass (optional) with block and bleed valve or blind
6. Temperature indicating device
7. Pressure indicating device
8. Test thermowell (optional)
9. Density measurement/verification point
10. Manual sample point or autosampler (optional) with probe
11. Proving connection, block valves
12. Block and bleed isolation valve for proving/zeroing
13. Control valve (as required)
14. Check valve (as required)

Note: All sections of line that may be blocked in must have provisions for pressure relief.

Figure 2—Typical Schematic for Coriolis Meter Installation

BLM Oil Measurement Guidelines – Crude Oil

Onshore Order 4

- Overall concept: Prescriptive requirements for equipment and procedures with opportunity to request meter-specific variances from the local field office.
- Approved Methods for Oil Custody Transfer:
  - Manual tank gauging
  - LACT using positive displacement meter

43 CFR 3174

- Overall concept: Provide prescriptive measurement procedures as a default with the option for national approval of new or alternative equipment or methods that meet well-defined performance criteria.
- Oil Custody Transfer Approved (default methods):
  - Manual tank gauging
  - Automatic tank gauging
  - LACT with positive displacement meter
  - LACT with Coriolis meter
  - Stand-alone Coriolis meter

Pressure Considerations

Pressure Drop

- Coriolis meters are sometimes smaller line sizes than the main pipeline
  - Sizing program calculates the pressure drop through the meter.
  - More pressure drop is created by pipe reducers and a prover.
  - Back pressure valves are often needed to increase pressure in the meter and the prover to prevent cavitation.

Minimum Back Pressure

- Back Pressure Valve should be installed downstream of the prover connections.
- The amount of backpressure recommended is calculated as follows:

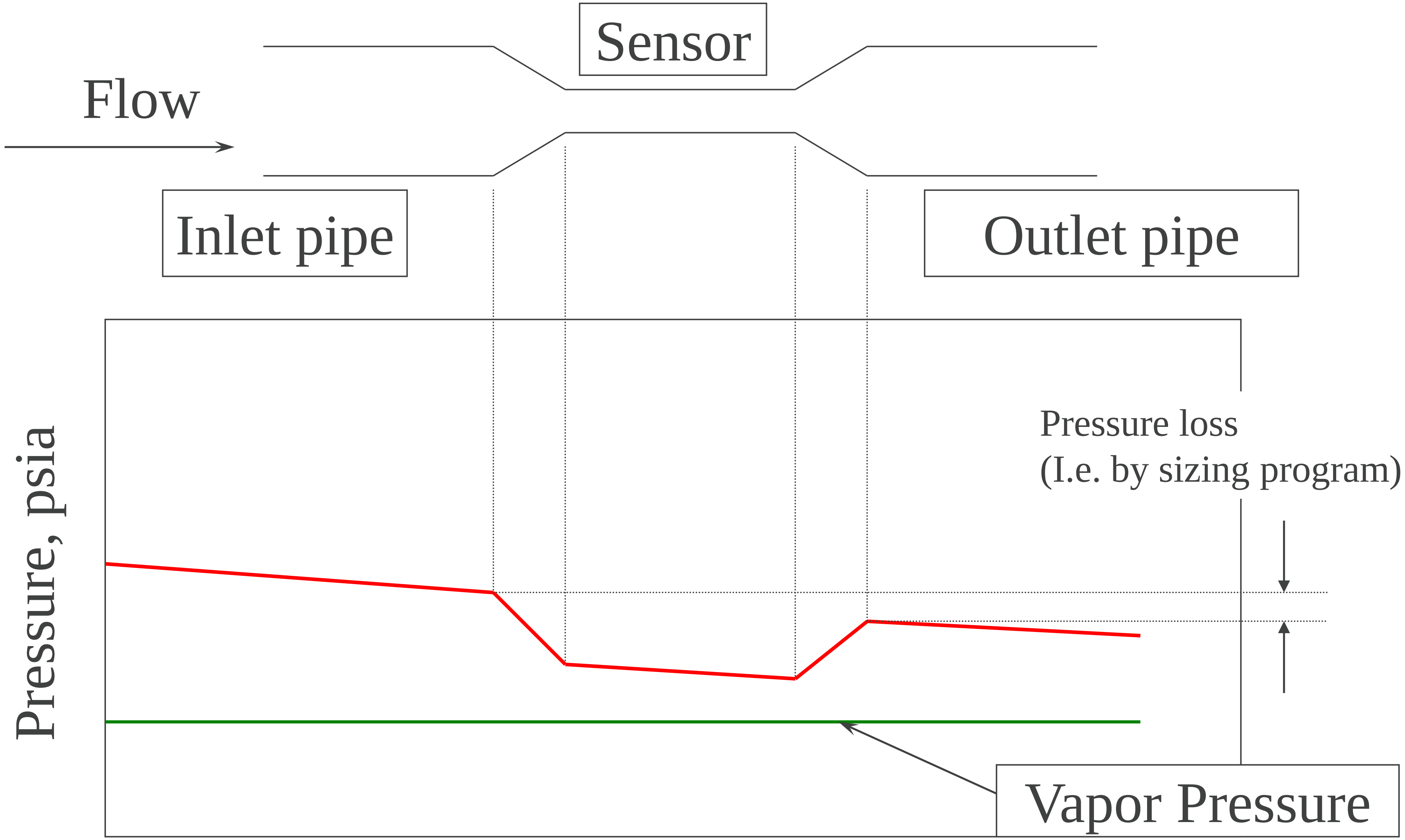
$$P_b = 2\Delta P + 1.25P_e$$

Where:

P_b = minimum backpressure required (psig)
ΔP= pressure drop across the meter at max rate
P_e = equilibrium vapor pressure of the fluid at operating temperature (psia)

Velocity and Recoverable Pressure Drop

Total energy = pressure head + velocity head + elevation head



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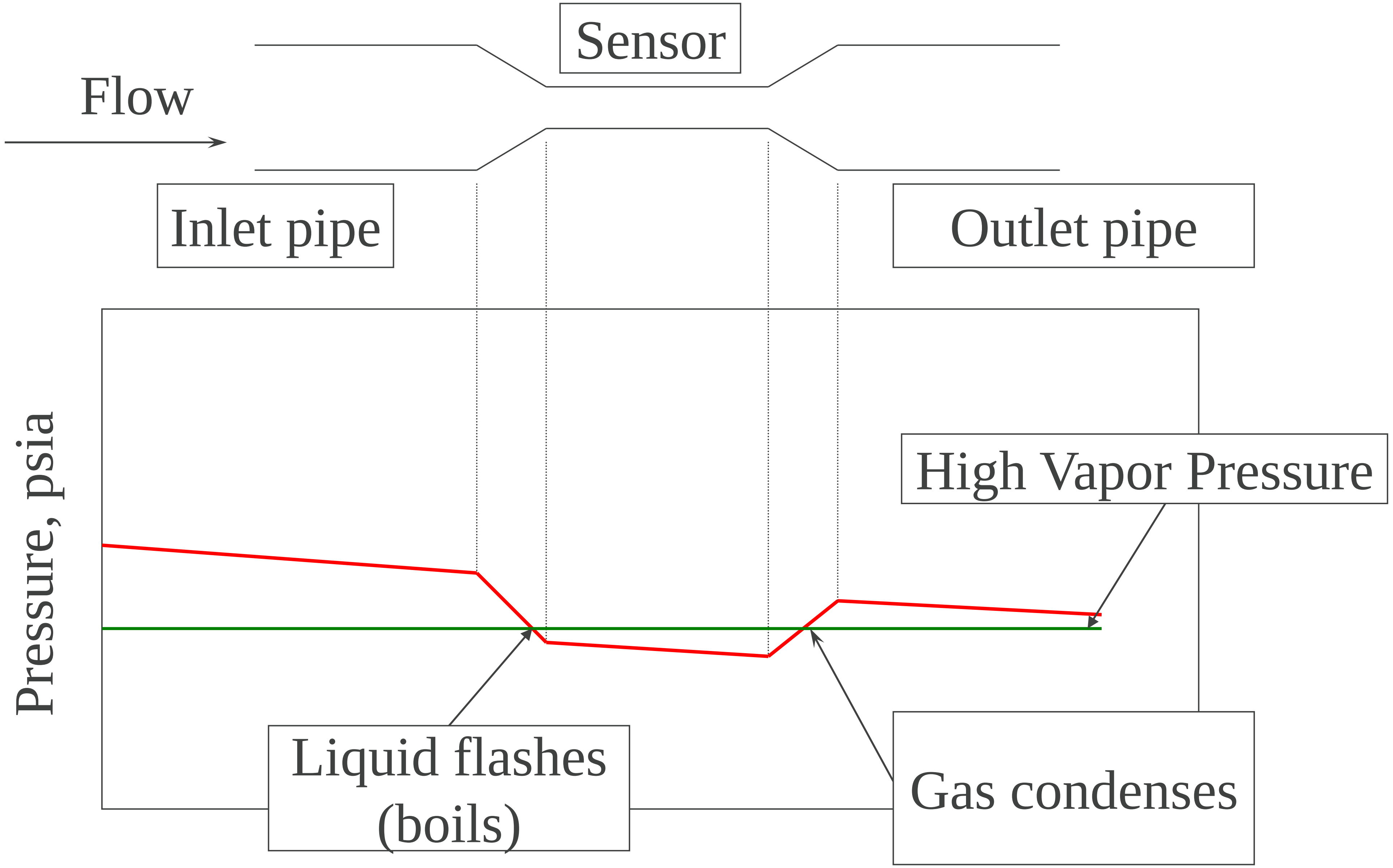
Avoid Pressure Below Vapor Pressure

Total energy = pressure head + velocity head + elevation head



Proving determines a Meter Factor

Known Volume

= Meter Factor

Indicated Volume

- If the meter factor is greater then 1.0000 the meter is under-registering (reading low).
- If the meter factor is less then 1.0000 the meter is over-registering (reading high).

Potential causes for Meter Factor Being Out – Crude Oil

- Meter Factor is High = Meter is reading low
  - Density reading is high?
    - Paraffin or other buildup
  - Meter bypass?
  - Missing pulses at a flow computer
    - Electrical issues
- Meter Factor is Low = Meter is reading high
  - Density reading is low?
    - Gas breakout or lack of meter back pressure
  - Prover bypass?
    - Double block and bleed seal
    - Four way valve seal on bi-di

Direct Mass Measurement

API MPMS 14.7 Standard for Mass Measurement of Natural Gas Liquids

- Direct Mass Measurement
  - Coriolis meter is programmed for mass pulse output

$$Q_m = Im_m \times MF_m$$

Where:

Q_m=mass flow

IM_m=indicated coriolis meter mass

MF_m=meter factor for coriolis meter mass

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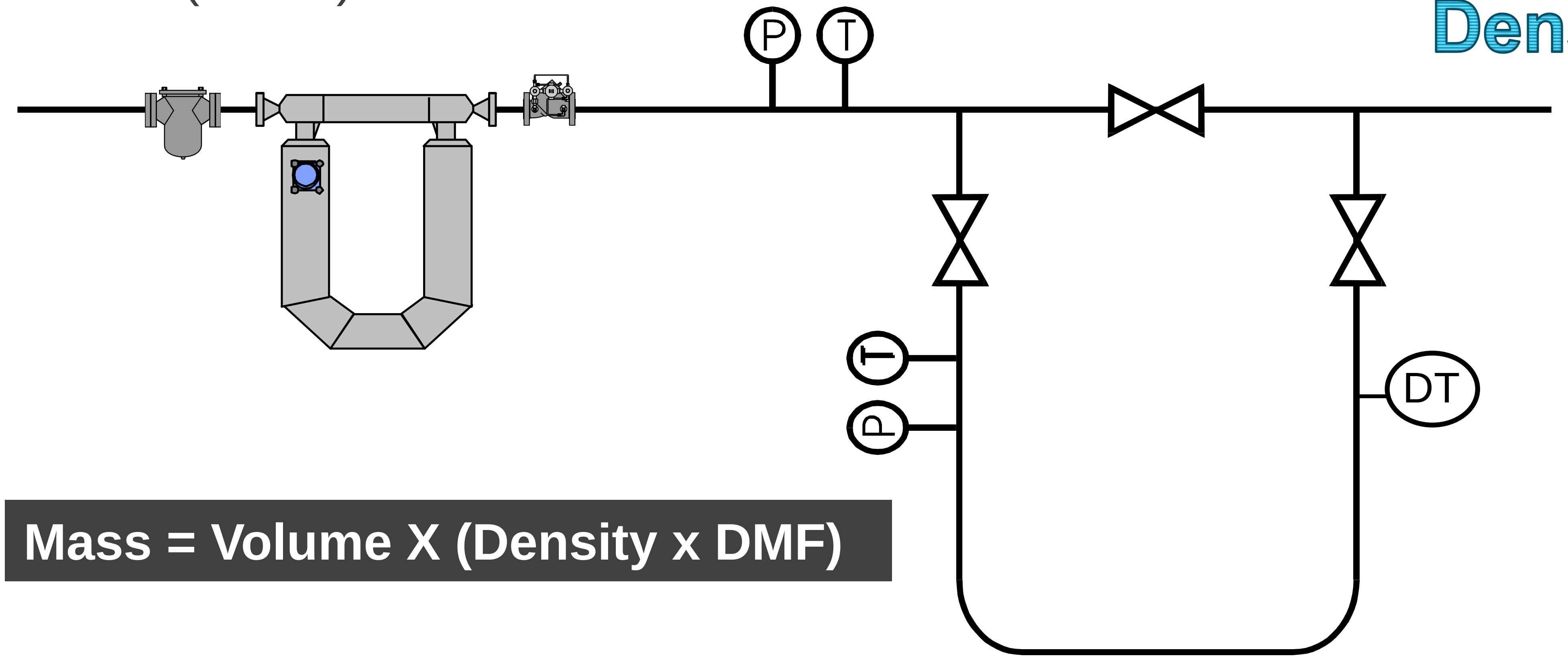
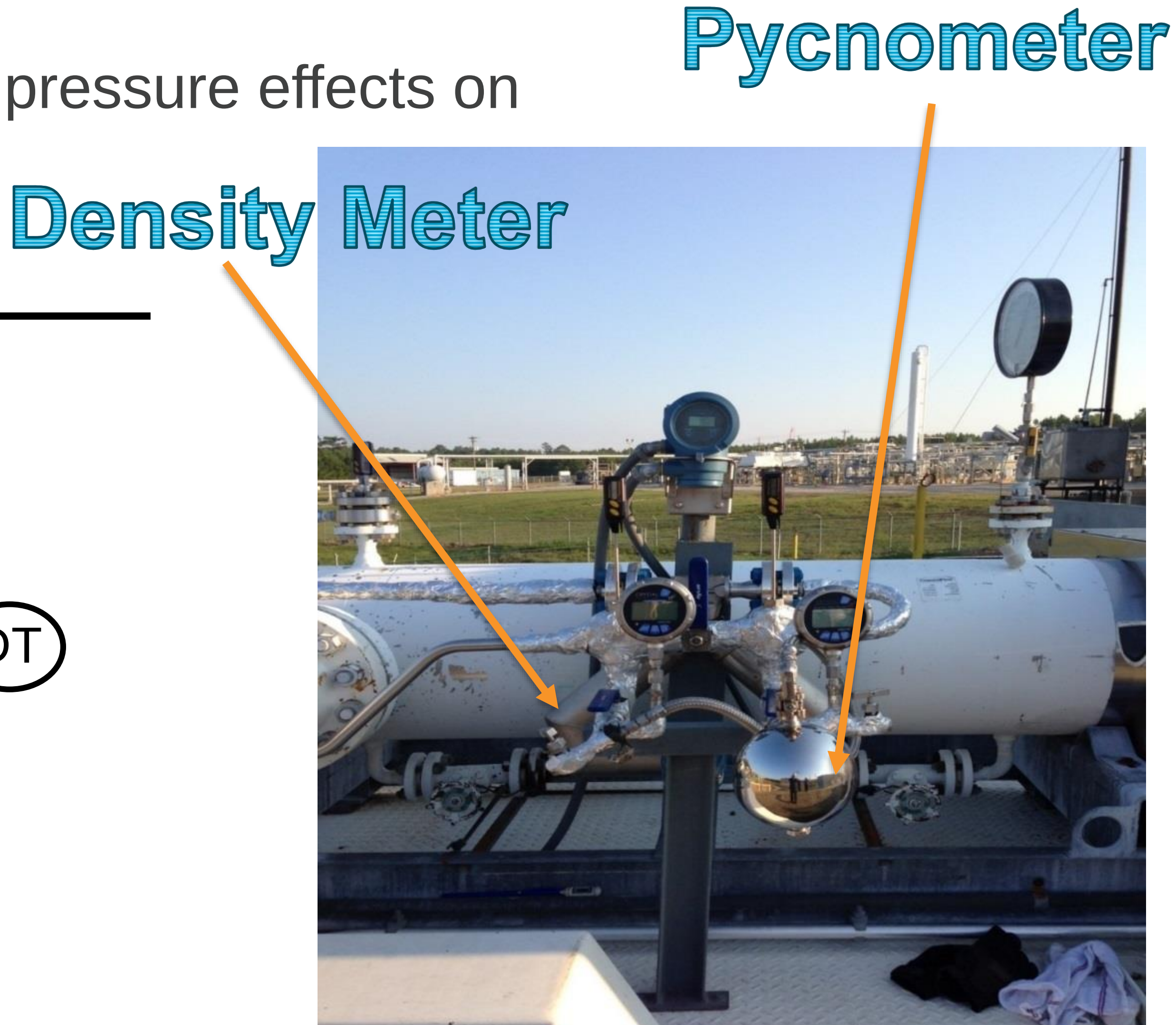
Proving – Direct Mass

- If the Coriolis meter is providing a mass pulse output, the prover reference volume must be converted to mass.
- Density for conversion must be measured at the prover (DMF is density meter factor).
- Meter and prover volumes are not corrected (no CTPL).
- Base prover volume (BPV) is corrected for temperature and pressure effects on steel (CTPS).



Mass = Volume X (Density x DMF)



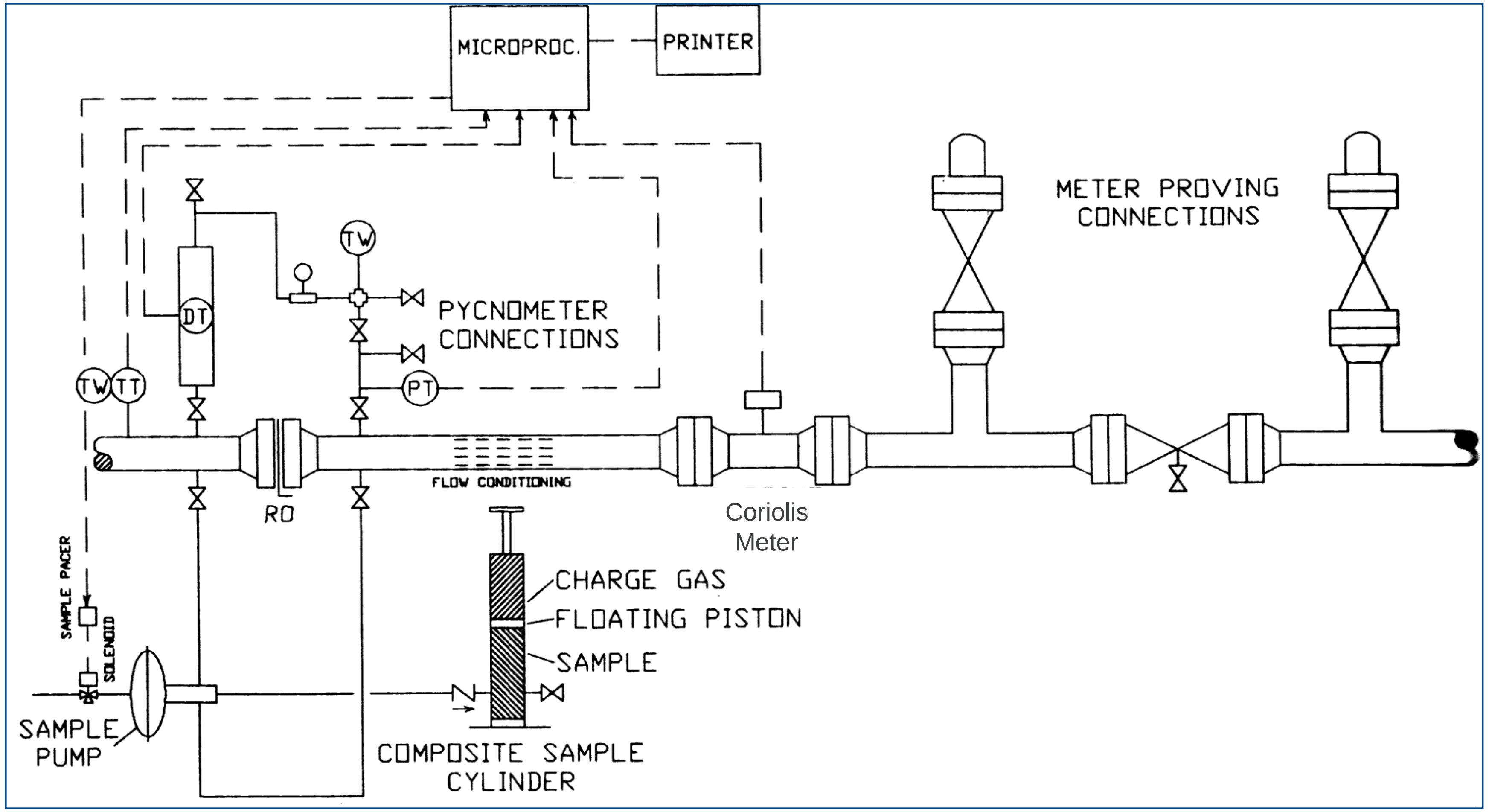
Inferred Mass Measurement
API MPMS 14.7 Standard for Mass Measurement of Natural Gas Liquids

- Inferred Mass Measurement
  - Volumetric flow measurement with on line density measurement

$$Q_m = IV \times MF_v \times \rho_f \times DMF$$

Where:

- Q_m = mass flow
- IV = indicated meter volume at operating conditions
- MF_v = volumetric meter factor
- ρ_f = indicated density at flowing conditions
- DMF = density meter factor



Repeatability

- Repeatability between proving runs
  - Repeatability is used to determine if conditions exist such that a valid meter factor can be obtained from the data.
    - API repeatability criteria is based on obtaining a random uncertainty of ±0.00027 or less for the meter factor

- The calculation of repeatability can be based on pulses from the meter or the meter factor which has been calculated for each proving run.
- Example of calculating repeatability with a 3.0 barrel prover with 10K pulses per barrel using the average data method:
    - 30001
    - 30005
    - 30005
    - 30010
    - 30015

$$\frac{\text{Maximum - Minimum}}{\text{Minimum}} \quad \text{X } 100 = 0.04\%$$

Reproducible Proving Results

- Meter factor shift from a previous proving is referred to as reproducibility.
  - Generally, a plus or minus 0.0025 shift in factor should be evaluated. This would indicate a change of 0.25% which was the traditional accuracy statement for a flow meter. Companies have internal standards that vary from changes of 0.1% to 0.5% from previous factor as case for pulling the meter for evaluation.
- A meter's specification for repeatability may be 0.05%. An interpretation of this as reflected in meter factor shift between provings would be a shift of 0.0005 in factor. It is not realistic to expect this type of reproducibility of proving results.

Potential causes for Meter Factor Being Out - NGLs

- Meter Factor is High = Meter is reading low
  - Density reading is high?
    - Paraffin or other buildup
  - Meter bypass?
  - Missing pulses at a flow computer
    - Electrical issues
- Meter Factor is Low = Meter is reading high
  - Density reading is low?
    - Gas breakout or lack of meter back pressure
  - Prover bypass?
    - Double block and bleed seal
    - Four way valve seal on bi-directional valve

- Factors that cause density changes
  - Temperature
  - Pressure
  - Composition

- If the density measurement conditions (temperature, pressure, and/or composition) differ from the conditions in the volume flow meter, inferred mass accuracy is impacted

- If the density measurement conditions (temperature, pressure, and/or composition) differ from the conditions in the volume prover, direct mass proving accuracy in impacted

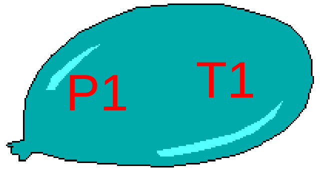
Gas Properties Overview

Seth Harris
Emerson O&G Manager

Using Mass Flow for Gas Measurement

Condition 1
"Actual" conditions

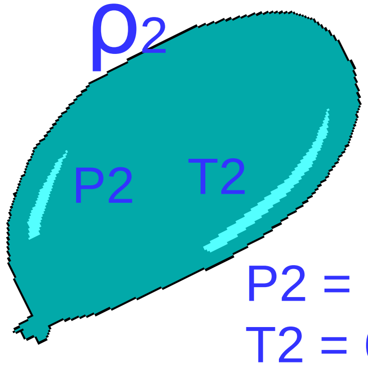
ρ_1



P1 = 150 psig
T1 = 150°F
ρ1 = 0.73 lb/ft3

Condition 2
"Standard" conditions

ρ_2



P2 = 0 psig
T2 = 60°F
ρ2 = 0.07 lb/ft3

Mass Flow is:

- **Independent of temperature and pressure**
- **Better mass & energy balance**
- **Reduced process variability**
- **Meaningful quantity measurement of compressible fluids**

Gas Density and Specific Gravity Definitions

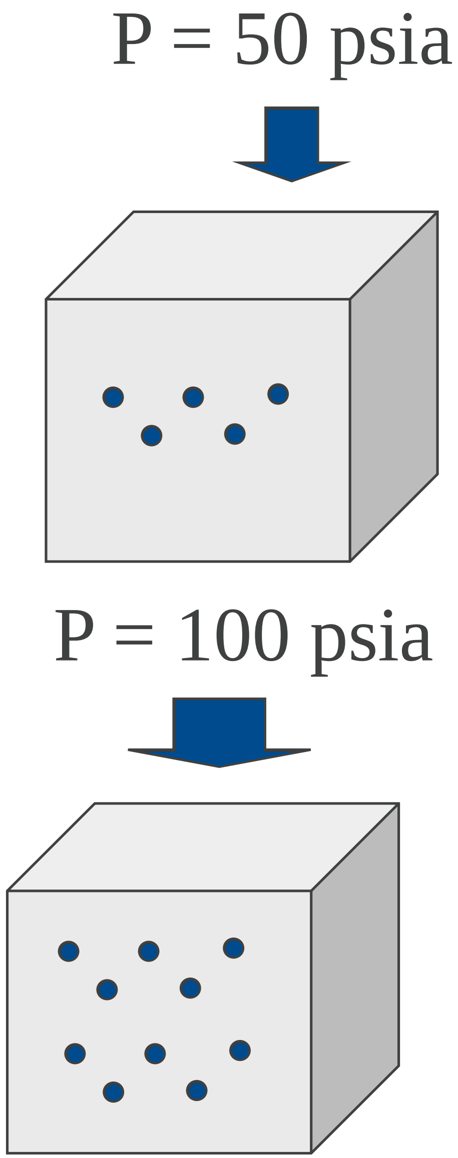
Term	Definition	Units
Gas Density	The mass of gas per unit volume at the actual pressure and temperature conditions (@ Line Conditions)	g/cc or kg/m^3
Standard Density *(Also known as: Base or Normal Density)*	This the density of a gas @ standard conditions of temperature or pressure (eg. 1 atm, 15.556°C or 1 Bar, 20°C)	g/cc or kg/m^3
Relative Density	Ratio of density of a gas to the density of air, where the density of both gasses are taken at identical conditions of temperature & pressure	None
Specific Gravity	The ratio of molecular weight of a gas to that of molecular weight of dry air. (Dry Air Density = 28.96469)	None

Why measure Mass directly for Gas Flow?

- Gases are compressible
  - Density changes with Pressure and Temperature

  **** Volumetric flow is *usually* meaningless: “acfm”**

  need mass **flow: “lb/hr”, “scfm”**

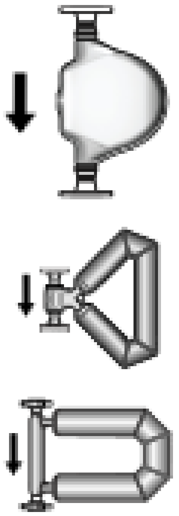
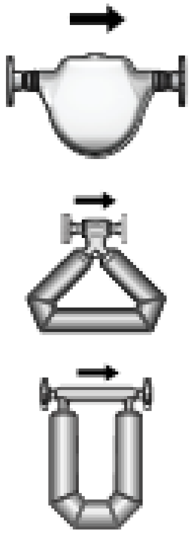


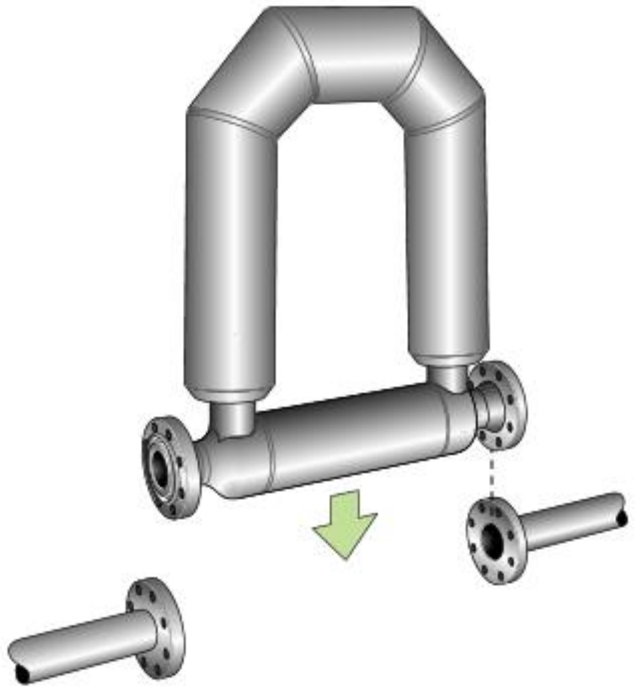
Same volume

2x the gas!

Gas Coriolis & Industry Guidelines

Mounting Considerations for Gas Service

Gases			



Use your common piping practices to minimize:

- Do NOT use the sensor to support the piping
- The sensor does not require external supports.

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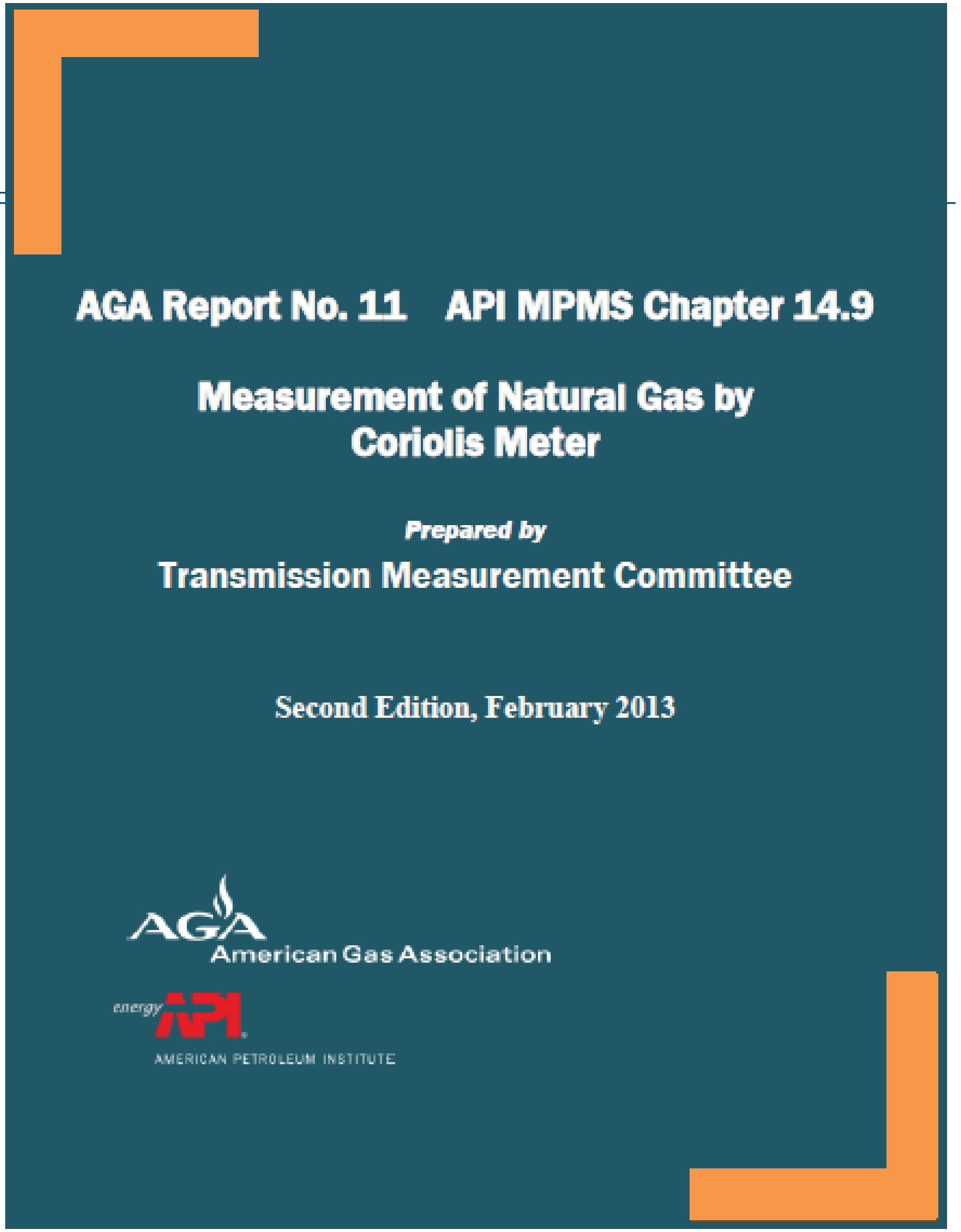
Oil & Gas Industry Approvals

API Manual of Petroleum Measurement Standards (MPMS) & AGA Standards

- AGA Report No. 11 Dec. (2003)
- API Chapter 14, Section 9 (2003)
  - The Measurement of Natural Gas by Coriolis Meters
  - Second edition Feb 2013


AGA Report No. 11 API MPMS Chapter 14.9

Measurement of Natural Gas by Coriolis Meter

Prepared by

Transmission Measurement Committee

Second Edition, February 2013

AGA American Gas Association

energy API AMERICAN PETROLEUM INSTITUTE

AGA Report No. 11 / API MPMS Ch. 14.9
Measurement of Natural Gas by Coriolis Meter

- **Tightening of performance requirements from ± 1.0% to ± 0.7%**
- **Water calibration transfers to gas only when the manufacturer has proof of testing by a 3rd party.**
- **Additional meter “verification” steps will guide the user on the need to flow test**
- **Flow testing can be performed in the field per new guidelines**
- **New appendices added:**
  - **Coriolis Gas Flow Measurement System**
  - **Coriolis sizing equation**
  - **Coriolis Uncertainty section and Example Uncertainty Calculation**

Conversion of Mass to Volume at Standard Conditions

$$SCF = \frac{Mass}{\rho_b}$$

- **AGA11 Eqn. D.2**
- lbs/day ÷ lbs/ft3 = ft3/day

$$SCF = \frac{Mass}{\left[\frac{P_b \text{ x } Mr(\text{Gas})}{Z_b \text{ x } R \text{ x } T_b}\right]}$$

- **AGA8 Detail**
- **Non-ideal** gas law:
  P_b, T_b, R are constants.
  Note: Z_b does not vary more than 0.02% at base conditions.

$$SCF = \frac{Mass}{\left[\text{Gr}_{(\text{Gas})} \text{ x } \rho_{(\text{Air})}\right]}$$

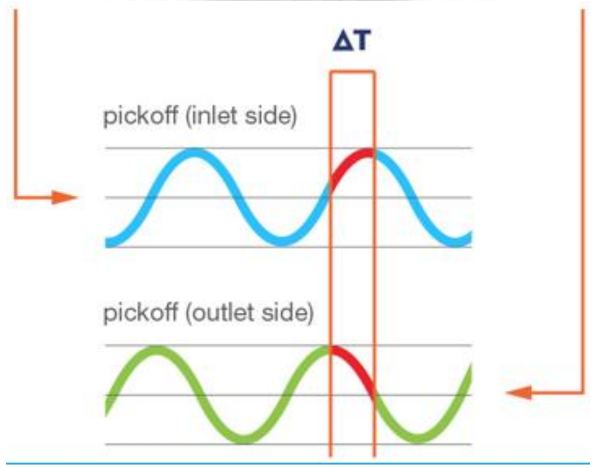
- **AGA8 Gross 1 or 2**
- **Note:** $\rho_{(Air)}$ is constant.

NO PRESSURE OR TEMPERATURE Measurement Required to Convert from Mass to Standard Volume. Molar weight, Base Compressibility, and Specific Gravity Are **ALL DETERMINED BY GAS COMPOSITION.**

Gas Volume Measurement Basics

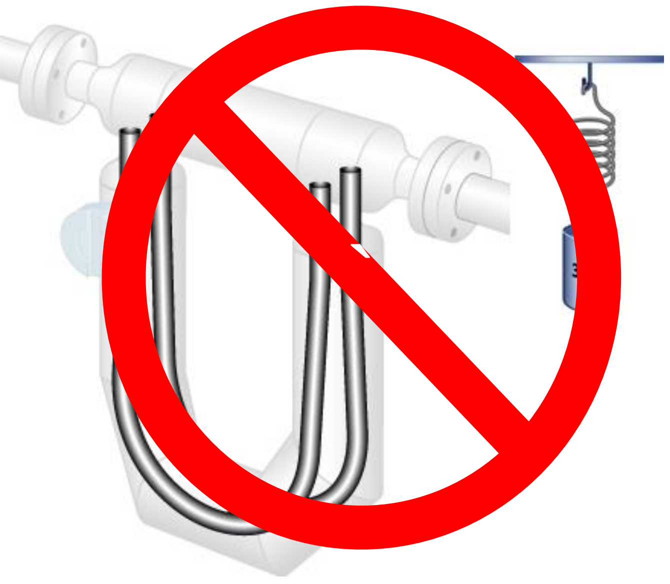
- Volumetric Flow is a Calculated Variable

$$\text{Volume Flow} = \frac{\text{Mass Flow}}{\text{Density}}$$



~~Lbs~~/Day

=



~~Lbs~~/SCF

Natural Gas Analysis Report
GPA 2145-09 Analysis

Sample Information

	Sample Information
Sample Name	Natural Gas
Operator	SYSTEM (SYSTEM)
Method Name	Natural Gas 2
Injection Date	2014-11-14 18:11:51
Report Date	2014-12-22 16:00:43
EZReporter Configuration File	Fusion.cfg
NGA Phys. Property Data Source	GPA Standard 2145-09 (FPS)
Data Source	EZIQ data system connection

Component Results

Component Name	Ret. Time	Peak Area	Raw Amount	Norm%	Gross HV (Dry) (BTU / Ideal cu.ft.)	Relative Gas Density (Dry)
Nitrogen	29.478	31421.8	1.5364	1.5326	0.0	0.01482
Methane	30.188	1466302.8	88.8958	88.6723	895.6	0.49116
CO2	34.703	30098.3	1.2117	1.2087	0.0	0.01837
Ethane	47.044	80328.2	3.0003	2.9928	53.0	0.03107
Propane	86.087	71652.8	1.9923	1.9873	50.0	0.03026
isobutane	113.327	43690.5	1.0055	1.0030	32.6	0.02013
n-Butane	118.478	45926.4	0.9964	0.9939	32.4	0.01995
isoPentane	136.398	16672.7	0.2997	0.2990	12.0	0.00745
n-Pentane	139.365	17691.0	0.3004	0.2996	12.0	0.00746
Hexanes	150.000	36660.0	0.6161	0.6145	29.2	0.01828
Heptanes	174.000	20141.0	0.3210	0.3201	17.6	0.01107
Octanes Plus	214.000	3234.0	0.0764	0.0762	4.8	0.00301
Total:			100.2520	100.0000	1139.2	0.67302

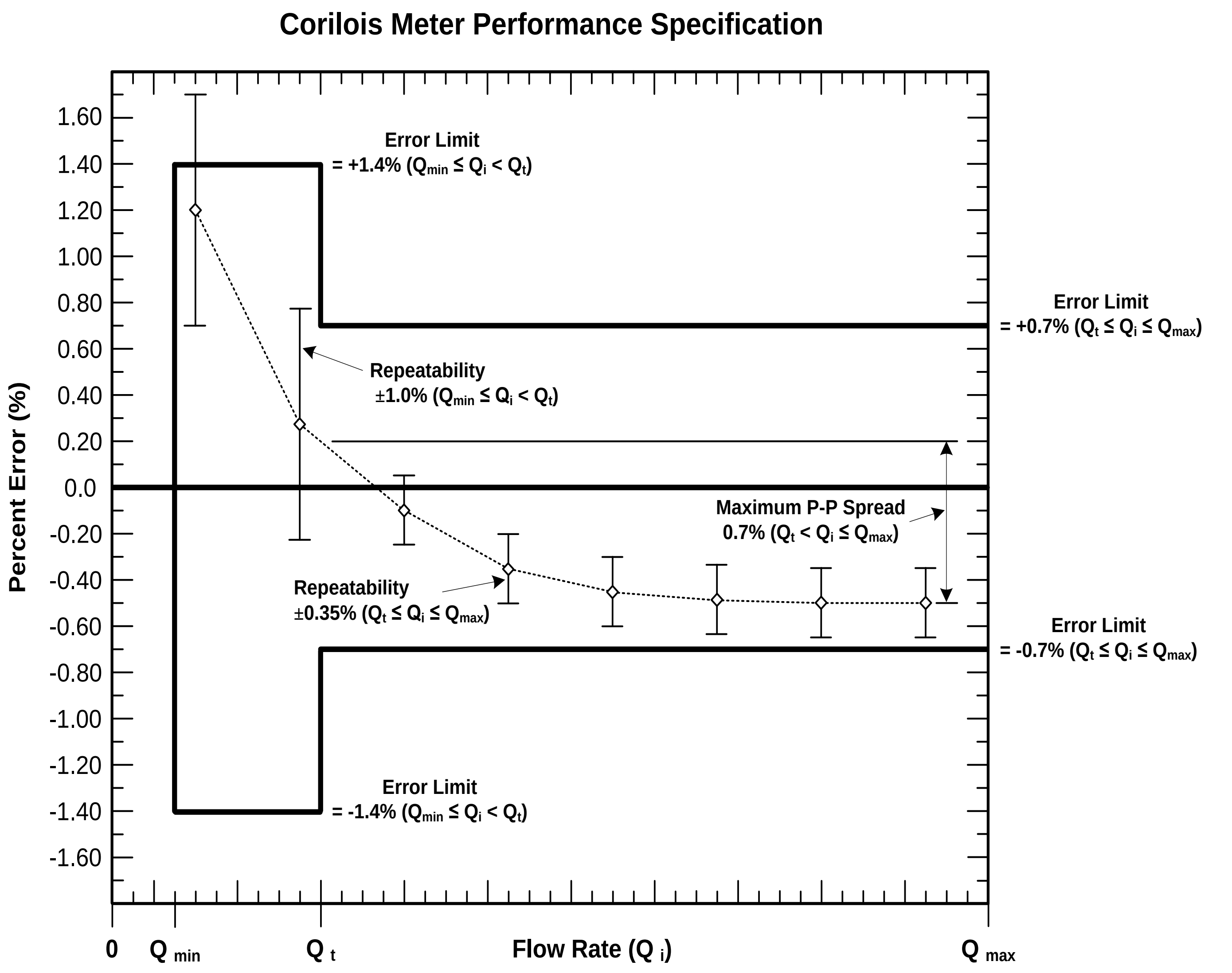
Results Summary

Result	Dry
Total Raw Mole% (Dry)	100.2520
Pressure Base (psia)	14.696
Temperature Base	60.0
Gross Heating Value (BTU / Ideal cu.ft.)	1139.2
Gross Heating Value (BTU / Real cu.ft.)	1142.5
Relative Density (G), Real	0.6747
Compressibility (Z) Factor	0.9971
Wobbe Index	1390.9

SCF/Day

API Chapter 14.9/AGA 11 Overview

- Meter Requirements
  - Documentation and Interface: Drawings, Outputs options (232, 485 or Pulse), Diagnostics, Documentation
  - Testing: Static Pressure Testing, Alternative Calibration Report/Traceability to National/International Standards
- Meters may be calibrated for natural gas in **liquid laboratories**
  - Better reference uncertainty possible in liquid (e.g., water) labs
- Meters may also be calibrated in **gas laboratories**
  - Option for Piece-Wise Linearization (PWL) used by ultrasonic meters is available for fine tuning by third-party gas labs
- Meter Sizing & Selection Criteria
  - Process Conditions
  - Required meter accuracy



API Chapter 14.9/AGA 11 Overview (cont'd)

- Gas Flow Calibration Requirements
  - Reports, Facility Requirements, Documentation

- Installation Requirements
  - Temperature (Ambient and Process, not required for mass based measurement)
  - Pressure – Upstream installation is preferred, if needed

- Field Meter Verification
  - Transmitter Verification – Cal Factors, etc.
  - Sensor Verification – Consult Meter Manufacturer → SMART Meter Verification
  - Temperature Verification
  - Meter Zero Verification – Verify Zero Function

API Chapter 14.9/AGA 11 Overview (cont'd)

- Flow Performance Testing – in-situ verification
  - Alternative Fluids

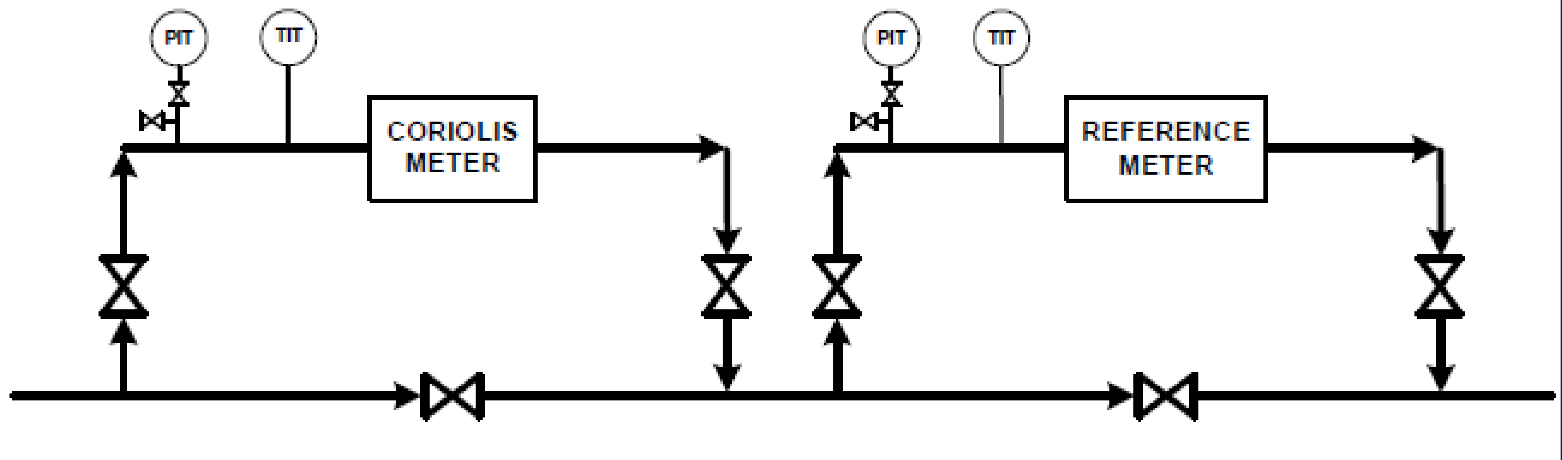


Figure 9.1
Example Configuration for Field Performance Testing

- Recalibration
  - AGA 6, Field Proving by Transfer Standard Method

Appendix E
Coriolis Gas Flow Measurement System

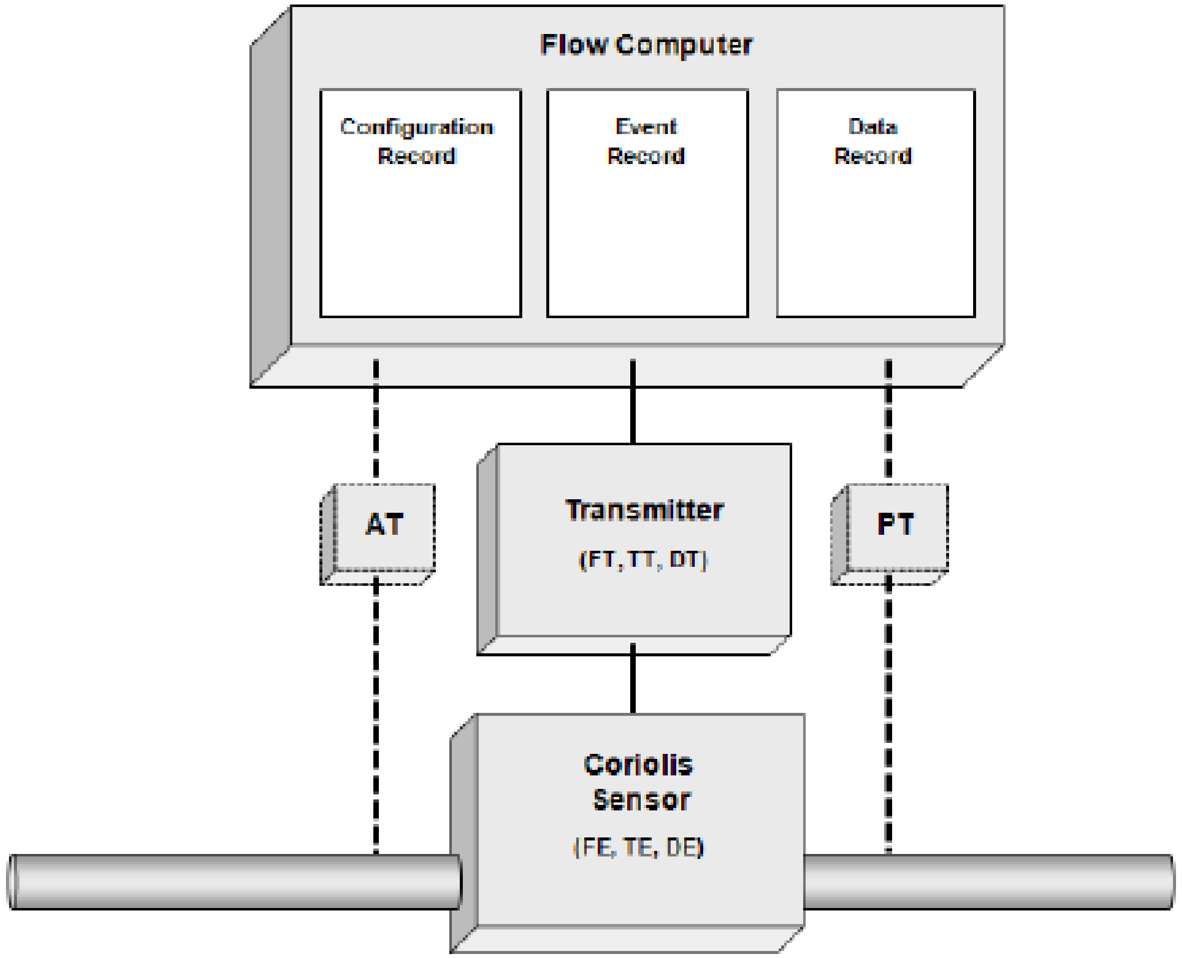


Figure E.1
Coriolis Gas Measurement System block diagram

BLM Measurement Guidelines – Natural Gas

Onshore Order 5

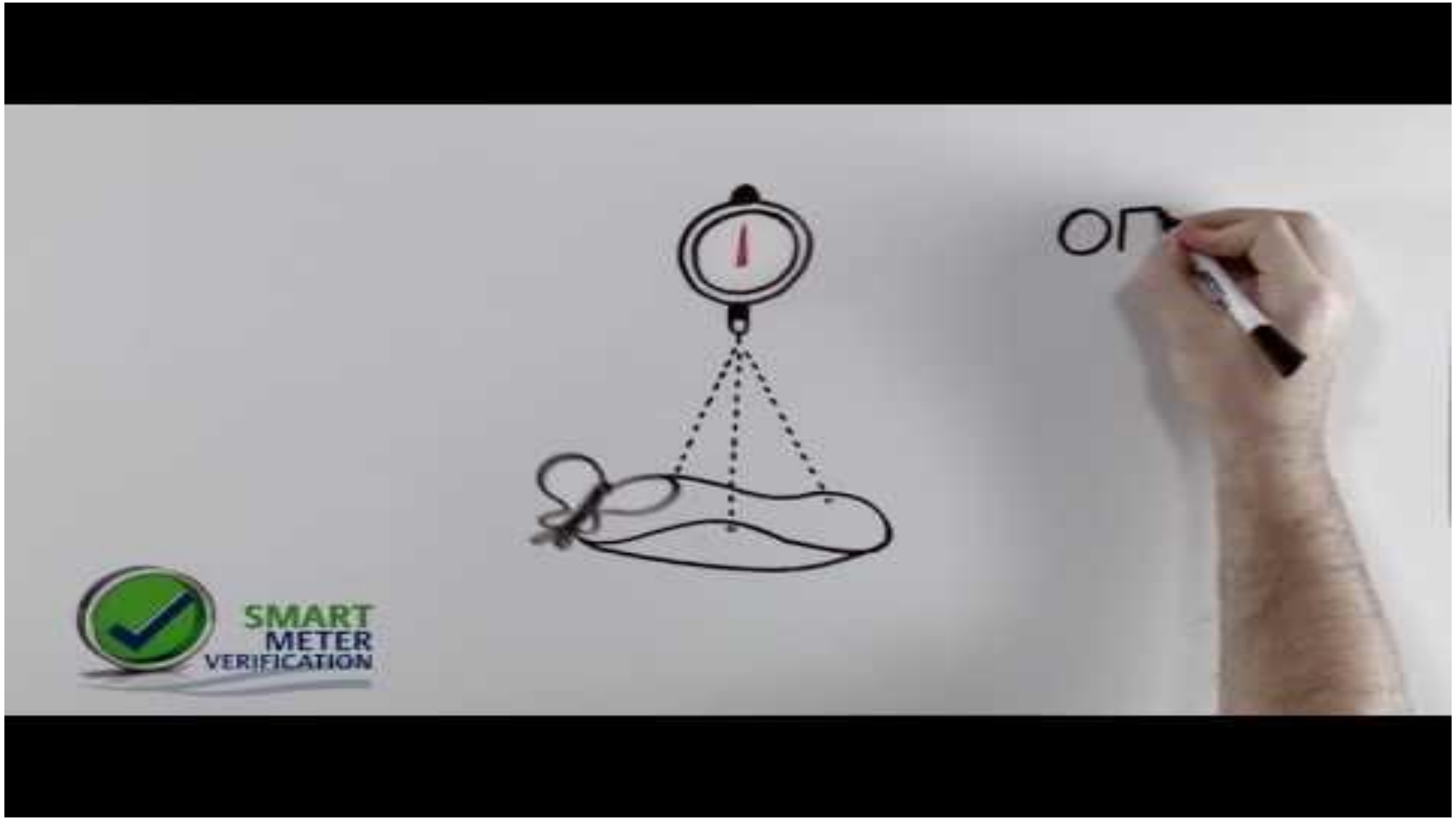
- Overall concept: Prescriptive requirements for equipment and procedures with opportunity to request meter-specific variances from the local field office.
- Approved Methods of Gas Custody Transfer:
  - Orifice meter with chart recorder
  - Electronic flow computer (statewide NTLs)

43 CFR 3175

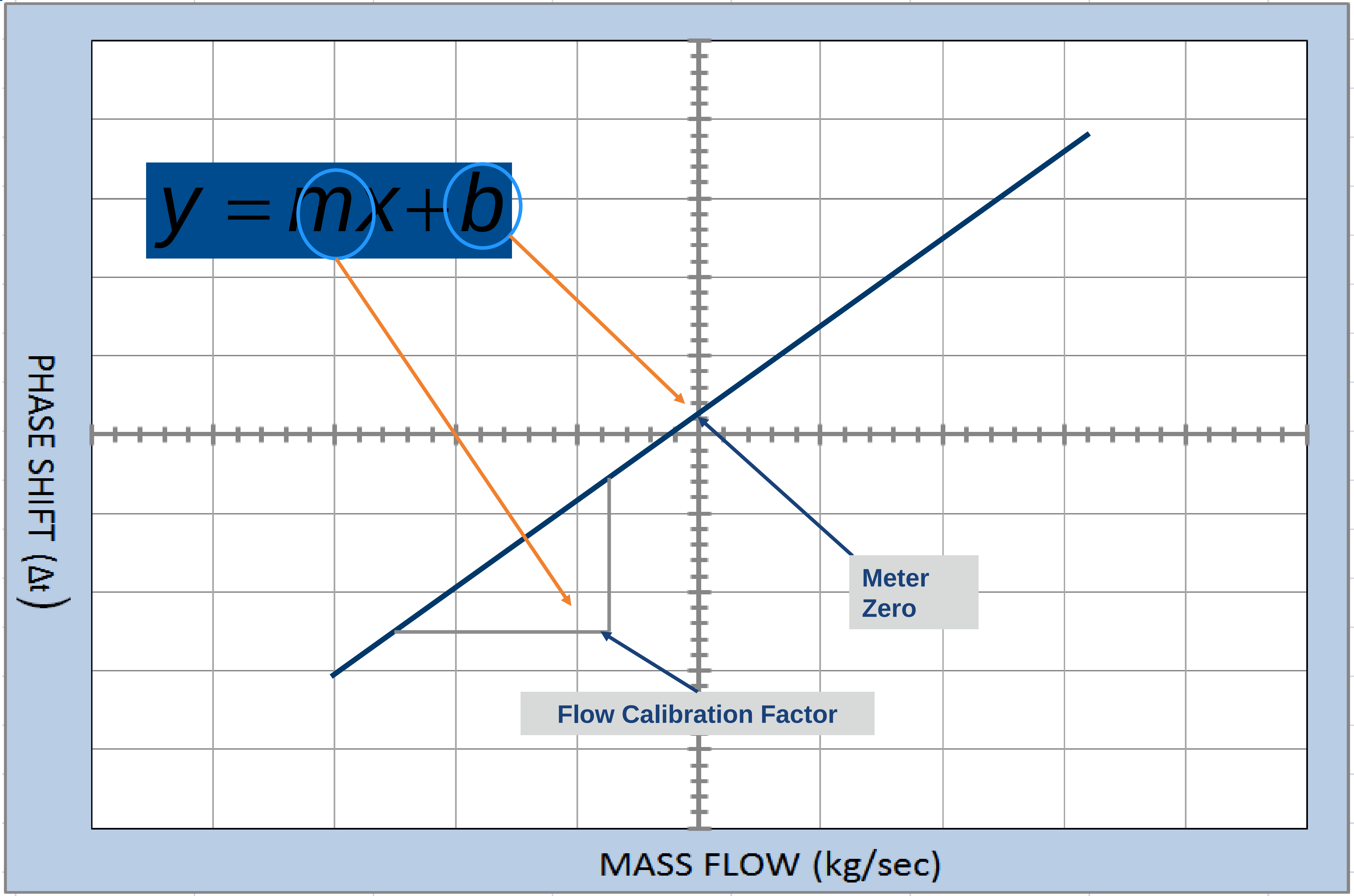
- Overall concept: Provide prescriptive measurement procedures as a default with the option for national approval of new or alternative equipment or methods that meet well-defined performance criteria.
- Gas Custody Transfer (default methods):
  - Flange-tapped orifice meter (primary device)
  - Chart recorders (less than 200 Mcf/day)
  - Electronic gas measurement (EGM)
  - Standard methods of gas sampling and analysis

Application Specific Technical Details, Troubleshooting and Prolink III Interface

Micro Motion Zero Verification Video - YouTube



Span vs. Zero



$y = mx + b$
Meter Zero
Flow Calibration Factor
PHASE SHIFT (Δt)
MASS FLOW (kg/sec)

Coriolis Meter Zeroing Best Practices

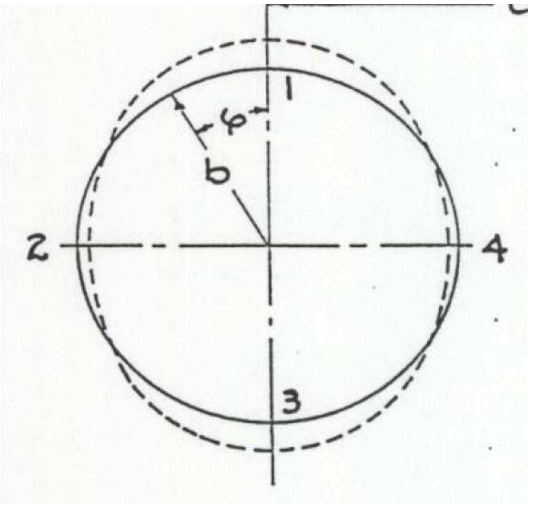
- Most applications → Use factory zero
- To verify zero after installation, first:
  - Ensure no flow condition
  - Ensure meter is full of fluid (gas or liquid, not both)
  - Ensure process conditions are stable
- Next: Initiate Micro Motion Zero Verification Tool
  - Monitors 8 parameters to check stability of process and check current zero value

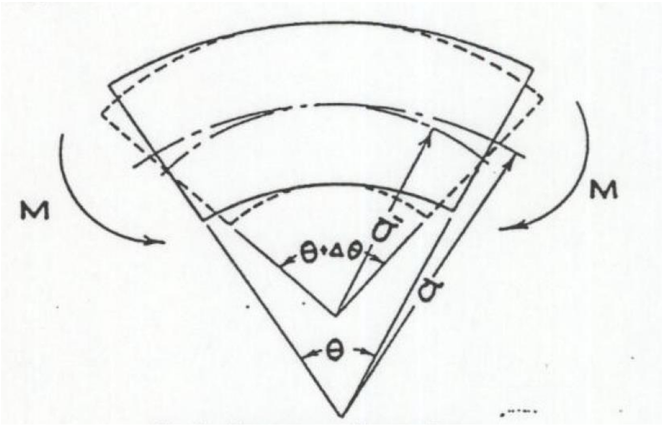
What is Pressure Effect on Round Tubes?

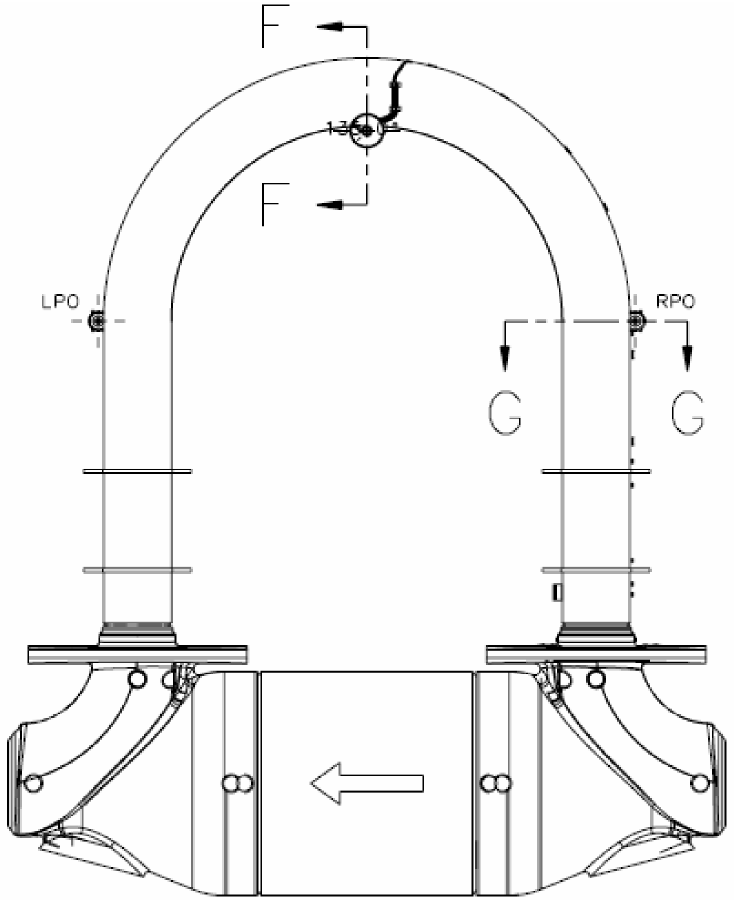
- Internal pressure changes the shape of the flow tube
  - Tube ovality becomes round
  - Tube bends straighten
- Changes in flow tube shape increases stiffness of flow tube
- Changes in tube stiffness directly affects sensor calibration

$$\dot{m} = FCF * \text{time delay}$$

$$FCF \propto \text{tube stiffness}$$







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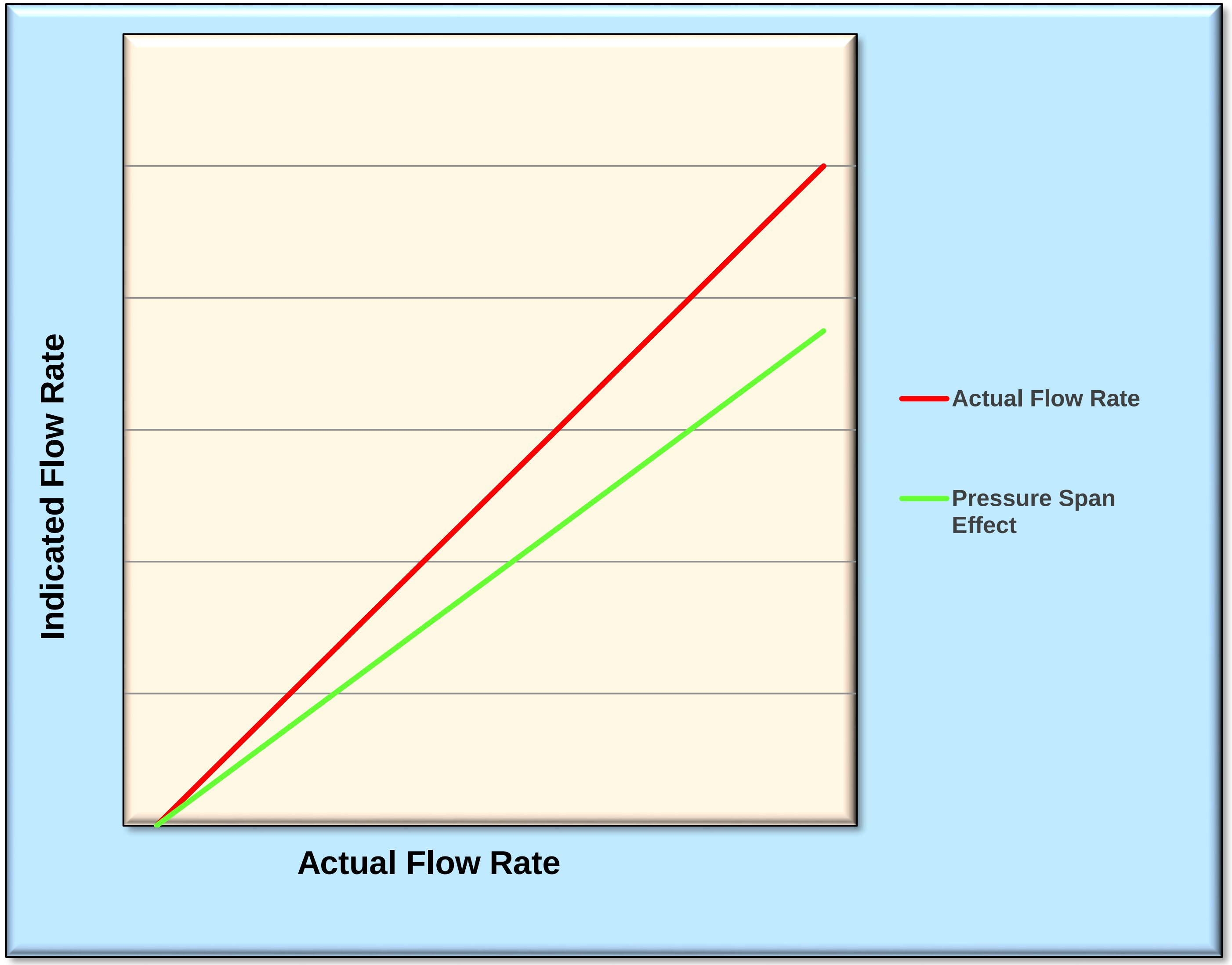
Pressure Effect on Coriolis Meters

- As pressure increases, tube stiffness increases
- For small sensors with relatively thick tube walls, this effect is small
- Amount of twist is less for the same mass flow as pressure/stiffness increases
- Pressure effect will cause an under reading therefore the correction required is in the positive direction

$$Q_{m-indicated} = MF_m * FCF * \left(1 - FT_{mimo} * t_{mimo}\right) * \boxed{\left(1 + FP_{mimo} * (P_{oper} - P_{cal})\right)}$$
$$* \left(\Delta T_{measured} - \Delta T_{zero-stored}\right) * LD * (1 - EDC)$$



Compensation Options

SMART METER VERIFICATION

Verification Addresses Challenges of Calibration and Proving

Calibration

- **Establish** relationship between **flow rate and signal produced** by sensor
- Should be *traceable and accredited*

Validation

- **Compare meter to a reference** to confirm performance
- *Example:* Prover or master meter

Verification

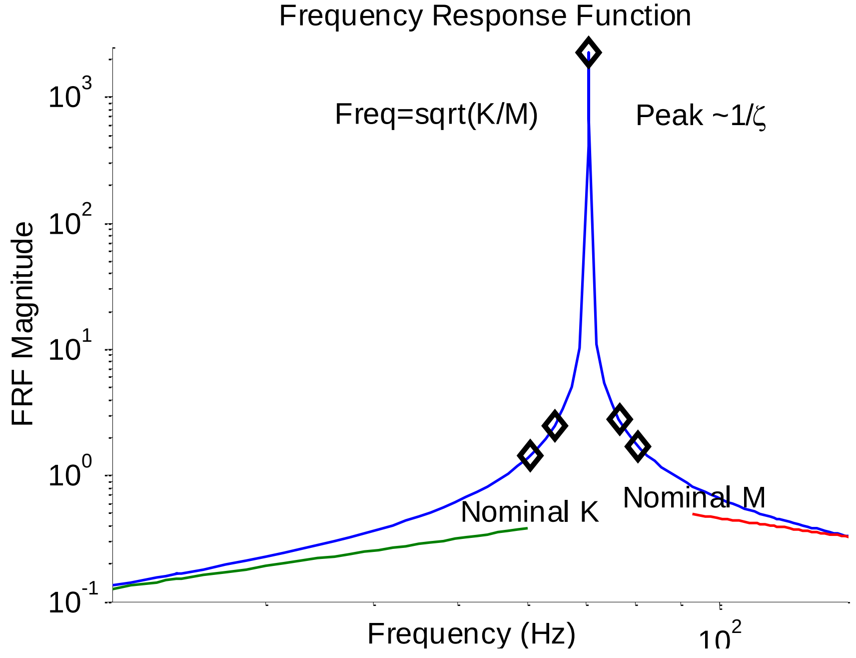
- **Correlate diagnostics to primary variables**
- *Example:* Structural integrity of tubes

In-situ Verification with Smart Meter Verification

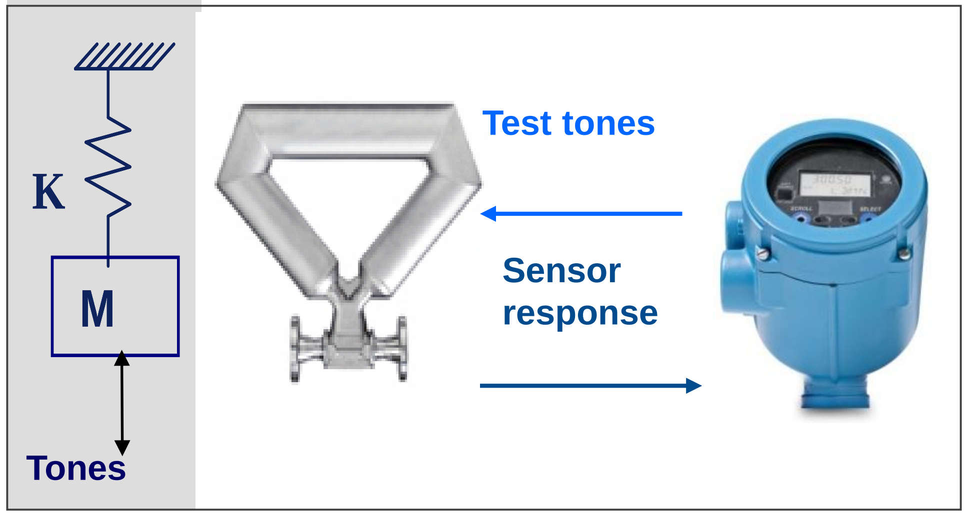
Typical internal SMV verification

- On-demand
- One button
- No extra equipment
- Formal report
- Less than 2 minutes
- No interruption to process or measurement
- Scales with host systems

SMART METER VERIFICATION



Meter verification procedure



Look Beyond the Meter with SMV Professional

Process

- Installation
- Multiphase Flow Detection
- Operating flow range

Sensor

- Tube stiffness
- Drive coil
- Pickoff coils
- RTD
- **Tube coating**

Transmitter

- Sensor signal
- Zero calibration
- Configuration
- Alerts

Updated SMV Capabilities

	Basic	Professional	
Compatibility	1500, 1700, 2400, 2500, 2700, 5700	1500, 1700, 2400, 2500, 2700	5700
	Included	*Licensed*	*90-DayTrial, Licensed*
Improved detection	X	X	X
Scheduler	X	X	X
Report		X	X
Coating detection			X
Installation verification			X*
Multiphase diagnostic			X*
Flow range diagnostic			X*

**** Additional functionality in ProLink III Professional***