M201 - Intermediate Measurement Theory

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Enbridge Gas Transmission and Midstream

Energy Nexus | Annual Technical Conference
Fuelling the Future

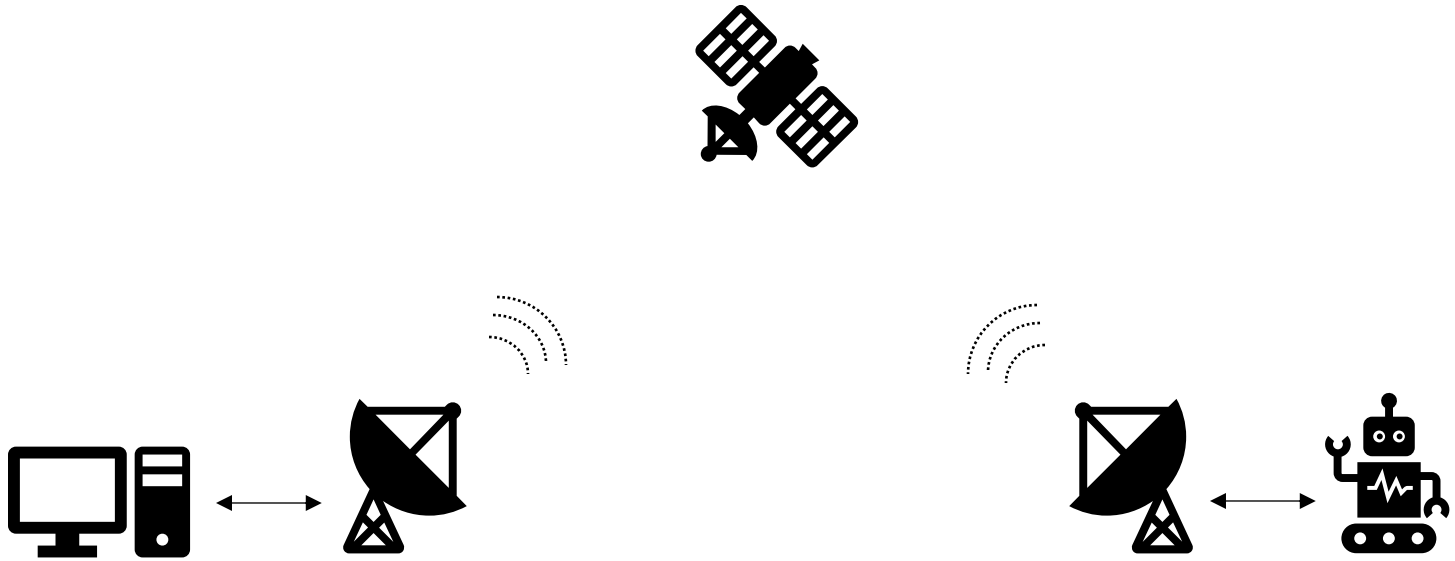
Introduction

Session Outline

1. SCADA and Telemetry
   - What is it
2. Measurement System Design
   - Pressure Factor Metering
   - Components
   - Communication
3. Meter Types – Application and Theory
   - Ultrasonic
   - Coriolis
   - Pitot Tube/Annubar

Title:	**Intermediate Measurement Theory**
Code:	M201
Overview:	Understanding measurement equipment used in the control of pipeline systems. Advanced metering devices such as, Pitot Tube, Coriolis, Annubar and Ultrasonic measurement devices . Define and explain the function of "Pressure Factor Measurement" in the pipeline system.
Learning Objectives:	
MRTT 22,30 Upon completion of this session, learners will be able to: 1. Navigate the RTU control screens (e.g., pressures, flows, temperatures). 2. Demonstrate manual EV actuator control. 3. Identify various instrumentation. 4. Explain where and why telemetry is required. 5. Describe instrumentation effects on stations (e.g., Coriolis pressure loss). 6. State the operational theory of Pitot tubes, Coriolis meters, Annubar meters, Ultrasonic meters, and pressure factor metering. 7. Identify Pitot tubes, Coriolis meters, Annubar meters, Ultrasonic meters, and pressure factor metering. 8. Perform the required checks and maintenance on Pitot tubes, Coriolis meters, Annubar meters, Ultrasonic meters, and pressure factor metering. 9. State the proper application/installation for each type of meter.	

SCADA and Telemetry



Supervisory Control and Data Acquisition (SCADA)

What is it?

- SCADA is an industrial control system architecture that uses computers, software, networked data communications and graphical user interfaces for high-level supervisory management

Supervisory Control and Data Acquisition (SCADA)

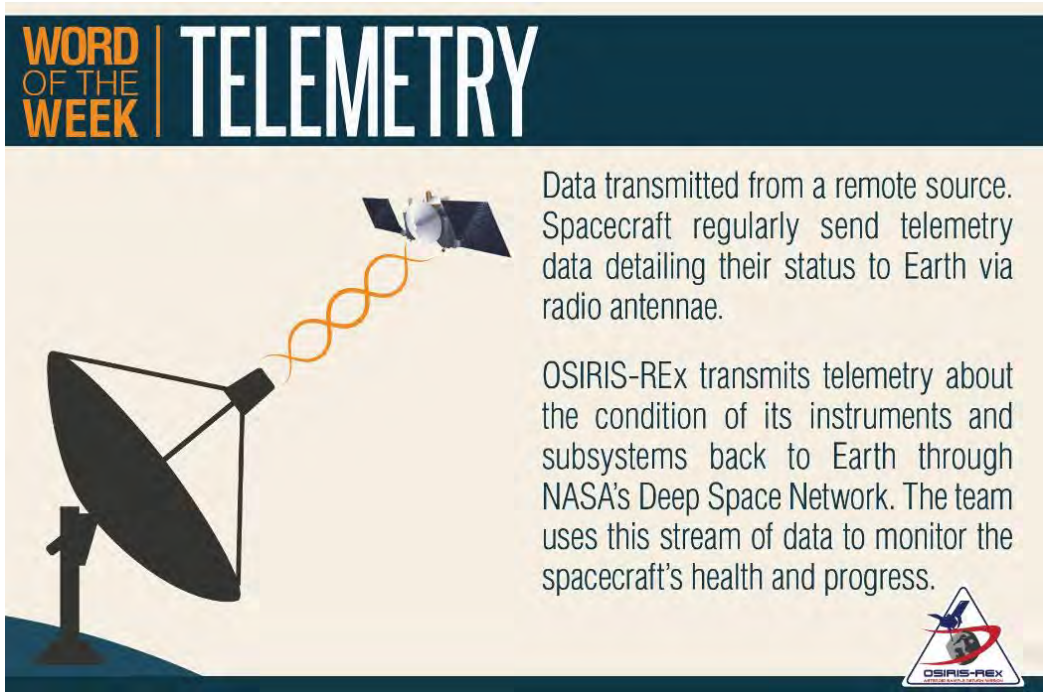
What is it?

- Used to monitor and control a natural gas pipeline system through
  - Remote Terminal Units (RTU) or Programmable Logic Controllers (PLC) interfacing directly with equipment at *facilities* to read sensor data and perform real time local control
  - *Communication* of remote RTU/PLC data to a central supervisory computer
  - Supervisory computer performing necessary *analysis and control*
  - Displaying acquired data on graphical user interfaces for operators to perform high-level supervisory management and *remote-controlled tasks*
- Positioned on top of real-time control systems that are controlling processes outside of the SCADA system, for example
  - Compressor units
  - Emergency shutdown systems

Telemetry

What is it?

- Telemetry is the automated measurement and transmission of data from remote or inaccessible sources to receiving equipment for monitoring
  - Derived from Greek roots: tele = remote, and metron = measure
- The remote monitoring function of a SCADA system is often referred to as telemetry



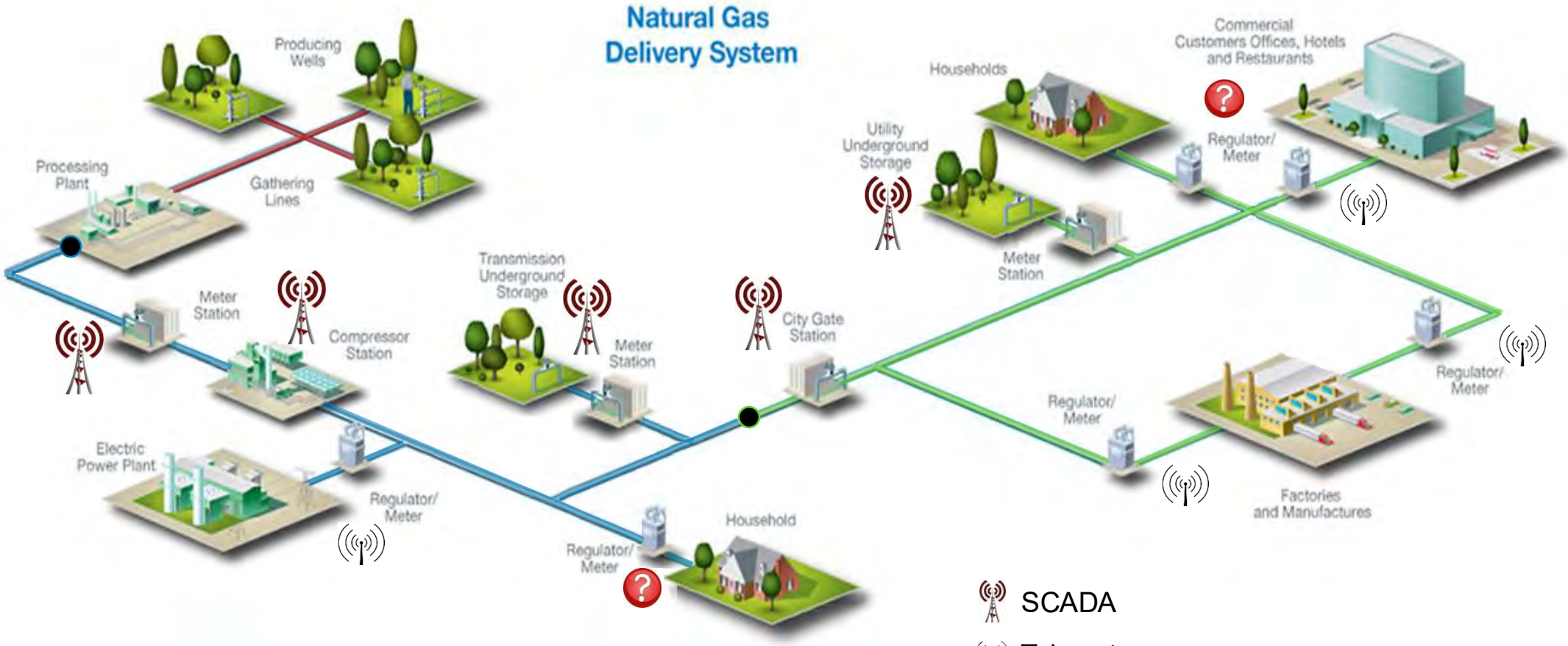
Pipeline SCADA/Telemetry

Why?

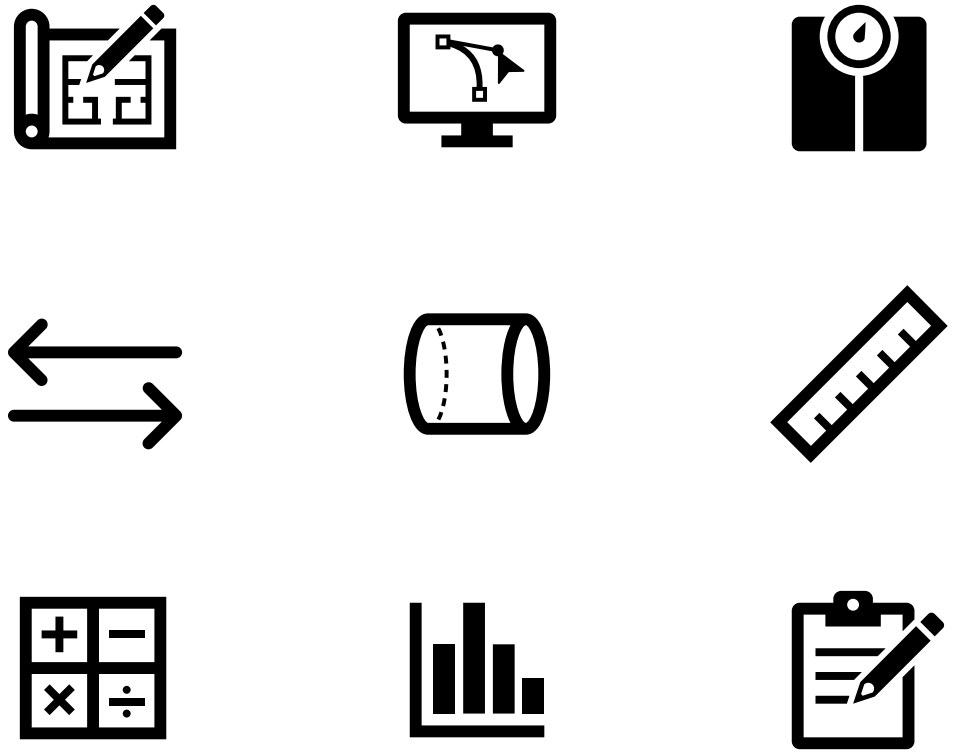
- Improved process safety and protection of the pipeline system
- Safeguard employees, the public and environment from system failures
- Increase personnel productivity
- Government regulations

Pipeline SCADA/Telemetry

Where?



Measurement System Design

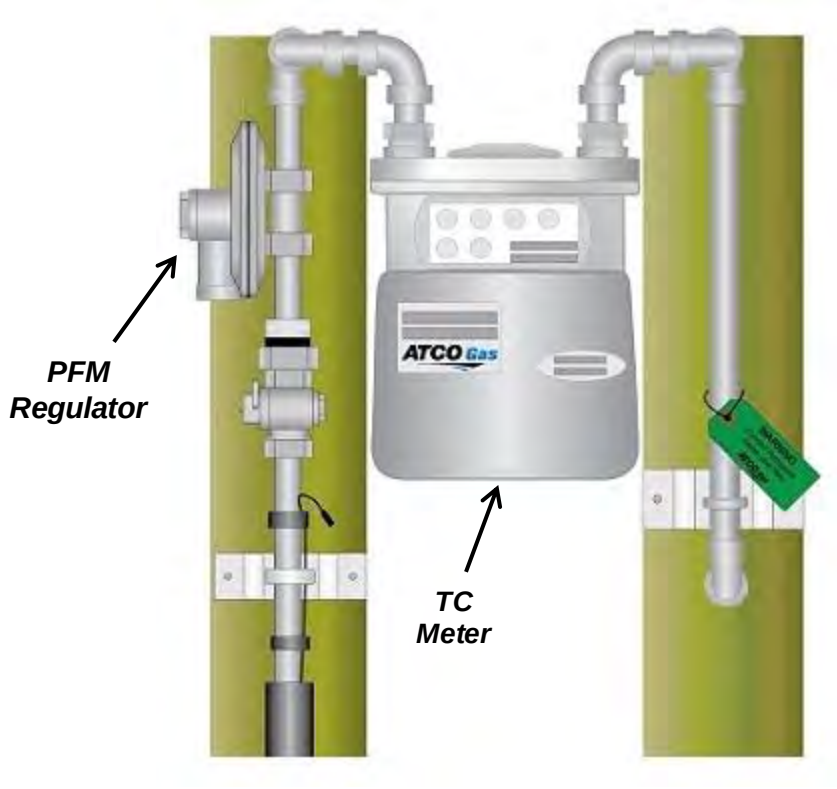


Measurement System Design

Small Delivery Point - Pressure Factor Metering (PFM)

- There are two primary components, a meter and a regulator
- The meter corrects for gas temperature, either mechanically or electronically, providing a readout that requires a simple pressure correction
- Approved regulator constantly and precisely maintains pressure to a set value used in determining the pressure correction factor to apply in the gas accounting system

$$Fp = \frac{Patm + Pgauge}{Pbase}$$



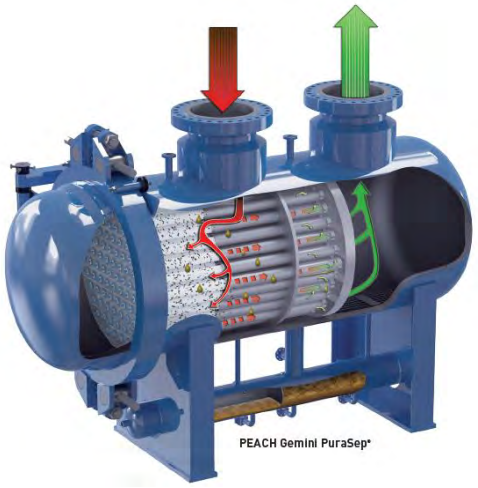
Measurement System Design

Large Meter Station

- Multi run stations
- Electronic flow measurement
- Automatic run staging
- Check metering
- Multi stream gas chromatographs, H_2S, H_2O analyzers
- Control RTUs
- Communication networks

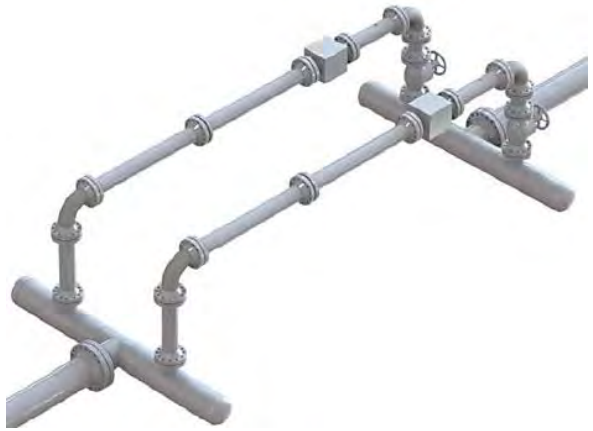
Measurement System Design

Primary Components



Gas Filtration/Separation

Removes contaminants to protect equipment and help ensure accurate measurement



Inlet Header

Designed to allow minimal installation effects upstream of meters

Meter Run Isolation Valves

Allows meter runs to be isolated for maintenance and automatic run staging, provides emergency shutdown capability and flow control if needed

Measurement System Design

Primary Components

Flow Conditioner

Removes majority of swirl and velocity profile asymmetry which causes increased meter uncertainty

Meter

Measures the actual volumetric or mass flow rate which will need to be corrected to base conditions

Transmitters

Measures the meter differential pressure (if required) and the static pressure and temperature of the gas for corrected volume calculations

Measurement System Design

Primary Components

Gas Chromatograph

Analyzes and reports the gas composition used for volume and energy calculations

H_2S/H_2O Analyzers

Analyzes and reports the level of undesirable gas contaminants

Electronic Flow Computer

Performs real time volume and energy calculations (at least once per second), historizes hourly and daily totals, and provides local control functionality

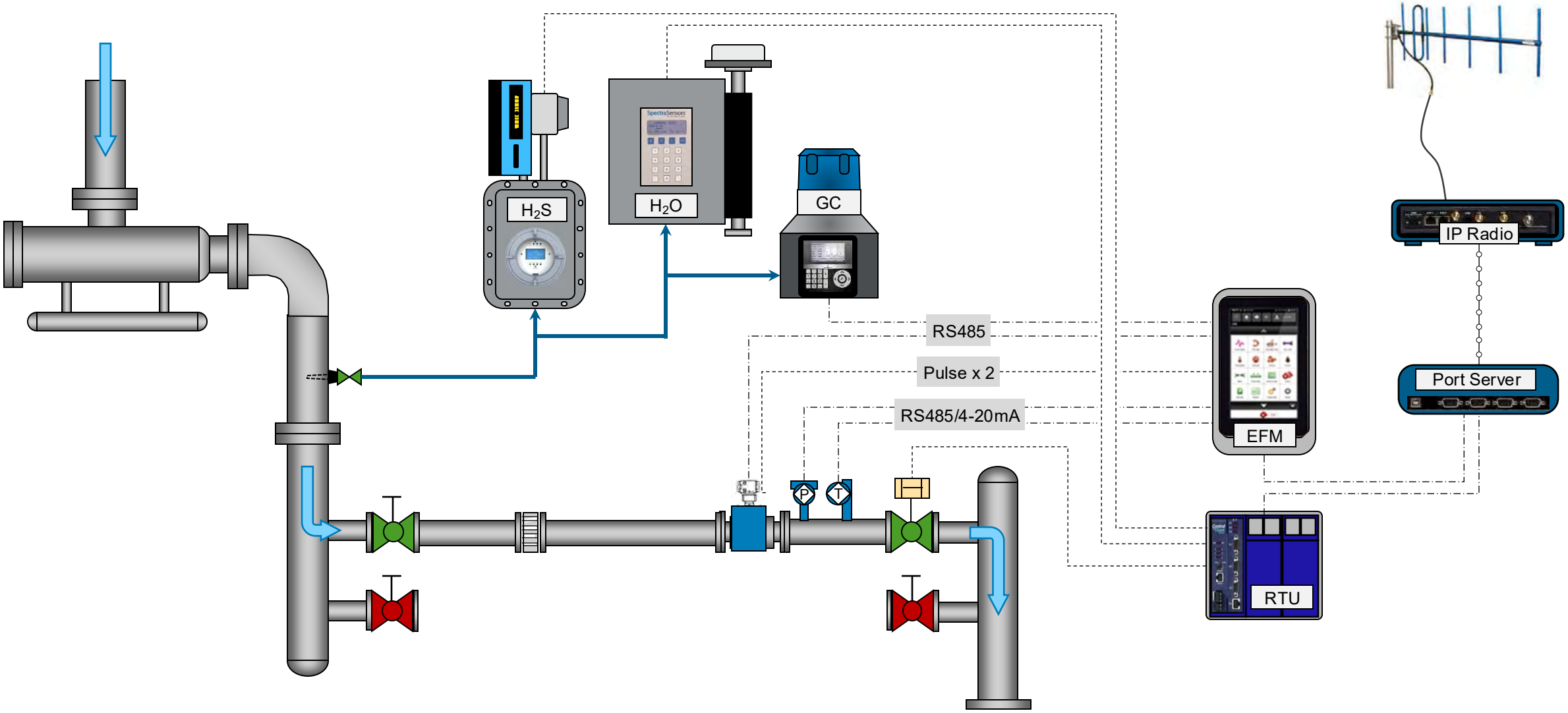
Measurement System Design

Primary Components

Network/Communications

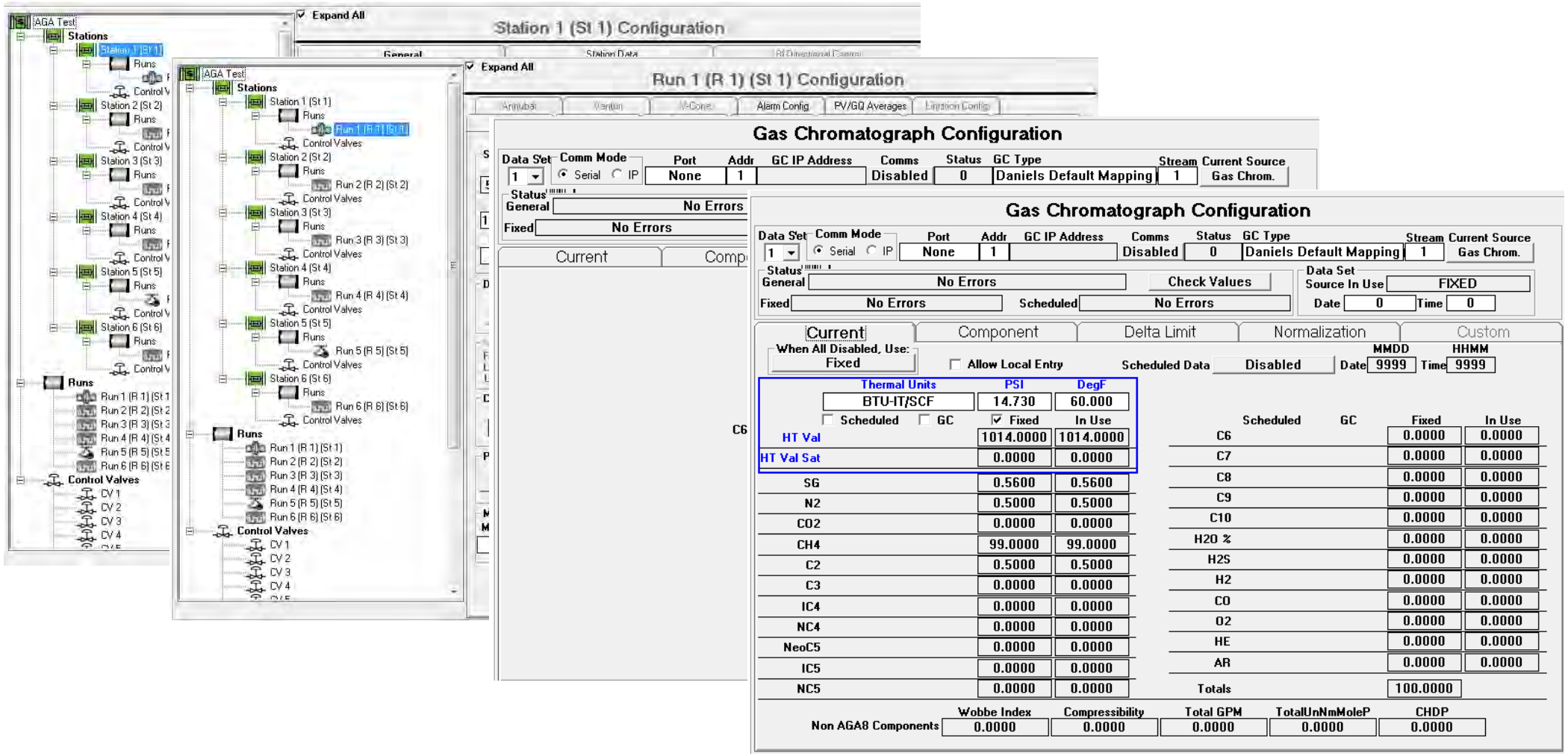
Networks on-site devices and transmits data to centralized SCADA host

Measurement System Layout

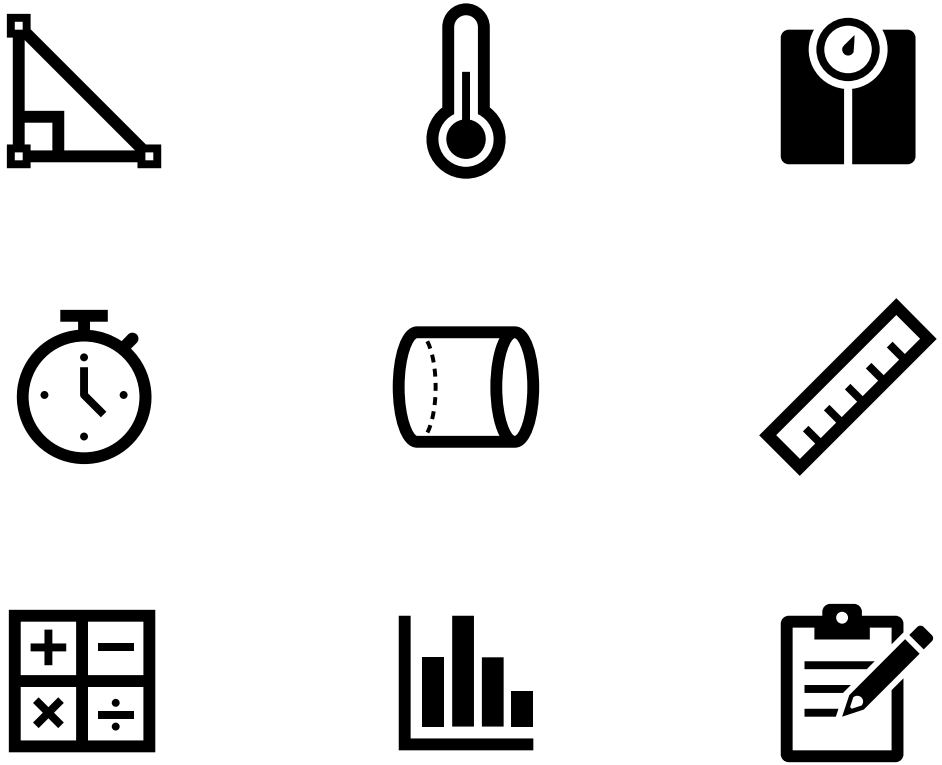


Navigating EFM/RTU Screens

Manufacturer Specific



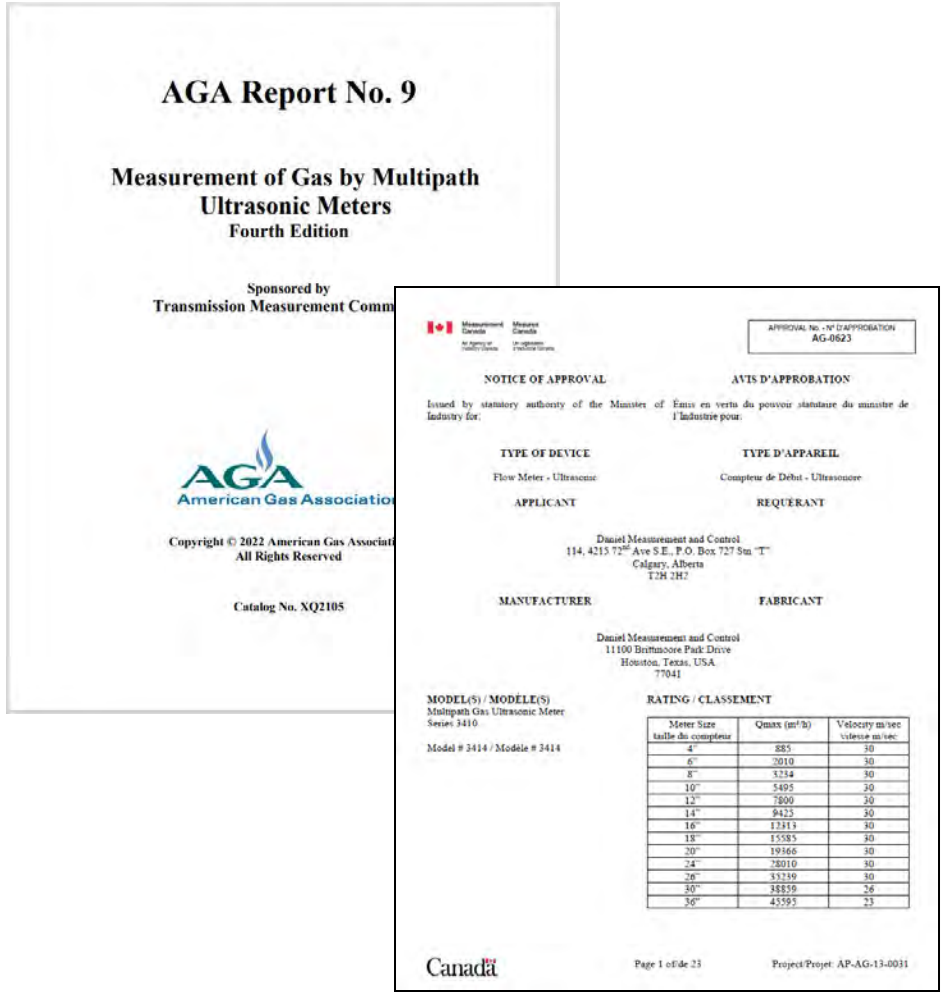
Meter Types – Application and Theory



Meter Types – Application and Theory

Ultrasonic Meter (USM) Application

- Inferential type meter that measures fluid velocity and outputs a volumetric flow rate in pulses
- Generally suited to applications where high turndown capability and low uncertainty are desired
- Wide range of sizes available from 4” to 48”
- Measurement Canada (MC) Notice of Approval (NOA) required for fiscal use
- Install per requirements of American Gas Association (AGA) Report No. 9 and the MC NAO



AGA Report No. 9

Measurement of Gas by Multipath Ultrasonic Meters

Fourth Edition

Sponsored by

Transmission Measurement Comm

AGA American Gas Associatio

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Catalog No. XQ2105

APPROVAL No. - N° D'APPROBATION
AG-0623

NOTICE OF APPROVAL — AVIS D'APPROBATION

Issued by statutory authority of the Minister of Industry for: — Émis en vertu du pouvoir statutaire du ministre de l'Industrie pour:

TYPE OF DEVICE — TYPE D'APPAREIL

Flow Meter - Ultrasonic — Compteur de Débit - Ultrasonore

APPLICANT — REQUÉRANT

Daniel Measurement and Control
114, 4215 72nd Ave S.E., P.O. Box 727 Stn "T"
Calgary, Alberta
T2H 2H2

MANUFACTURER — FABRICANT

Daniel Measurement and Control
11100 Brittmoore Park Drive
Houston, Texas, USA
77041

MODEL(S) / MODÈLE(S)
Multipath Gas Ultrasonic Meter Series 3410

Model # 3414 / Modèle # 3414

RATING / CLASSEMENT

Meter Size taille du compteur	Qmax (m³/h)	Velocity m/sec vitesse m/sec
4"	885	30
6"	2010	30
8"	3254	30
10"	5495	30
12"	7800	30
14"	9423	30
16"	12413	30
18"	15585	30
20"	19166	30
24"	28010	30
26"	33739	30
30"	38859	26
36"	45595	23

Canada

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Project/Projet: AP-AG-13-0031

Meter Types – Application and Theory

USM Application

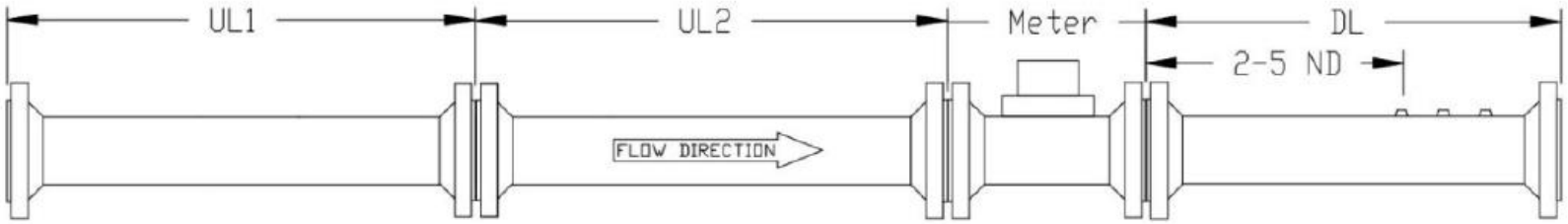
- Advantages
  - Turndown ratios up to 100:1 *(limited to 35:1 by NOA)*
  - Very low measurement uncertainty *(~+/-0.25%)*
  - Low maintenance
  - Bi-directional capability *(reduced capital costs)*
  - Highly reliable, no moving parts
  - Negligible pressure drop *(lower compression costs)*
  - Sophisticated diagnostic capabilities *(determine meter health and alert on process abnormalities)*
  - Multiple manufacturers with MC approved models
- Disadvantages
  - High capital and calibration costs
  - Straight pipe requirements for installation

Meter Types – Application and Theory

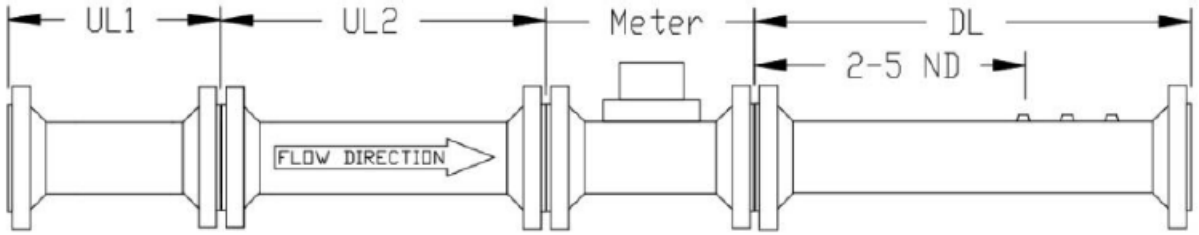
USM Application

- AGA 9 Installation Options

1. $UL_1 = UL_2 = 10ND$, manufacturer specified flow conditioner



2. UL_1 = manufacturer specified, UL_2 = manufacturer specified, manufacturer specified flow conditioner

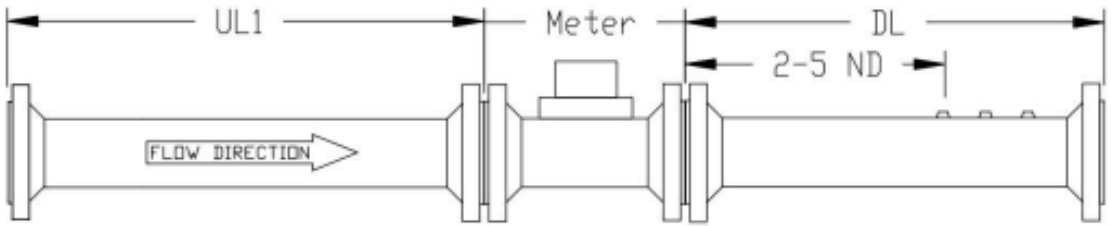


Meter Types – Application and Theory

USM Application

- AGA 9 Installation Options

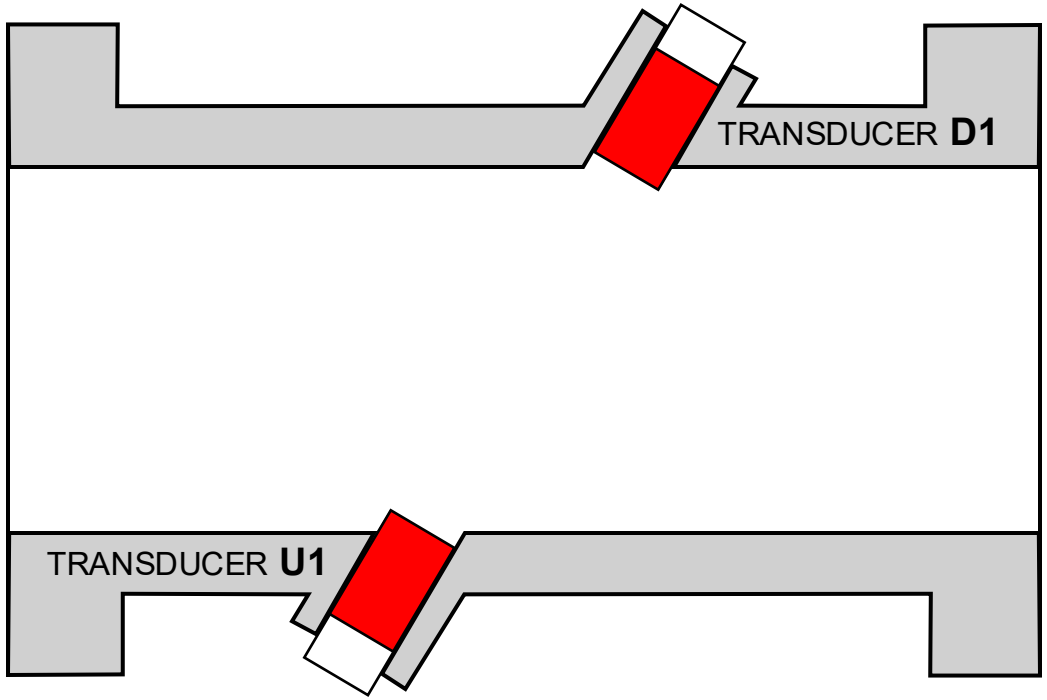
3. UL_1 = manufacturer specified, UL_2 = manufacturer specified, no flow conditioner



Meter Types – Application and Theory

USM Operational Theory

- Operates on the transit time measurement principle
- Two opposing transducers, angled relative to the fluid flow direction, send and receive ultrasonic pulses between each other

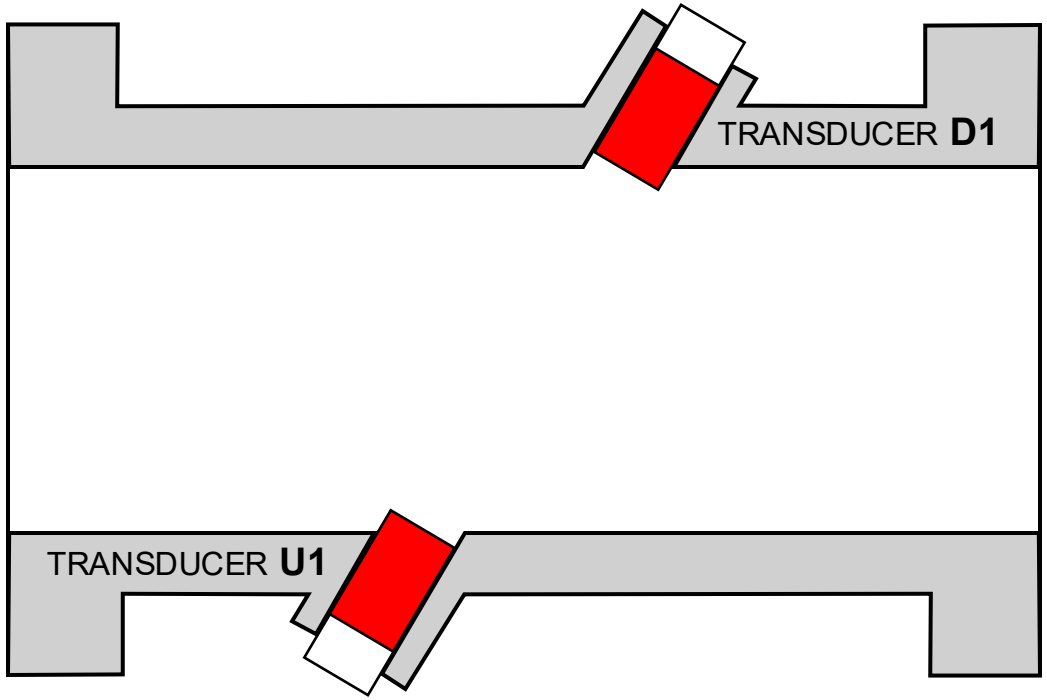


Meter Types – Application and Theory

USM Operational Theory

- At zero flow it takes the same time for a pulse to travel from TU1 to TD1 and from TD1 to TU1

$$t_{U1 \rightarrow D1} = t_{D1 \rightarrow U1}$$

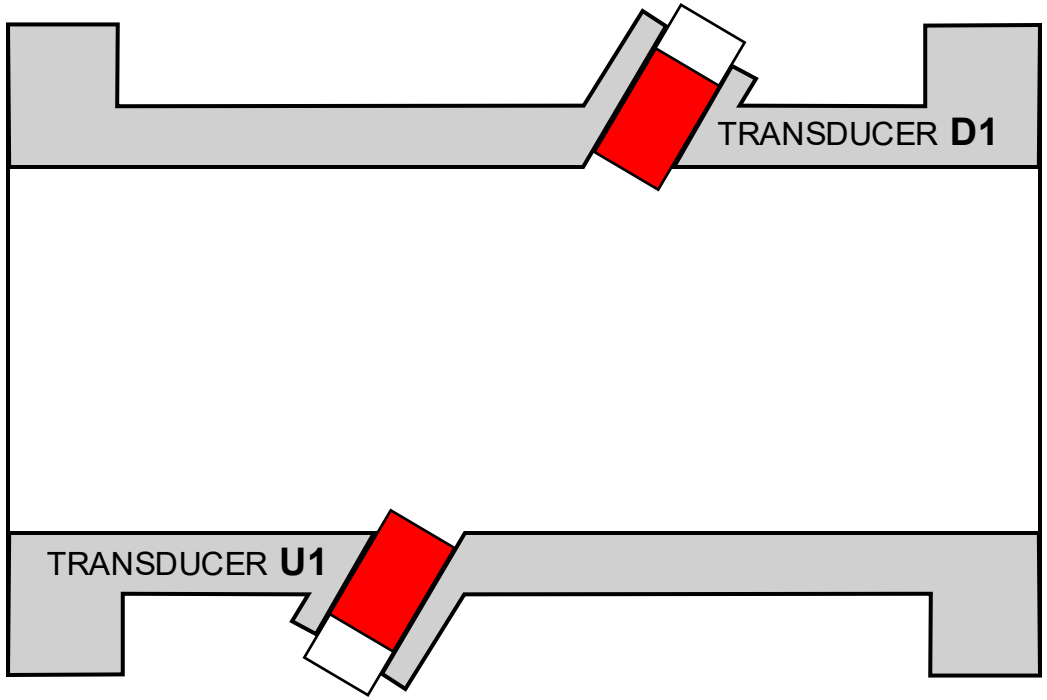


Meter Types – Application and Theory

USM Operational Theory

- With flow it takes less time for a pulse to travel from Transducer U1 to D1 than it does for a pulse to travel from Transducer D1 to U1

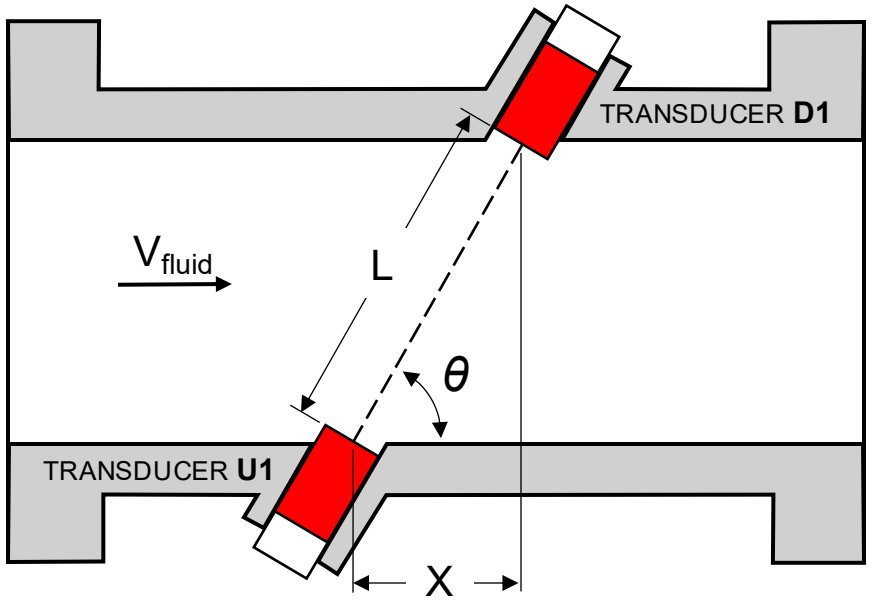
$$t_{U1 \rightarrow D1} < t_{D1 \rightarrow U1}$$



Meter Types – Application and Theory

USM Operational Theory

- Flow velocity calculations based on velocity equals distance over time
- Transit times are measured with nanosecond precision



$$t_{ud} = \frac{L}{C + V_i \cos\theta} \quad \textit{and} \quad t_{du} = \frac{L}{C - V_i \cos\theta}$$

Rearrange and substitute to solve for Vi

$$V_i = \frac{L}{2\cos\theta} \cdot \frac{t_{du} - t_{ud}}{(t_{ud})(t_{du})} = \frac{L^2}{2x} \cdot \frac{t_{du} - t_{ud}}{(t_{ud})(t_{du})}$$

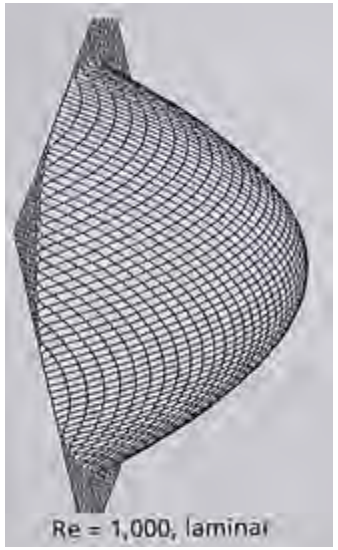
$$C = \frac{L}{2} \cdot \frac{t_{du} + t_{ud}}{(t_{ud})(t_{du})}$$

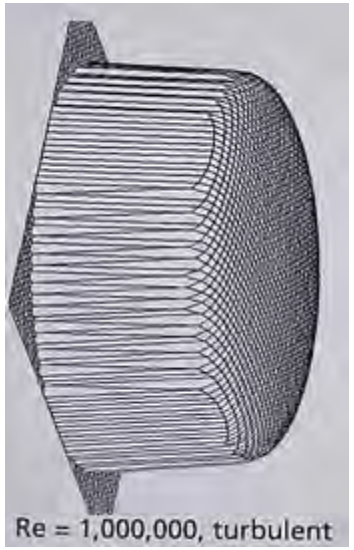
Where: t_{ud} = *transit time from U to D*
t_{du} = *transit time from D to U*
L = *transducer path length*
x = *transducer axial spacing*
C = *velocity of sound in still fluid*
V_i = *mean chordal velocity*
θ = *acoustic transmission angle*

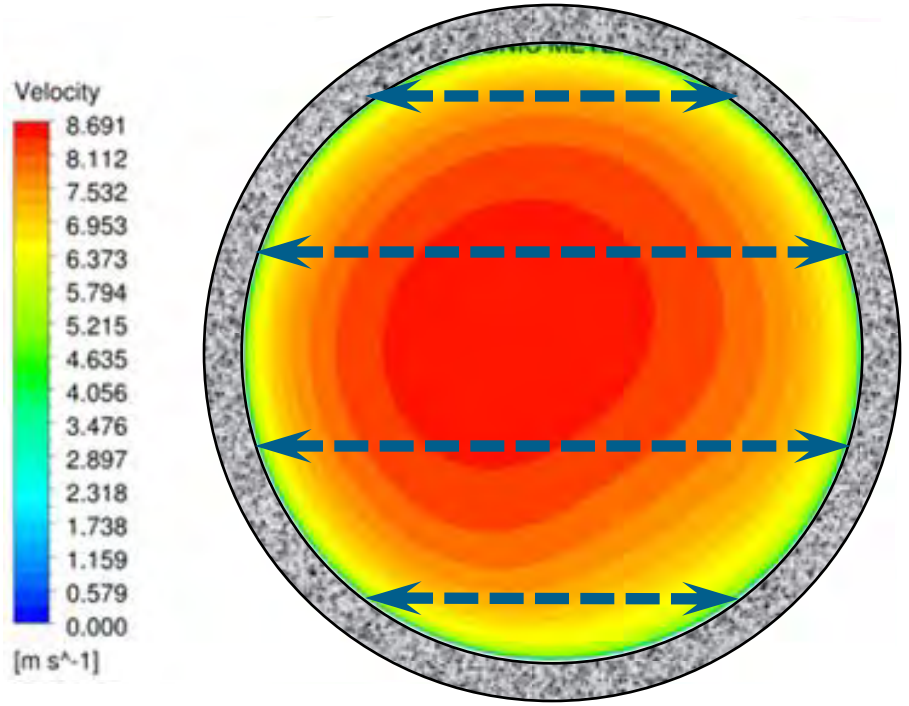
Meter Types – Application and Theory

USM Operational Theory

- Chordal velocities are measured at multiple locations and used to calculate a mean, or bulk, fluid velocity

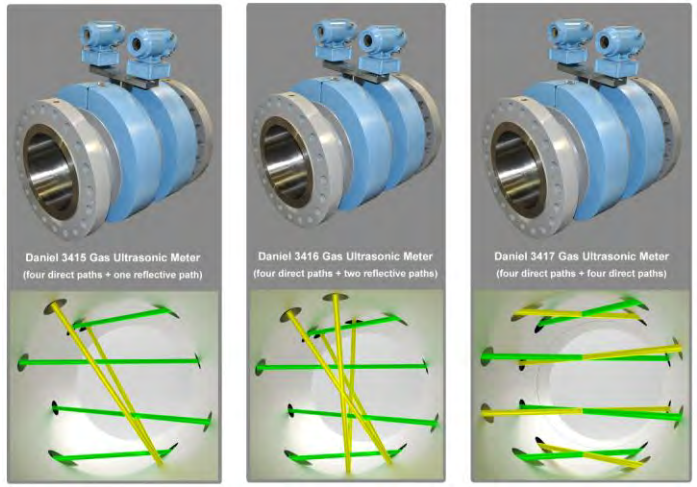


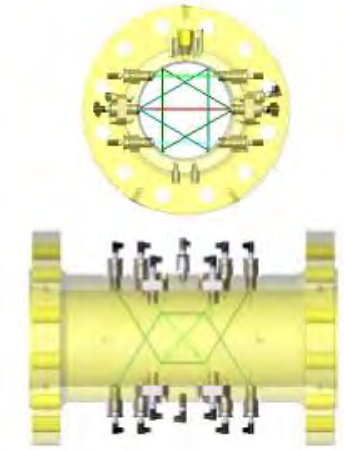


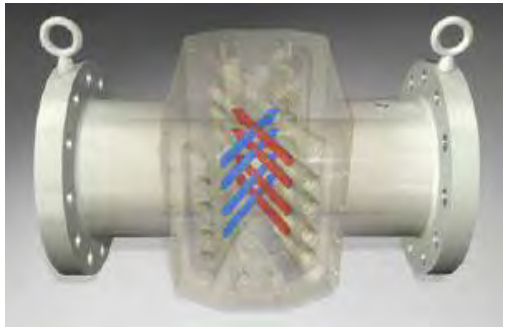


Meter Types – Application and Theory

USM Operational Theory



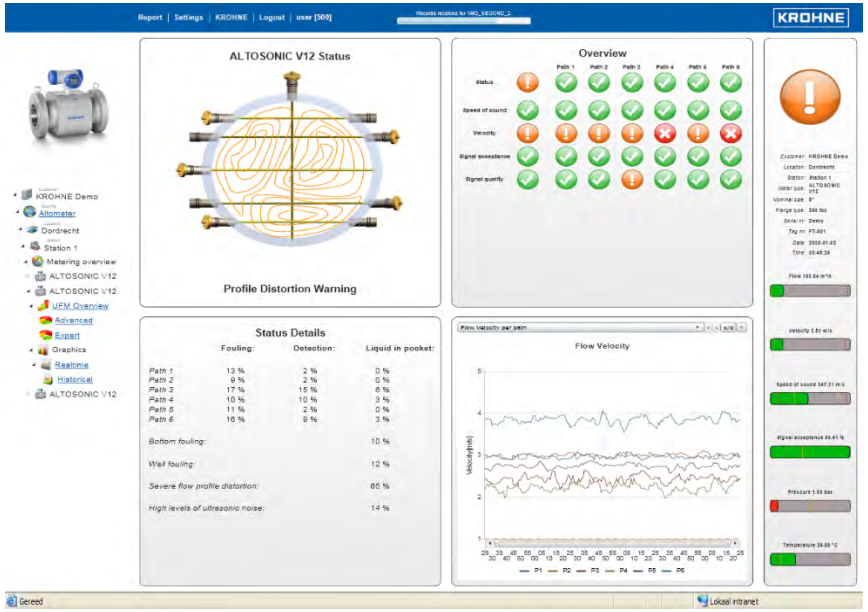




Meter Types – Application and Theory

USM Maintenance Checks

- Regular review of diagnostic data



- Periodic recalibration at a flow laboratory

Meter Types – Application and Theory

Coriolis Meter Application

- Mass type meter that provides a direct measurement of mass flow rate and density
- Generally suited to smaller size applications where high turndown capability and low uncertainty are desired
- MC NOA required for fiscal use, sizes limited from ¼” to 4”
- Install per requirements of American Gas Association (AGA) Report No. 11 and the MC NOA

Meter Types – Application and Theory

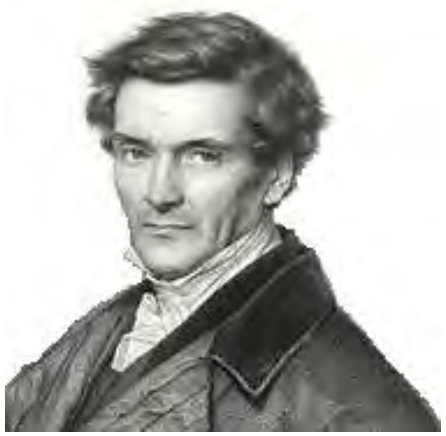
Coriolis Meter Application

- Advantages
  - Turndown ratios up to 60:1 *(limited by pressure drop)*
  - Very low measurement uncertainty *(~+/-0.25%)*
  - Low maintenance
  - Direct mass measurement *(No P&T compensation necessary)*
  - Bi-directional capability *(reduced capital costs)*
  - Highly reliable, no moving parts
  - No straight pipe requirements for installation *(reduced capital costs)*
  - Diagnostic capabilities *(determine meter health and alert on process abnormalities)*
- Disadvantages
  - Potential high pressure drop
  - Only one manufacturer with MC approved gas models
  - High capital and intermediate calibration costs

Meter Types – Application and Theory

Coriolis Meter Operational Theory

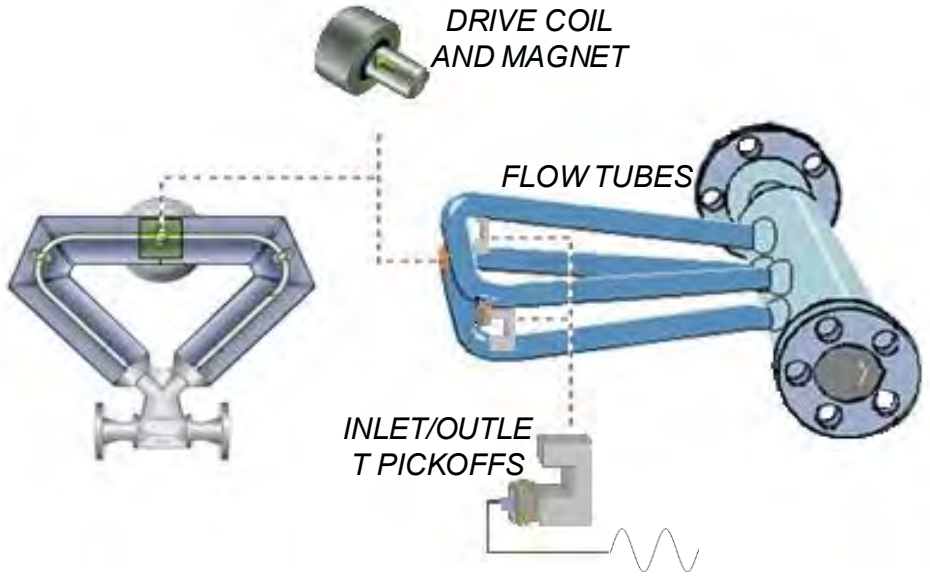
- The Coriolis effect was first described in 1835 by Gaspard-Gustave de Coriolis, a French mathematician and engineer
- In physics, the Coriolis force is an apparent force that seems to act on objects that are in motion within a frame of reference that is rotating with respect to the inertial frame of reference
- Meter is based on the principle that inertia created by the fluid flow causes two vibrating parallel tubes to twist proportional to the mass flow rate



Meter Types – Application and Theory

Coriolis Meter Operational Theory

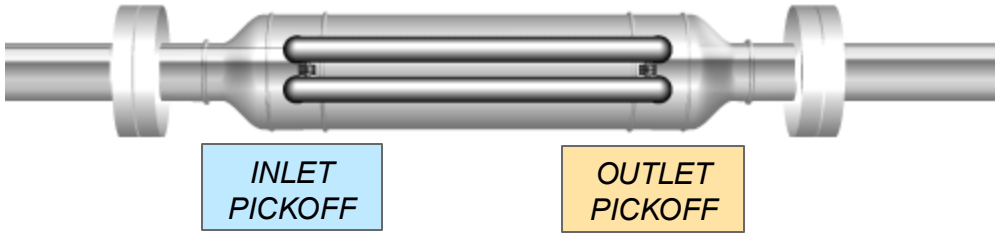
- Fluid is split equally at the meter inlet and sent through two flow tubes
- Drive coil forces the flow tubes to vibrate at their resonant frequency
- Tube oscillation is sensed at each end of the flow tubes with magnetic pickups

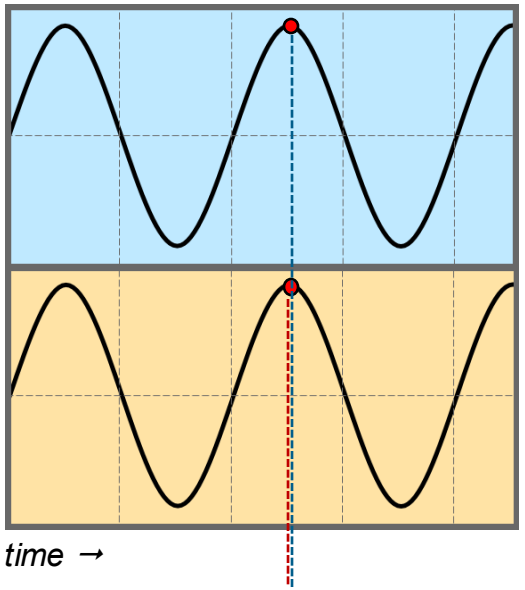


Meter Types – Application and Theory

Coriolis Meter Operational Theory

- With no flow, there is no Coriolis effect, the tubes will oscillate symmetrically, and the pickoffs will generate signals that are in phase with each other



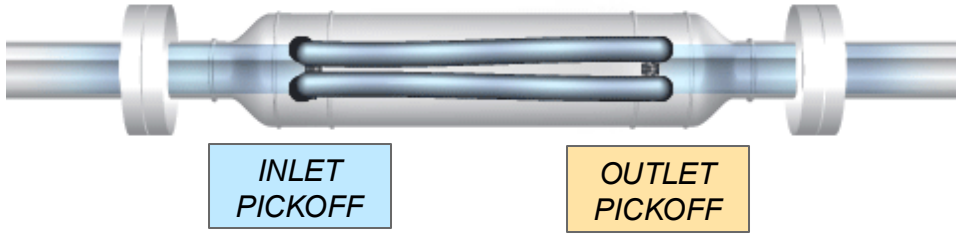


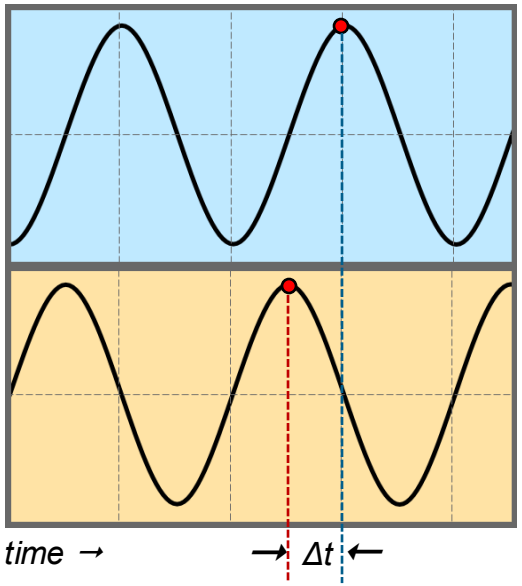
- The oscillations are extremely small and not seen with the naked eye

Meter Types – Application and Theory

Coriolis Meter Operational Theory

- With flow, Coriolis forces are induced, causing the tubes to twist in opposition to each other, and the pickoffs will generate signals that are out of phase with each other





- The phase shift (*Δt),* measured in micro seconds, is directly proportional to mass flow rate

Meter Types – Application and Theory

Coriolis Meter Maintenance Checks

- Scheduled Smart Meter Verifications
  - Enables checking the meter's health without taking it out of service
  - Diagnostics continuously monitor meter health to identify possible issues resulting from corrosion, erosion, over-pressurization, build-up and other sources of potential meter damage
- Periodic recalibration at a flow laboratory

Smart Meter Verification
Structural Integrity Method

Tuesday, December 12, 2017
17:18:27 PM

Instrument Owner: Bob Smith
Company: ABC Organization, Inc

Contact Name / Tested by: SS
Telephone: 123 456 7890

Transmitter Identification
Transmitter Tag: M. RESET
Transmitter Model: 2400S Analog
Transmitter Serial Number: ABCD
Core Processor Unique ID: 0123456

Sensor Identification
Sensor Model: CMF025+
Sensor Serial Number: 0123456

Flow Configuration
Flow Damping: 0.64000 Sec
Flow Calibration Factor: 5.00004.75
Mass Factor: 1.00000
Density Factor: 1.00000
Volume Factor: 1.00000
Factory Zero: 0.00000 µSec

Density Configuration
Density Damping: 0.64000 Sec
K1: 6445.17627 µSec
K2: 7566.00000 µSec
D1: 0.00100 g/cm3
D2: 0.99800 g/cm3

Test Definition
Test Name: Sample Test
Process Fluid: Empty
Note: Sample Screen Shot
Test Fluid:
Spec Uncertainty Limit: 4.00%

Sensor Operating Conditions
Mass Flow: 0.00000 g/sec
Volume Flow: 0.00000 l/sec
Density: 0.00000 g/cm3
Temperature: 22.27187 °C
External Pressure: 0.00000 PSI
Current Zero: 0.01897µSec

Test Condition
Configuration Changed: No
Zero Changed: No

Meter Verification Test Results
Meter Verification: **PASS**
Meter Verification Counter: 22

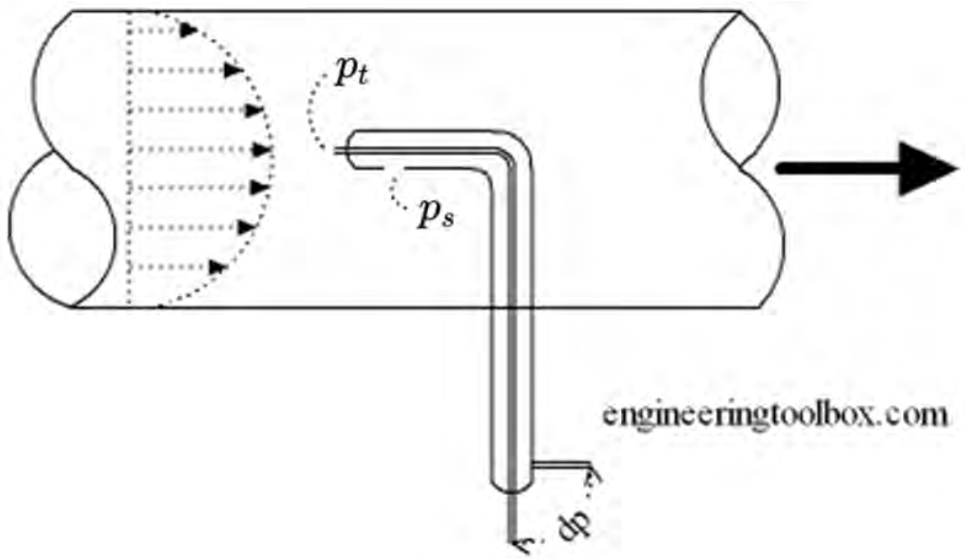
Micro Motion

EMERSON

Meter Types – Application and Theory

Pitot Tube

- Differential pressure device used to measure fluid flow velocity
- Heavily used in the aviation and boating industry to measure velocity
- Provides a single point velocity measurement, not a bulk velocity
- Not approved for custody transfer, used mostly for process measurements



$$u = \sqrt{\frac{2(p_t - p_s)}{\rho}}$$

Meter Types – Application and Theory

Annubar

- Insertion style meter with rugged design that withstands extreme conditions
- Averaging design reduces uncertainty associated with single point measurement
- Available as a fully integrated meter
- Low obstruction with little permanent pressure loss
- Used for process measurements, not approved for custody transfer
- Not suitable for dirty or sticky fluids

Questions?

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