FLUID COMPONENTS INTERNATIONAL LLC

Best Practices for Air and Gas Flow Measurement in WTP and WWTP Operations

Virtual Water Expo – September 2022

Air & Gas Mass Flow Meters | Gas & Liquid Flow Switches, Level Switches

Fluid Components International & Reps Have Supported Flow Measurement in Water & Wastewater Industry for 50+ Years

Common Customer Concerns Related to Piping

Gas Flow Measurements

<u>Inadequate Straight Run</u>
Inaccurate meter readings compared to published specifications

<u>Permanent Pressure Loss</u>
Is my chosen technology wasting energy and driving up my operational costs?

The Ideal World is Based on Ideal Lab Conditions

Actual Gas Calibration Enable .5% Reading and Below Across 100 Turndowns

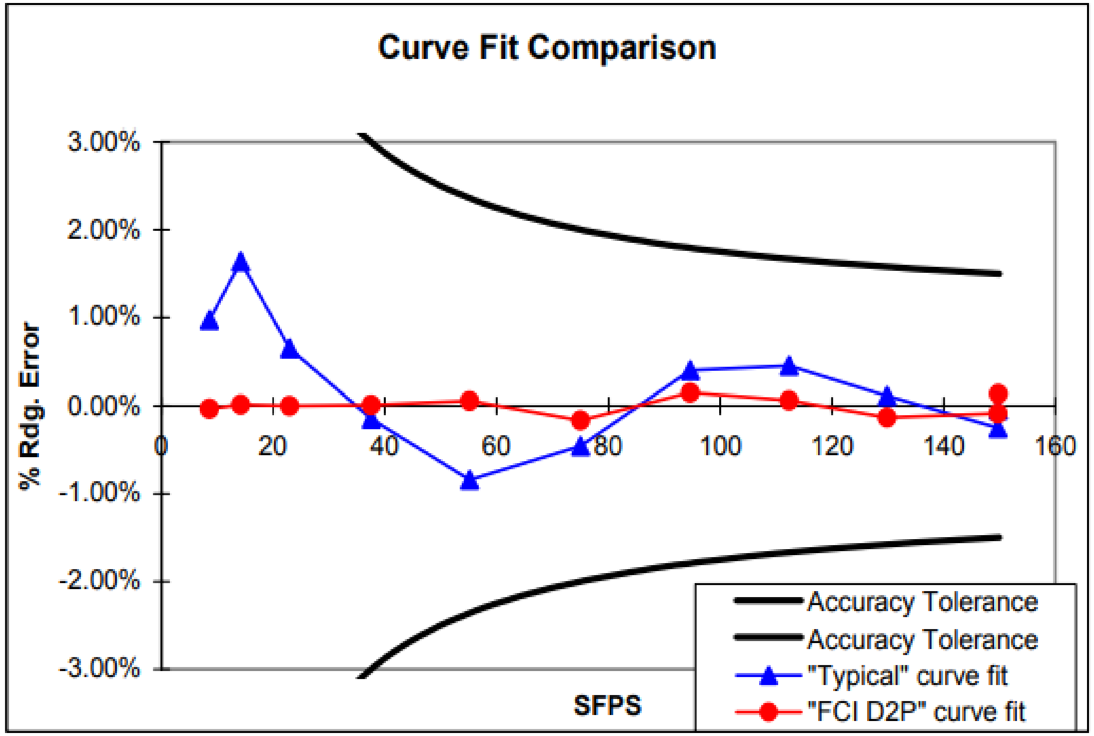
"The capability to match actual fluid calibrations with automated data collection routines & high accuracy flow reference standards **results in instrument calibrations that are consistently better than 0.5% of reading.**"

**Advances in Thermal Dispersion Mass Flow Meter Accuracy* by Dan McQueen

Ideal Lab Conditions

Fully Developed Flow Profile = Most Accurate Measurement

- Plenty of Straight Run, Clean Dry Gas, Reference Meters of Higher Accuracy



Point of Maximum Velocity of Fully Developed Profile

Where the most accurate measurement is made

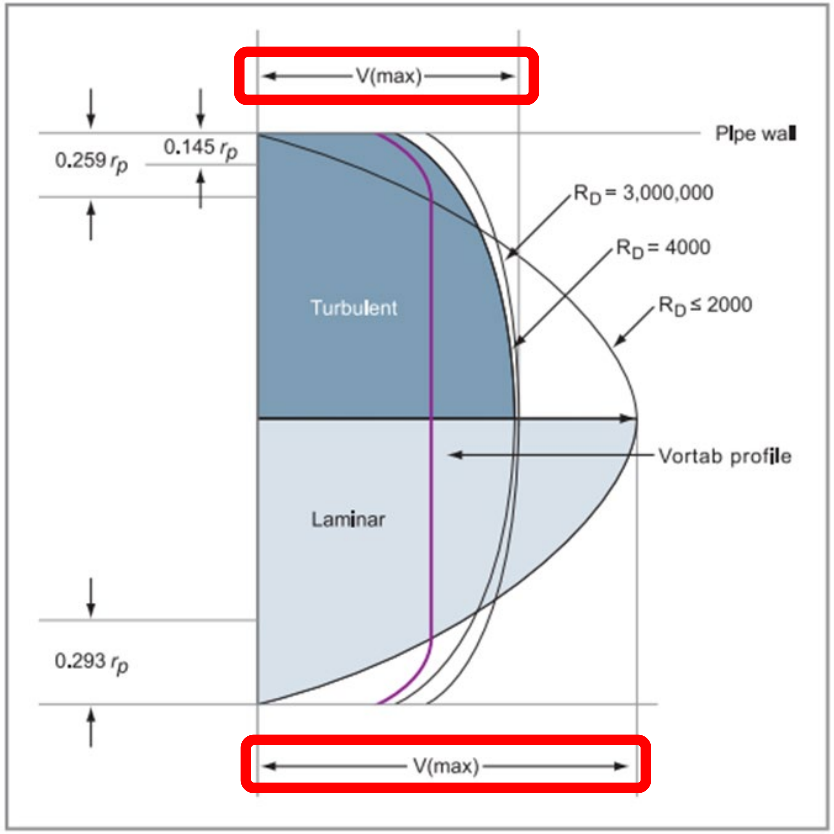


Figure 1. Laminar vs. turbulent flow profiles

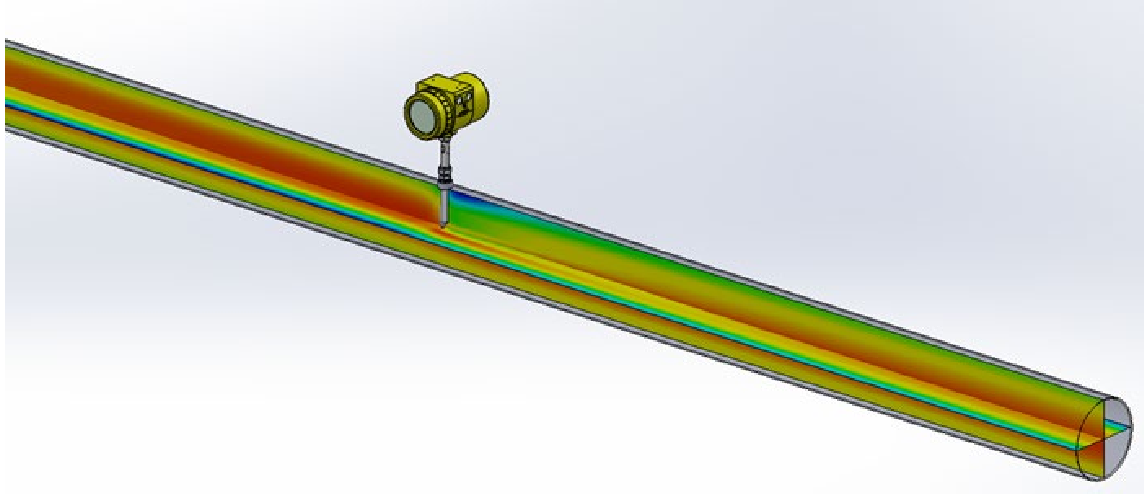
The laminar profile takes on a parabolic shape where the relationship between the average velocity and centerline velocity is quite dramatic when compared to the turbulent flow profile.

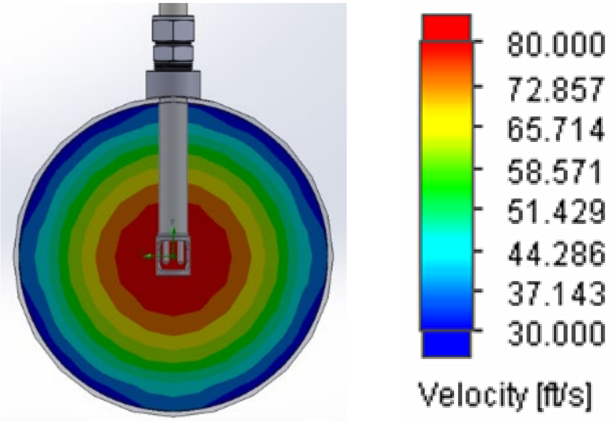
Source: Richard Miller, *Flow Measurement Engineering Handbook*; Vortab profile added by FCI

Velocity Profiles

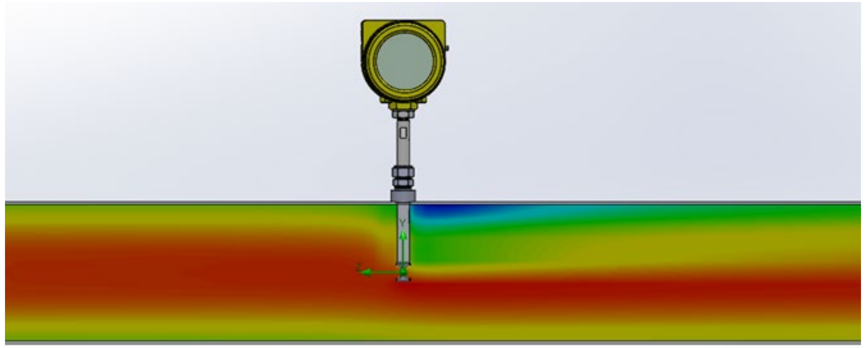
Ideal Straight Run Conditions: 20 Pipe Diameters Upstream/10D Downstream

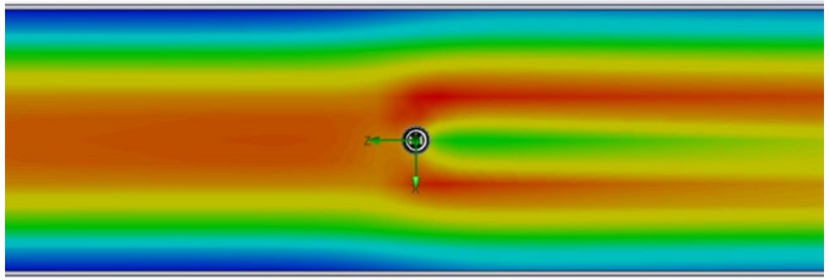
- Mirrors factory calibration conditions – Fully Developed Velocity Profile





Ideal





“Real World” Rarely Matches Ideal Lab Conditions

Metering sometimes an afterthought,

- Elbows, Valves, Inadequate Straight Run, Other Obstructions Are Common

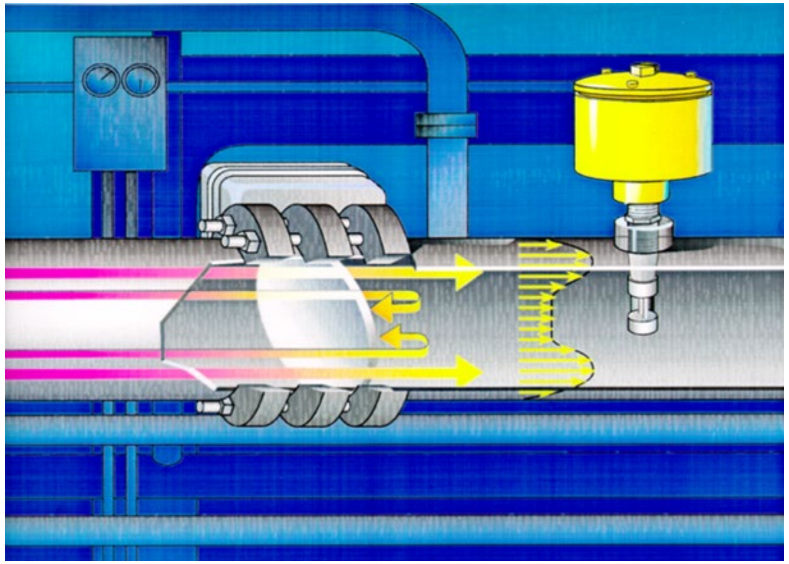


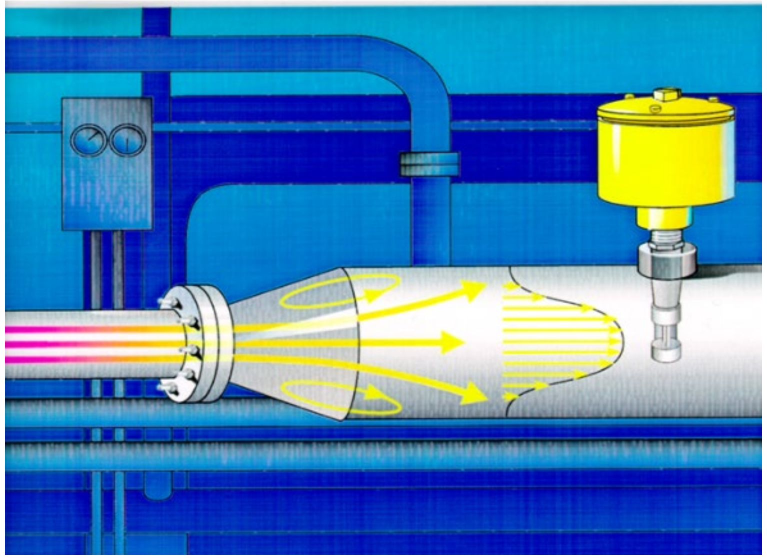


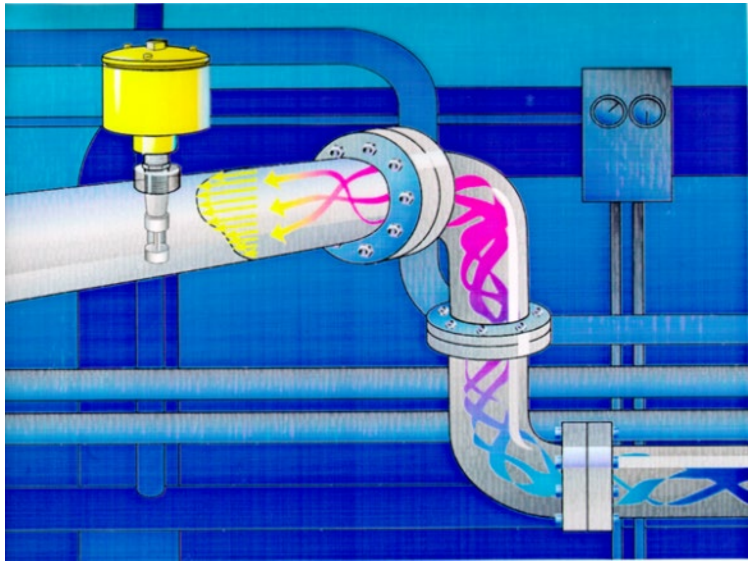

Gas Flow Measurement

Upstream / Downstream Obstructions

- Piping constraints will prevent achieving fully developed flow profiles

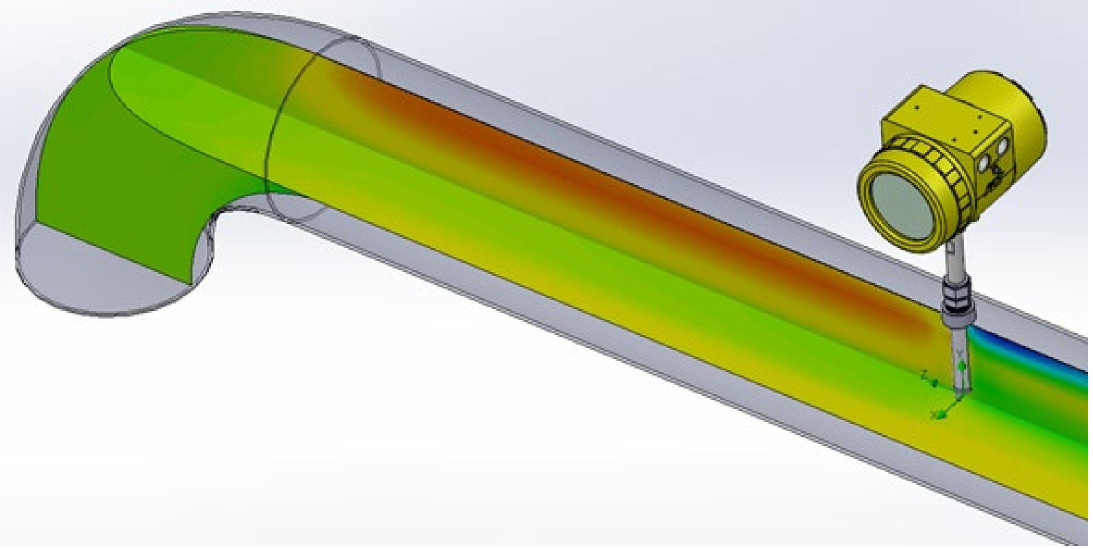


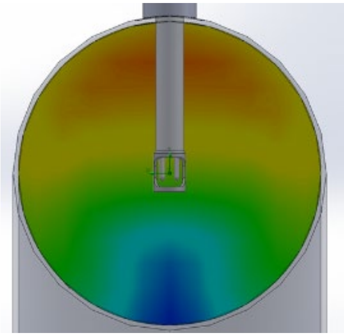




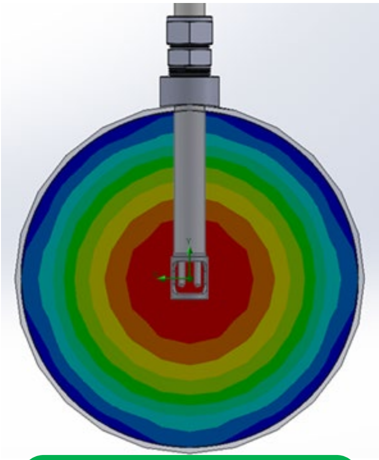
An Elbow 4D Upstream Introduces 4.3% Additional Inaccuracy

- Impact on Accuracy: 4.3%





Actual



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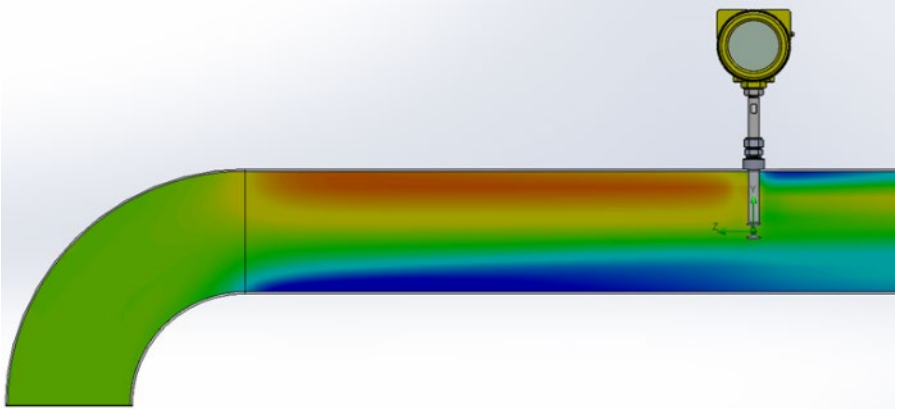
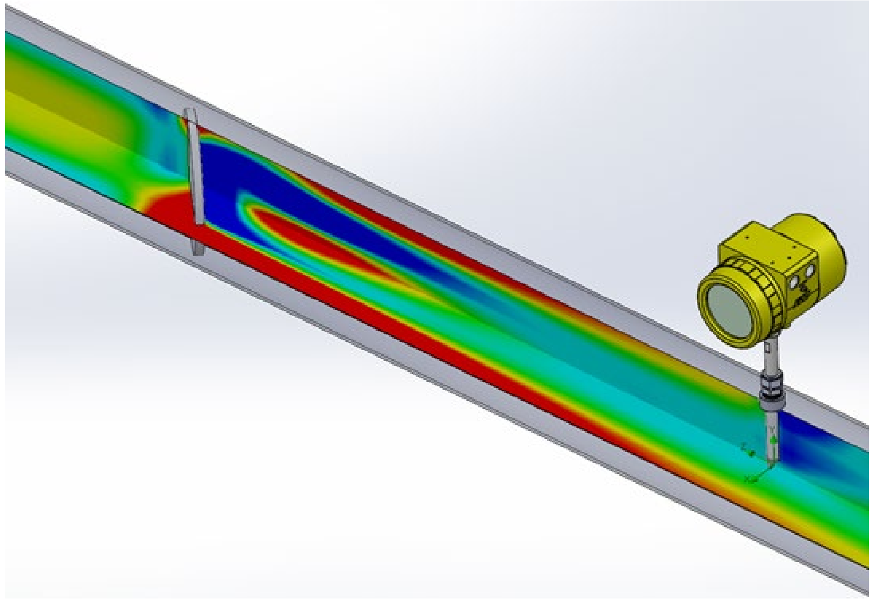
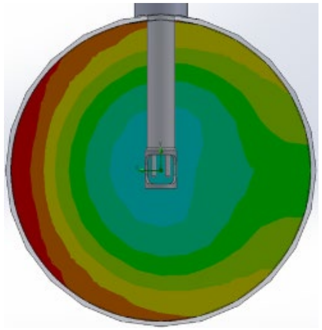


Butterfly Valve (50% Open) 5D Upstream Introduces 15% Inaccuracy





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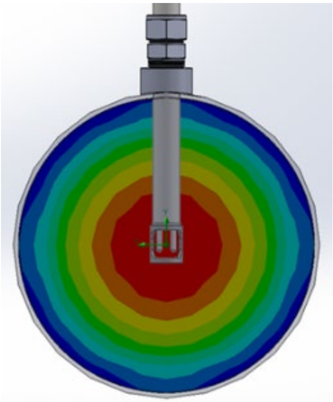

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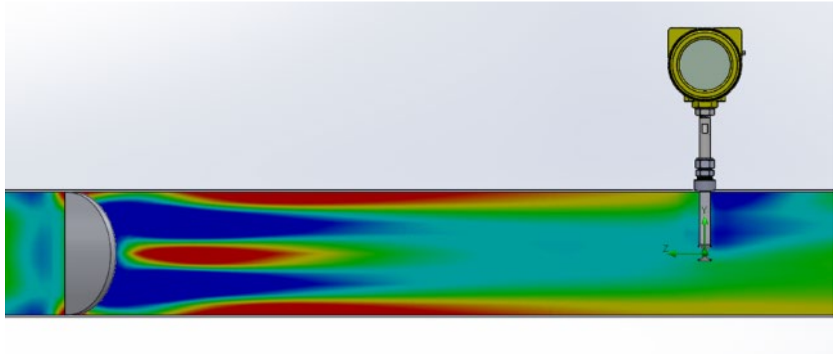
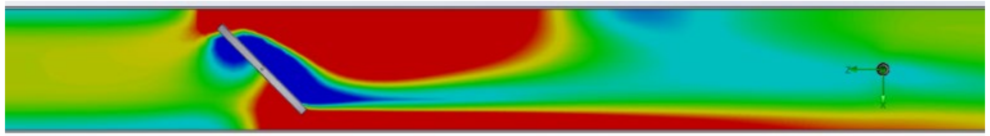
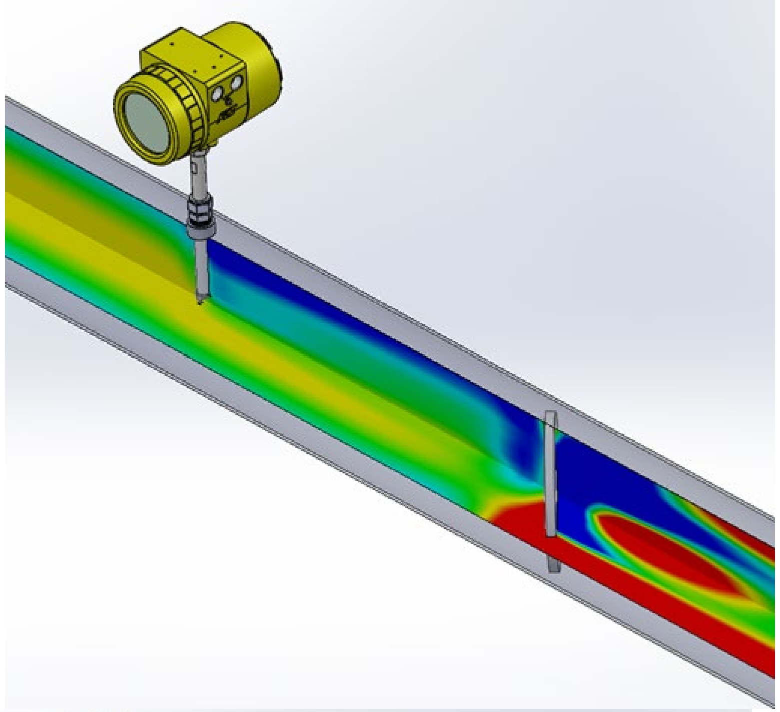
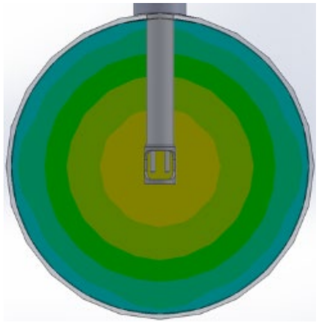




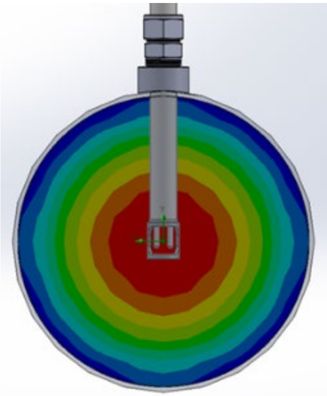
Same Valve 3D Downstream Introduces 1.7% Inaccuracy

Obstruction: Butterfly Valve 3 Pipe Diameters Downstream (50% Open)





Actual



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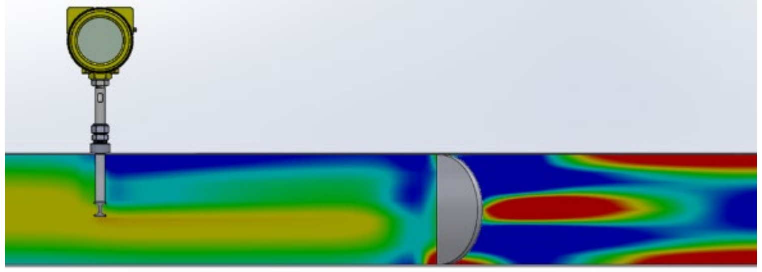
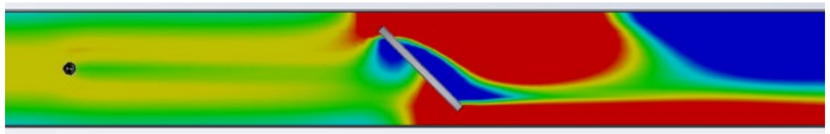
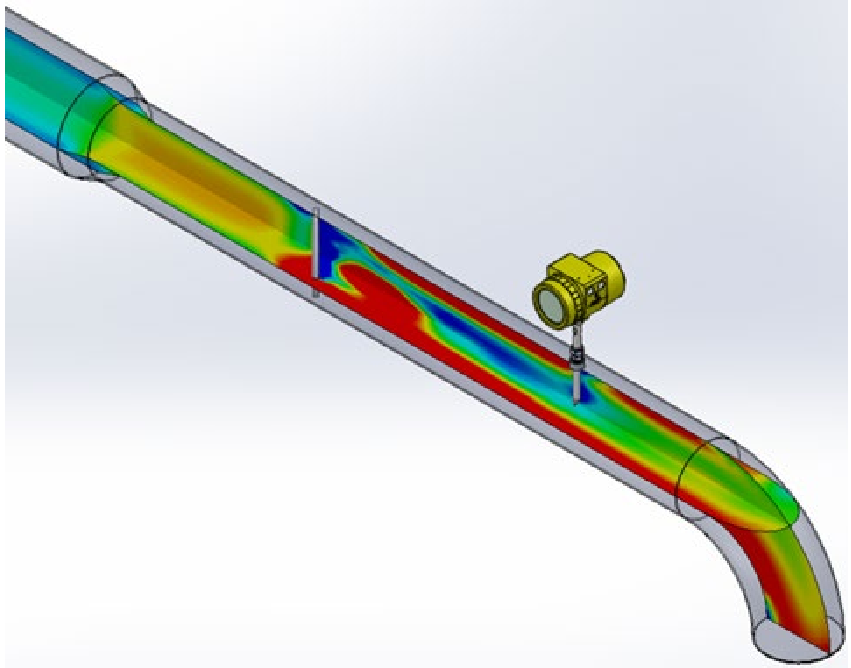


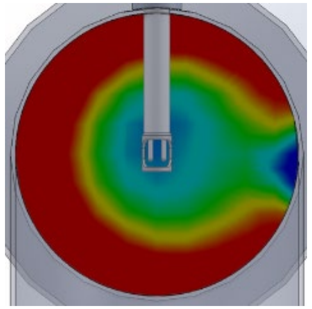


Multiple Common Obstructions Introduce 18% Inaccuracy

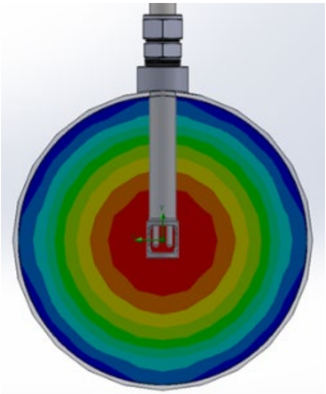
Obstructions: Convergence 7D Up, Butterfly Valve 4D Up (50%), Elbow 2D Down

- Impact on Accuracy: 18% (worst case)

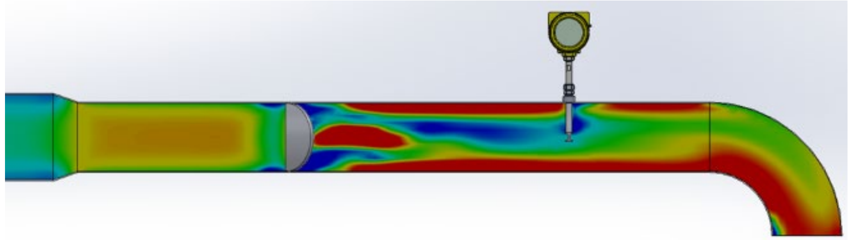


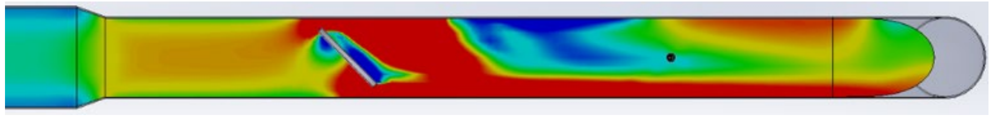


Actual



Ideal





Upstream Modulating Valve Adds 8.76% Uncertainty

Aeration / Blower Applications – Common to have Modulating Valve Upstream

Application Parameters

Media	Air - 100%			
Line Description	6.065 Inches I.D. pipe. (6 inch sch. 40).			

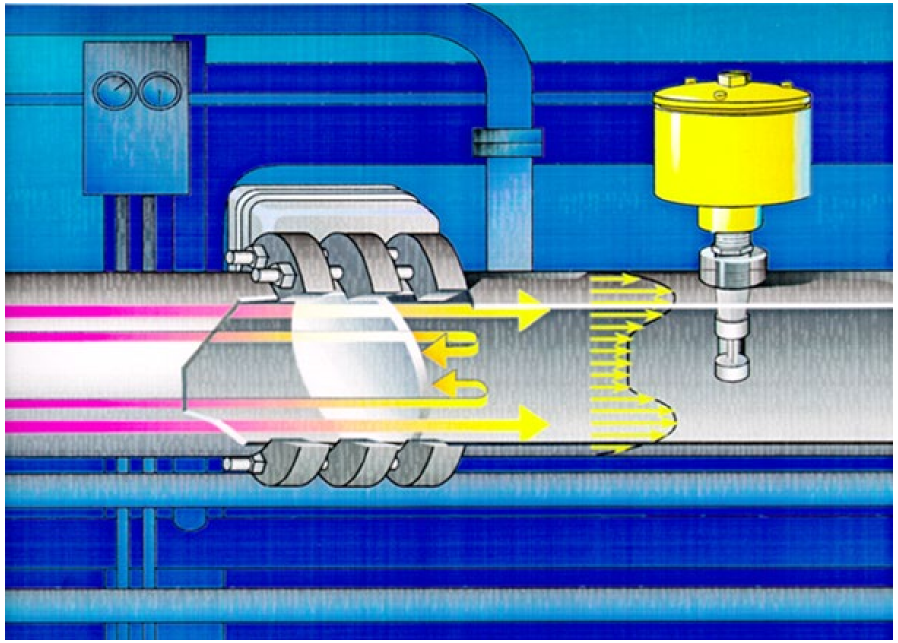
Pipe Diagram

9D	90	2D	bv	7D	X	3D	90	6D

90=90 Deg Elbow; bv=Butterfly Valve Or Damper; X = Install location;

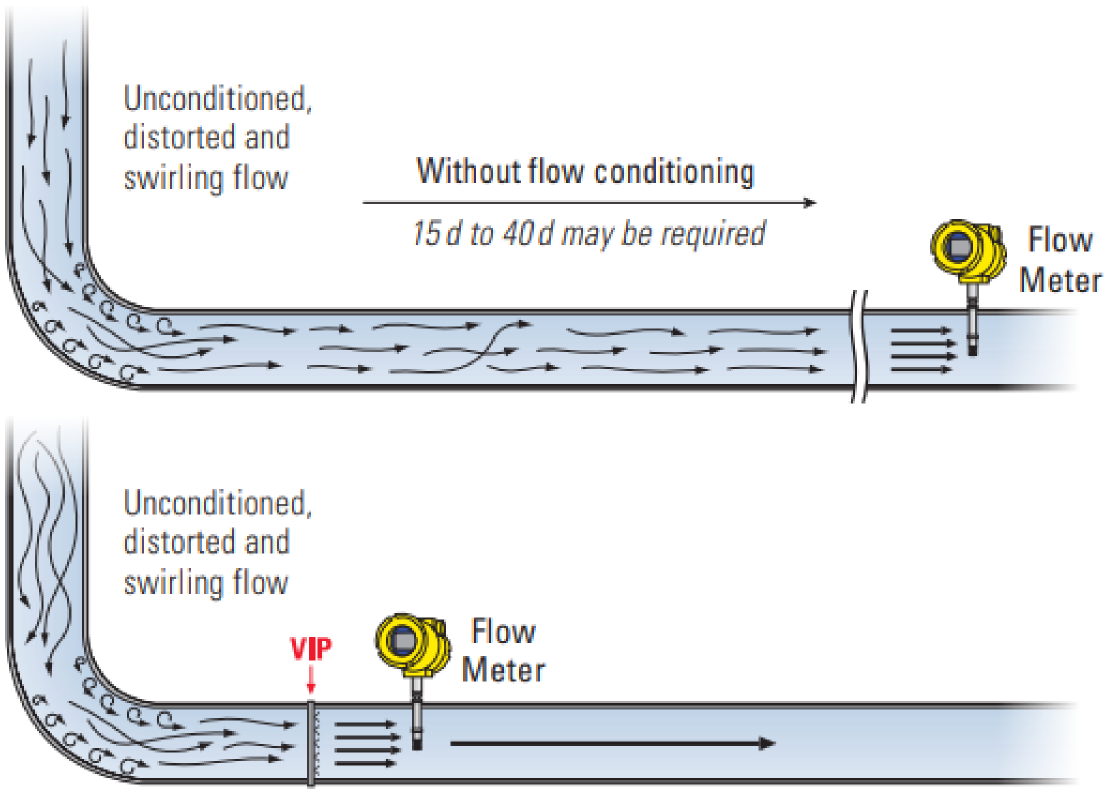
	Min	Normal	Max	Units
Flow	300	15000	30000	SCFH
Temperature	40	70	200	deg F
Pressure	5	8	10	psig
Standard Conditions	14.70 psia and 70 deg F			
Calibration Options	None			
Analog Output 1	4-20 mA = 0 to 30000 SCFH (Set for Flow)			
Analog Output 2	4-20 mA = 0 to 150 deg F (Set for Temperature)			

Recommended Model	ST80
Base Accuracy	1.00% rdg. + 0.50% of full scale.
App Uncertainty Est.	8.76% rdg. + 0.50% of full scale.
Repeatability	0.50% rdg.



Gas Flow Measurement

Flow Conditioners Create a Swirl Free, Uniform Velocity Flow Profile



- Benefit: Improved accuracy in less than ideal conditions

Gas Flow Measurement

Example: Lack of Ideal Straight Run

- Same piping constraints but now utilizing a flow conditioner

Application Parameters

Media	Air - 100%			
Line Description	6.065 Inches I.D. pipe. (6 inch sch. 40).			

Pipe Diagram

9D	90	2D	bv	4D			X	3D	90	6D

90=90 Deg Elbow; bv=Butterfly Valve Or Damper; =Vip3; X = Install location; VIP covers 3D (VIP & 3D straight run)

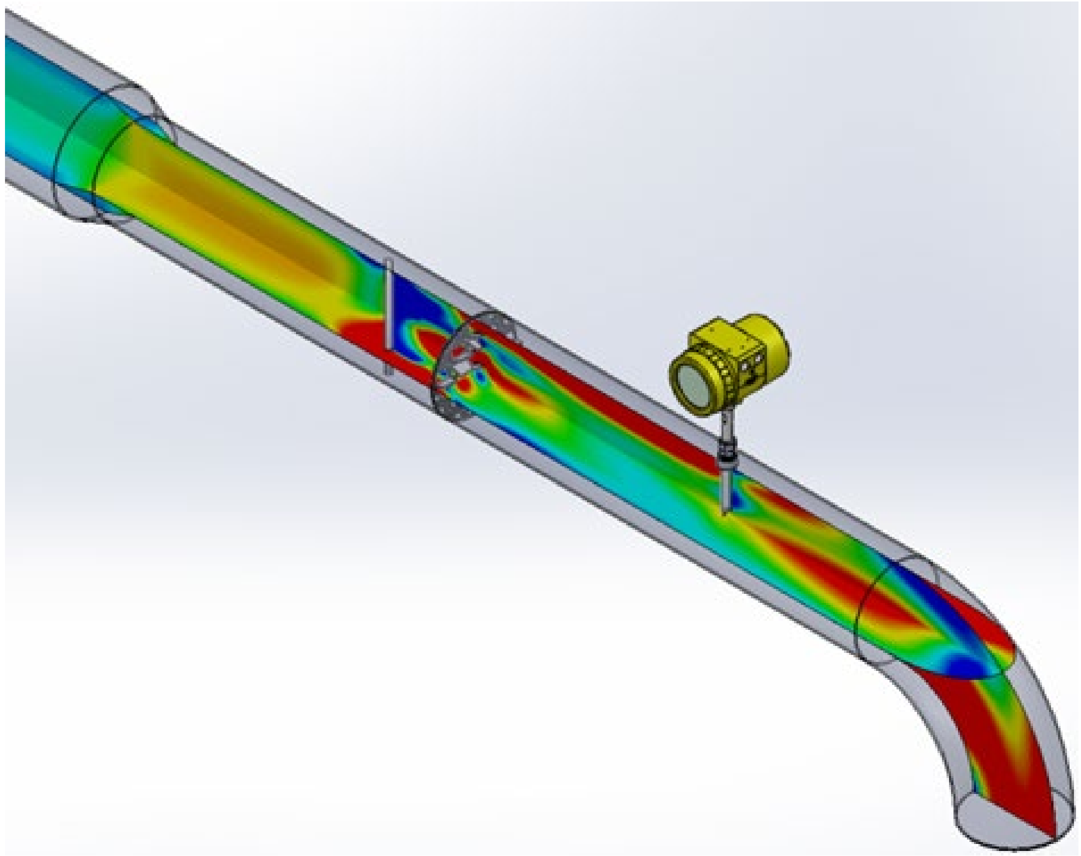
	Min	**Normal**	**Max**	**Units**
Flow	300	15000	30000	SCFH
Temperature	40	70	200	deg F
Pressure	5	8	10	psig
Standard Conditions	14.70 psia and 70 deg F			
Calibration Options	VIP			
Analog Output 1	4-20 mA = 0 to 30000 SCFH (Set for Flow)			
Analog Output 2	4-20 mA = 0 to 150 deg F (Set for Temperature)			

Recommended Model	**ST80**
Base Accuracy	1.00% rdg. + 0.50% of full scale.
App Uncertainty Est.	1.04% rdg. + 0.50% of full scale.
Repeatability	0.50% rdg.

Velocity Profiles

Obstructions: Convergence 7D Up, Butterfly Valve 4D Up (50%), Elbow 2D Down

- Inaccuracy without flow conditioner: 18% (worst case)
- Inaccuracy utilizing flow conditioner: 0.8% (worst case)



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Gas Flow Measurement

A Look at Permanent Pressure Loss

- Limited Piping Configuration – No Flow Conditioning

Application Parameters

Media	Air - 100%
Line Description	8.329 Inches I.D. pipe. (8 inch Sch 10S).

Pipe Diagram

13D	cn	2D	bv	3D	X	4D	90	5D

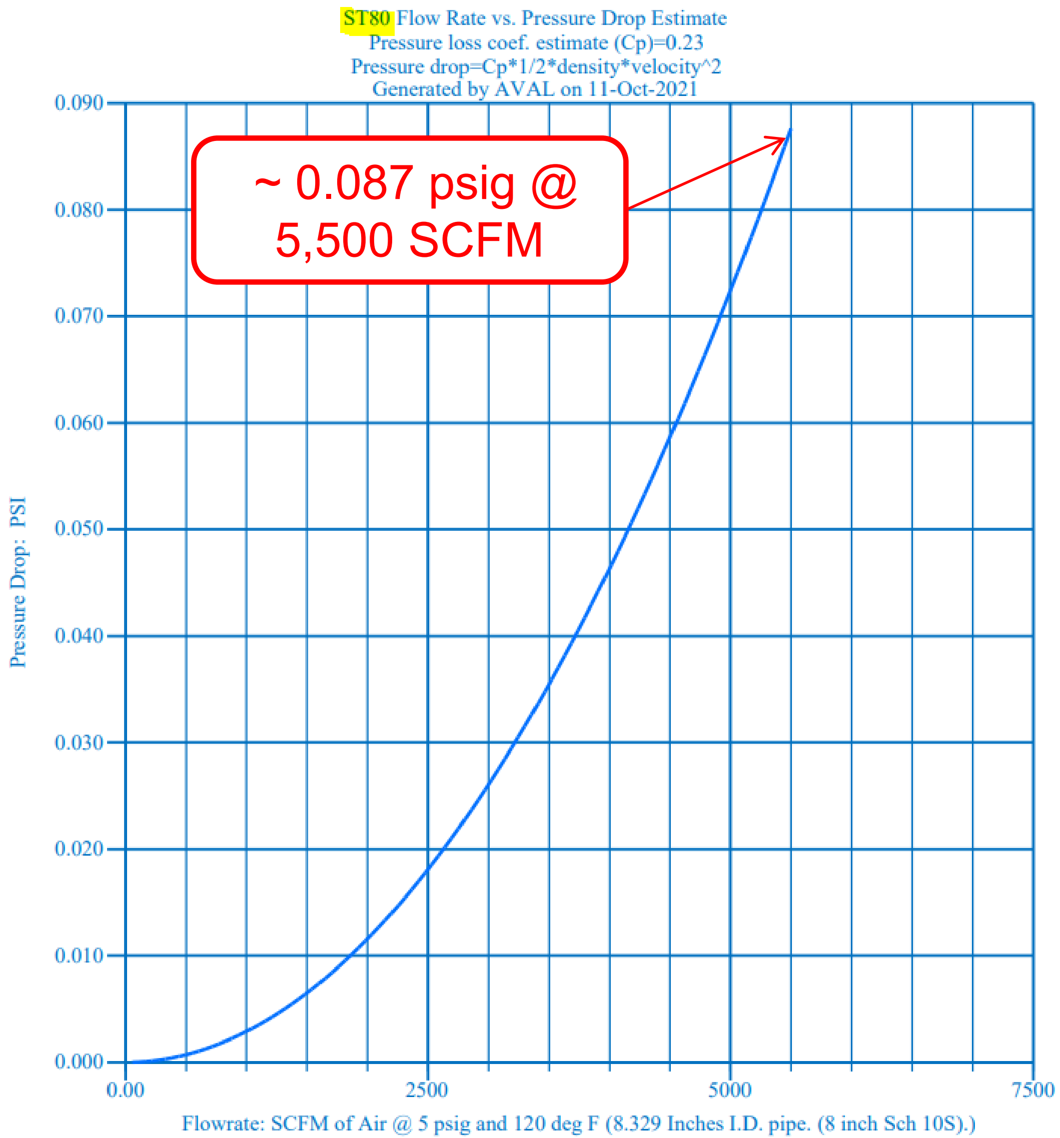
cn=Convergence; bv=Butterfly Valve Or Damper; X = Install location; 90=90 Deg Elbow

	Min	Normal	Max	Units
Flow	55	2250	5500	SCFM
Temperature	40	120	200	deg F
Pressure	2	5	10	psig
Standard Conditions	14.70 psia and 70 deg F			
Calibration Options	None			
Analog Output 1	4-20 mA = 0 to 5500 SCFM (Set for Flow)			
Analog Output 2	4-20 mA = 0 to 250 deg F (Set for Temperature)			

Recommended Model	ST80
Base Accuracy	1.00% rdg. + 0.50% of full scale.
App Uncertainty Est.	17.43% rdg. + 0.50% of full scale.
Repeatability	0.50% rdg.

Gas Flow Measurement

Permanent Pressure Loss – Insertion Style Flow Meter



Gas Flow Measurement

Permanent Pressure Loss – Meter with Flow Conditioner

- Limited Piping Configuration – Flow Conditioner Utilized

Application Parameters

Media	Air - 100%			
Line Description	8.329 Inches I.D. pipe. (8 inch Sch 10S).			

Pipe Diagram

13D	cn	2D	bv			X	4D	90	5D

cn=Convergence; bv=Butterfly Valve Or Damper; =Vip3; X = Install location; 90=90 Deg Elbow; VIP covers 3D (VIP & 3D straight run)

	Min	Normal	Max	Units
Flow	55	2250	5500	SCFM
Temperature	40	120	200	deg F
Pressure	2	5	10	psig
Standard Conditions	14.70 psia and 70 deg F			
Calibration Options	VIP			
Analog Output 1	4-20 mA = 0 to 5500 SCFM (Set for Flow)			
Analog Output 2	4-20 mA = 0 to 250 deg F (Set for Temperature)			

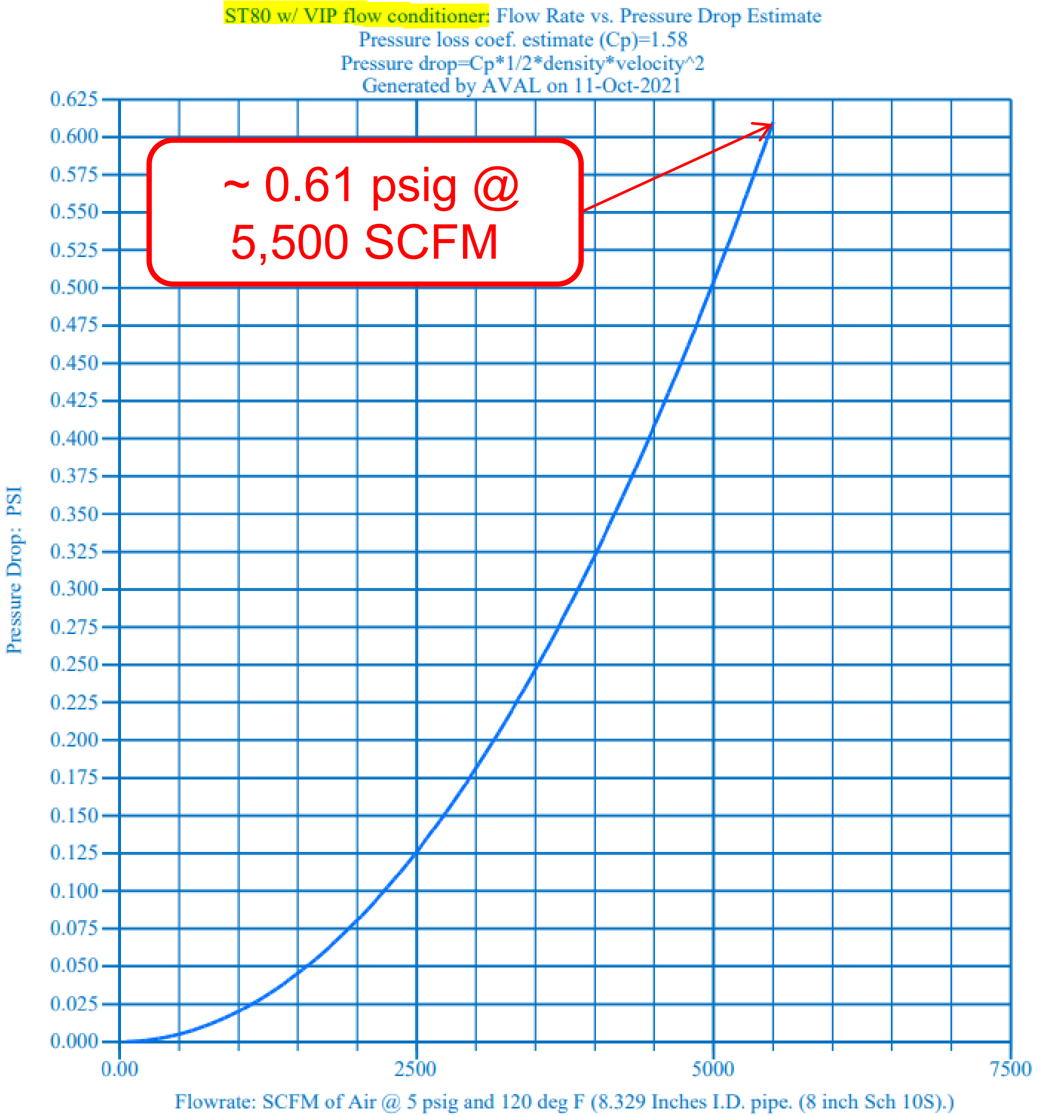
Recommended Model	**ST80**
Base Accuracy	1.00% rdg. + 0.50% of full scale.
App Uncertainty Est.	1.00% rdg. + 0.50% of full scale.
Repeatability	0.50% rdg.

Flow Conditioner Adds .523 PSIG Permanent Pressure Loss

Flow Conditioner Accounts for 87% of Pressure Loss

- Flow conditioner accounts for roughly 0.523 psig @ 5,500 SCFM

Question Raised: Do Different Flow Conditioning Technologies Cause Greater Pressure Loss?



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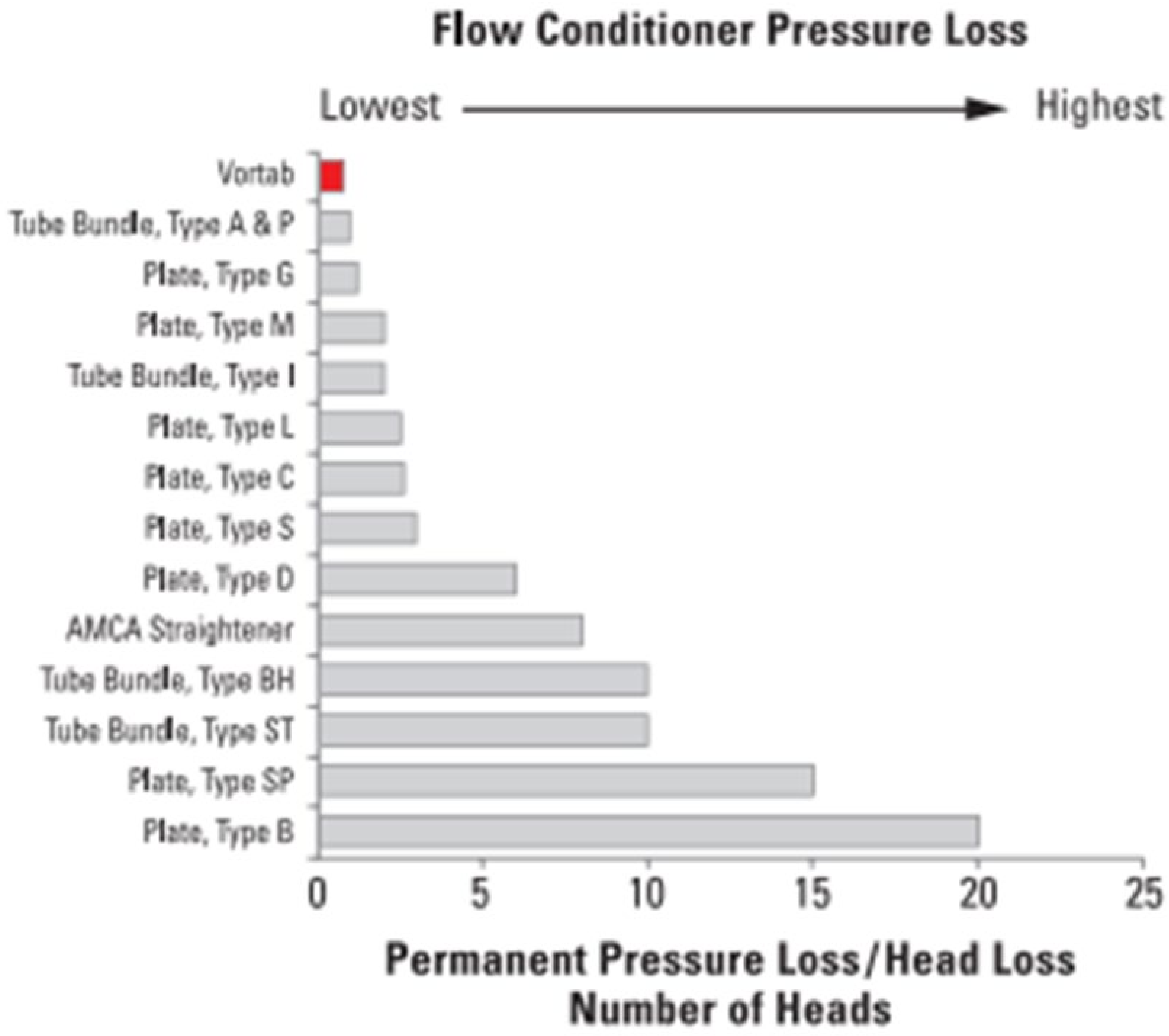
Common Designs Can Add 33%-90% Additional Pressure Loss Compared to Minimum Achievable Head Loss Design



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Work with Your Suppliers

Properly address your primary measurement requirement(s)

Inadequate Straight Run

1. Know Accuracy Requirements of the Application
2. Work with Knowledgeable Suppliers to Understand Potential Impact on Accuracy
3. If Needed, Look at Impact of Utilizing a Flow Conditioner

Permanent Pressure Loss

1. Insertion Meter Technology is Advantageous Over Those that Utilize Restrictions
2. Flow Conditioner Pressure Loss Varies by Design

Beyond the Specifications

We are Here to Assist!

- Local Rep – Review Application Requirements
  - www.fluidcomponents.com/sales/sales-offices
- Additional Material
  - FCI e-Book: Air/Gas Flow Measurement Solutions Handbook
  - Request a copy today!
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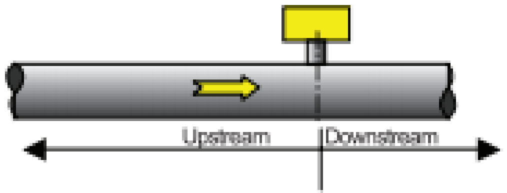
Q & A

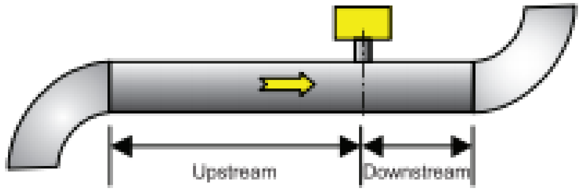
Gas Flow Measurement

Recommended Straight Run = Fully Developed Flow Profiles



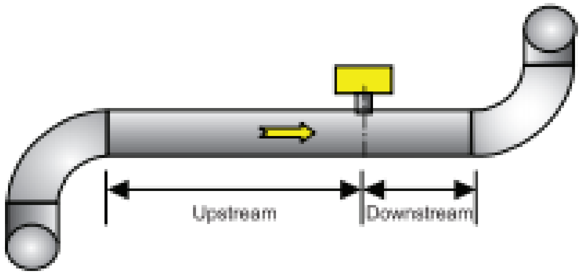
Default Recommendation for Required Straight-runs with Undefined Obstructions

Pipe Size	Upstream	Downstream
< 6 inches [150 mm]	20 x Pipe ID	10 x Pipe ID
≥ 6 inches [150 mm]	15 x Pipe ID	7.5 x Pipe ID
with Vortab flow conditioner	6 x Pipe ID	2 x Pipe ID



Recommendation for 45° or 90° Elbows in Plane

Pipe Size	Upstream	Downstream
< 6 inches [150 mm]	15 x Pipe ID	7.5 x Pipe ID
≥ 6 inches [150 mm]	10 x Pipe ID	5 x Pipe ID
with Vortab flow conditioner	6 x Pipe ID	1 x Pipe ID

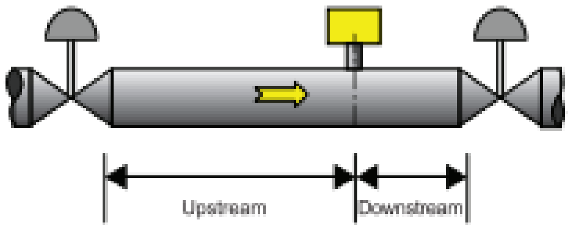


Recommendation for 45° or 90° Elbows OUT of Plane (Swirl Effect)

Pipe Size	Upstream	Downstream
< 6 inches [150 mm]	20 x Pipe ID	10 x Pipe ID
≥ 6 inches [150 mm]	15 x Pipe ID	5 x Pipe ID
with Vortab flow conditioner	6 x Pipe ID	2 x Pipe ID

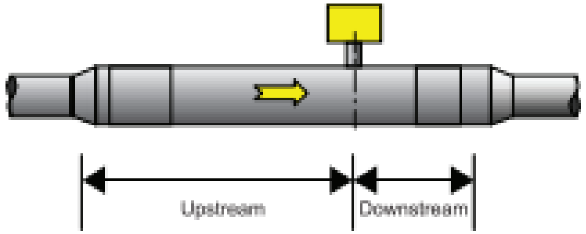
Gas Flow Measurement

Recommended Straight Run = Fully Developed Flow Profiles



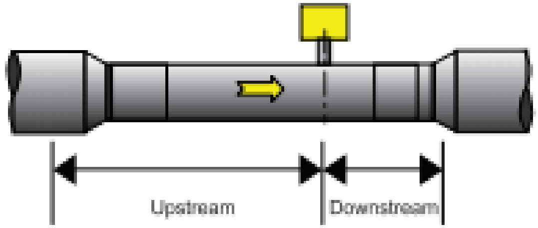
Recommendation for Flow Controlling Valves Upstream or Downstream

Pipe Size	Upstream	Downstream
< 6 inches [150 mm]	20 x Pipe ID	10 x Pipe ID
≥ 6 inches [150 mm]	15 x Pipe ID	5 x Pipe ID
with Vortab flow conditioner	9 x Pipe ID	2 x Pipe ID



Recommendation for Pipe Adaptor Upstream or Downstream

Pipe Size	Upstream	Downstream
< 6 inches [150 mm]	20 x Pipe ID	10 x Pipe ID
≥ 6 inches [150 mm]	15 x Pipe ID	5 x Pipe ID
with Vortab flow conditioner	9 x Pipe ID	2 x Pipe ID



Recommendation for Pipe Reducers Upstream or Downstream

Pipe Size	Upstream	Downstream
< 6 inches [150 mm]	15 x Pipe ID	5 x Pipe ID
≥ 6 inches [150 mm]	10 x Pipe ID	3 x Pipe ID
with Vortab flow conditioner	6 x Pipe ID	1 x Pipe ID

Total Cost of Ownership

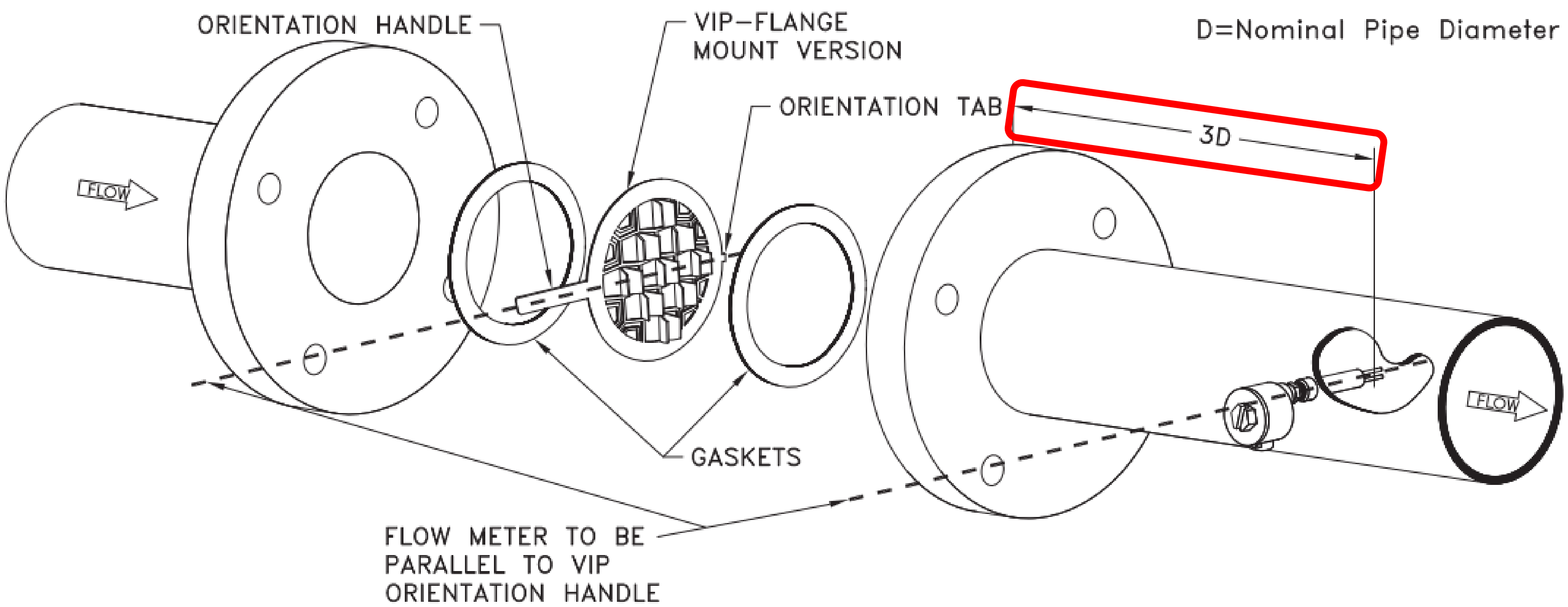
Thermal v DP/MV with Orifice

	Differential Pressure	Multivariable	Thermal
Transmitter	$1,500	$4,000	$4,200
Isolation Valve Manifold (5-valve)	$300	$300	-
Isolation Ball Valve (Full Port)	-	-	$175
Pressure Transmitter	$1,000	Integral	n/a
Temperature Transmitter/RTD	$450	Integral	Integral
Thermowell	$350	$350	-
Primary Flow Element - Orifice Plate (6-inch)	$200	$200	-
Impulse Tubing/Fittings	$50	$50	-
300 lb. Weld Neck Orifice Flange Union	$1,200	$1,200	-
Threadolet/Half Coupling	-	-	$25
Separate AC/DC Instrument Power	-	-	$100
Hardware Subtotal	**$5,050**	**$6,100**	**$4,375**
Installation Costs	$840	$600	$240
Maintenance Costs, Annual	$420	$240	$120
Energy Loss, Annual	$33,750	$33,750	$8,665
Initial 1-Year Cost of Ownership Total	**$38,860**	**$39,490**	**$13,400**

- Energy loss based on a blower producing 8 psig @ 250 KW, 8,000 hours of operation at a cost of $0.15 /KWH
- Pressure loss at Max Flow: DP/MV ~ 25” w.c., Thermal ~ 8” w.c.

Flow Conditioning

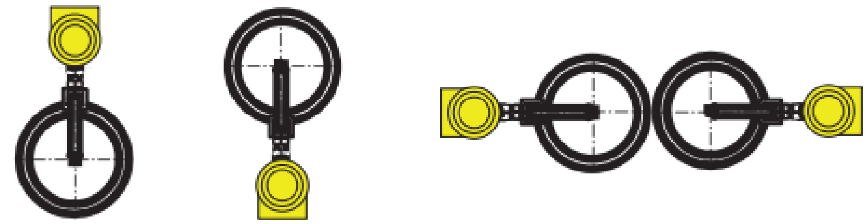
Pay Attention to the Installation Details



Gas Flow Measurement

Installation Recommendations – Dry v “Wet” Gases

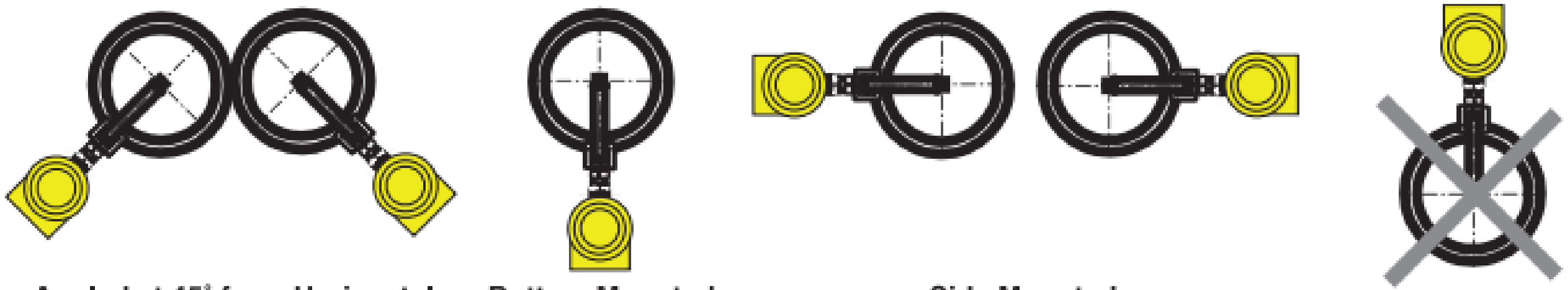
Installation in Horizontal Pipe: For General Air/Gas Applications



Top Mounted | Bottom Mounted | Side Mounted

Installation in Vertical Pipe: For All Gas Applications

Installation in Horizontal Pipe: High Humidity/Wet Gas Applications



Angled at 45° from Horizontal | Bottom Mounted | Side Mounted

Gas Flow Measurement

“Wet Gas” Solutions

- Wet Gas
  - Relative Humidity >100% and/or flow velocity >10 fps
  - Up to 10% Entrained Moisture (not Dual-Phase)
  - A challenge for any flow technology

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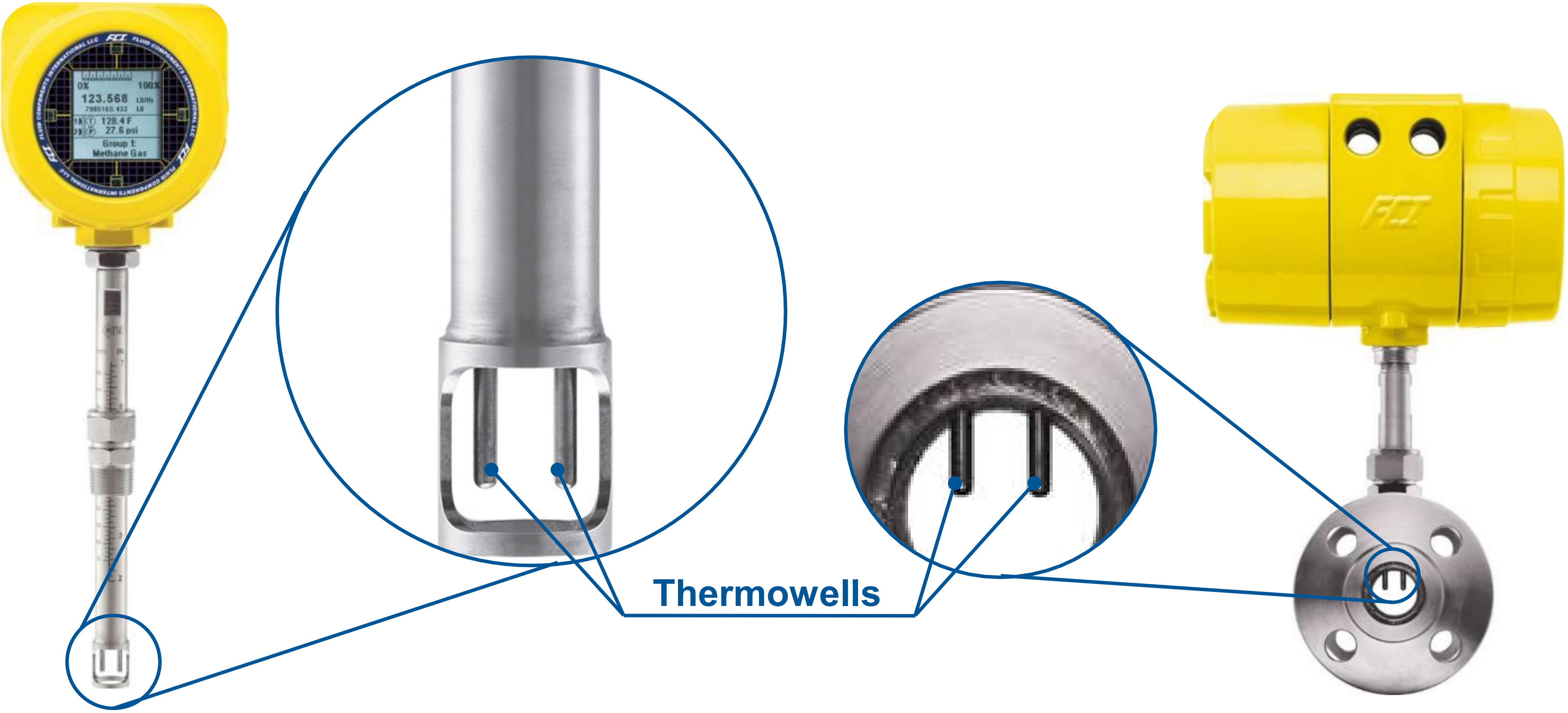
Thermal Technology [Gas Flow Meters]

Basic Sensor Design

- Flow element consists of (2) thermowells [aka tips] welded to an extension tube



Insertion
Thermal Mass flowmeter

In-line Type
Thermal Mass flowmeter

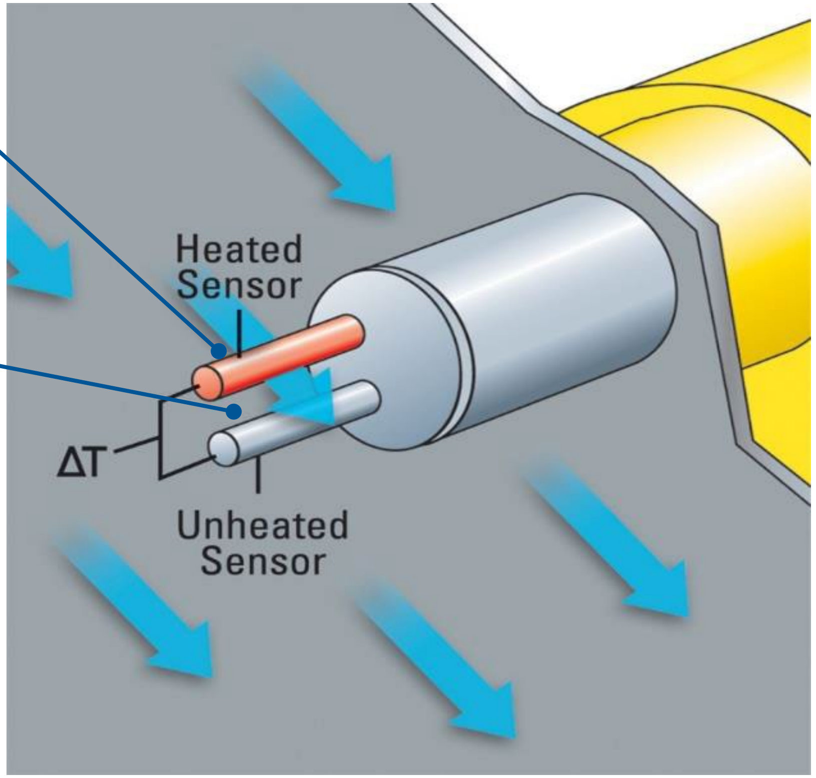
Thermal Technology [Gas Flow Meters]

Temperature Difference is Proportional to Mass Flow of the Medium

Active sensor:
Temperature sensor (Pt1000) plus Heater elements installed in one thermowell

Reference sensor:
Temperature sensor (Pt1000) installed in one thermowell

Signal processing:
Electronics supplies **constant power** to Heater element and senses the Temperature difference between Active and Reference flow sensor



Simplified Mass Flow Equation

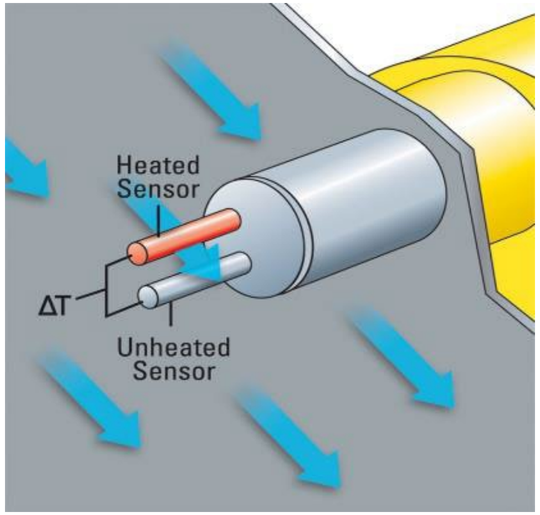
Heat loss equation converts to:

$$\Delta T \propto \rho \times v \times A = M \rightarrow$$

Meters Indicate Mass Flow in:
Lbm/Hour or
Standard Cubic Feet/Hour [SCFH] or
Standard Feet/Second [SFPS]

Legend

- ΔT = Temperature Difference
- ρ = Density (actual)
- v = Velocity (actual)
- A = Area of the pipe
- M = Mass flow



Flow Meter Technologies

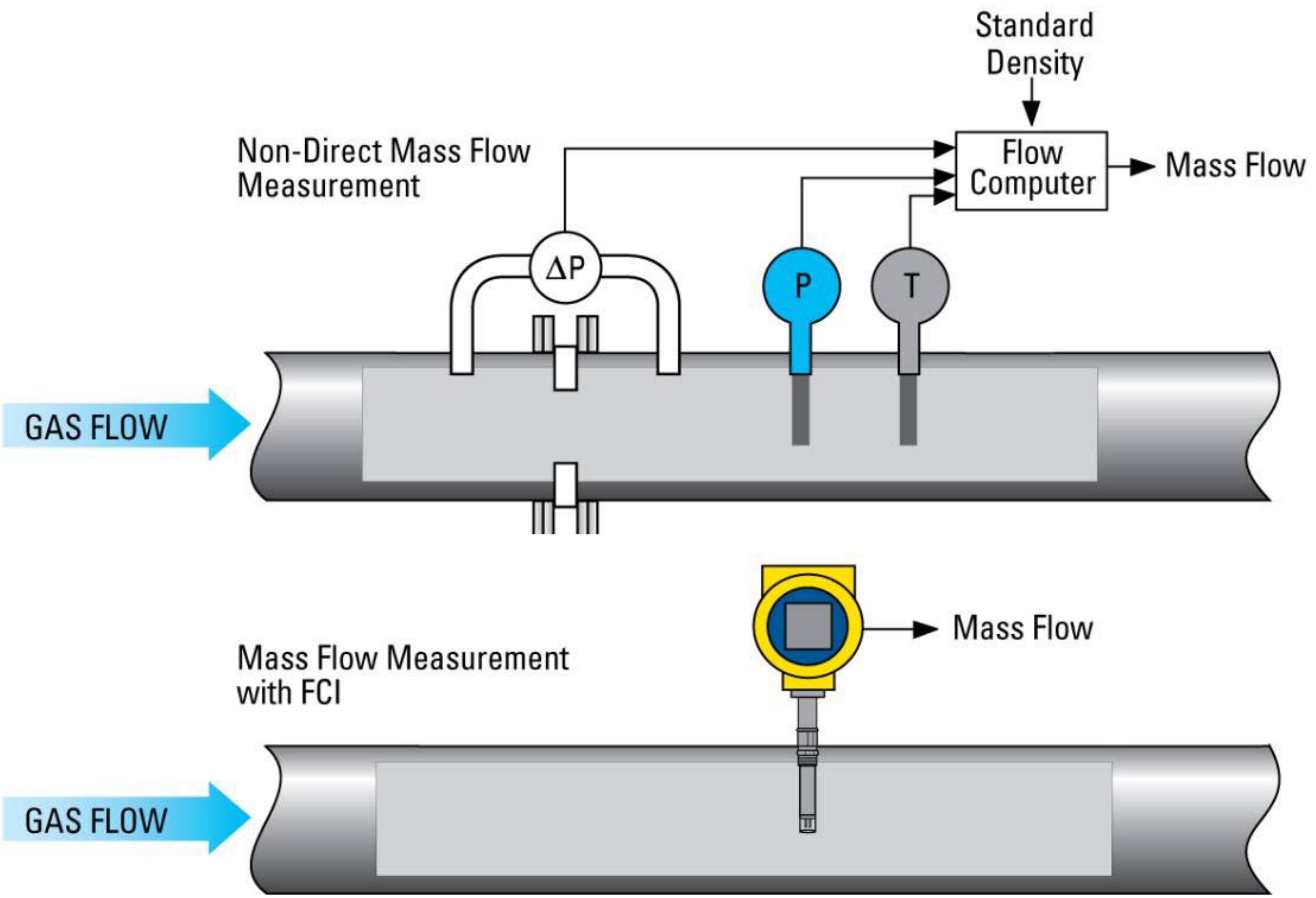
Mass or Volumetric

Volumetric flow meters

- Differential Pressure/Multivariable with primary flow elements
  - Orifice Plates
  - Averaging pitot tube
  - Venturi
  - V-cone
- Ultrasonic
- Vortex shedding
- Turbine
- Variable Area (VA)

Mass flow meters

- **Thermal Dispersion**
- Coriolis



FLUID COMPONENTS INTERNATIONAL LLC