



สถาบันมาตรวิทยาแห่งชาติ
National Institute of Metrology (Thailand)



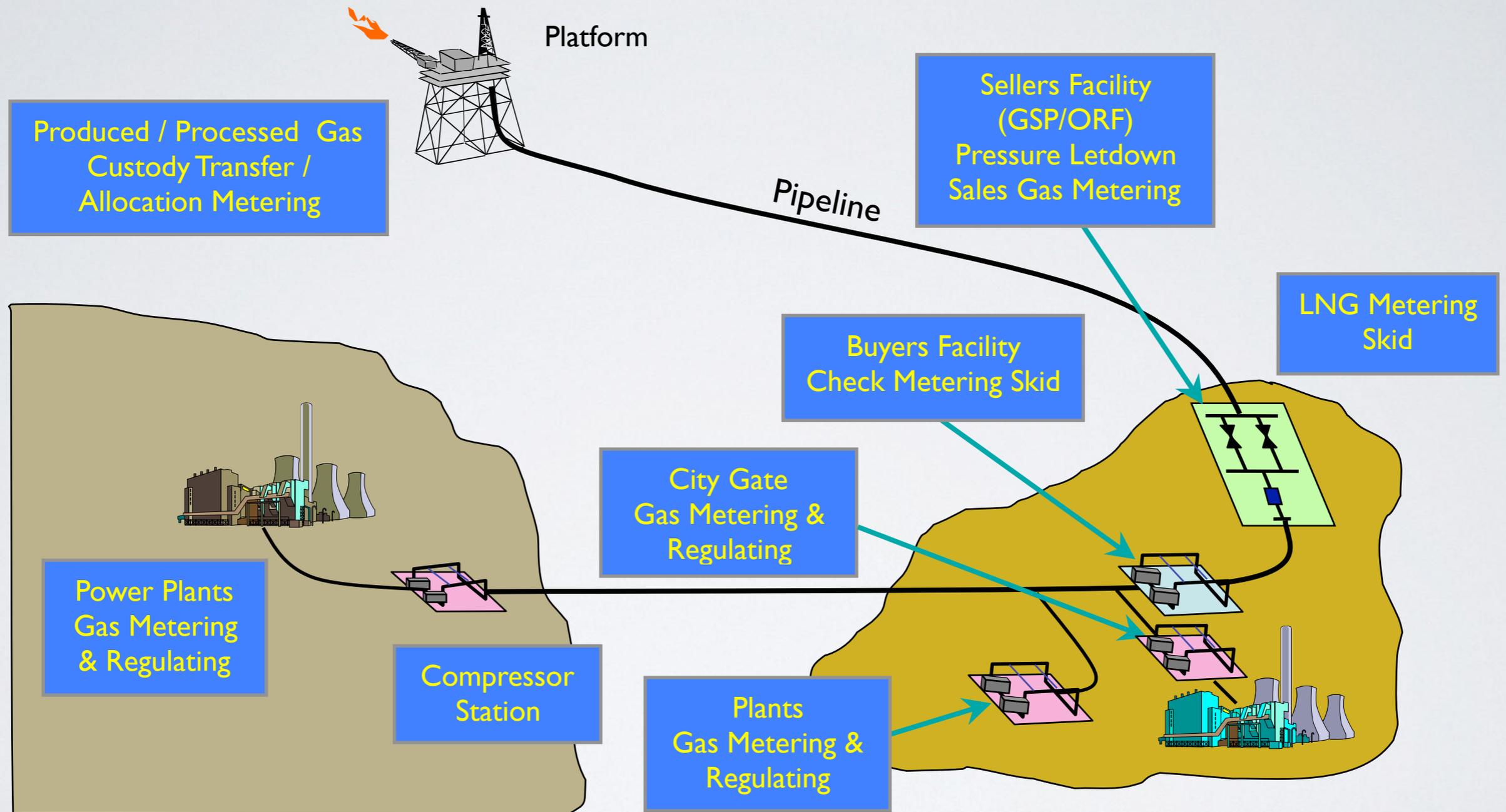
การวัดเพื่อการซื้อขายก๊าซธรรมชาติ

Flow metrology day "we go together"

19 ธันวาคม 2560 สถาบันมาตรวิทยาแห่งชาติ

- ▶ Typical Gas Process Flow Diagram
- ▶ โครงข่ายระบบท่อส่งก๊าซธรรมชาติ ในประเทศไทย
- ▶ Gas Regulating & Metering station
- ▶ Gas Measurement
 - ▶ Meter
 - ▶ Field Instrument
 - ▶ Equipment Maintaining
 - ▶ Gas RealTime Measurement (GRTM)

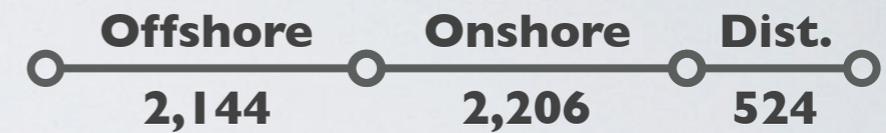
Typical Gas Process Flow Diagram



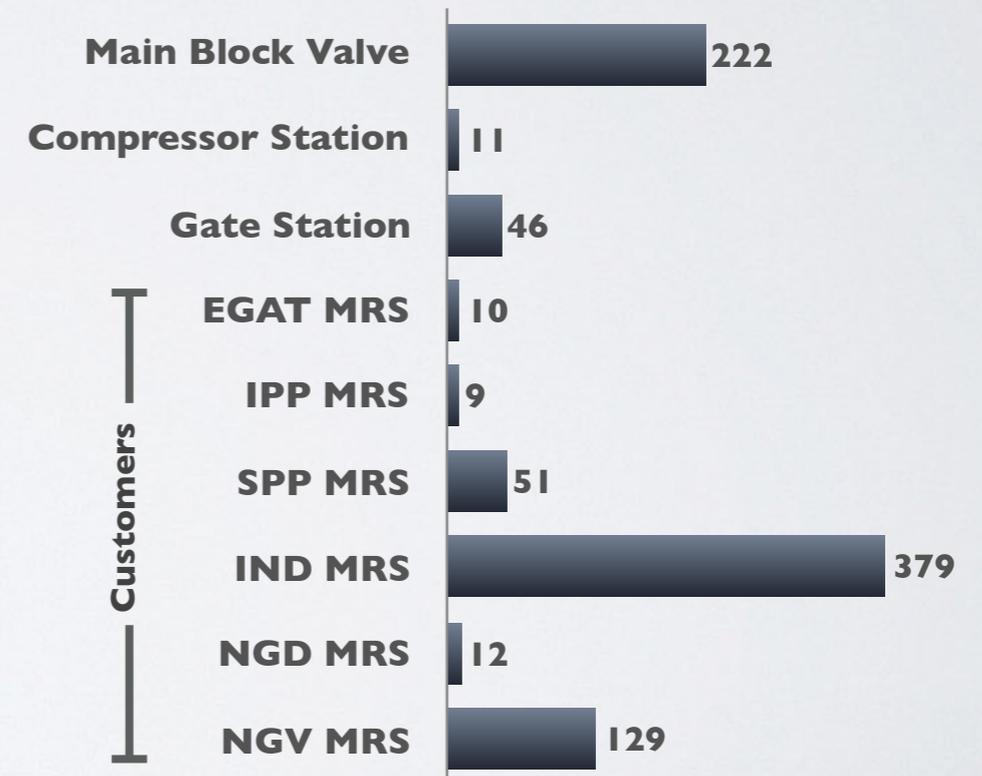
โครงข่ายระบบท่อส่งก๊าซธรรมชาติในประเทศไทย



ความยาวท่อส่งก๊าซธรรมชาติ (กม.)



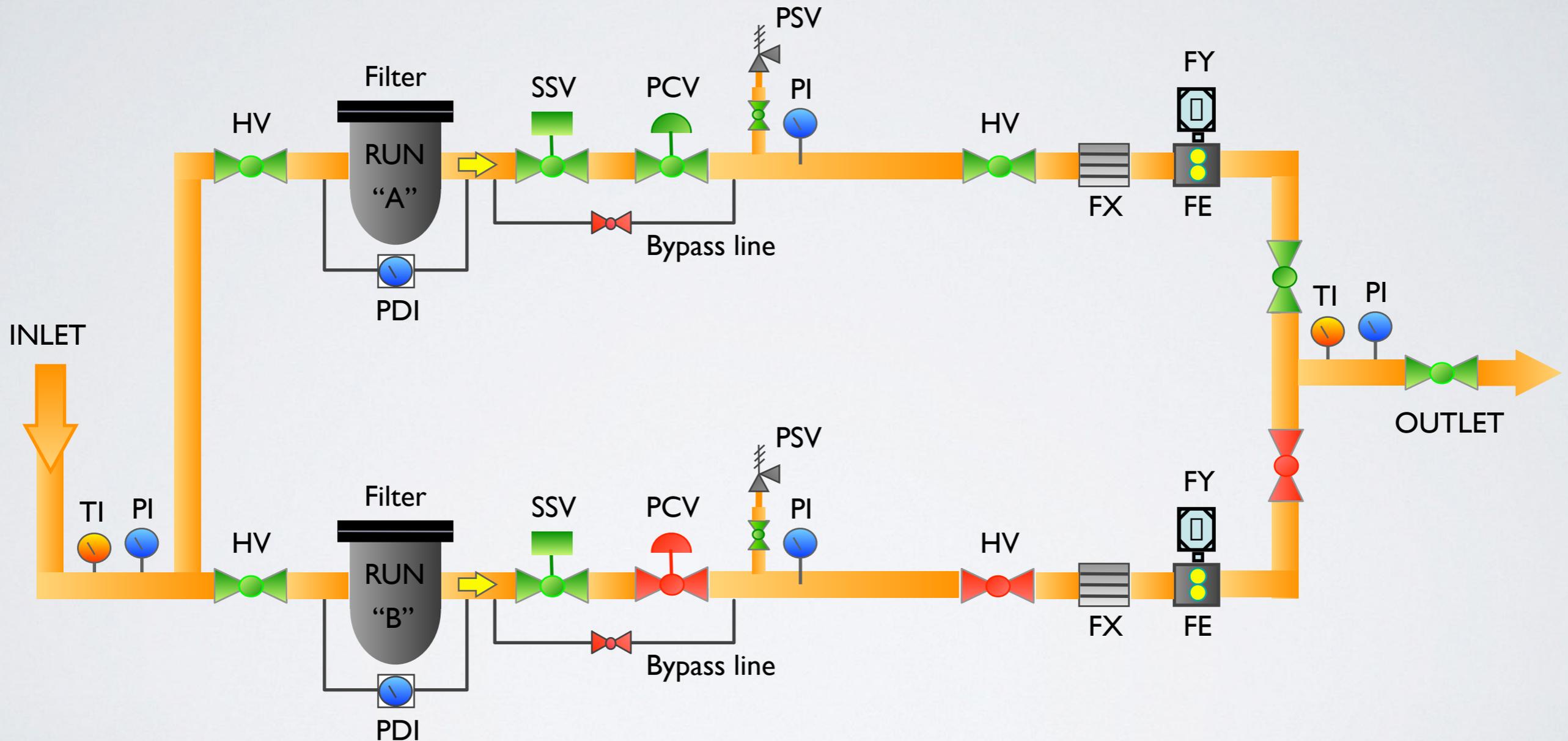
จำนวนสถานีก๊าซธรรมชาติ



GAS REGULATING & METERING STATION

Gas Regulating & Metering Station

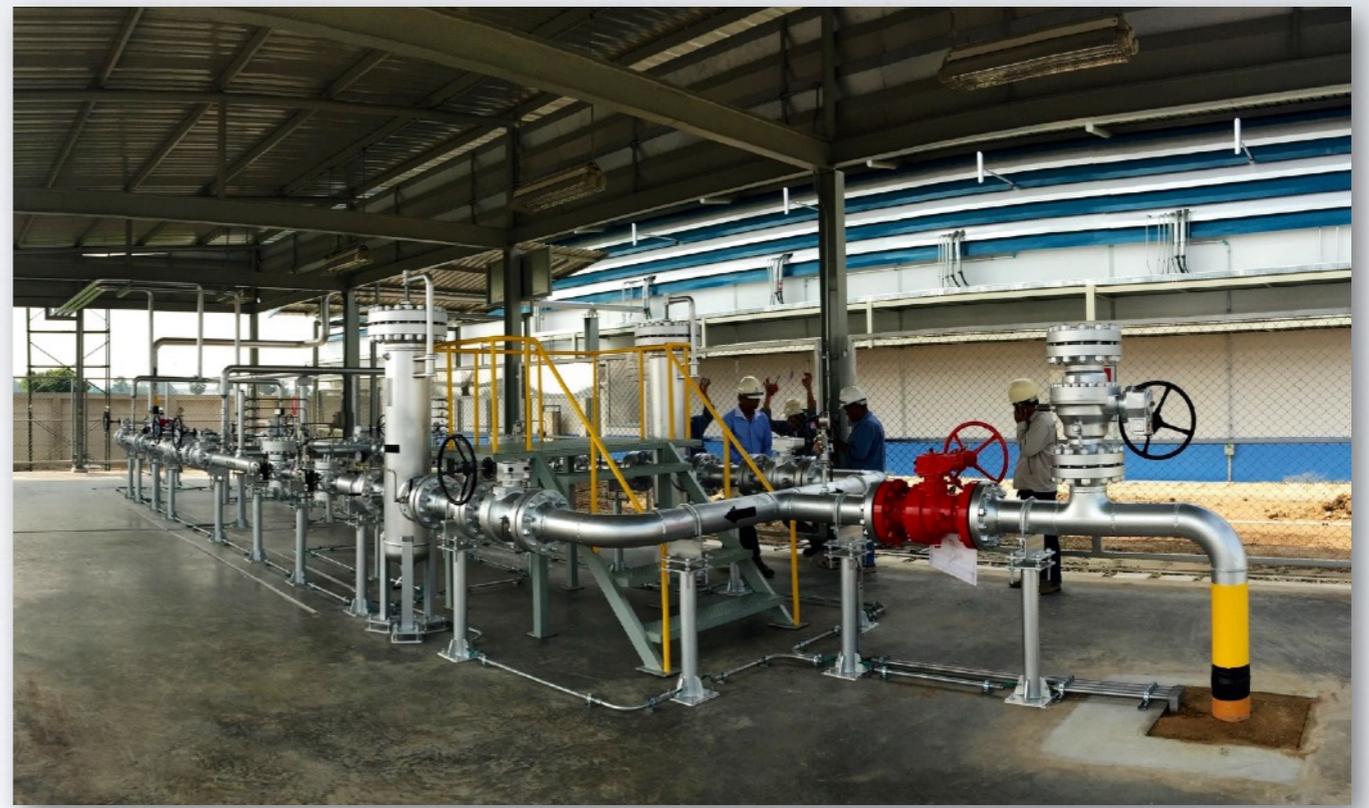
Industrial & NGV



Gas Regulating & Metering Station

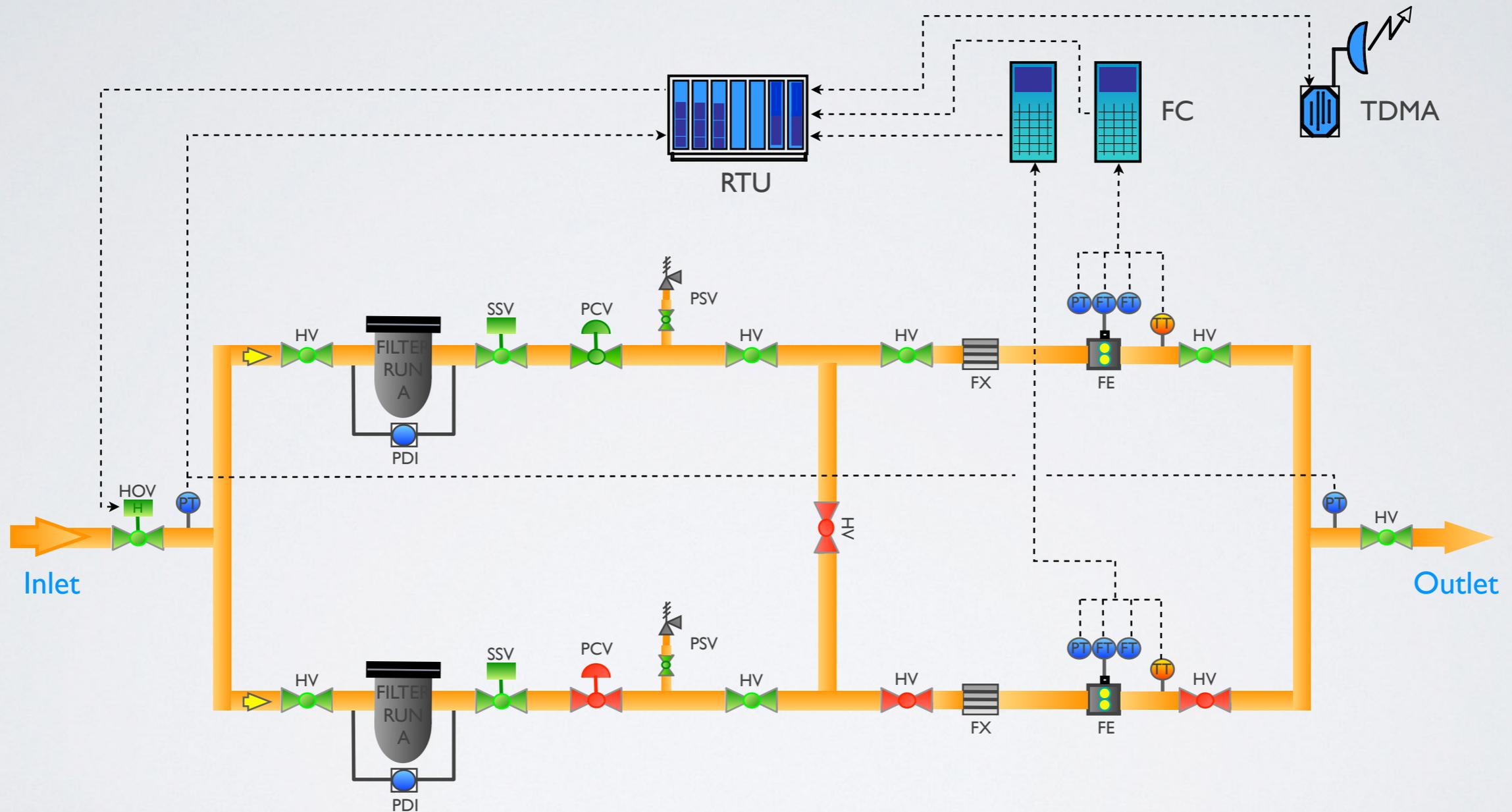


Industrial & NGV



Gas Regulating & Metering Station

Small Power Producer (SPP)

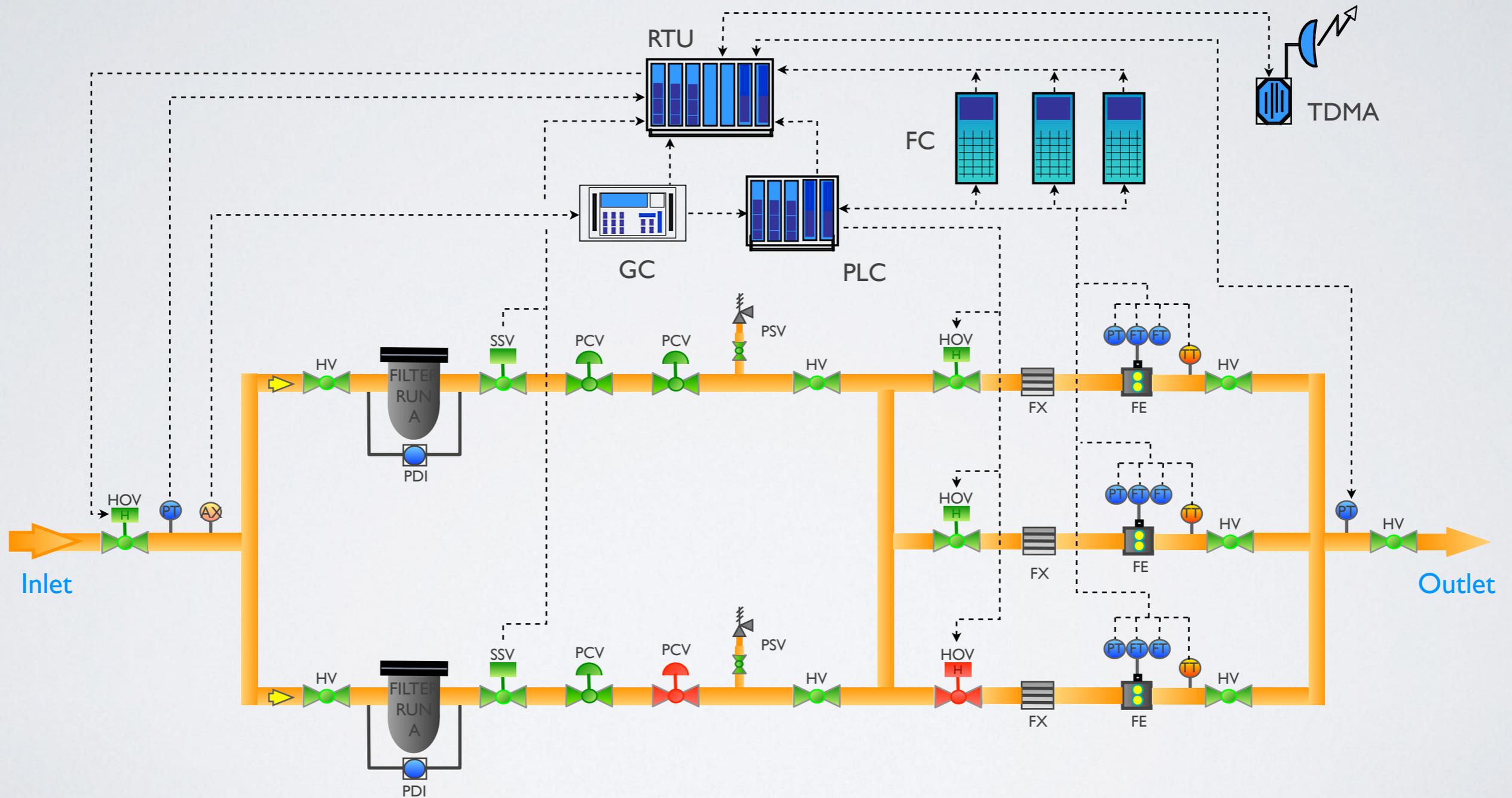


Small Power Producer (SPP)



Gas Regulating & Metering Station

Independent Power Producer (IPP)



Gas Regulating & Metering Station

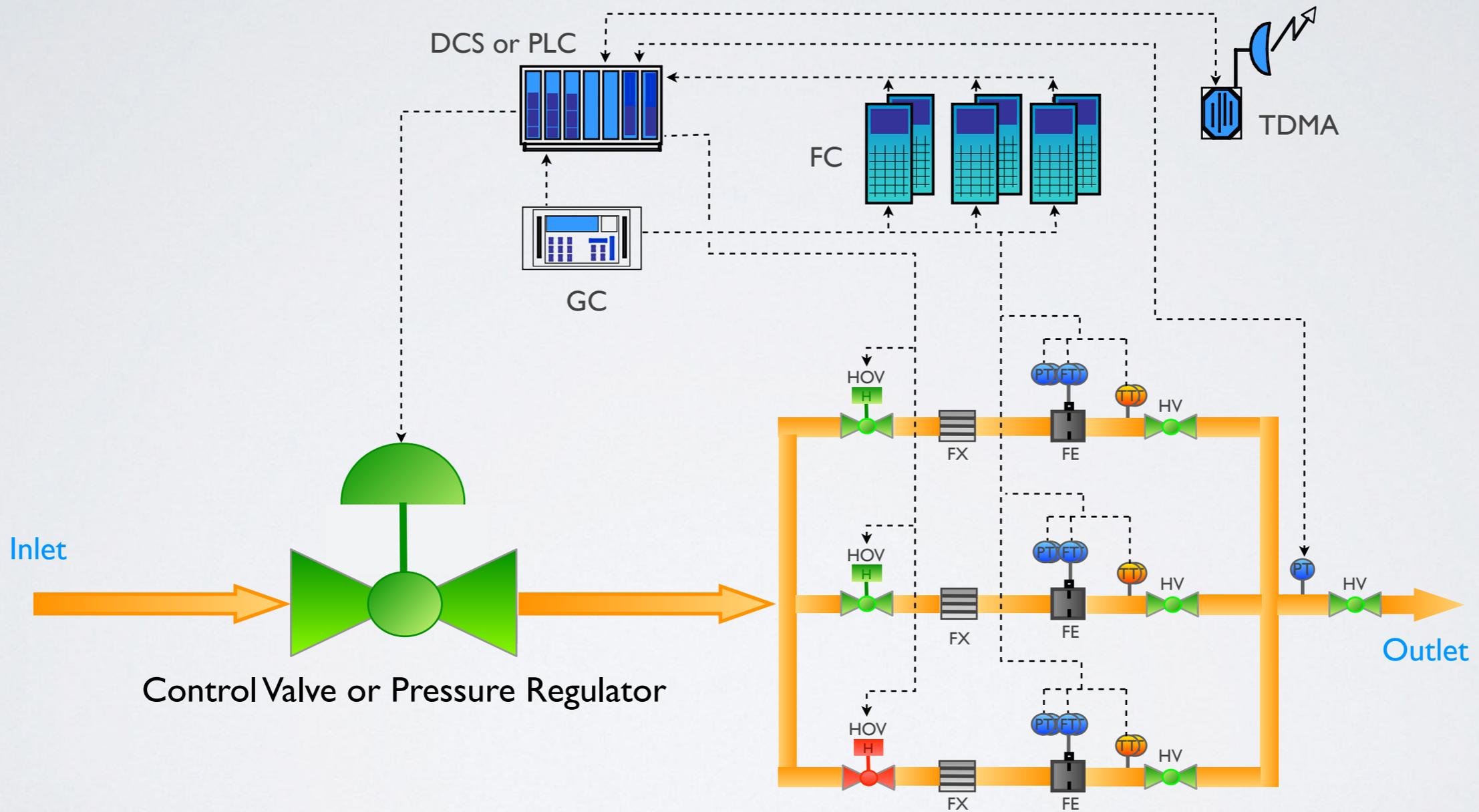


Independent Power Producer (IPP)



Gas Regulating & Metering Station

Electricity Generating Authority of Thailand (EGAT)



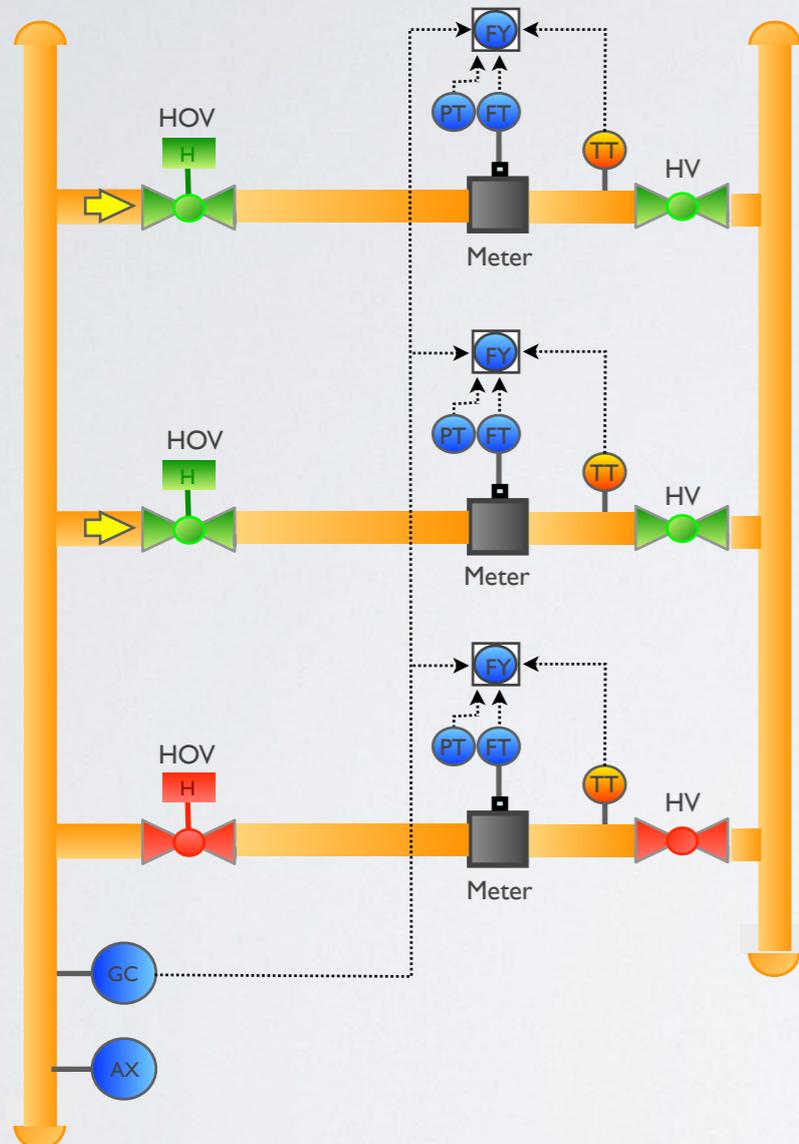
Gas Metering Station



Electricity Generating Authority of Thailand (EGAT)



GAS MEASUREMENT DEVICE



The value of sale gas is its energy, not only volume, so to measure the gas we have to measure both quantity and quantity of gas.

$$\text{ENERGY} = \text{VOLUME} \times \text{HEATING VALUE}$$

Gas is a compressible or expansible fluid. Volume of the same amount of gas can be different in different condition.

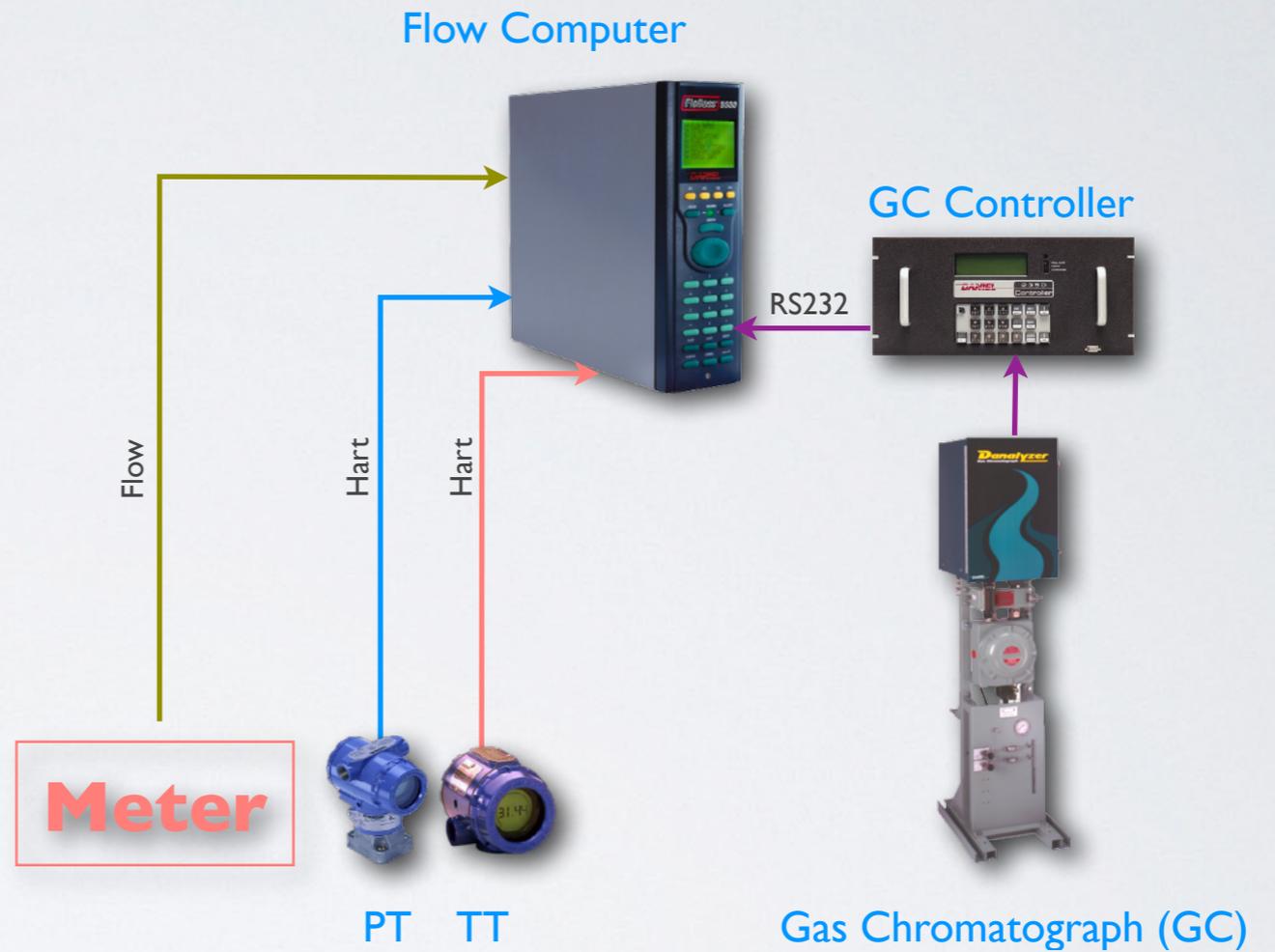
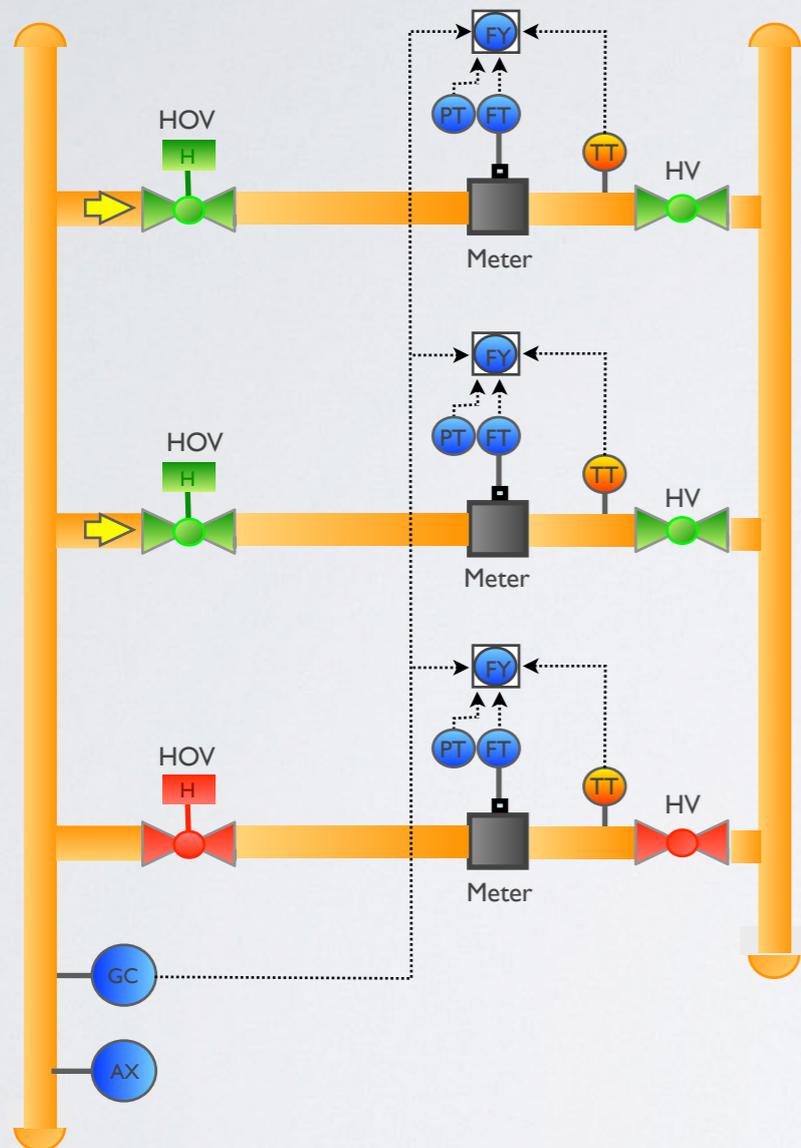
$$PV = znRT$$

To use the same condition we convert volume from actual condition to base condition.

PTT use base condition at $P = 14.73 \text{ PSIA}$, $T = 60 \text{ F}$.

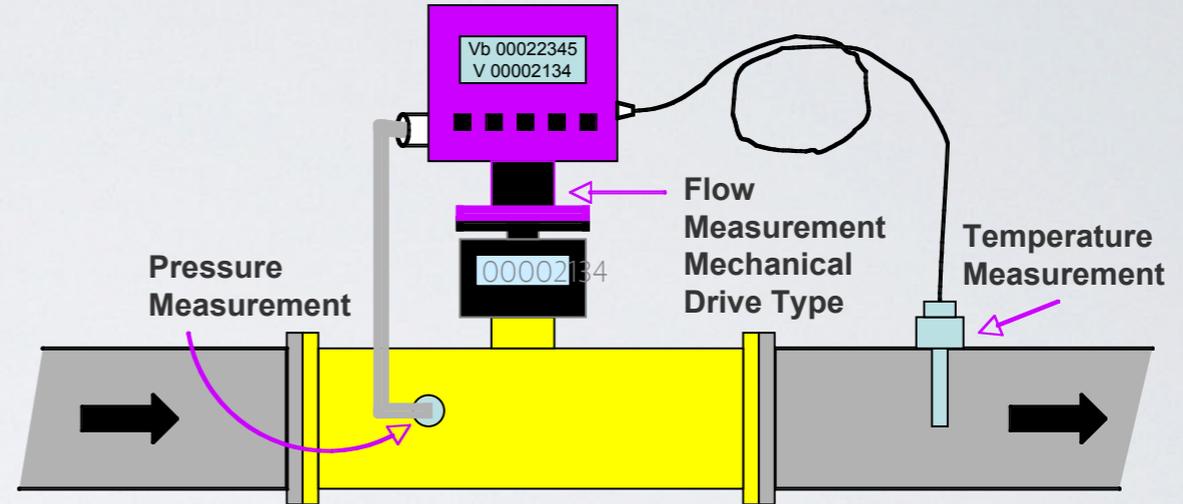
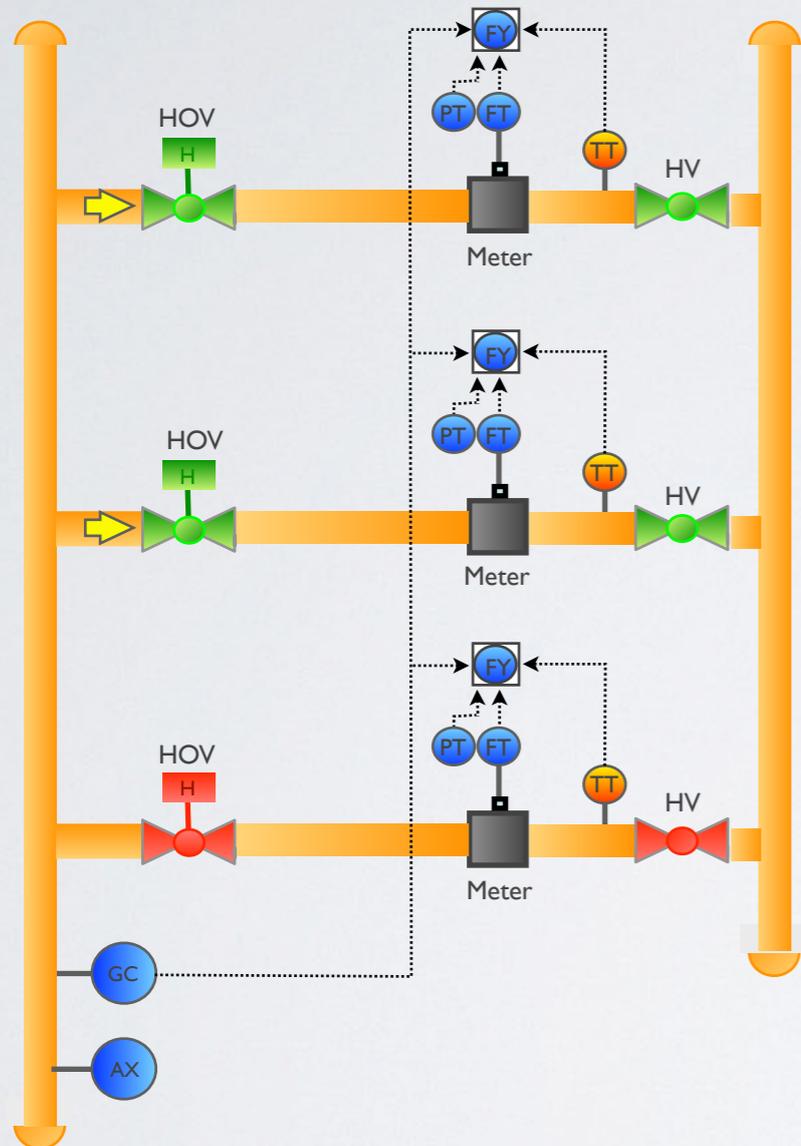
$$V_b = V_f \left(\frac{P_f}{P_b} \right) \left(\frac{T_b}{T_f} \right) \left(\frac{Z_b}{Z_f} \right)$$

Gas Measurement Device (อุปกรณ์ตรวจวัดซื้อขายก๊าซ)



Source: emerson.com

Gas Measurement Device (อุปกรณ์ตรวจวัดซื้อขายก๊าซ)



Source: emerson.com

GAS MEASUREMENT DEVICE - METER

Volume Measurement - Meter



Orifice Meter



Turbine Meter



Diaphragm



Rotating vane



Rotary

Positive Displacement Meter



Vortek Meter

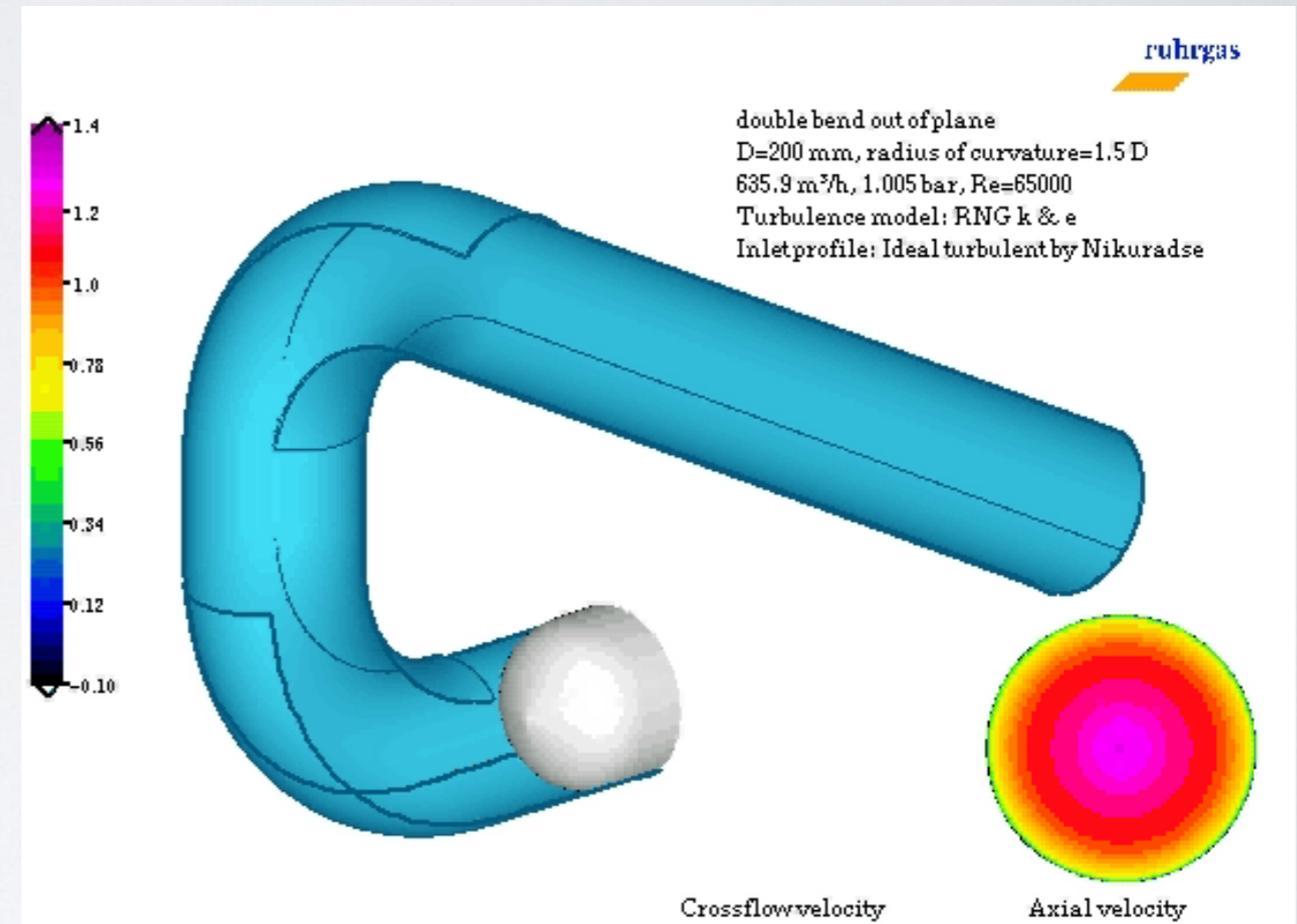
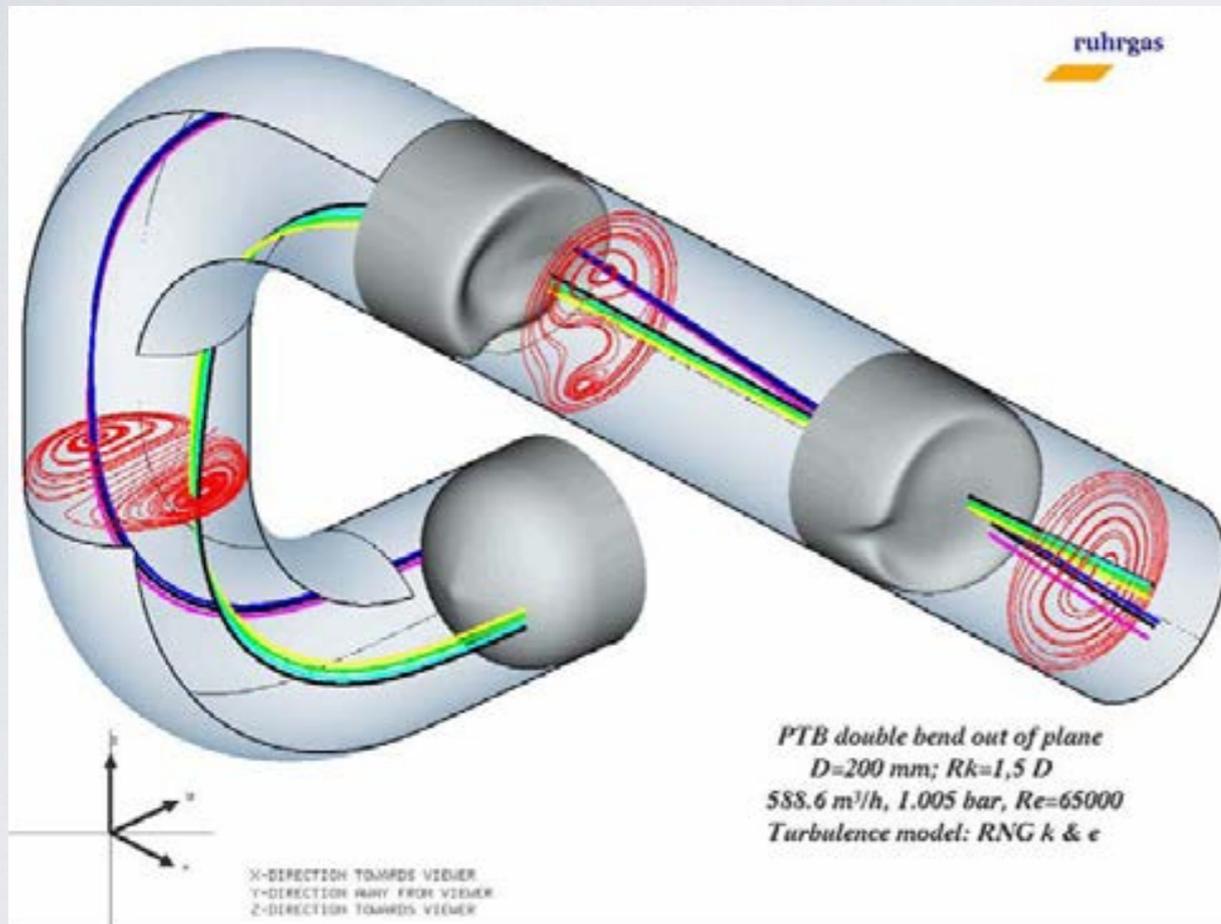


Coriolis Meter



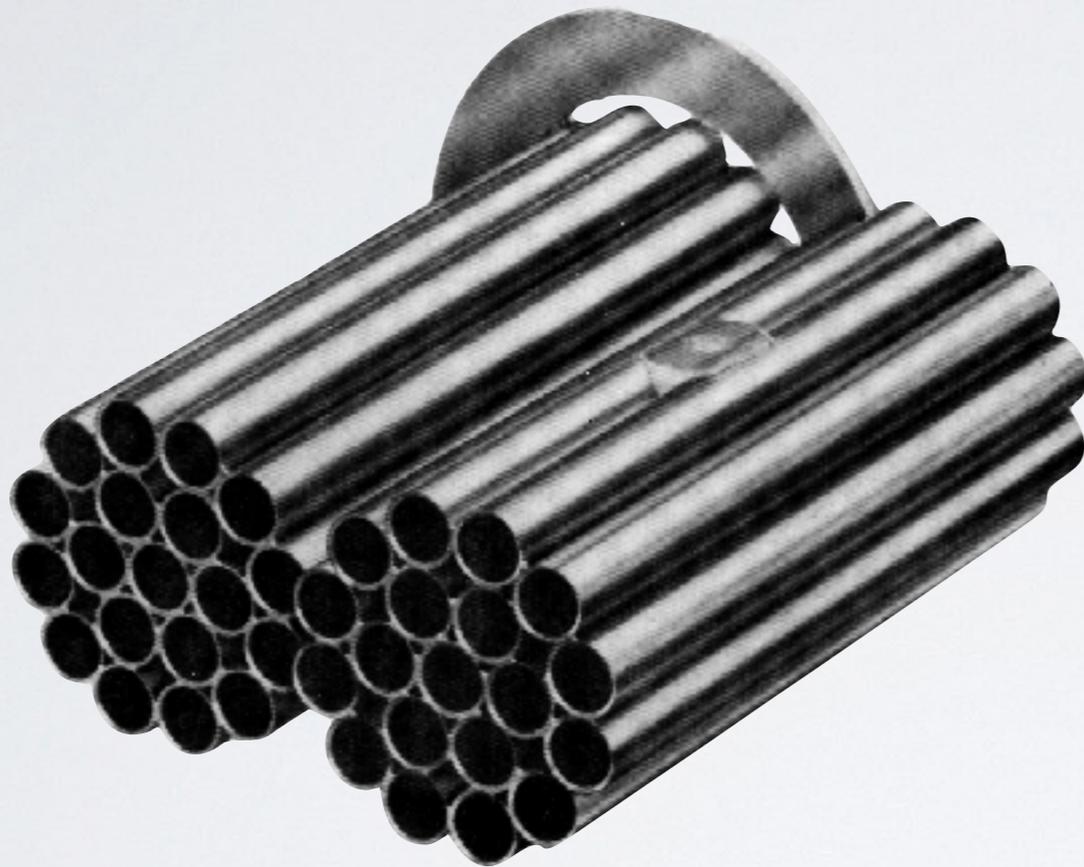
Ultrasonic Meter

Flow Distortion Caused by Two Close-coupled 90° Elbows, 90° Out of Plane



Source: Image courtesy of Ruhrgas

Flow Conditioner



AGA3 Tube Bundle



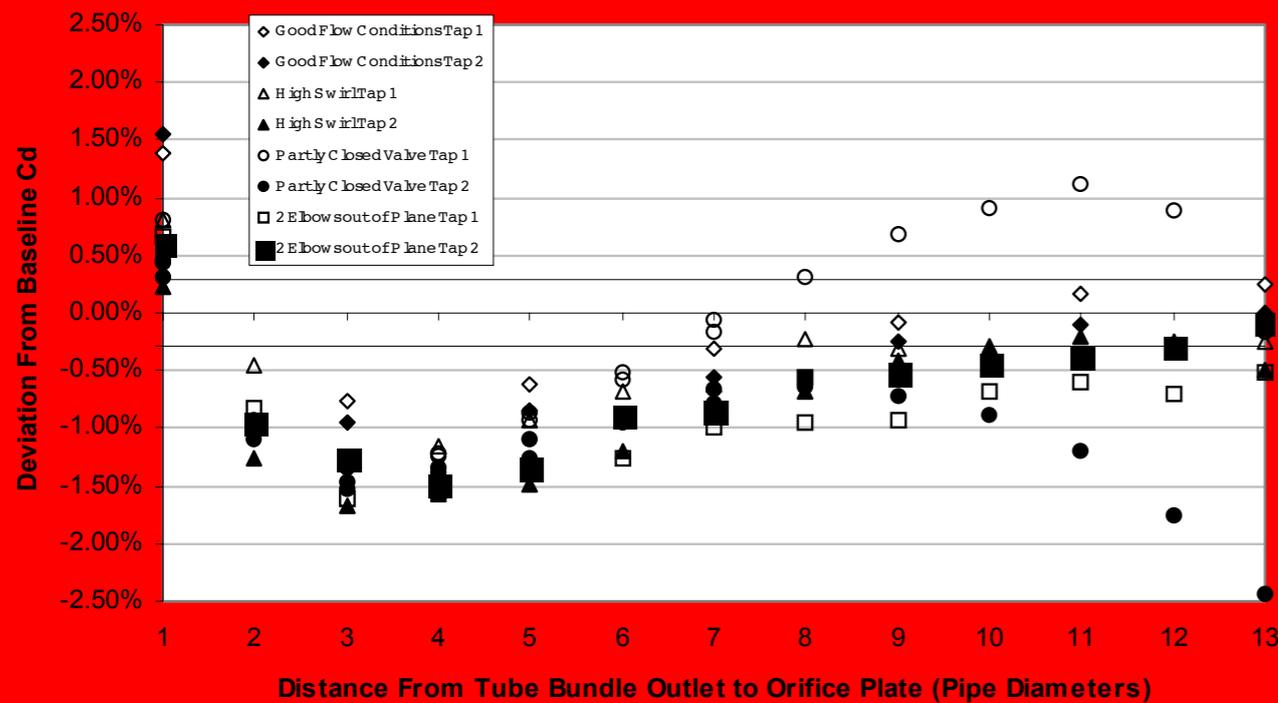
Plate Flow Conditioner

Tube Bundle Straightening Vanes / Plate Flow Conditioners



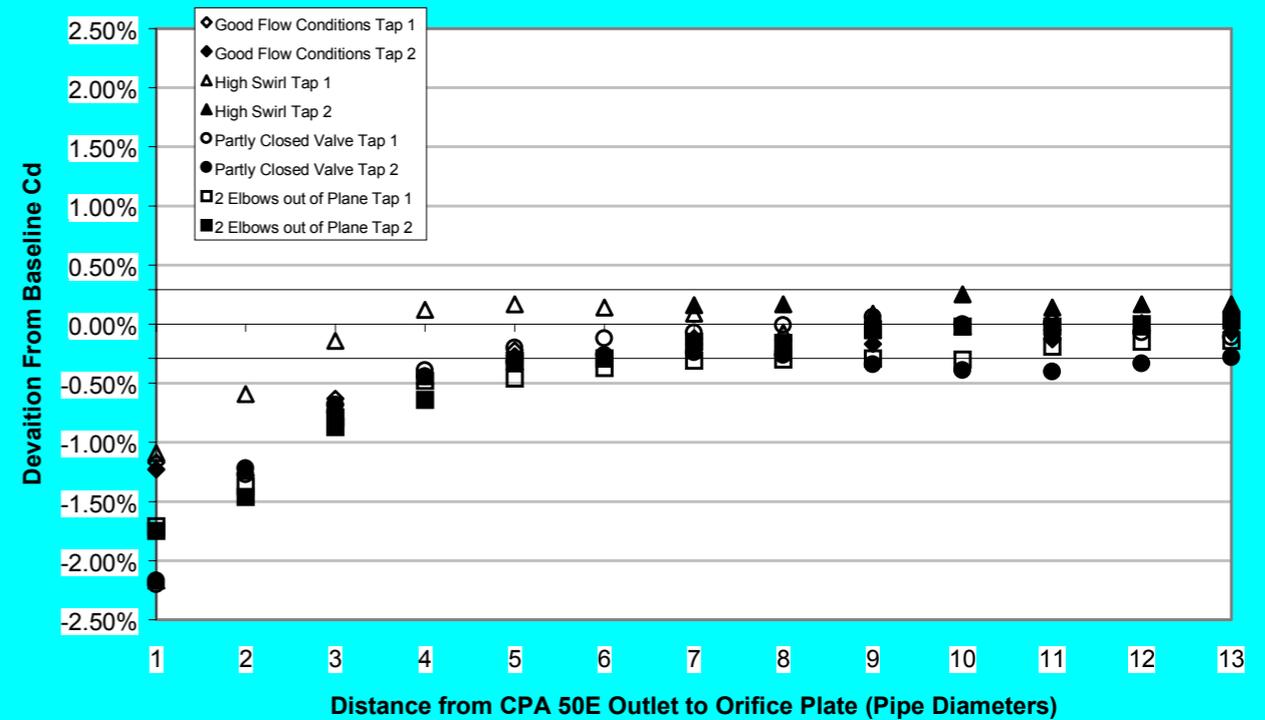
Tube Bundle Performance at Beta 0.75
17D Meter Run

Results from GRI Report No. 97/0207 "Development of a Flow Conditioner Performance Test"



CPA 50E Performance at Beta 0.75
17D Meter Run

Results from GRI Report No. 97/0207 "Development of a Flow Conditioner Performance Test"

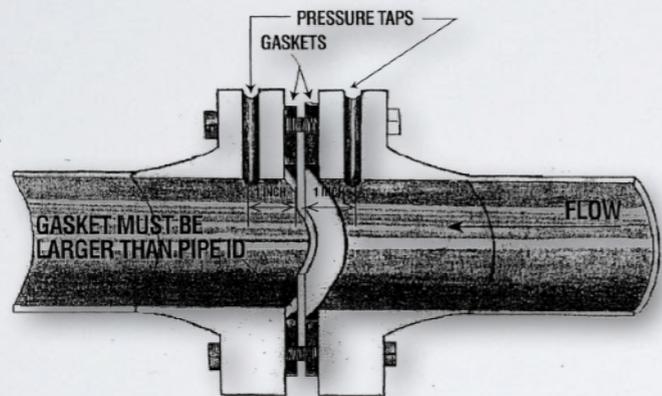


Comparison Chart

Orifice Meter



Orifice Meter



Flange Type



Single Chamber Type

Dual Chamber Type



Daniel

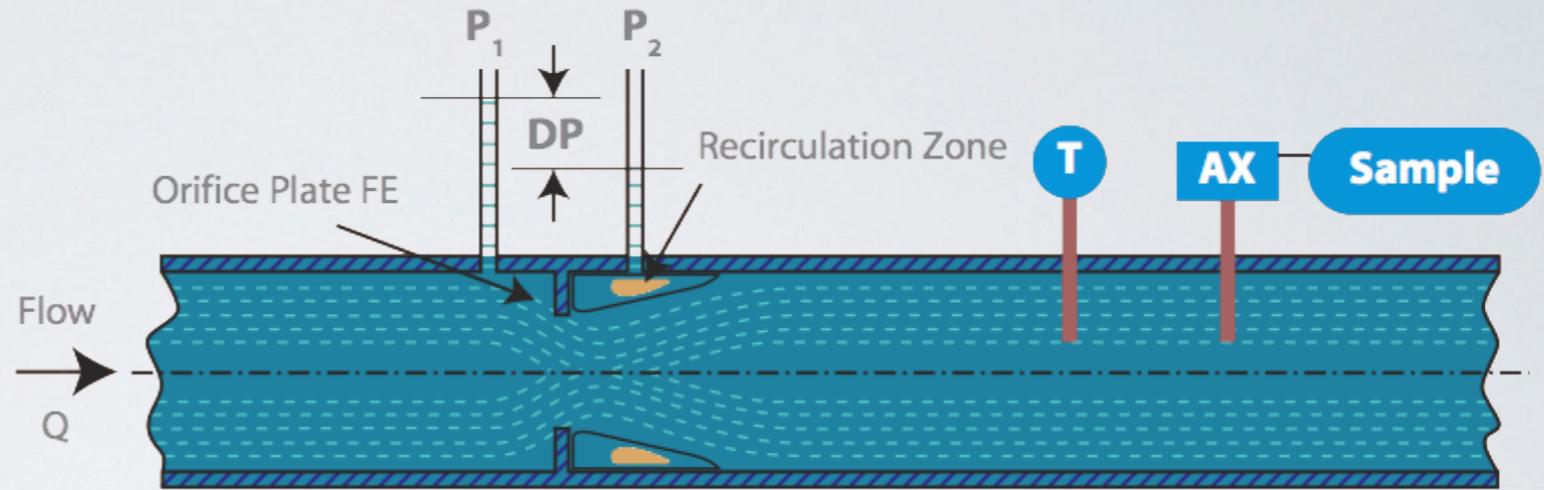
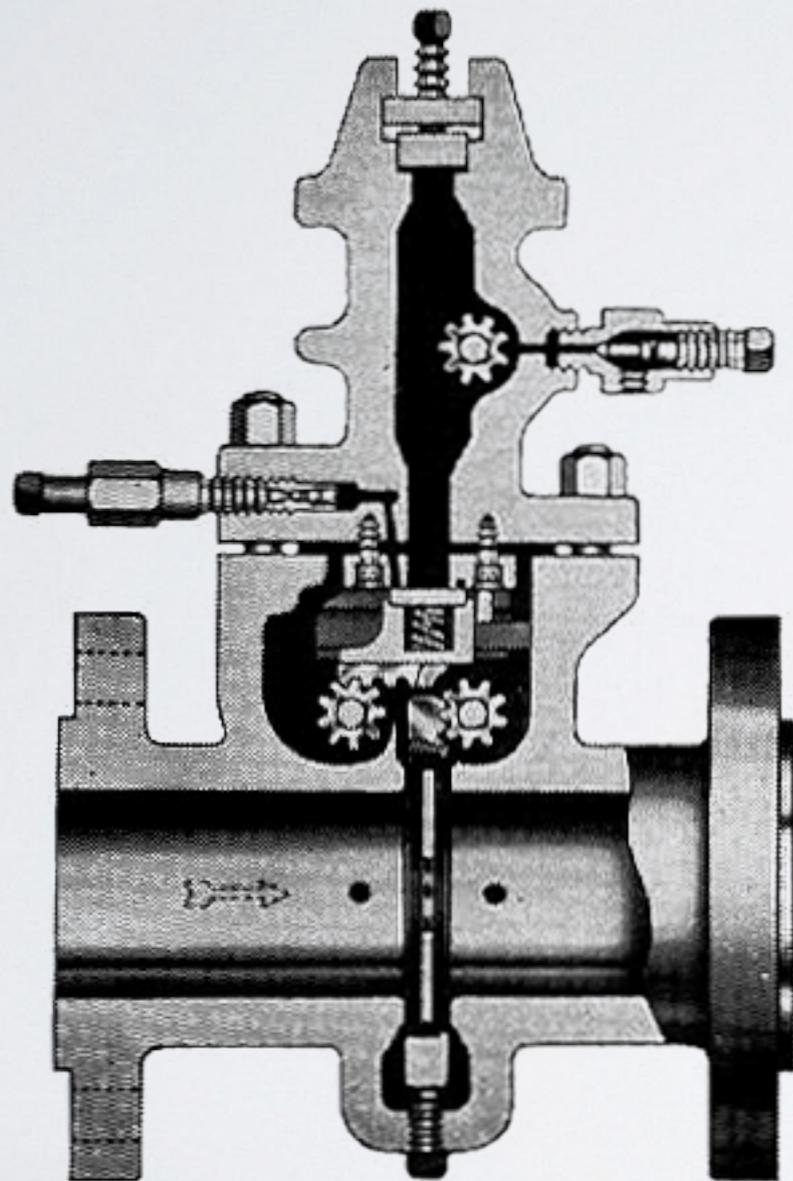


FMC/Peco

Orifice Meter



Orifice Meter



Q	Flowrate; ปริมาณการไหลก๊าซ
P₁	Upstream Pressure; ความดันก๊าซหน้าแผ่น Orifice
P₂	Downstream Pressure; ความดันก๊าซหลังแผ่น Orifice
DP	Differential Pressure (P ₁ - P ₂); ความดันตกคร่อมแผ่น Orifice
T	Temperature; อุณหภูมิก๊าซ
AX	Automatic Gas Sampler; อุปกรณ์เก็บตัวอย่างก๊าซ

$$\text{Quantity rate of flow } (Q_h) = C' \sqrt{h_w p_f}$$

HOURLY FLOW @ 14.73 psia & 60°F

$$Q_v = 7709.61 \times C_d \text{ (FT)} \times E_y \times Y_1 \times d^2 \sqrt{\frac{P_{f1} \times Z_s \times h_w}{G_r \times Z_{f1} \times T_f}}$$

Discharge Coefficient from Reader-Harris/Gallagher Equation

Expansion Factor

Upstream Pressure

Compressibility Factor at 14.73 psia & 60°F

Differential Pressure in Inches of H₂O at 60°F

Velocity of Approach Factor

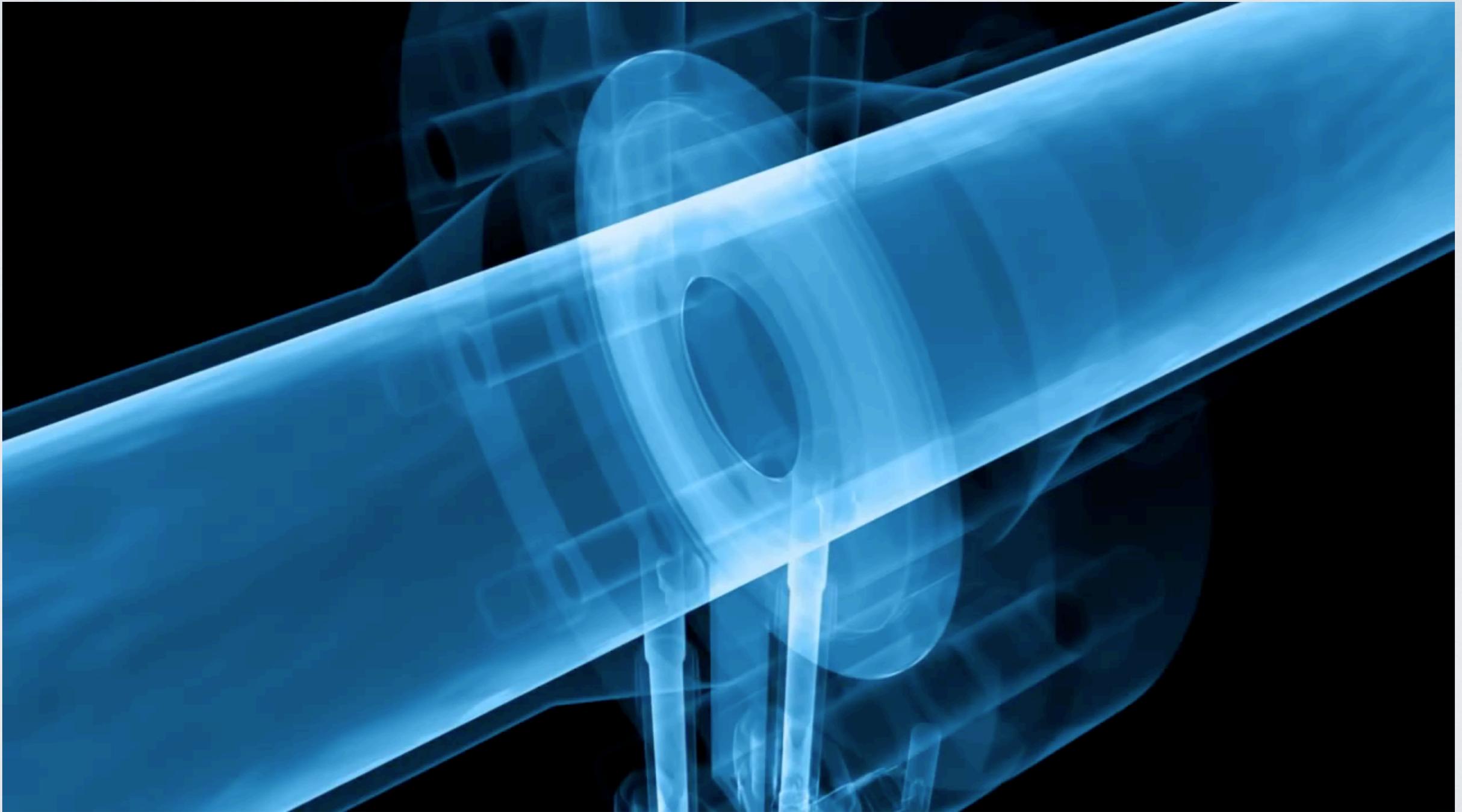
Orifice Diameter at Flowing Temperature

Real Gravity

Flowing Compressibility

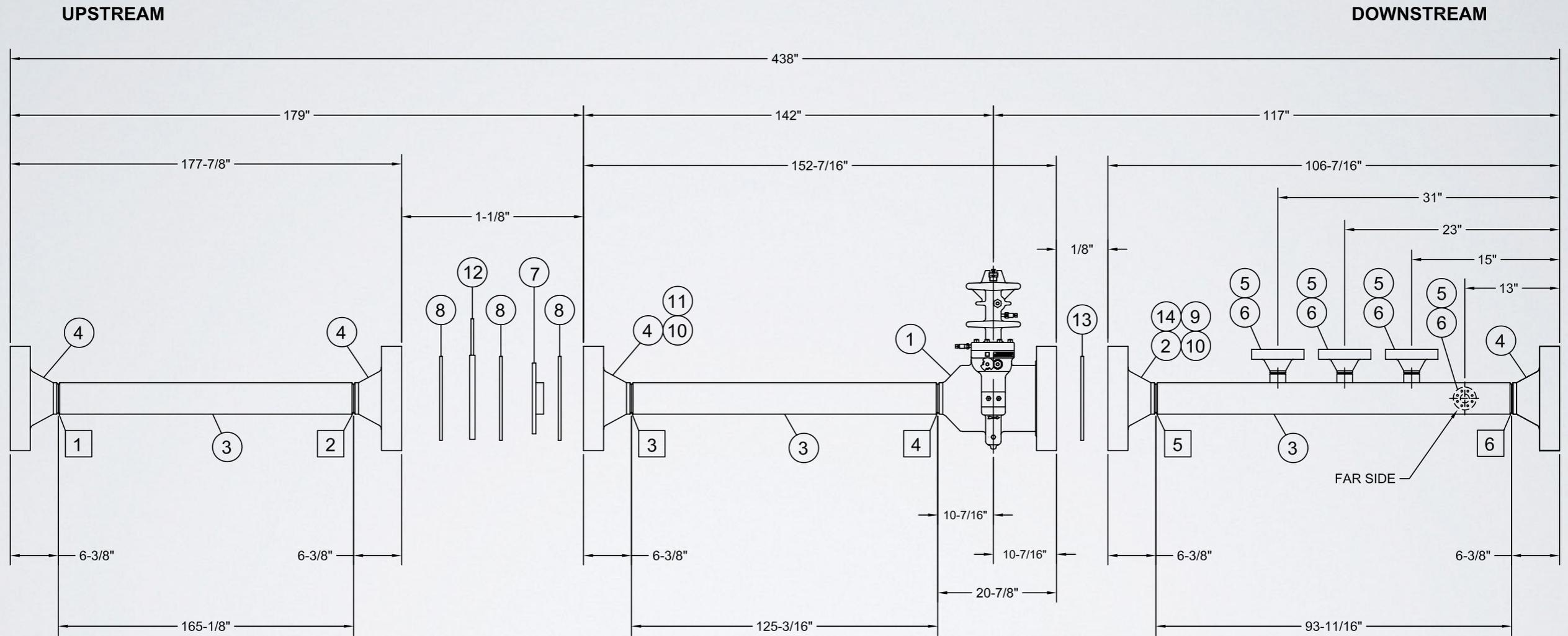
Flowing Temperature

Orifice Meter



Source: [youtube.com](https://www.youtube.com) | Endress Hauser

Orifice Meter



Orifice Meter

Construction and installation of orifice meter are extremely important

Standards covered for orifice

- ▶ AGA -3/API MPMS 14.3/GPA 8185
 - ▶ Part 1 - General Equations and Uncertainty Guidelines
 - ▶ Part 2 - Specification and Installation Requirements
 - ▶ Part 3 - Natural Gas Applications
 - ▶ Part 4 - Background, Developments and Implementation Procedure and Subroutine Documentation for Empirical Flange-Tapped Discharge Coefficient Equation
- ▶ ISO 5167 - Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full
 - ▶ ISO 5167-1:2003 - Part 1 - General Principles and Requirements
 - ▶ ISO 5167-2:2003 - Part 2 - Orifice Plates
 - ▶ ISO 5167-3:2003 - Part 3 - Nozzles and Venturi Nozzles
 - ▶ ISO 5167-4:2003 - Part 4 - Venturi tubes

Orifice Meter

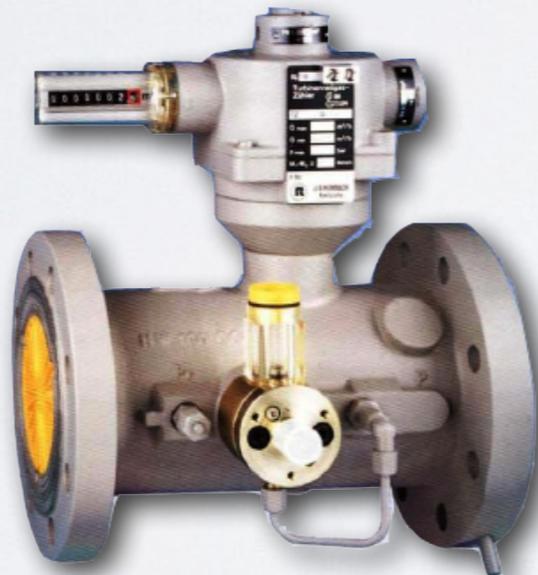
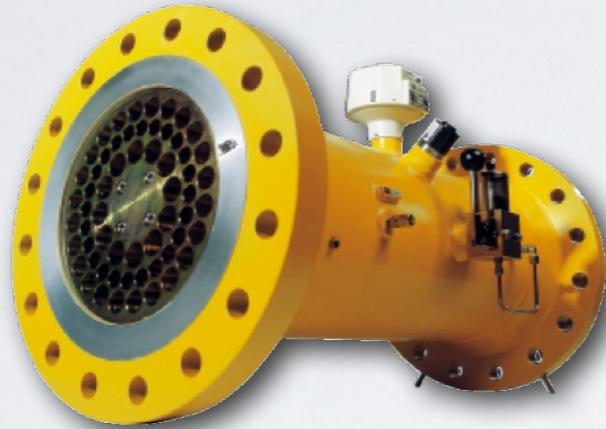
Advantage of orifice meter

- ▶ Well-documented in standards
- ▶ Enjoys wide acceptance; personnel knowledge across the industry about requirements for use and maintenance
- ▶ Relatively low cost to purchase and install
- ▶ No moving parts in the flow stream
- ▶ When built to standards requirements, does not require calibration beyond confirming mechanical tolerances when purchased and periodically in use

Disadvantages of orifice meter

- ▶ Low range ability with a single readout
- ▶ Relatively high pressure loss for a given flow rate, particularly at lower beta ratios
- ▶ More sensitive to flow disturbances at higher beta ratios than some meters
- ▶ Flow pattern in the meter does not make meter self-cleaning

Turbine Meter

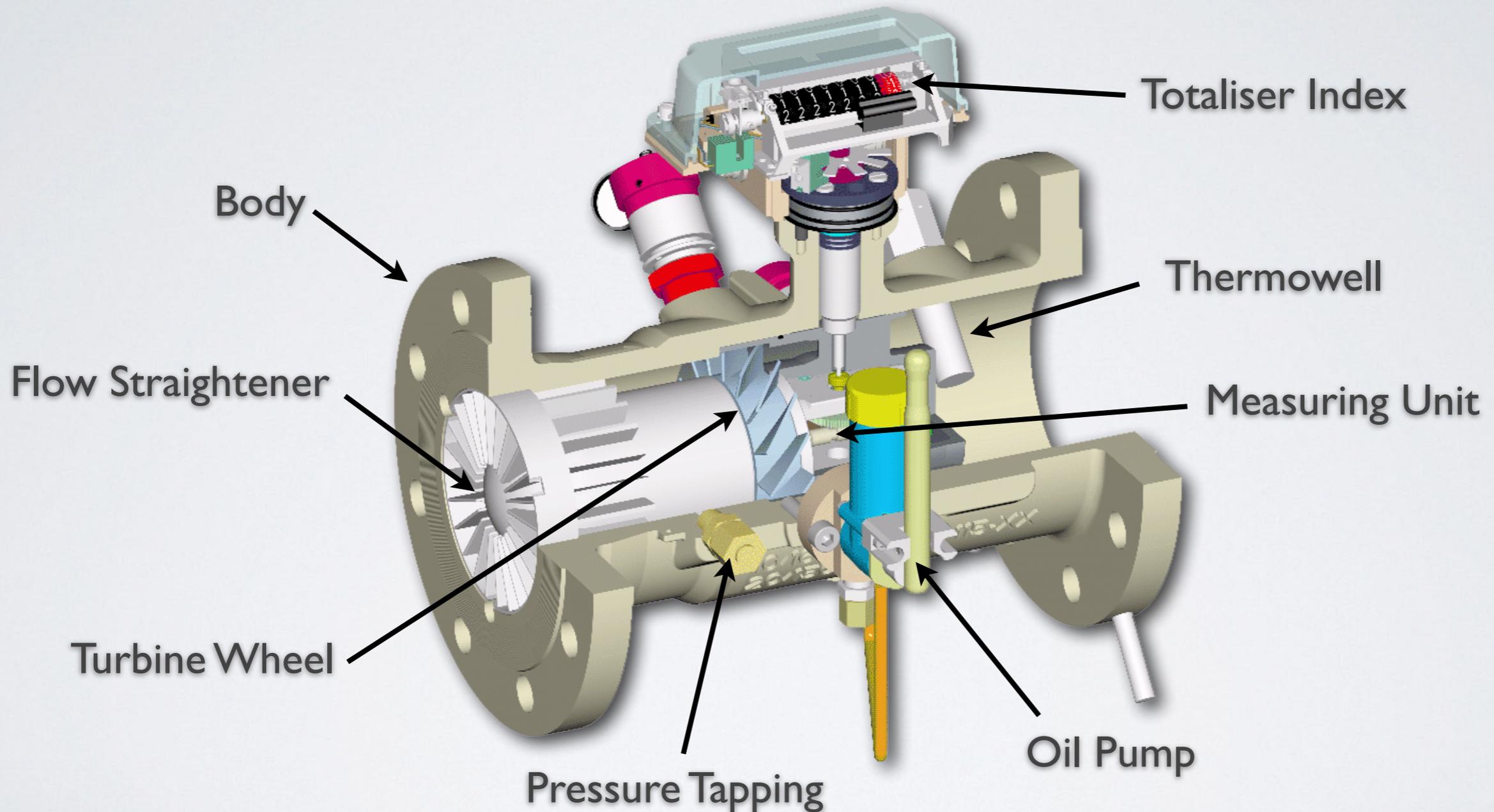


Custody Transfer Type



Industrial Type

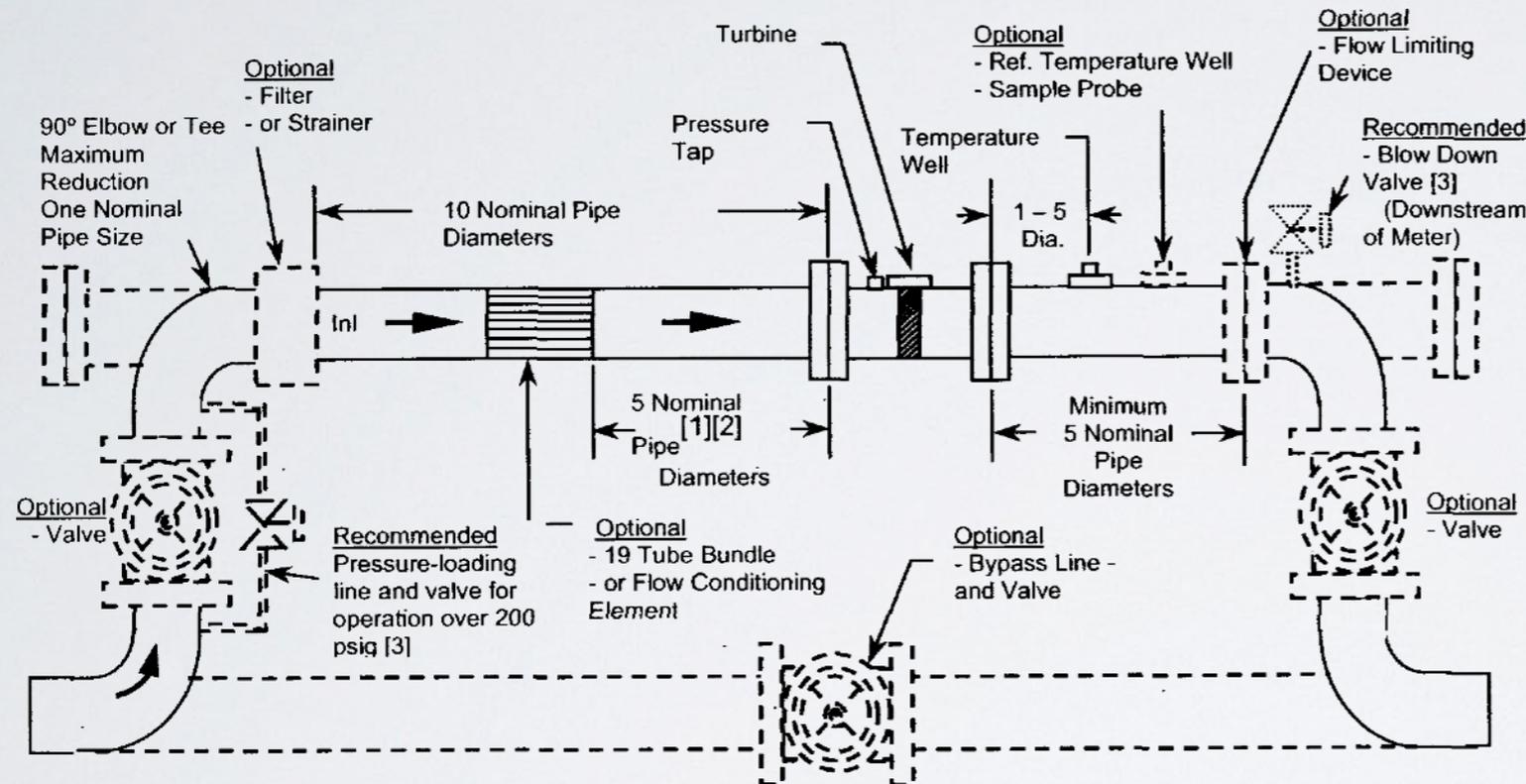
Turbine Meter



Turbine Meter

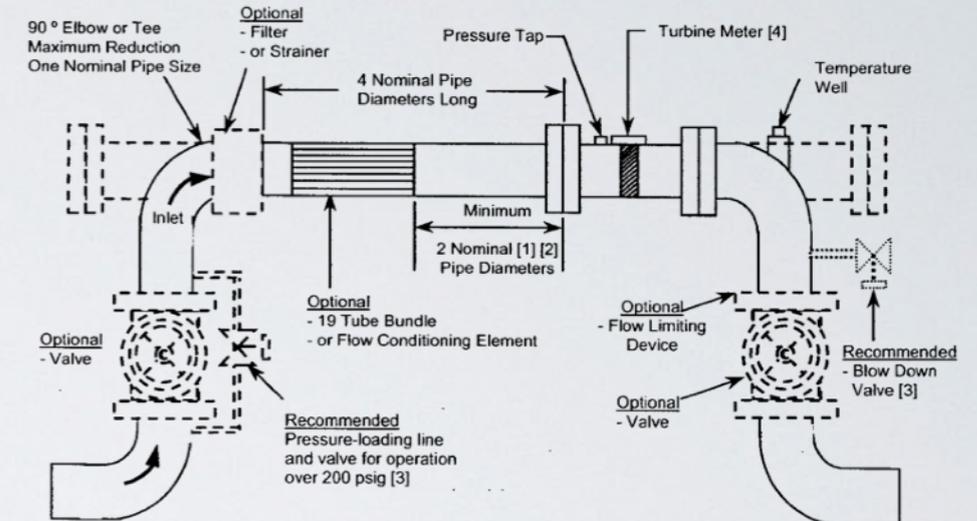


Turbine Meter



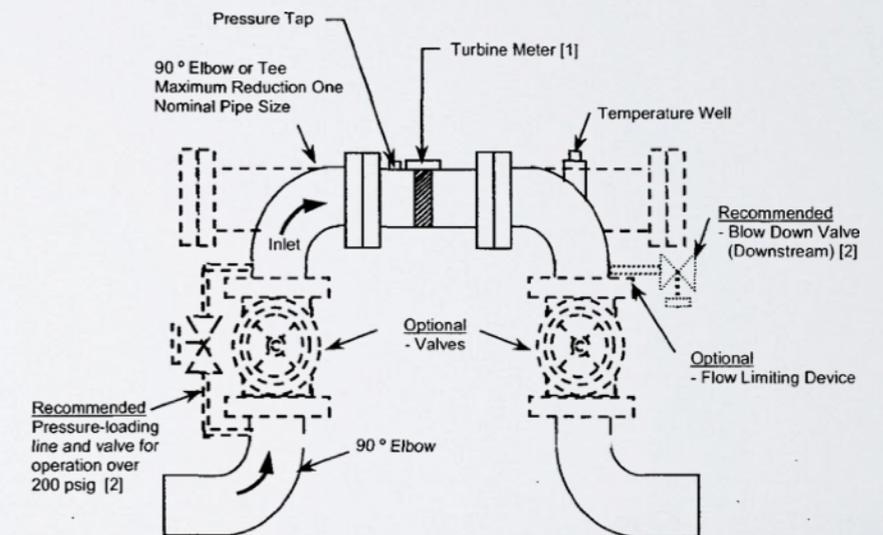
NOTES: [1] Recommended spacing, unless otherwise supported by published test data for the flow conditioning element.
 [2] No pipe connections or protrusions allowed within this upstream section.
 [3] Size of pressure loading line and valve to be the same as recommended blow down valve sizing, (see Table 1).

Recommended Installation



NOTES: [1] Recommended spacing, unless otherwise supported by published test data for the flow conditioning element.
 [2] No pipe connections or protrusions allowed within this upstream section.
 [3] Size of pressure loading line and valve to be the same as recommended blow down valve sizing, (Table 1).
 [4] Turbine meter must have integral flow conditioner.

Short-Coupled Installation



NOTES: [1] Turbine meter must have integral flow conditioning element.
 [2] Size of pressure-loading line and valve to be the same as recommended blow down valve sizing, (Table 1).

Closed-Coupled Installation

Turbine Meter

Installation of gas turbine meter must be in accordance to AGA-7, or ISO 9951

Use of Pulse Security, eg. Level A or B, API MPMS Ch. 5.5 - Fidelity and Security of Flow Measurement Pulsed-data Transmission Systems

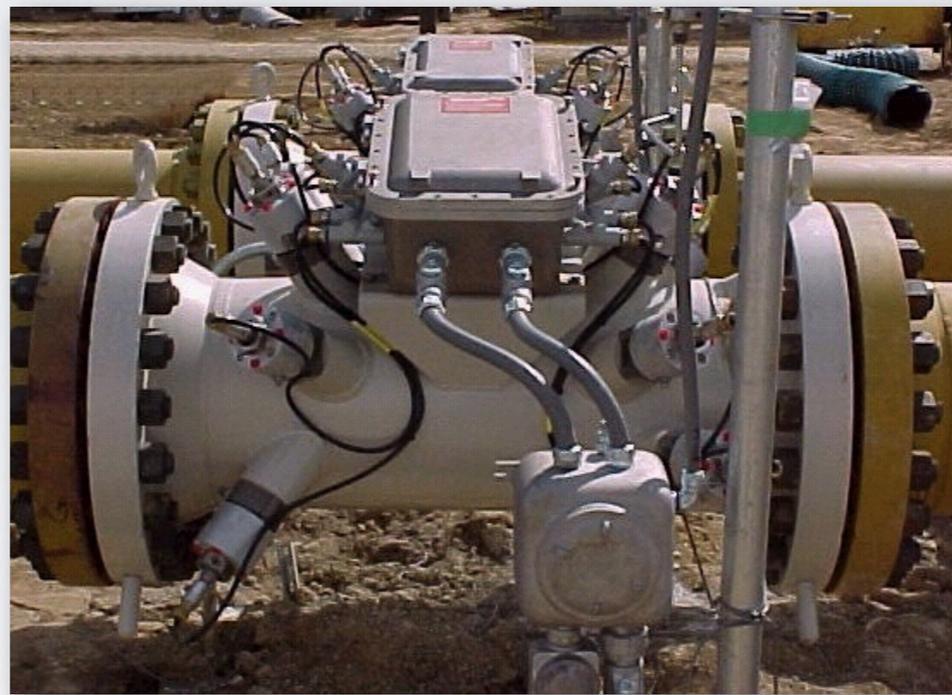
Advantages of turbine meter

- ▶ Good accuracy over full linear range of meter
- ▶ Electronic output available directly at high resolution rate.
- ▶ Meter cost is medium, but total meter station is low-to-medium cost because of high flow rate for given line size.
- ▶ Excellent range ability on gas meters at high pressure.
- ▶ Integrated totaliser index for actual volume.

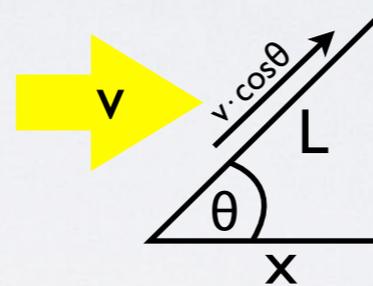
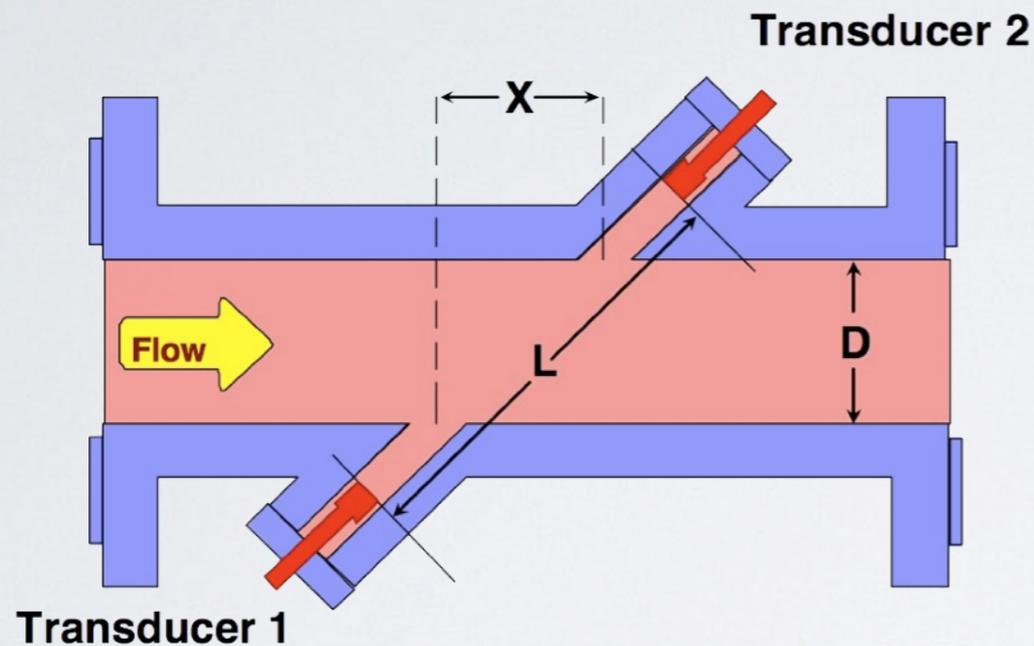
Disadvantages of turbine meter

- ▶ Range ability at low pressures about the same as other gas meters.
- ▶ Require upstream flow pattern to be non-swirling.

Ultrasonic Meter



Ultrasonic Meter



v = flow velocity

c = speed of sound

t_{up} = upstream transit time

t_{dn} = downstream transit time

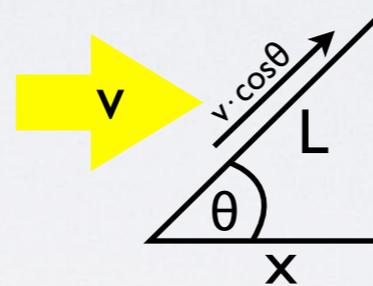
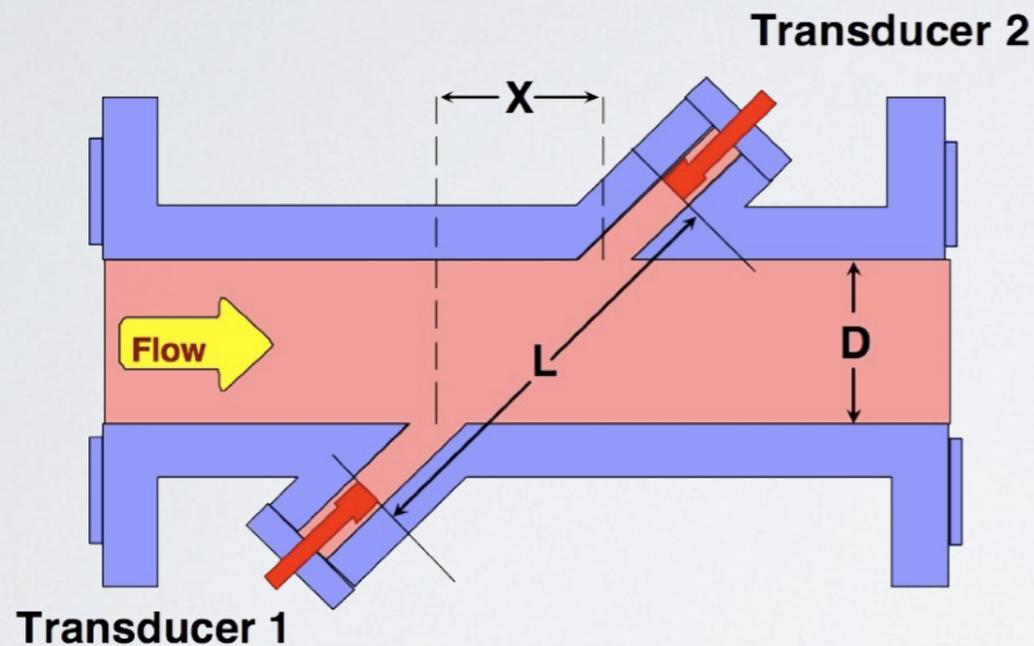
$$t_{up} = \frac{L}{c - v(x/L)}$$

$$t_{dn} = \frac{L}{c + v(x/L)}$$

$$v = \frac{L}{2x} \frac{t_{up} - t_{dn}}{t_{up}t_{dn}}$$

$$c = \frac{L}{2} \frac{t_{up} + t_{dn}}{t_{up}t_{dn}}$$

Ultrasonic Meter

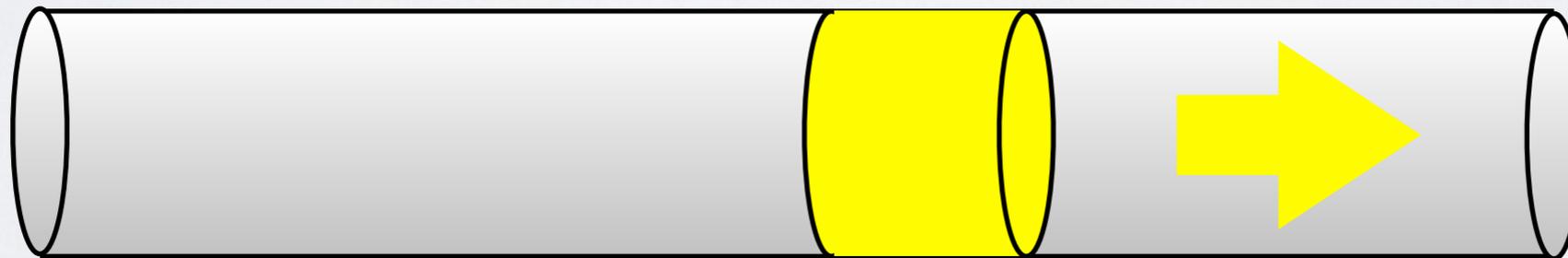


v = flow velocity

c = speed of sound

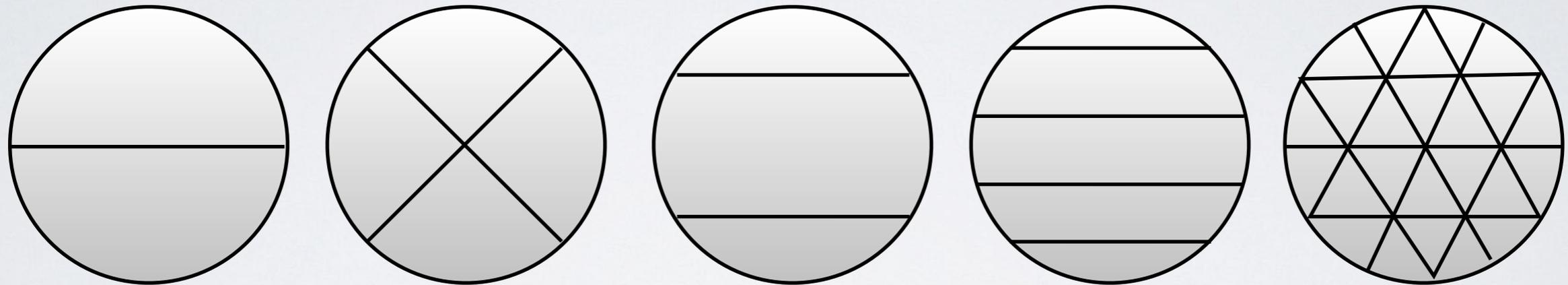
t_{up} = upstream transit time

t_{dn} = downstream transit time



$$\text{Flowrate} = \text{velocity} \times \text{area}$$

Ultrasonic Meter



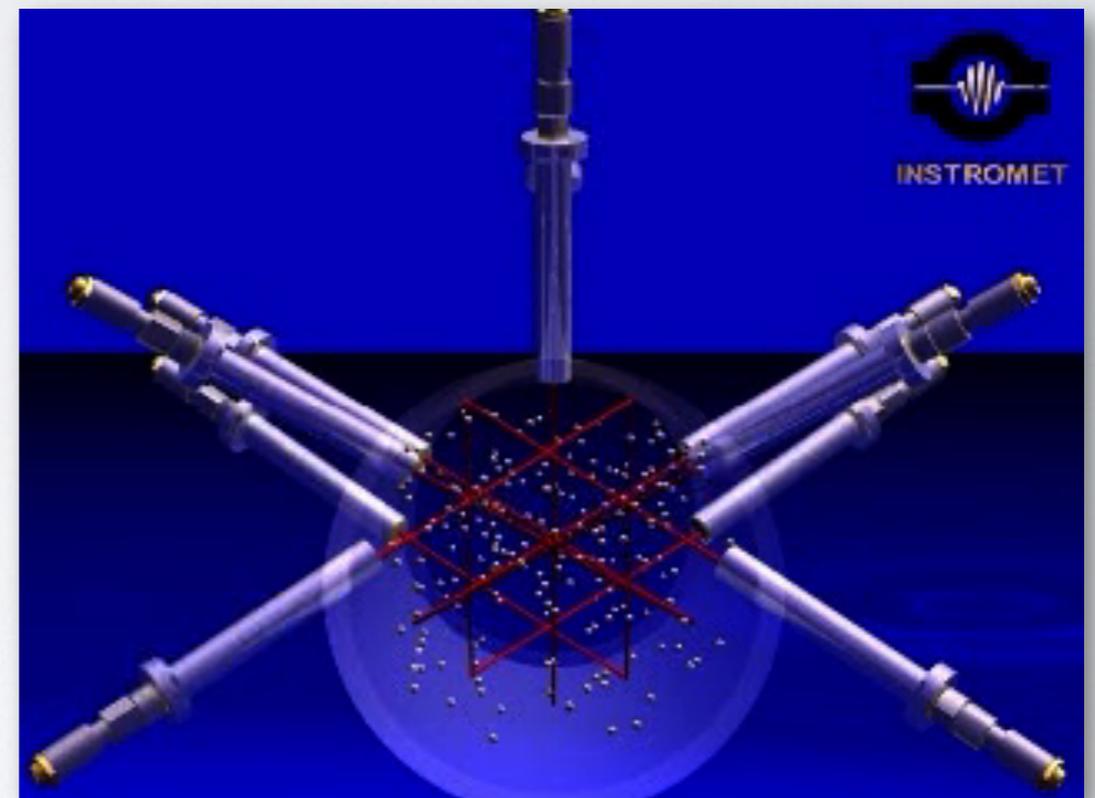
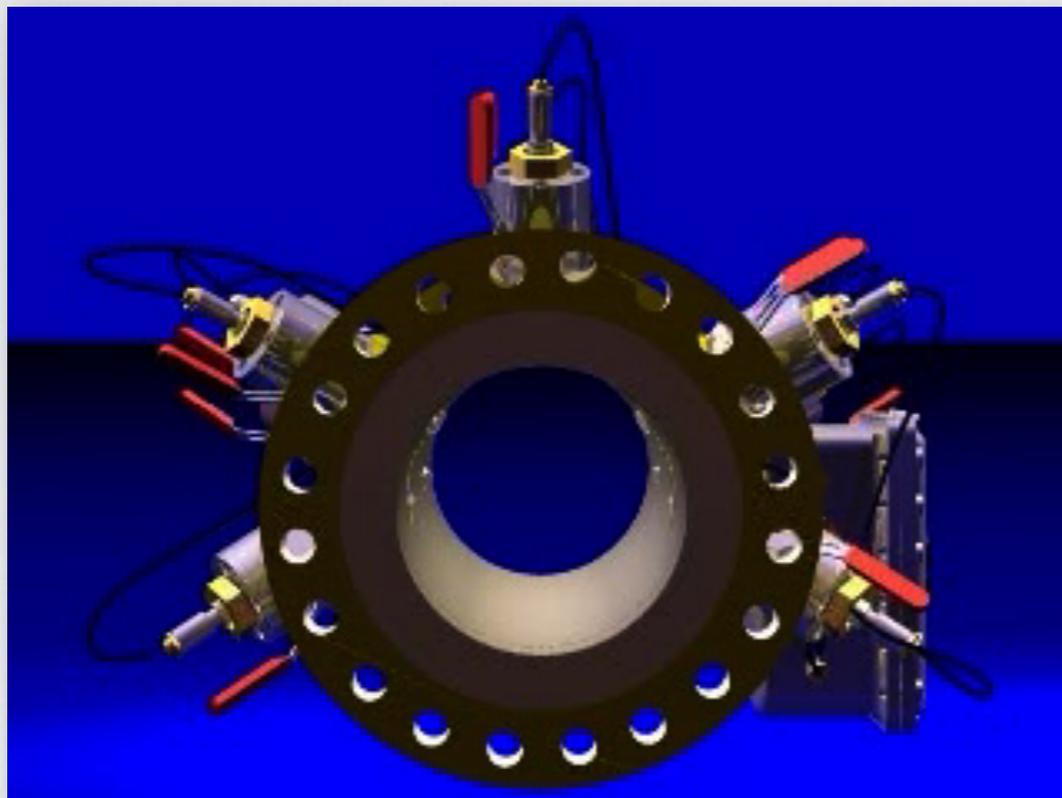
Ultrasonic Meter Design (Paths)

Ultrasonic Meter



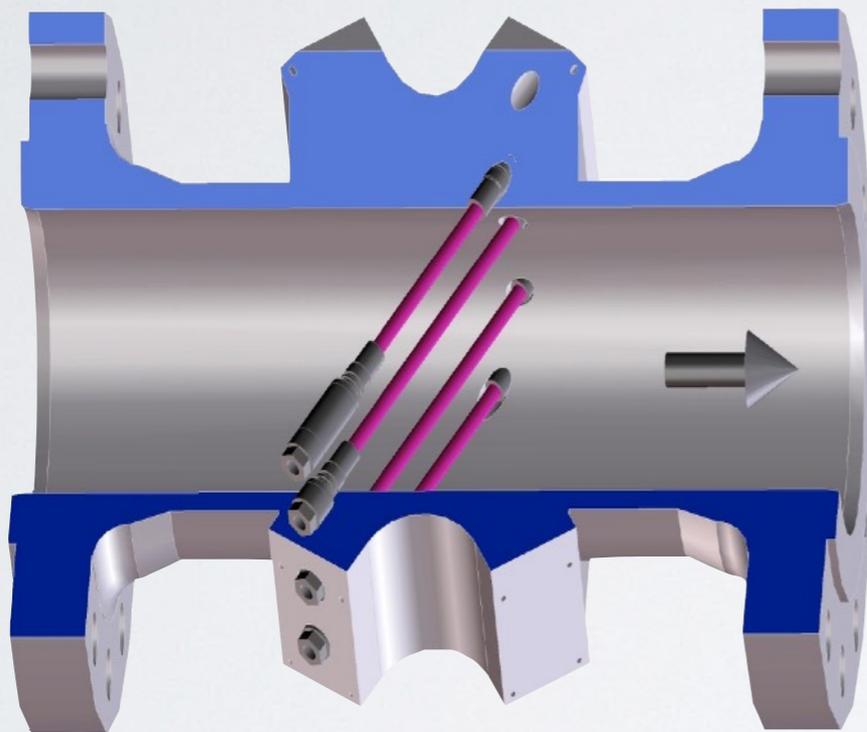
Source: sick.com

Ultrasonic Meter



Source: Instromet

Ultrasonic Meter - BASIC DIAGNOSTIC INDICATORS



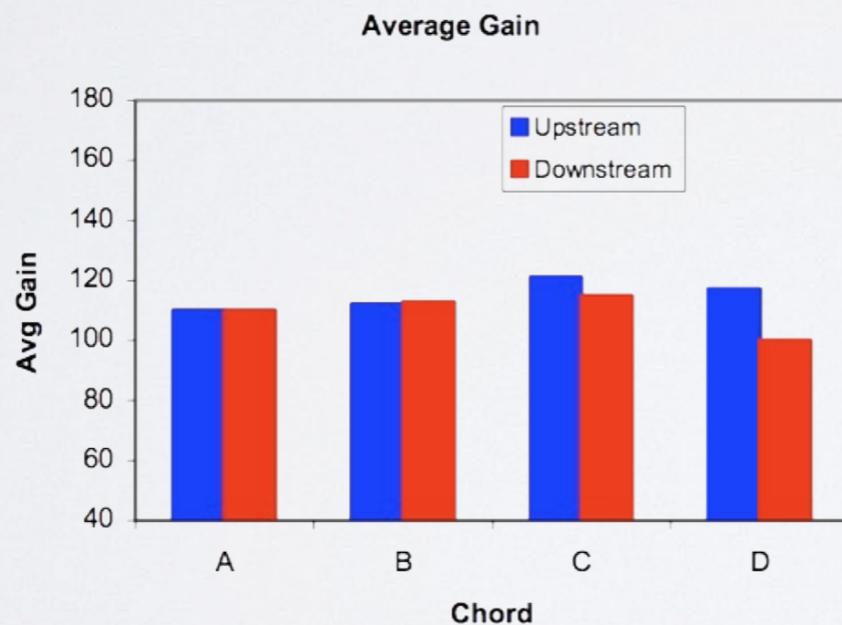
One of the principal attributes of modern ultrasonic meters is the ability to monitor their own health, and to diagnose any problems that may occur. Multi-path meters are unique in this regard, as they can compare certain measurements between different paths, as well as checking each path individually.

Ultrasonic Meter - Gain

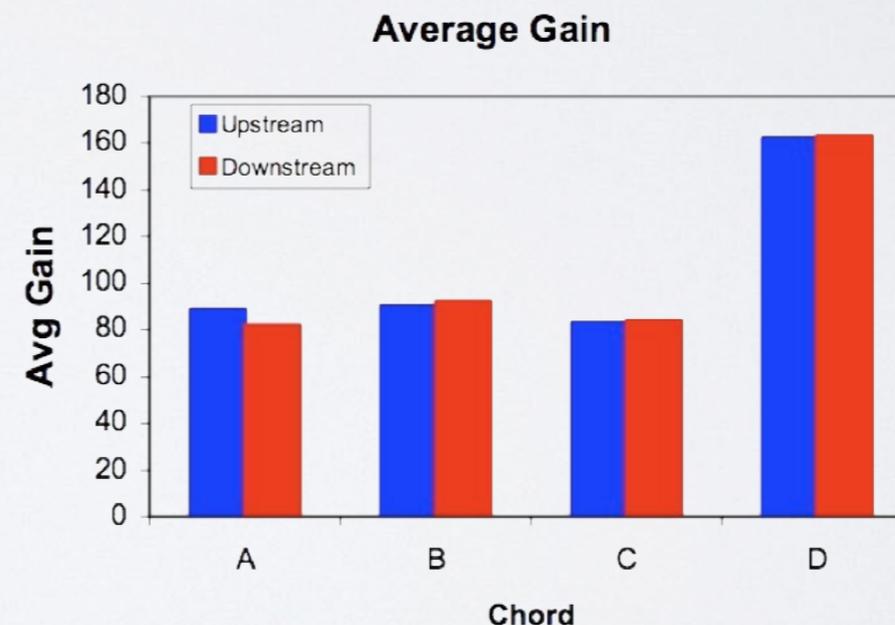


One of the simplest indicators of a meter's health is the presence of strong signals on all paths.

Any increase in gain on any path indicates a weaker signal at the receiving transducer. This can be caused by a variety of problems such as transducer deterioration, fouling of the transducer ports, or liquids in the line.



Transducer Gains - Normal

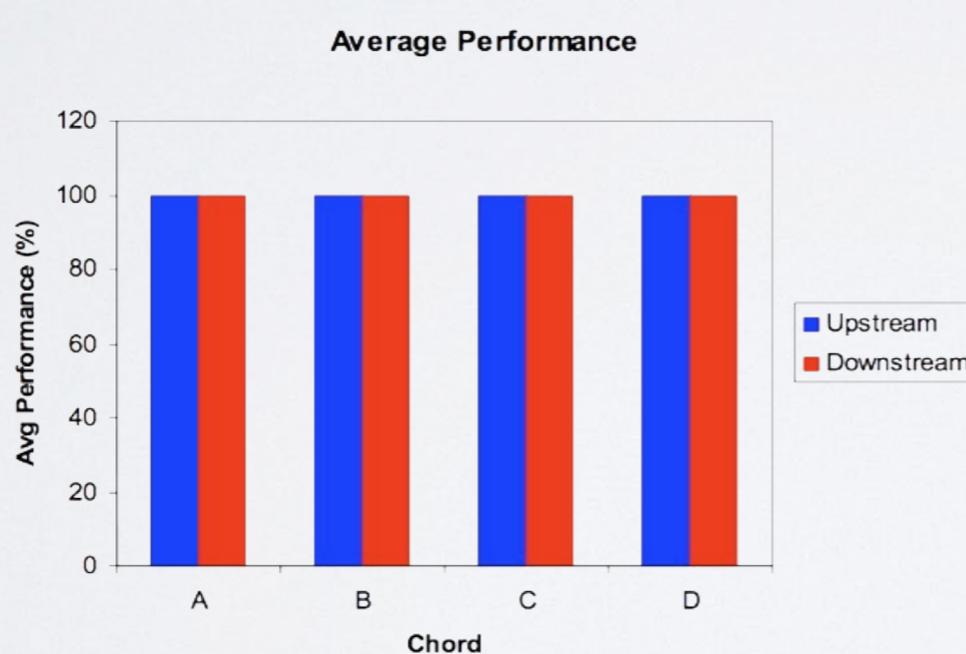


Transducer Gains - Abnormal

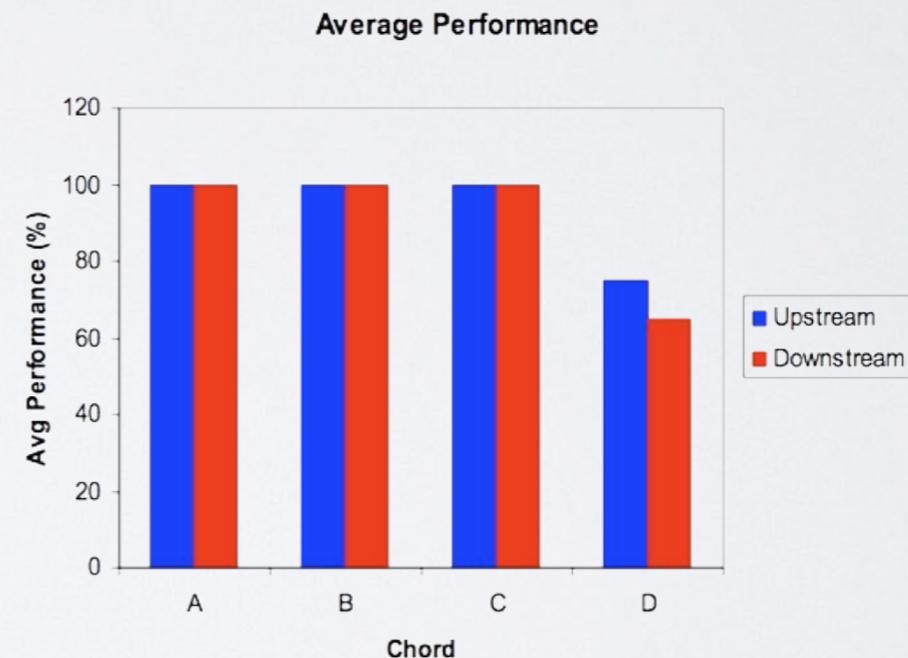
Ultrasonic Meter - Signal Quality – Transducer Performance



There are several reasons why pulses can be rejected. Additional causes may include extraneous ultrasonic noise in the same region the transducer operates, distorted waveforms caused by excessive gas velocity, and to some degree, contamination on the face of the transducer.



Performance - Normal



Performance - Abnormal

Ultrasonic Meter - Signal-to-Noise Ratio



The measure of signal strength to the level of “background” noise is called the Signal to Noise Ratio, or SNR

SNR is generally not an issue unless there is a control valve or other noise generating piping component present. When that occurs, the SNR values will drop.

	Perf (%)	Gain	SNR
Chord A Up	100	44	2292
Chord A Dn	100	43	2533
Chord B Up	100	45	340
Chord B Dn	100	46	329
Chord C Up	100	44	482
Chord C Dn	100	44	498
Chord D Up	100	43	2306
Chord D Dn	100	43	2258
Average Up	100	44	1355
Average Dn	100	44	1404.5

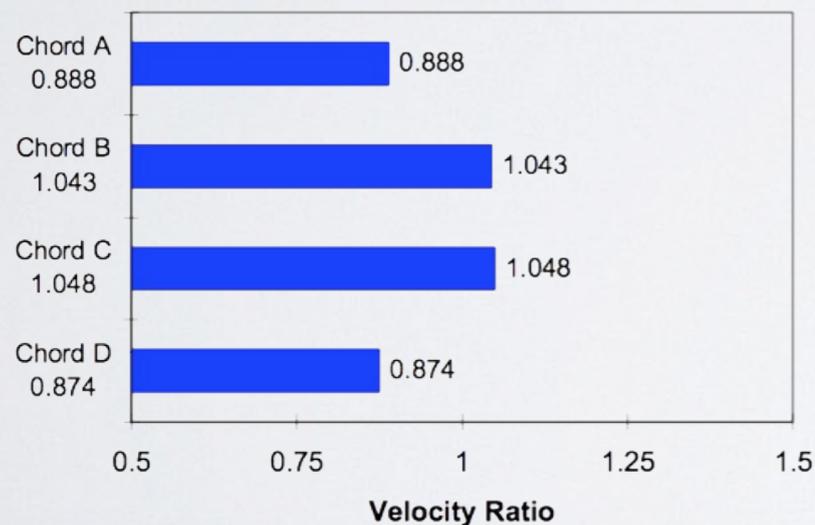
SNR of Meter with Stacking

Ultrasonic Meter - Velocity Profile



Monitoring the velocity profile is possibly one of the most overlooked and under-used diagnostic tools of today's ultrasonic meter.

Flow Velocity Ratios

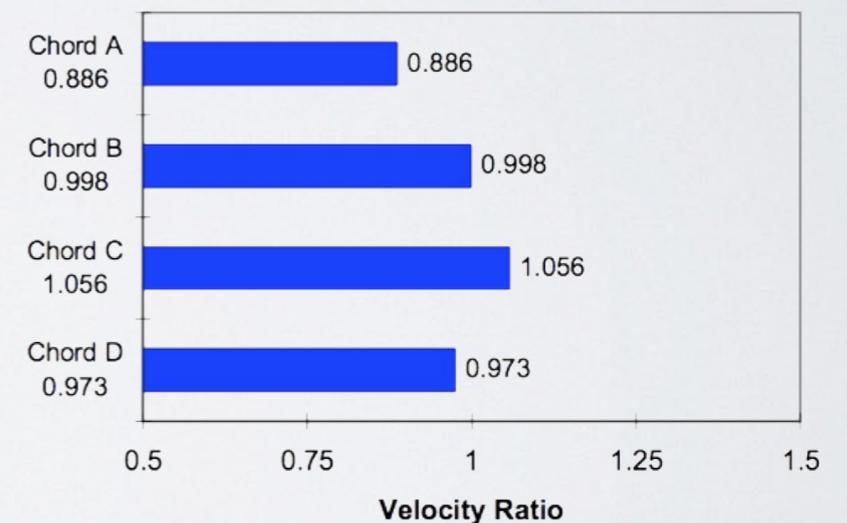


Velocity Ratios - Normal



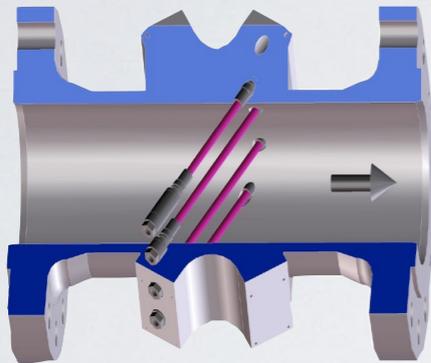
Blocked Flow Conditioner

Flow Velocity Ratios



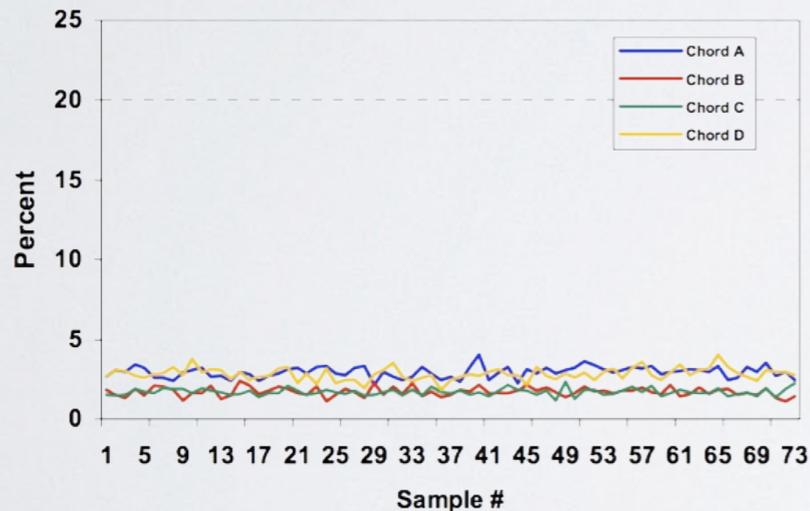
12-inch Meter Profile – Blocked

Ultrasonic Meter - Turbulence



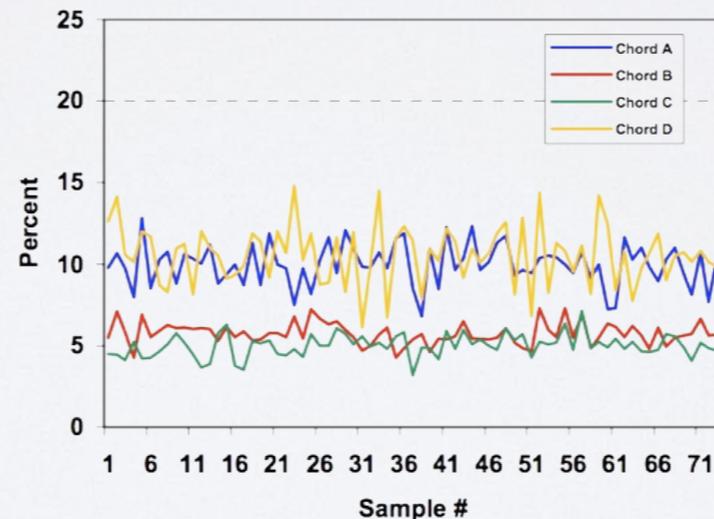
Turbulence is a measure of the variability of each chord's velocity readings during the time the meter was sampling, and is provided each time it updates the velocity information.

Turbulence - 40ft/sec -No Blockage



Normal Turbulence

Turbulence - 40ft/sec Blocked



High Turbulence of 12-inch Meter



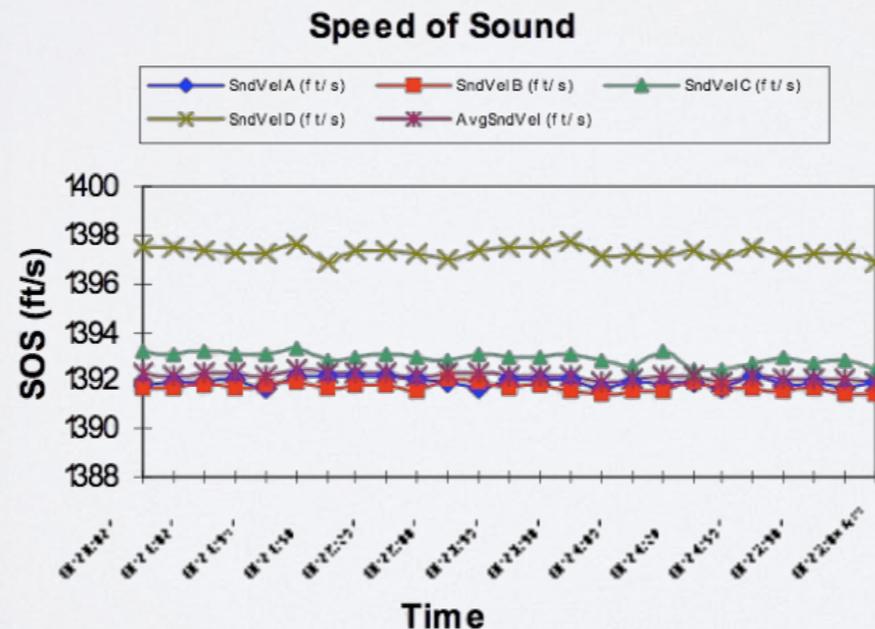
12-Inch Meter Blockage

Ultrasonic Meter - Speed of Sound (SOS)



Speed of sound on an individual chord is basically the sum of the transit times divided by their product, all then multiplied by the path length.

There are at least 2 ways of looking at SOS. The first would be to compare each path's SOS to the meter, or to the other paths. Typically the agreement with today's technology is within ± 0.3 m/s during normal operation.



Typically all SOS values will be within 1 m/s maximum spread, but here there is about 5 m/s difference in Chord D relative to all others

Ultrasonic Meter

Installation of gas ultrasonic meter must be in accordance to AGA-9, or ISO/TR 12765. Another accepted standards is BS 7965.

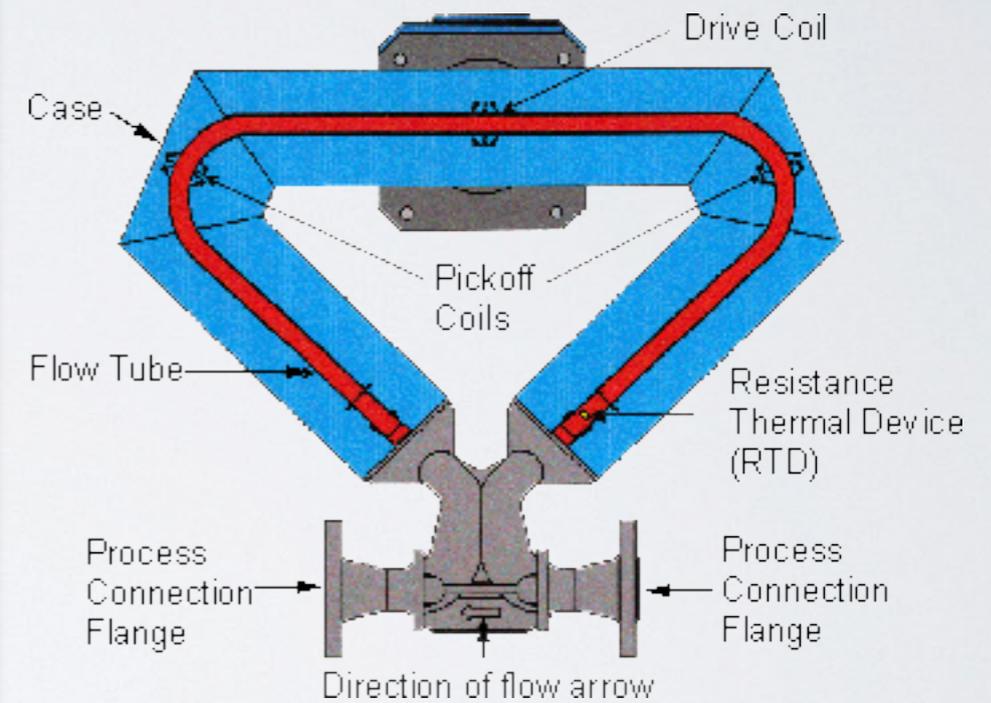
Advantages of ultrasonic meter

- ▶ No pressure drop, since meters are same diameter as adjacent piping
- ▶ High frequency pulse rate of output minimizes errors from effects of pulsation and fluctuating flow
- ▶ Installation can be simple and inexpensive
- ▶ High range-ability
- ▶ No moving parts in contact with flowing fluid
- ▶ Simple mechanical calibration easily checked without a throughput test
- ▶ Capable of bi-directional operation.

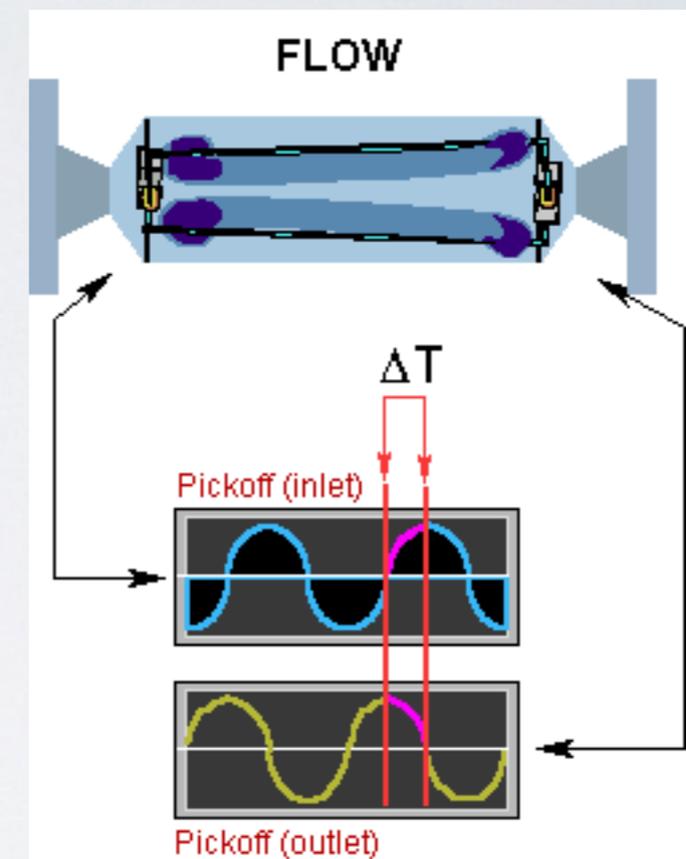
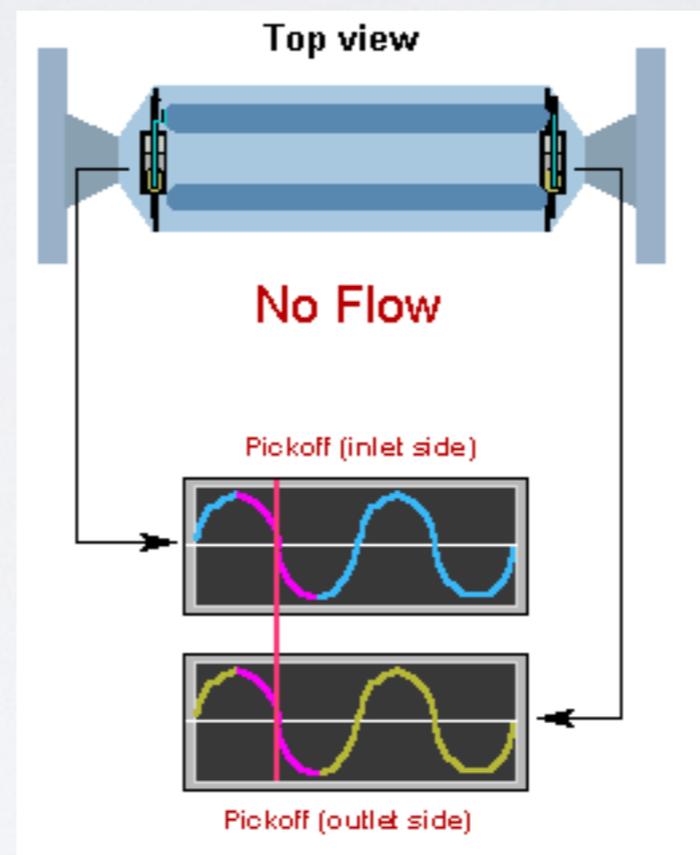
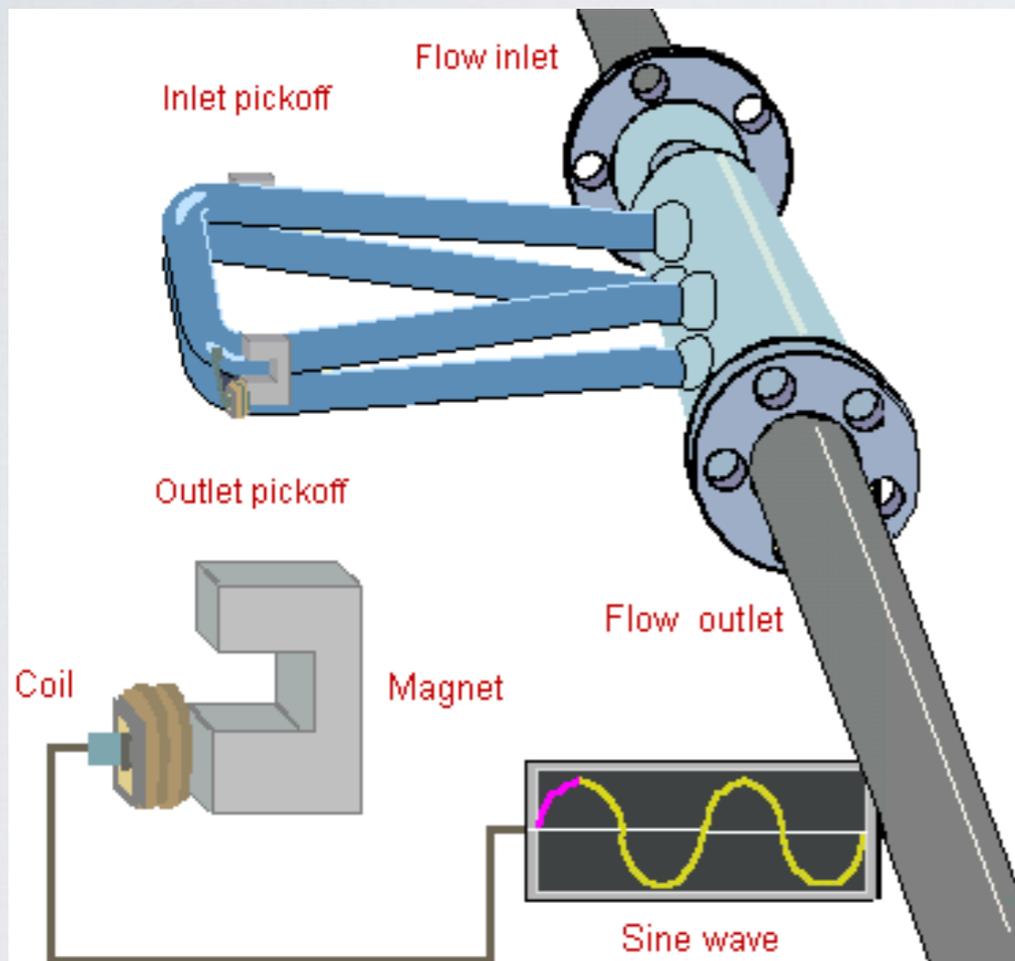
Disadvantages of ultrasonic meter

- ▶ Power required for operation
- ▶ Flow profile must be fully developed for an average velocity to be determined from a single path or reflection unit. (Note : multiple-path units average disturbed flow patterns, including swirl to minimize flow profile problems)
- ▶ High initial cost
- ▶ Close proximity of control valve shall effect the meter's performance

Coriolis Meter

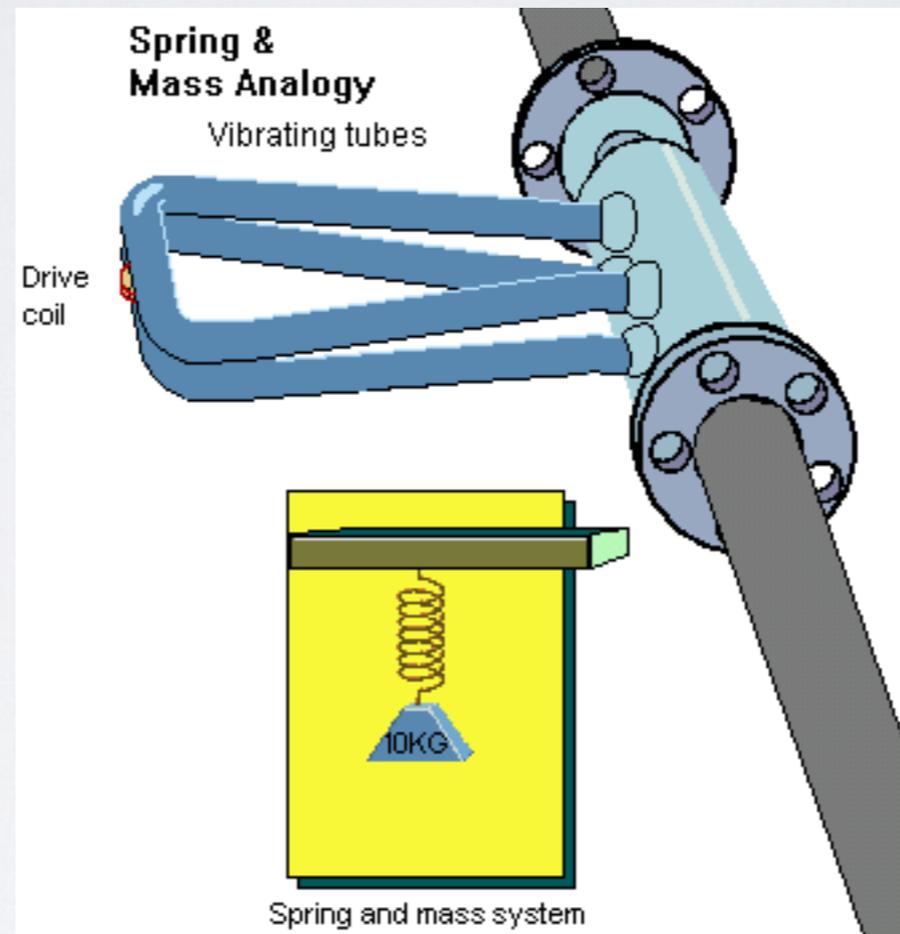


Coriolis Meter



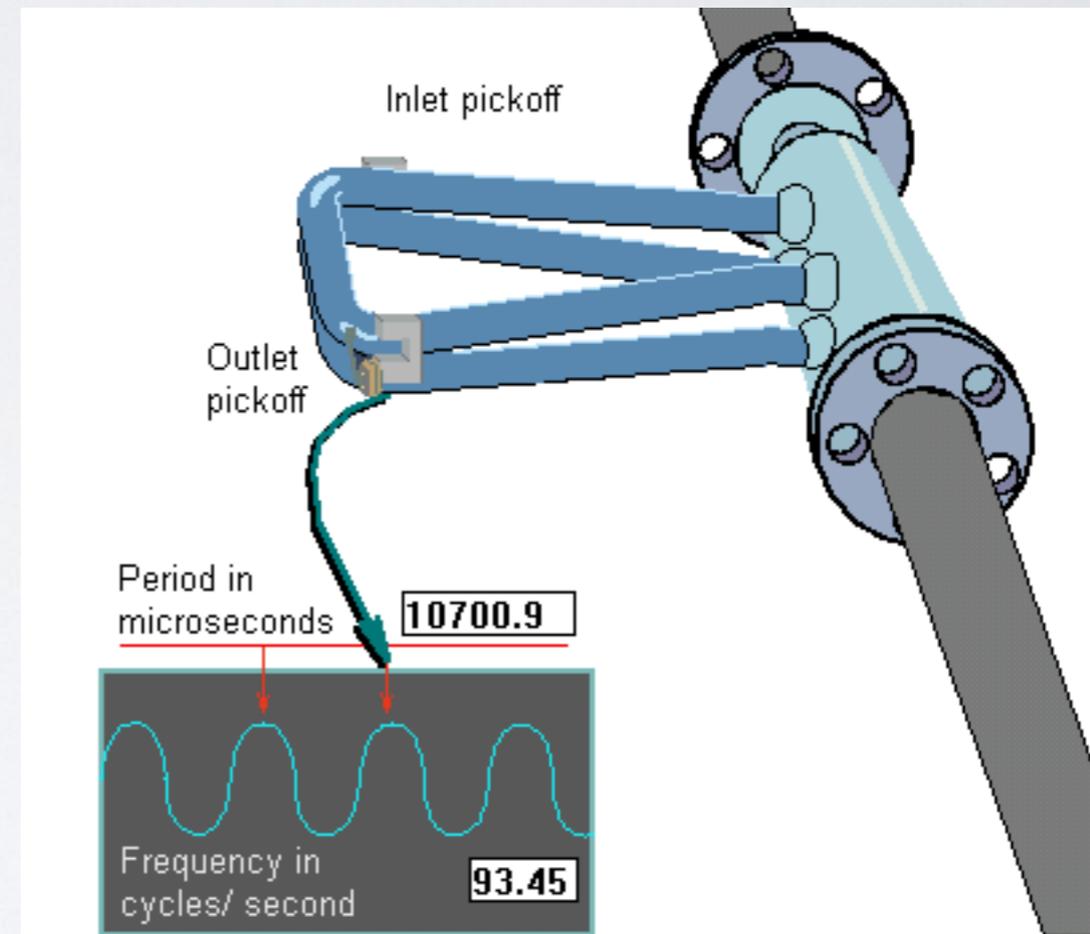
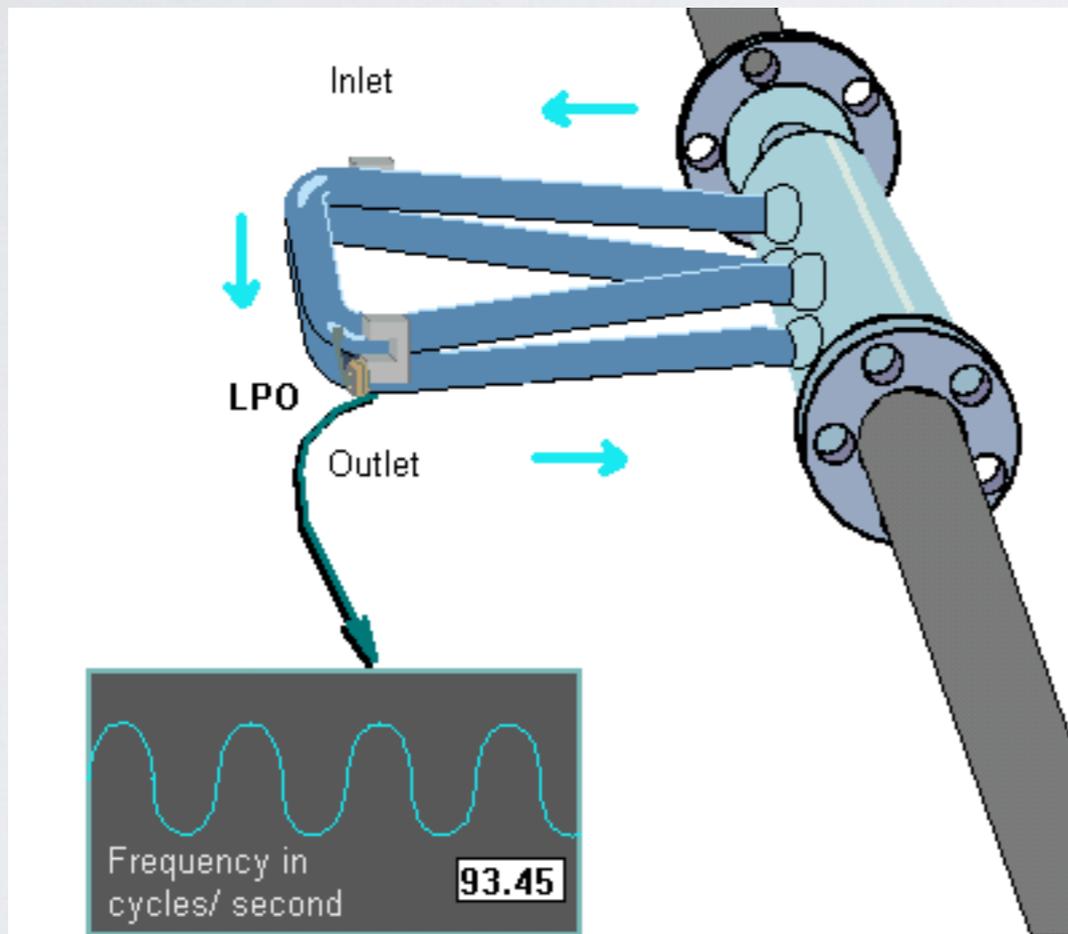
Flow Operating Principle

Coriolis Meter



Mass & Frequency Relationship

Coriolis Meter



Density and Frequency Relationship

Coriolis Meter

Installation of gas Coriolis meter must be in accordance to AGA-11

Advantages of Coriolis meter

- ▶ Not affected by flow disturbances such as swirl and uneven flow profile, therefore there is no requirement for flow conditioners and upstream/downstream straight piping.
- ▶ Good accuracy and linearity over its entire flow range.
- ▶ No internal moving and wearable parts.
- ▶ Density is normally available as a secondary output signal from the meter as a function of the frequency of the vibration of the tube.
- ▶ Capable of bi-directional operation.

Disadvantages of Coriolis meter

- ▶ Small diameter of the measurement tube results in high pressure loss across the meter.
- ▶ Limited size availability due to mechanical constraints for the vibrating tube. Typical size range from 1/16 inch to 6 inch. Therefore not suitable for high flow rate applications.
- ▶ Suitable for high pressure gas measurements only as low pressure gas lacks sufficient mass to be accurately measured.
- ▶ Meter is potentially sensitive to piping vibration when the frequency is close to the vibration frequency of the meter tube.

Meter Comparison

Comparison Item	Orifice Meter	Turbine Meter	Ultrasonic Meter	Coriolis Meter	Rotary Meter
1. Maximum Flowrate	High	Med to High	High	Low	Med to High
2. Minimum Flowrate	Med	Med	Low	Low	Low
3. Range Ability (for Custody Only)	3:1	10:1	100:1	20:1	20:1
4. Accuracy	0.5%	0.5%	0.1% (Wet Calibration)	0.3%	0.3%
5. Flow Disturbance	Sensitive	Sensitive	Not Sensitive (Multi-Path)	Not Sensitive	Not Sensitive
6. Pulsation	Sensitive	Sensitive	Not Sensitive	Not Sensitive	Not Sensitive
7. Mechanical Vibration	Not Sensitive	Sensitive	Not Sensitive	Sensitive	Sensitive
8. Pressure Drop	Med to High	Med	Zero	Med to High	Med to High
9. Calibration/Verification Method	Dimensional	Flow	Zero Flow	Zero Flow	Flow
10. Robustness	High	Low	High	Med	Low
11. Maintenance Cost	Low	Med	Low	Low	High
12. Meter Cost	Med to High	Med	Med to High	Med	Med
13. Standard	AGA3	AGA7	AGA9	AGA11	N/A - can use AGA7
14. Remark	<ul style="list-style-type: none"> No moving parts in the flow stream Low range ability with a single readout More sensitive to flow disturbances at higher beta ratios than some meters Flow pattern in the meter does not make meter self-cleaning 	<ul style="list-style-type: none"> Good accuracy over full linear range of meter Integrated totalizer index for actual volume Require upstream flow pattern to be non-swirling. 	<ul style="list-style-type: none"> No pressure drop High range ability No moving parts in contact with fluid Capable of bi-directional operation High initial cost Online Transducer Maintenance 	<ul style="list-style-type: none"> Not affected by flow disturbances Capable of bi-directional operation High pressure loss Suitable for high pressure gas measurements Meter is potentially sensitive to piping vibration 	<ul style="list-style-type: none"> Good accuracy over full linear range of meter Integrated totalizer index for actual volume No flow when meter stuck High pressure loss across the meter

GAS MEASUREMENT - FIELD INSTRUMENT

Transmitter



Pressure/Differential Pressure Transmitter

Pressure/Differential Pressure Transmitter use for measuring static pressure and transmit to flow computer by using HART Protocol.



Temperature Transmitter

Temperature Transmitter use for measuring gas temperature and transmit to flow computer by using HART Protocol.

Electronic Volume Corrector



Electronic Volume Corrector (EVC) use for converts the actual volume measured by the gas meter to reference conditions.

Integrated with Pressure and Temperature Measurement.

Battery life time approximate 5 years.

Overall accuracy on conversion factor is better than $\pm 0.5\%$ at reference condition and better than $\pm 1\%$ at rated operating condition.

Flow Computer



The Flow Computer is designed for use with Orifice/turbine/USM meters and implements mass, standard volume and energy flow computation of hydrocarbon gases to international standards.

Totalisation of mass, standard volume, gross volume and energy. Cumulative, daily and previous day totals.

Printer output for reports and event logging.

Input Scan Time < 1 sec

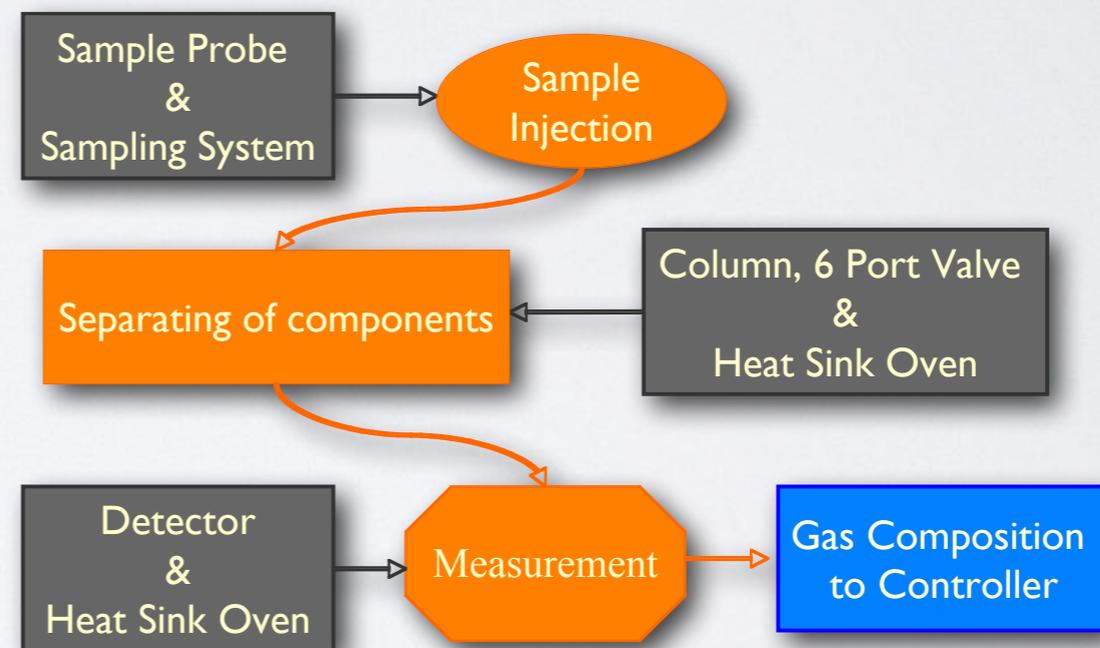
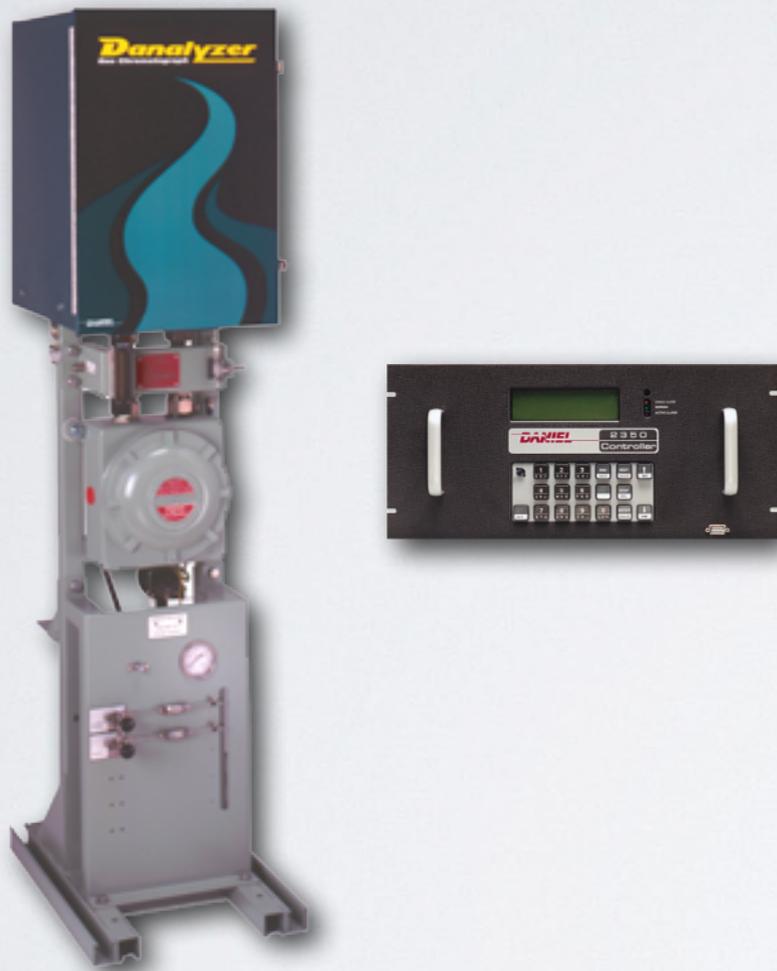
Calculation Scan Time < 500 msec

Calculation Accuracy ≤ 10 ppm

Gas Chromatograph

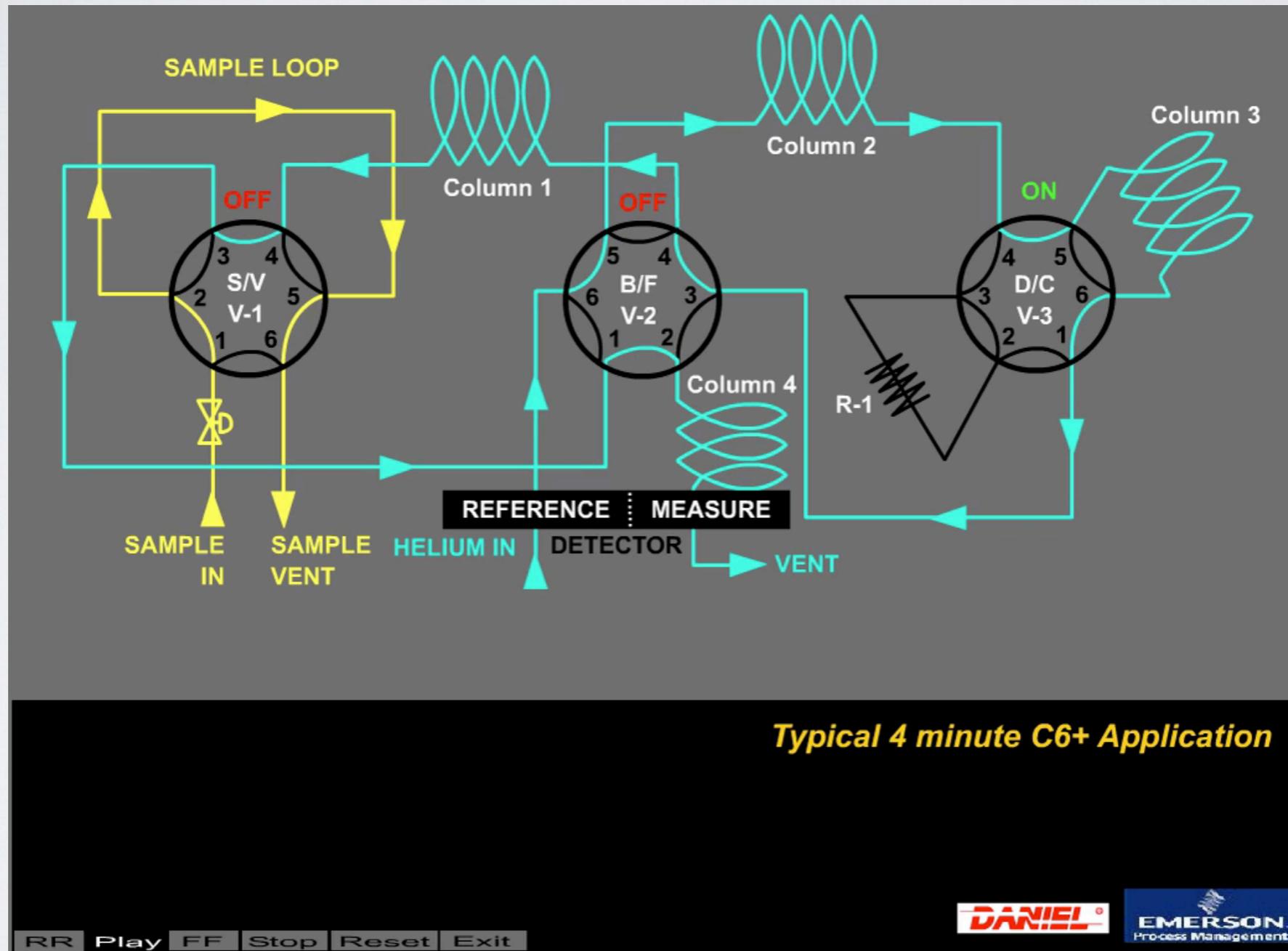
The primary purpose of an online gas chromatograph is to measure the gas composition of a flowing pipeline stream.

Typical natural gas components: C1, C2, C3, i-C4, n-C4, i-C5, n-C5, C6, CO2, N2.



Accuracy ± 0.5 BTU

Gas Chromatograph



Source: Daniel

GAS MEASUREMENT - EQUIPMENT MAINTAINING

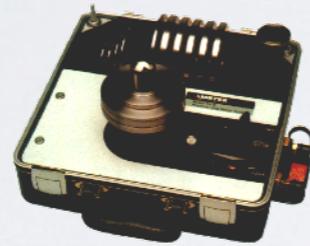
Test Equipment



Standard Gas



Gas Chromatograph



Pneumatic Dead Weight Tester



Differential Pressure Transmitter



Hydraulic Dead Weight Tester



Pressure Transmitter



Decade Resistance Box



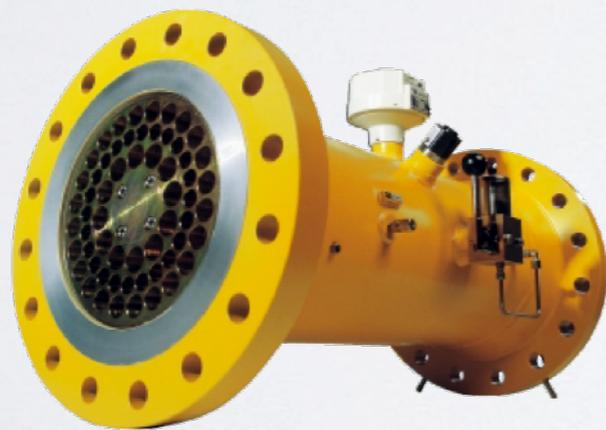
Temperature Transmitter

Meter Calibration & Inspection



Orifice Meter

Cleaning & Inspection



Turbine Meter

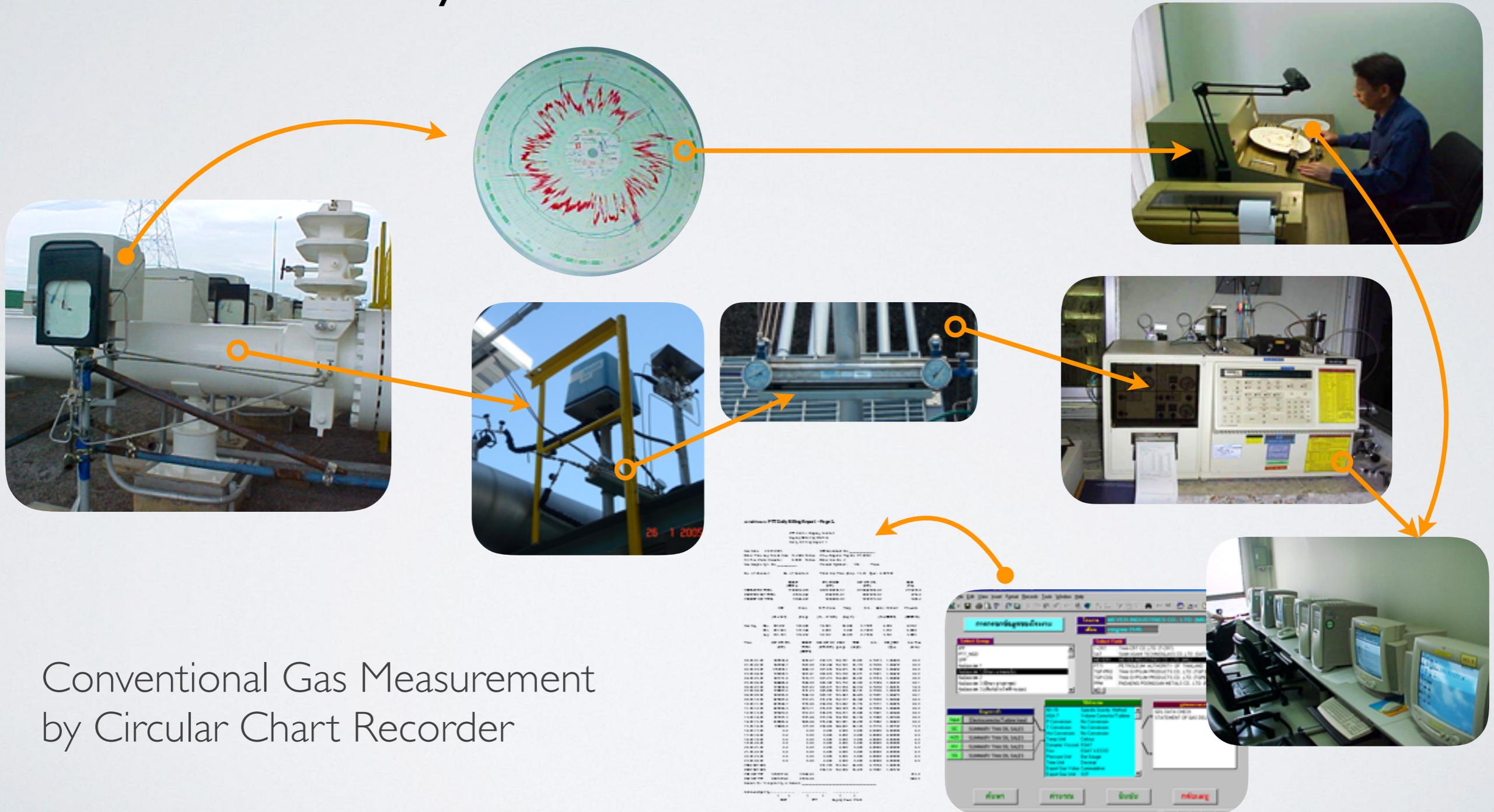
Cleaning & Proving



GAS REALTIME MEASUREMENT (GRTM)

Gas Realtime Measurement (GRTM)

GRTM: Gas energy measurement for custody transfer that can report flow event in the field at any time

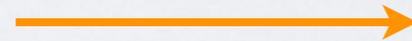


Conventional Gas Measurement by Circular Chart Recorder

Gas Realtime Measurement (GRTM)



GRTM: Gas energy measurement for custody transfer that can report flow event in the field at any time



รายงาน PTT Daily Billing Report - Page 1

Area	Flow	Rate	Volume	Energy	Cost	Revenue
Area 1	1000	1000	1000	1000	1000	1000
Area 2	2000	2000	2000	2000	2000	2000
Area 3	3000	3000	3000	3000	3000	3000
Area 4	4000	4000	4000	4000	4000	4000
Area 5	5000	5000	5000	5000	5000	5000
Area 6	6000	6000	6000	6000	6000	6000
Area 7	7000	7000	7000	7000	7000	7000
Area 8	8000	8000	8000	8000	8000	8000
Area 9	9000	9000	9000	9000	9000	9000
Area 10	10000	10000	10000	10000	10000	10000

Fully Digital System

Gas Realtime Measurement (GRTM)

GRTM: Gas energy measurement for custody transfer that can report flow event in the field at any time

