GUSM Basics

Presented by Martin Schlebach

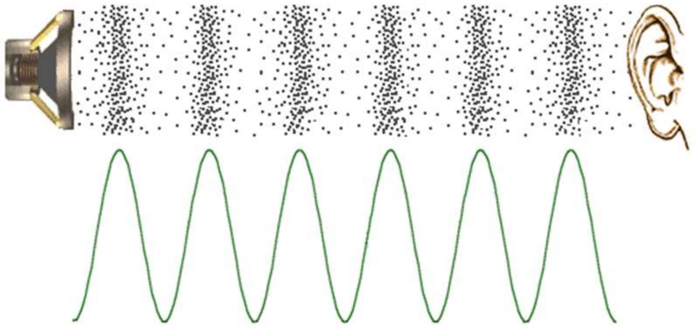
May 2024

EMERSON.

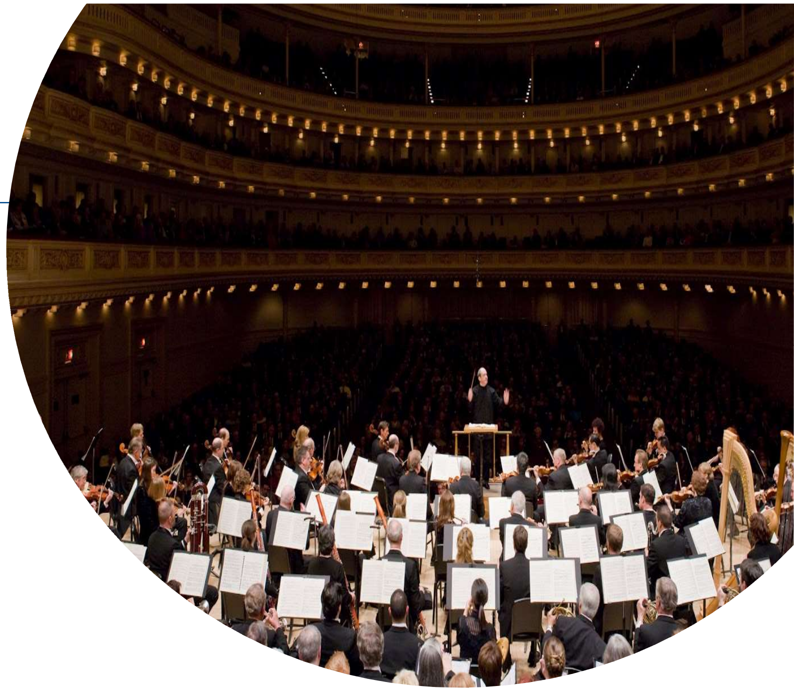
Ultrasound and Flow Measurement

What is Sound?

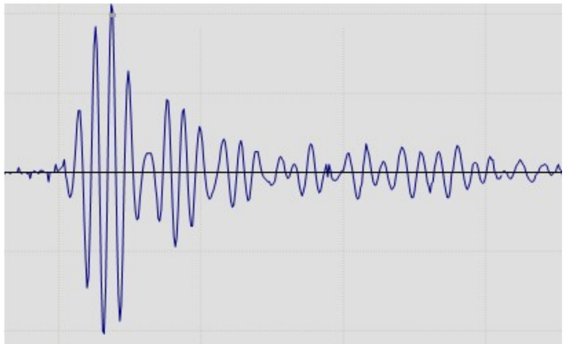
- Mechanical energy that is transmitted in waves (**pressure waves**) in a medium.
- Produced when a vibrating object comes into contact with a medium
- Sound is audible and inaudible
- Can travel in gas, liquid and solids
- Above the human hearing (20,000 Hz) is inaudible and called **Ultrasound**



Speed of Sound (SOS)



- **Speed** at which the sound wave is propagated through a medium
- **Power** or **frequency** of the wave does not affect its velocity
- **Pressure, temperature and composition** of the medium can change the speed of sound

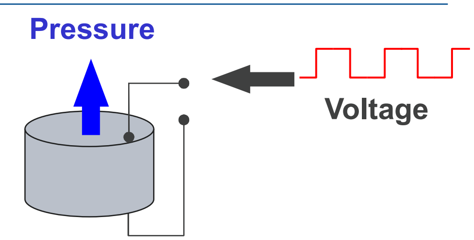


Producing Ultrasonic Energy

- We use a **piezo-electric** crystal to generate ultrasound
- Applying a voltage across the face of the piezo crystal causes it to vibrate
- Vibration excite the molecules of the fluid and a **pressure wave** is sent out across

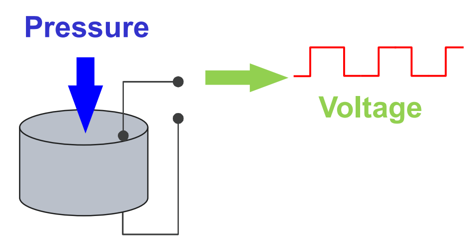
Transducer

- When a voltage is applied across a piezo-electric crystal it change its shape or vibrate and send a pressure wave



Produce **sound**
when voltage is applied

- When a piezo-electric crystal is squeezed by a received sound pressure wave there is a voltage produced across the crystal



Produce **voltage**
when pressure is sensed

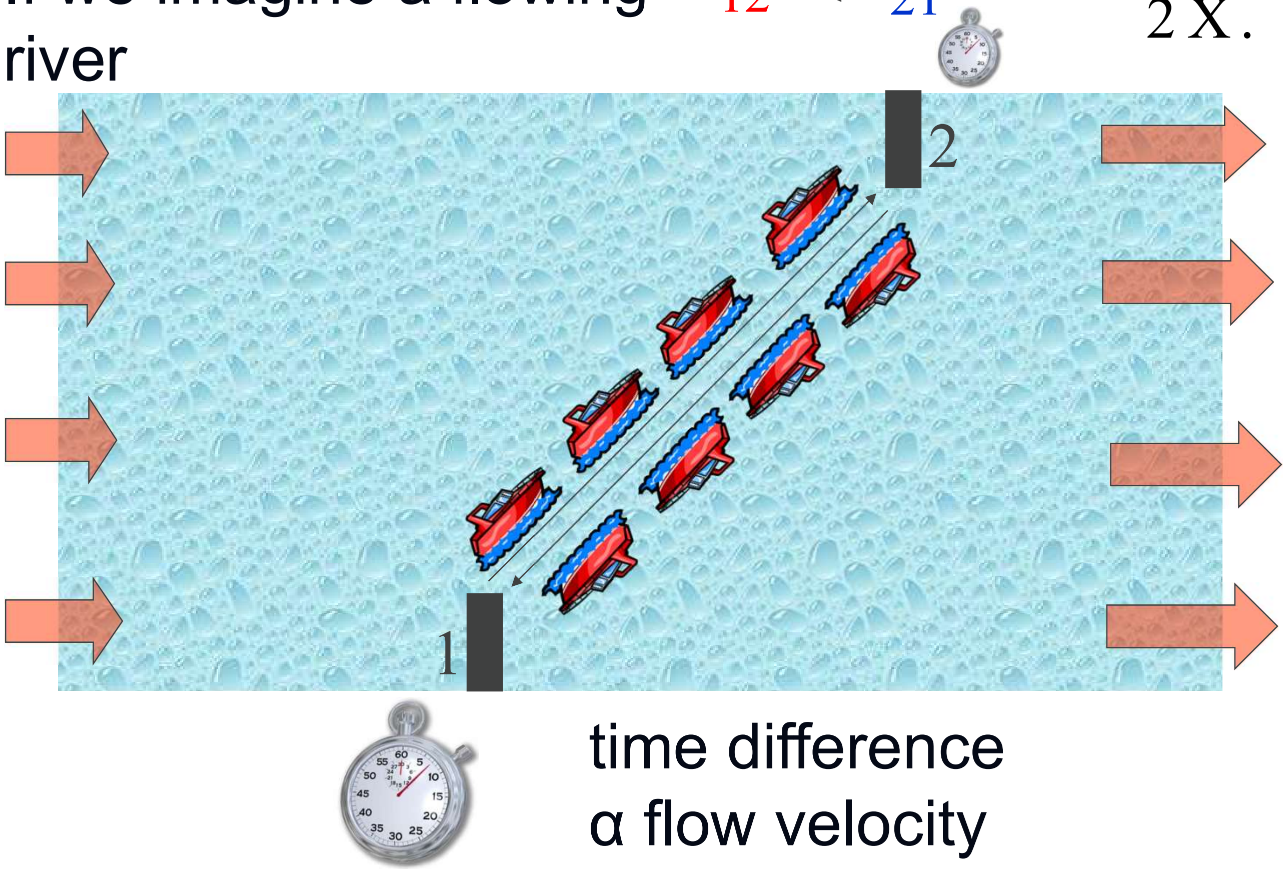
Transit Time Basics

Theory of Operation - Transit Times

If we imagine a flowing river

$t_{12} < t_{21}$

$$V = \frac{L^2}{2X.} \frac{t_{21} - t_{12}}{t_{21} . t_{12}}$$



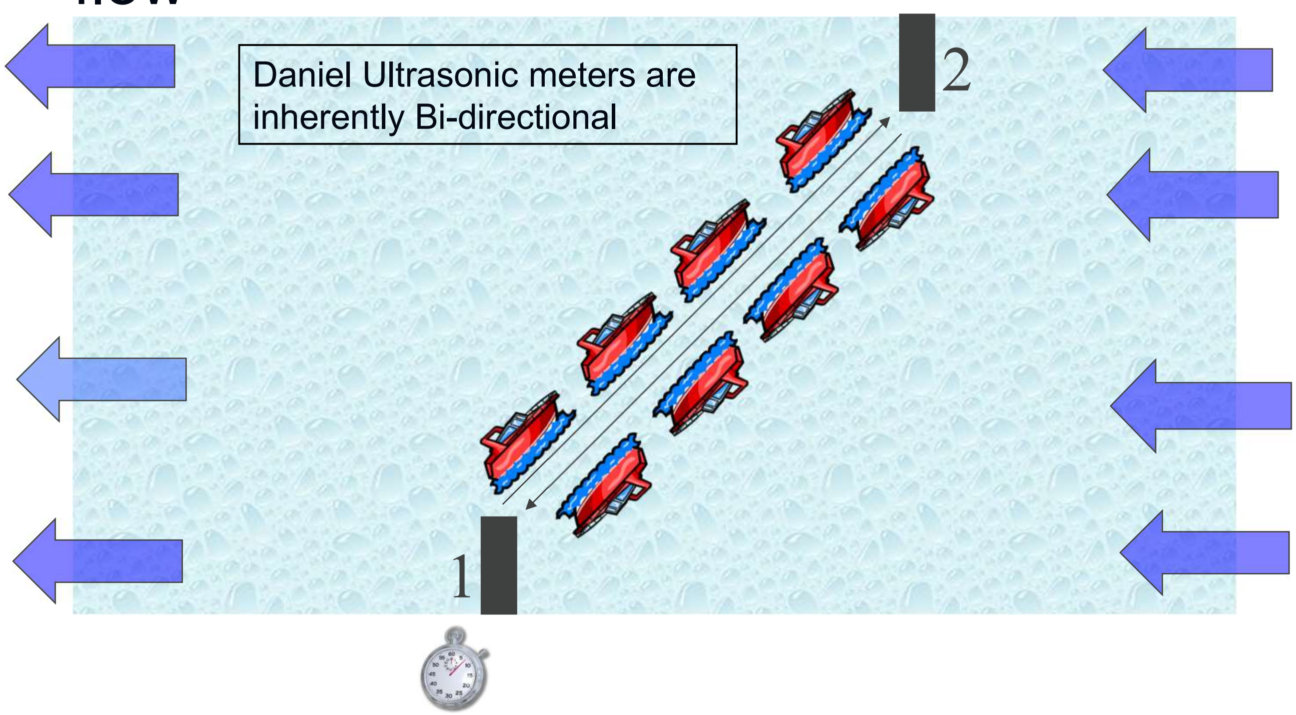
time difference
α flow velocity

Theory of Operation - Transit Times

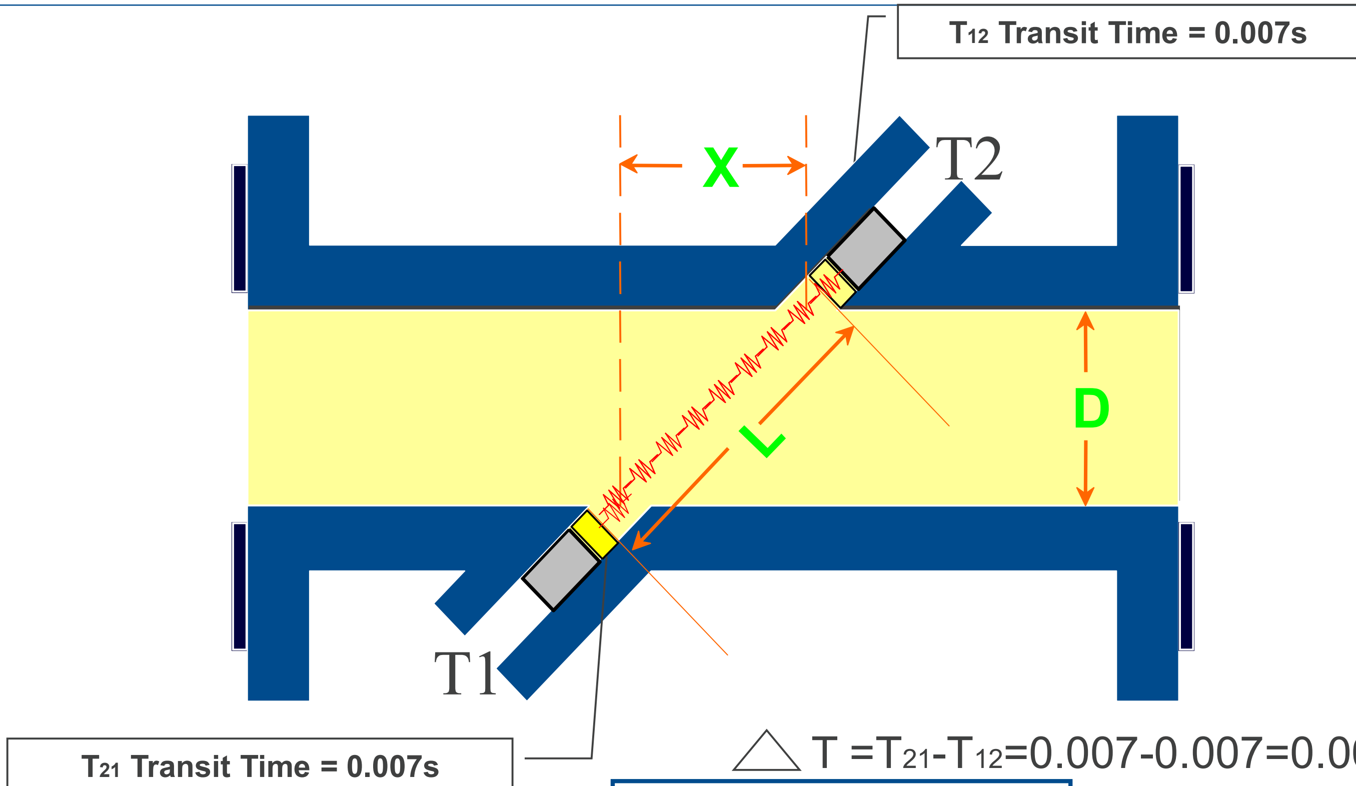
If we reverse the flow

$t_{12} > t_{21}$

$$V = \frac{L^2}{2X} \cdot \frac{t_{21} - t_{12}}{t_{21} \cdot t_{12}}$$



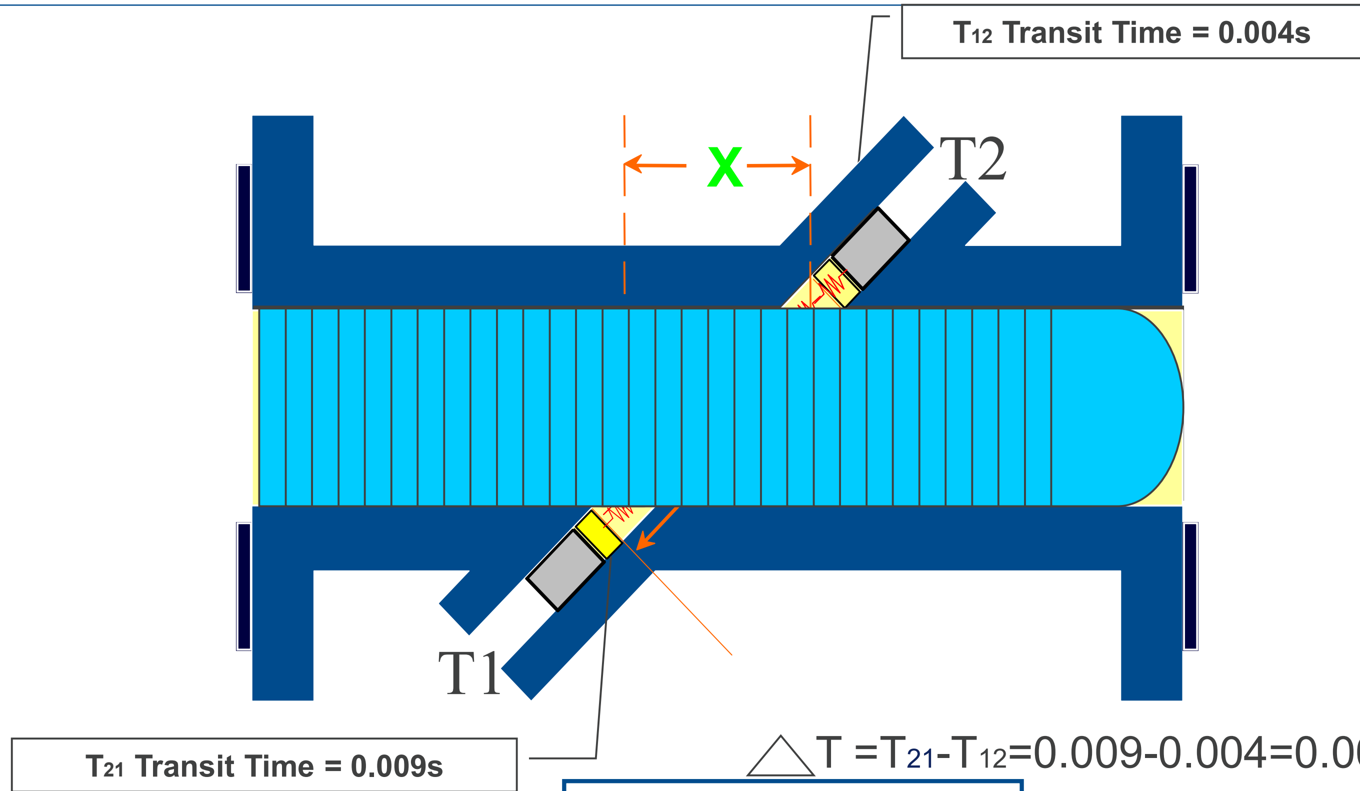
Transit Time Measurements (No Flow)



$\Delta T = T_{21} - T_{12} = 0.007 - 0.007 = 0.000s$

$$V = \frac{L^2}{2X} \cdot \frac{t_{21} - t_{12}}{t_{21} \cdot t_{12}}$$

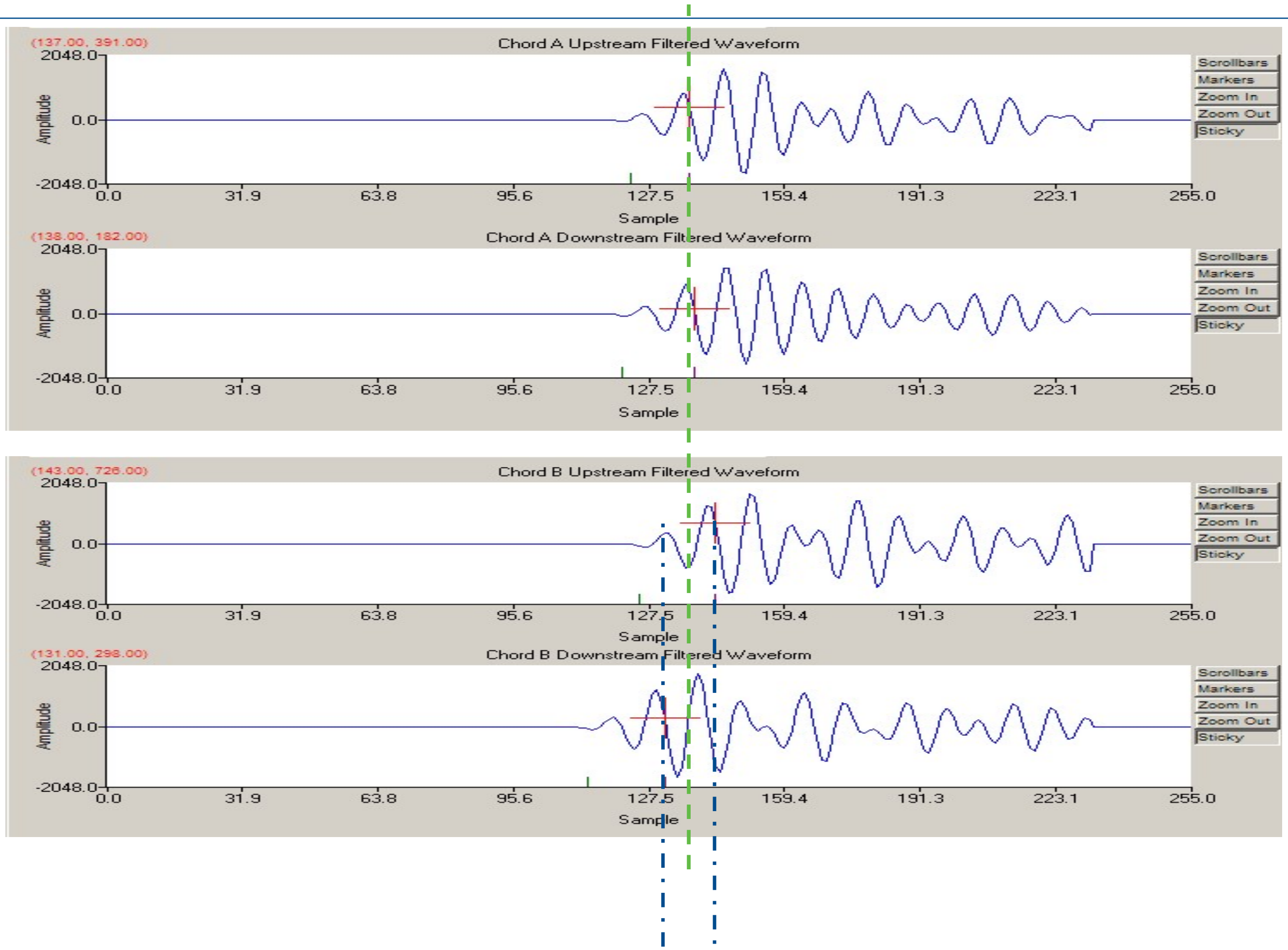
Transit Time Measurements



$\triangle T = T_{21} - T_{12} = 0.009 - 0.004 = 0.005s$

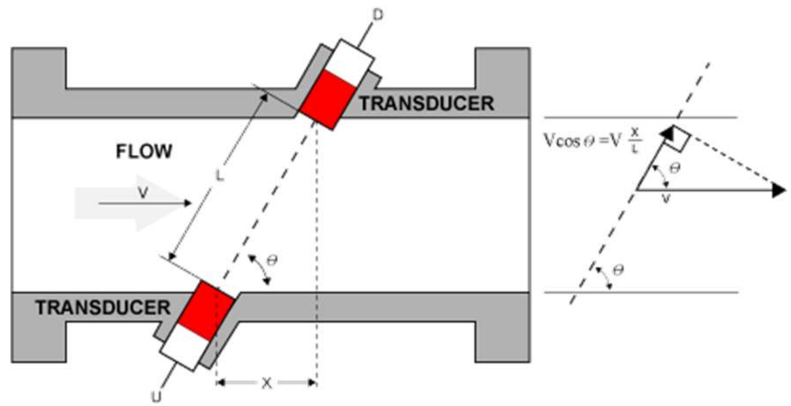
$$V = \frac{L^2}{2X.} \frac{t_{21} - t_{12}}{t_{21} . t_{12}}$$

Waveform Time Shifts

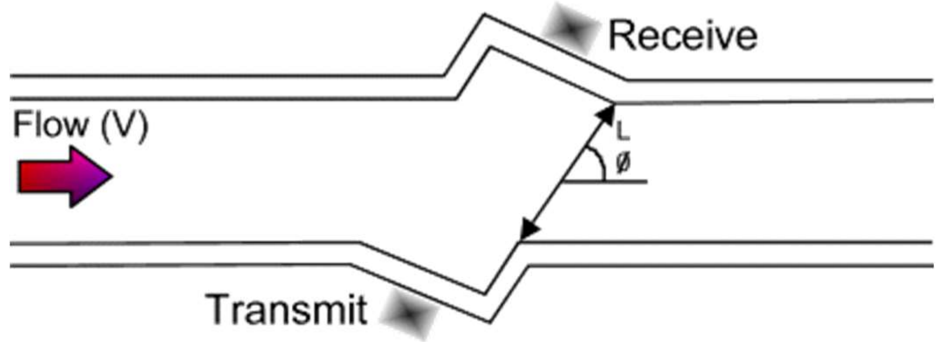


Flow Velocity Calculations

$$V = \frac{L^2}{2X.} \frac{t_{21} - t_{12}}{t_{21} . t_{12}}$$



$$SOS = \frac{L}{2} . \frac{(t_{21} + t_{12})}{(t_{21} . t_{12})}$$



EMERSON

Chords contribution to Average Flow

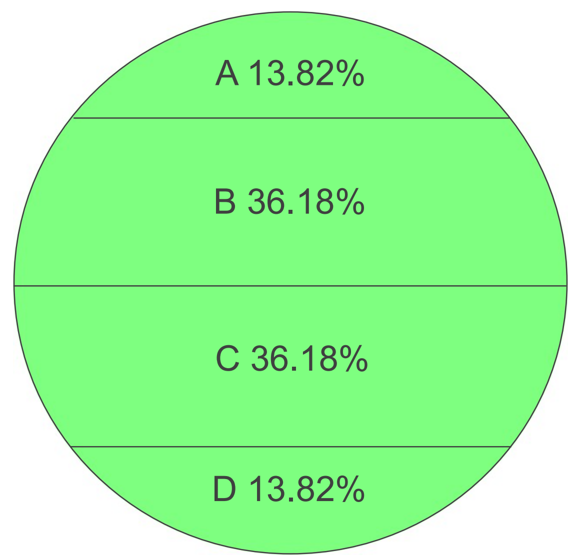
- By installing the transducers as shown, we can calculate their contribution (by area) to the total flow

- If we had square pipes……

Chord Weighting Factors

- Weighting factors for calculating the average flow velocity derived using established mathematical techniques

Weight A = 0.1382
Weight B = 0.3618
Weight C = 0.3618
Weight D = 0.1382
Total = 1.000



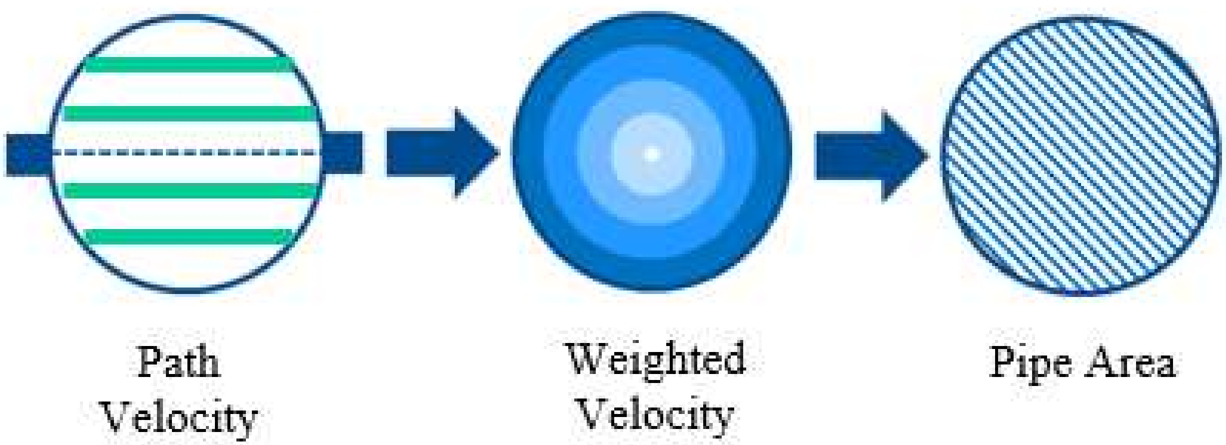
$$V_{average} = \sum_{1}^{n} w_i v_i = 0.1382 \cdot v_1 + 0.3618 \cdot v_2 + 0.3618 \cdot v_3 + 0.1382 \cdot v_4$$

EMERSON

Calculating Volume Flow Rate

- Once the average flow velocity has been calculated it is multiplied by the pipe area to give the average flow rate

$$Q = \bar{V} \, . \, \frac{\pi D^2}{4}$$



EMERSON

Calculation Summary

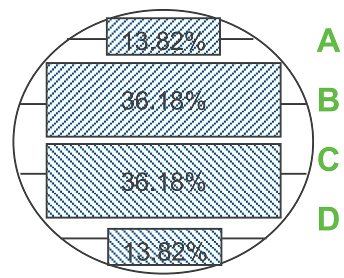
- Measure transit times

$$T_{12} = \frac{L}{C + V \cdot \frac{X}{L}} \qquad T_{21} = \frac{L}{C - V \cdot \frac{X}{L}}$$

- Calculate individual chord velocities

$$V = \frac{L^2}{2\,X\,.}\ \frac{t_{21} - t_{12}}{t_{21}\,.\,t_{12}}$$

- Weight chord velocities



- Calculate average flow velocity

$$V_{average} = \sum_{1}^{n} w_i v_i = 0.1382 \cdot v_1 + 0.3618 \cdot v_2 + 0.3618 \cdot v_3 + 0.1382 \cdot v_4$$

- Calculate average volume flow rate

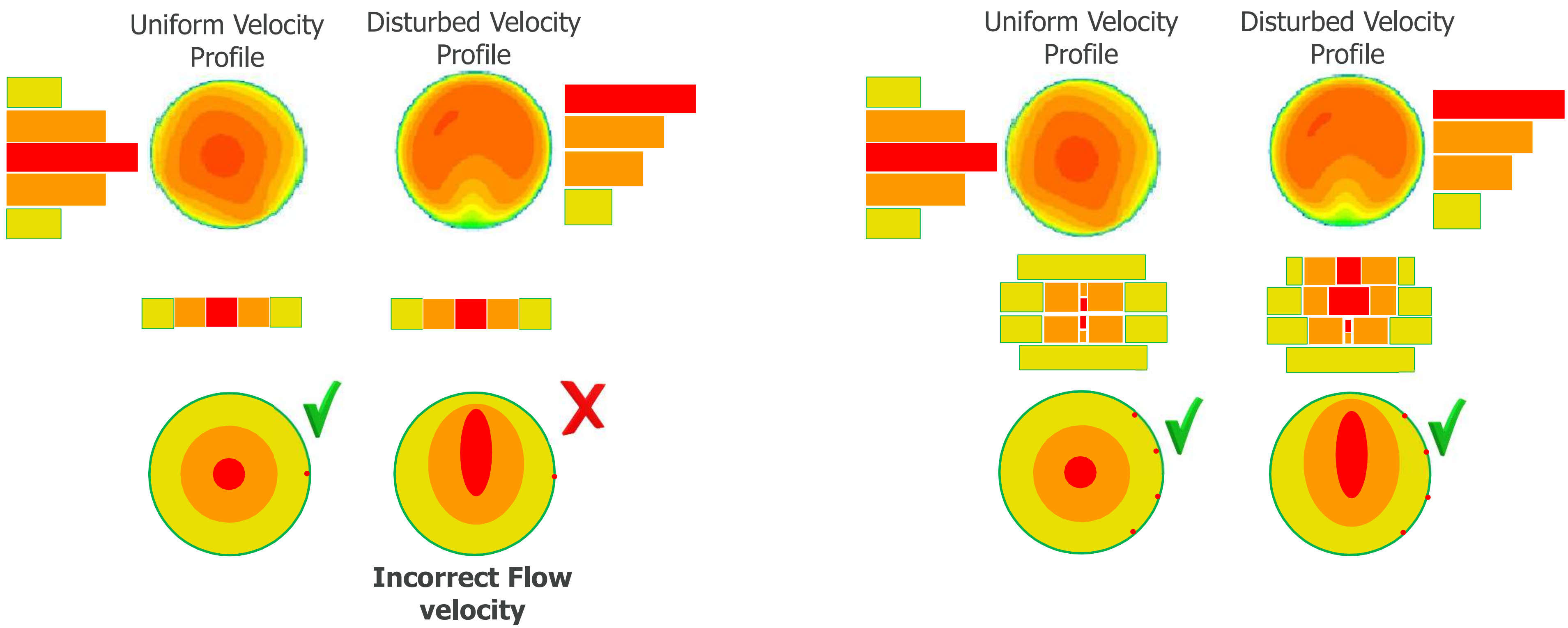
$$Q = V_i \,.\, \frac{\pi D^2}{4}$$

Why do we need more than a pair of transducers?

Single Path Measurement

Multipath Measurement

4 velocity measurements



Standards & Reports

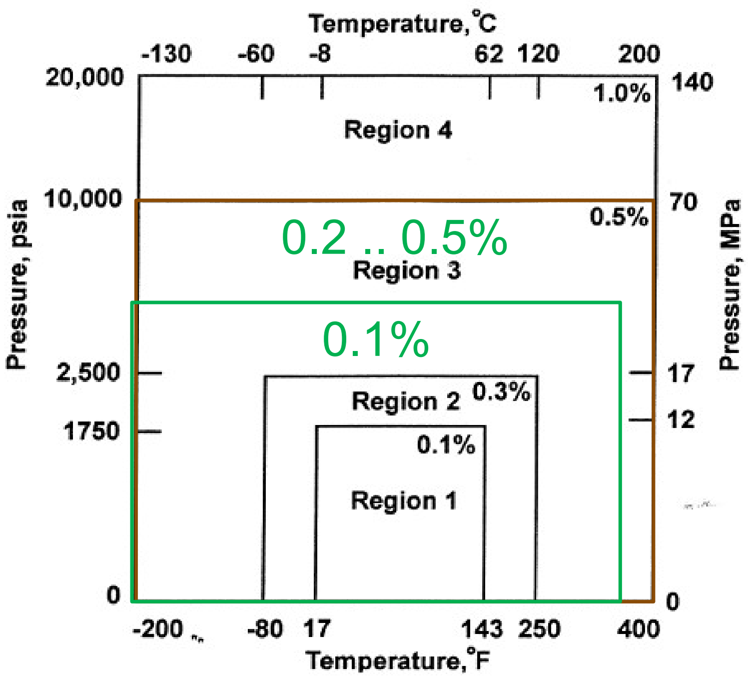
Reports

- AGA 9 - The American Gas Association report for the use of Ultrasonic meters in gas Transmission Systems
- AGA 10 - A non-proprietary calculation for Speed of Sound using Pressure, Temperature and Composition
- AGA 8 - Thermodynamic Properties of Natural and Related Gases
- PS-G-06 – Measurement Canada

AGA Updates

- AGA 8 Part 2 completed and was released in 2017, uses GERG 2008 calculation to expand operational ranges for Temperature, Pressure and Composition
- Rich gases, high pressure and high and low temperatures are all covered to a greater extent
- AGA 10 will no longer be an active report as the SOS from GERG 2008 EOS will be used for future comparisons
- AGA 9 2021 has been completed with minimal changes, consolidation of data, revised piping requirements, addition of check and redundant meters, the addition of expand diagnostic parameters and surrogate calibration spools, released Jan 2022
- Gas Measurement Manual (GMM) is being updated, sections on all types of gas measurement devices are either completed or close to being finalized.

AGA 8 & AGA 8 Part 2 (GERG-2008) Uncertainty



0.1%

- -183 .. + 177 °C
- Up to 35 Mpa

0.2 .. 0.5%

- -213 .. + 427 °C
- Up to 70 Mpa

No limits on composition

Quantity	Normal Range	Expanded Range
Relative Density*	.554 to .87	0.07 to 1.52
Gross Heating Value**	477 to 1150 Btu/scf	0 to 1800 Btu/scf
Gross Heating Value***	18.7 to 45.1 MJ/m^3	0 to 66 MJ/m^3
Mole Percent Methane	45.0 to 100.0	0 to 100.0
Mole Percent Nitrogen	0 to 50.0	0 to 100.0
Mole Percent Carbon Dioxide	0 to 30.0	0 to 100.0
Mole Percent Ethane	0 to 10.0	0 to 100.0
Mole Percent Propane	0 to 4.0	0 to 12.0
Mole Percent Total Butanes	0 to 1.0	0 to 6.0
Mole Percent Total Pentanes	0 to 0.3	0 to 4.0
Mole Percent Hexanes Plus	0 to 0.2	0 to Dew Point
Mole Percent Helium	0 to 0.2	0 to 3.0
Mole Percent Hydrogen	0 to 10.0	0 to 100.0
Mole Percent Carbon Monoxide	0 to 3.0	0 to 3.0
Mole Percent Argon	#	0 to 1.0
Mole Percent Oxygen	#	0 to 21.0
Mole Percent Water	0 to 0.05	0 to Dew Point
Mole Percent Hydrogen Sulfide	0 to 0.02	0 to 100.0

* Reference Condition: Relative density at 60°F, 14.73 psia

** Reference Conditions: Combustion at 60°F, 14.73 psia; density at 60°F, 14.73 psia.

*** Reference Conditions: Combustion at 25°C, 0.101325 MPa; density at 0°C, 0.101325 MPa.

\# The normal range is considered to be zero for these compounds.

AGA 8 & AGA 8 Part 2 (GERG-2008) Uncertainty

Components used to calculate Corrected Volumes and SOS are the same ones required for Energy rate measurement, they are USM flowing rate, Pressure, Temperature and Gas Composition

Gas USM
Measured SOS

Ultrasonic Meter, pressure and temperature for standard rates and the GC for energy value

GC

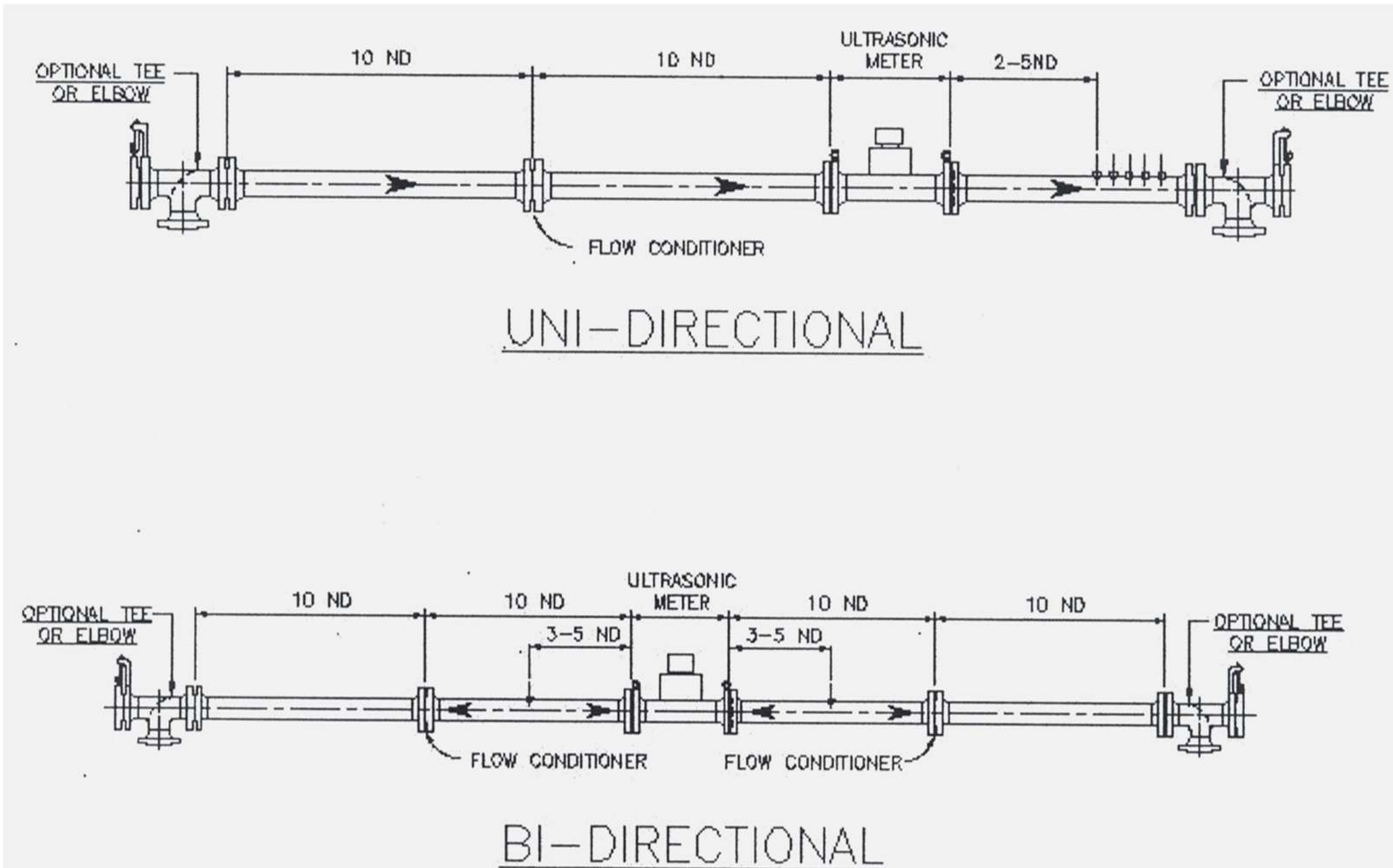
P&T

$$Q_b = Q_f \ (P_f/P_b)\ (T_b/T_f)\ (Z_b/Z_f)$$

$$Energy_b = Q_b * \ BTU_b$$

EMERSON

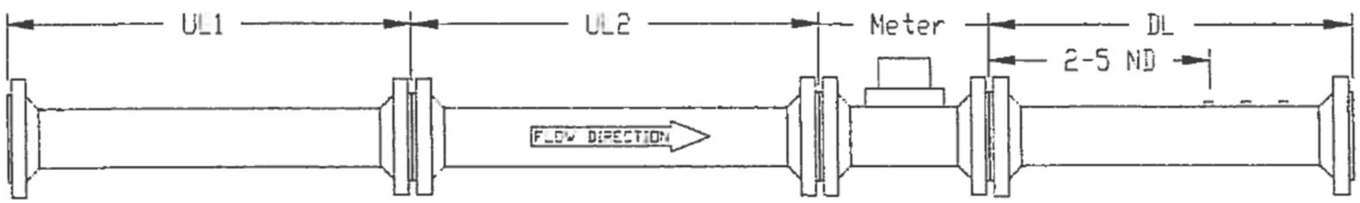
Recommended Piping Design in 2007 AGA 9 Report



AGA 9 2022 Updates

The following options for configuration of an installed metering package are available for selection by the designer/operator. The validity of each option to a specific meter model shall be confirmed by the meter manufacturer and supported by test data. Data shall be obtained from an independent flow calibration laboratory verifying the metering package design performs within the ±0.3% limit described in Appendix C (Normative) when subjected to the required flow disturbance tests. The meter manufacturer shall provide such test data when requested by the designer/operator.

Option 1: A conservative configuration with a flow conditioner (between spools UL1 and UL2) as shown below. The manufacturer shall specify the flow conditioner(s) approved for use in this configuration based on independently certified test data.

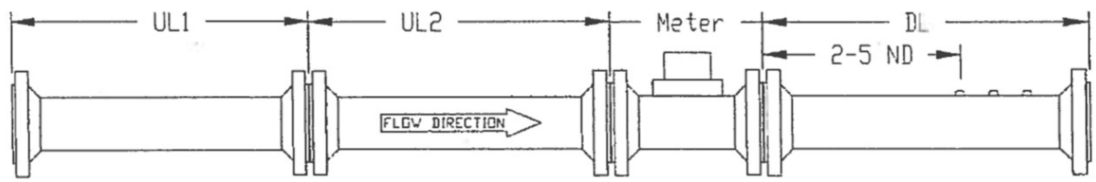


Where: UL1 = min. 10 ND length
UL2 = min. 10 ND length
DL = Variable

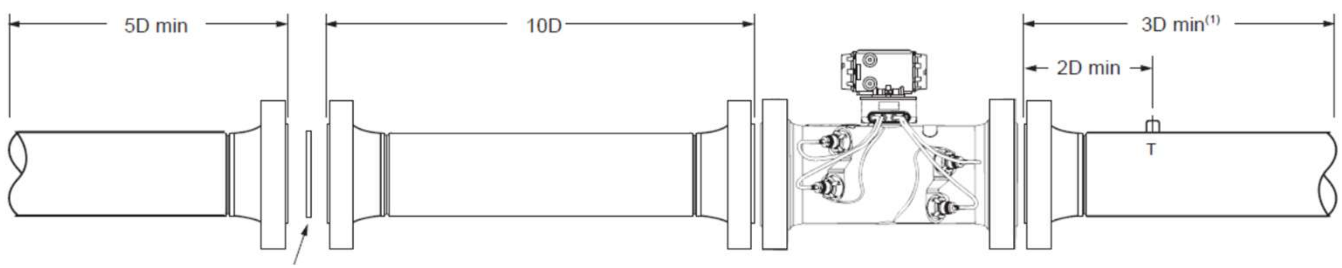
EMERSON

AGA 9 & Published Meter Run Configurations

Option 2: Manufacturer-recommended configuration with use of a flow conditioner between spools UL1 and UL2 as shown below. The manufacturer shall specify the lengths of UL1 and UL2, as well as the flow conditioner(s) approved for use in this configuration, based on independently certified test data.



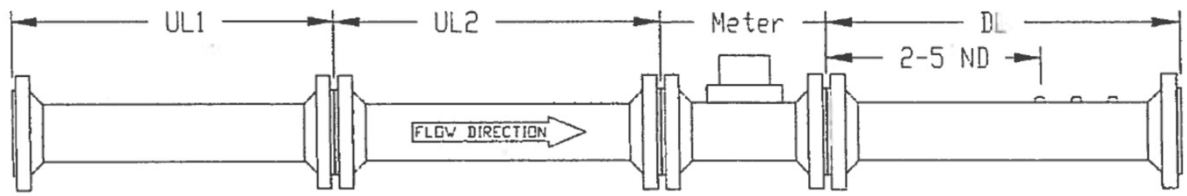
Where: UL1 = Manufacturer-specified
UL2 = Manufacturer-specified
DL = Variable



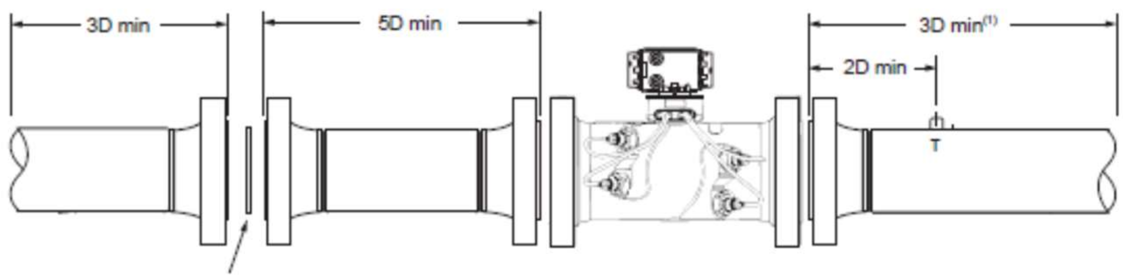
EMERSON.

Short Coupled 3414 Meter Run Configuration

Option 2: Manufacturer-recommended configuration with use of a flow conditioner between spools UL1 and UL2 as shown below. The manufacturer shall specify the lengths of UL1 and UL2, as well as the flow conditioner(s) approved for use in this configuration, based on independently certified test data.



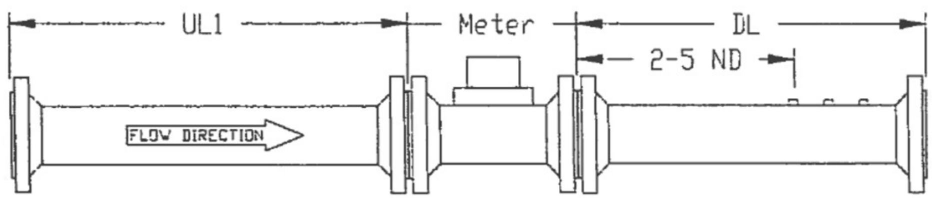
Where: UL1 = Manufacturer-specified
UL2 = Manufacturer-specified
DL = Variable



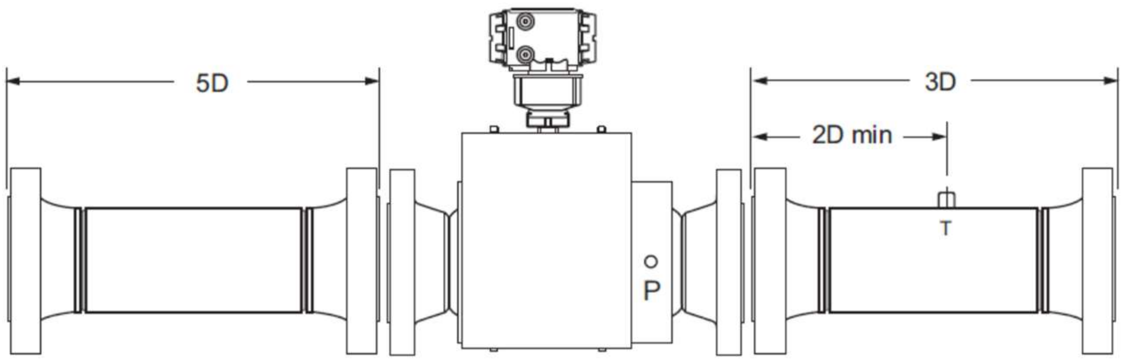
EMERSON

AGA 9 & Published Meter Run Configurations

Option 3: Manufacturer-recommended configuration with one upstream spool and no flow conditioner as shown below. The manufacturer shall specify the length of UL1 based on independently certified test data.



Where: UL1 = Manufacturer-specified
DL = Variable



USM Diagnostics

Viewing Data: Meter Monitor Screen

Shows the velocities at each chord

Shows the speed of sound (SOS) at each chord

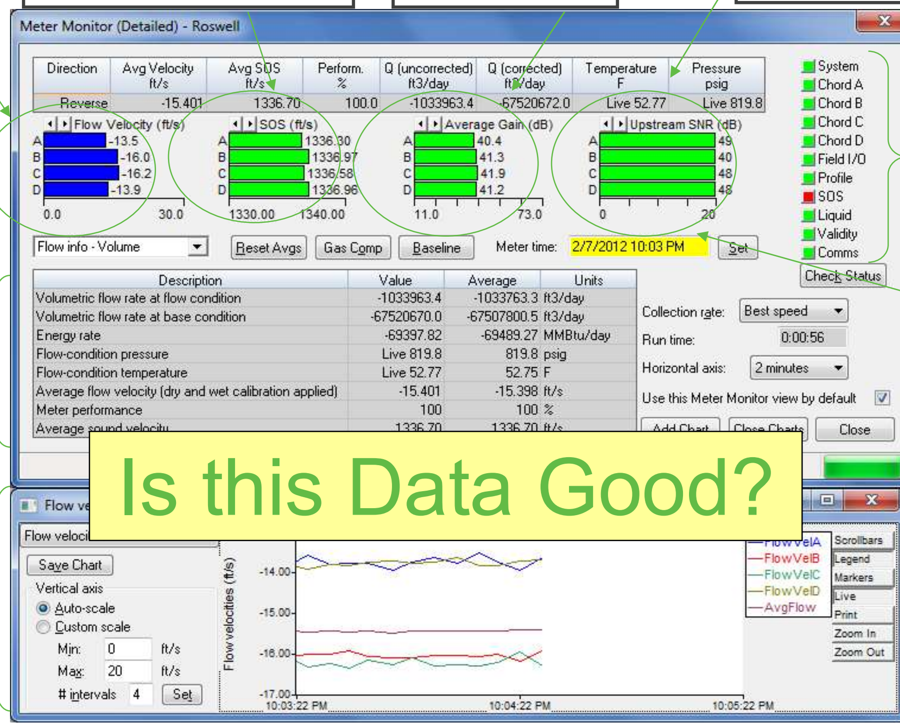
Shows the gain levels at each chord

Shows the Signal to Noise ratios at each chord

Status indicator LED's

User Selectable Table

User Selectable Charts



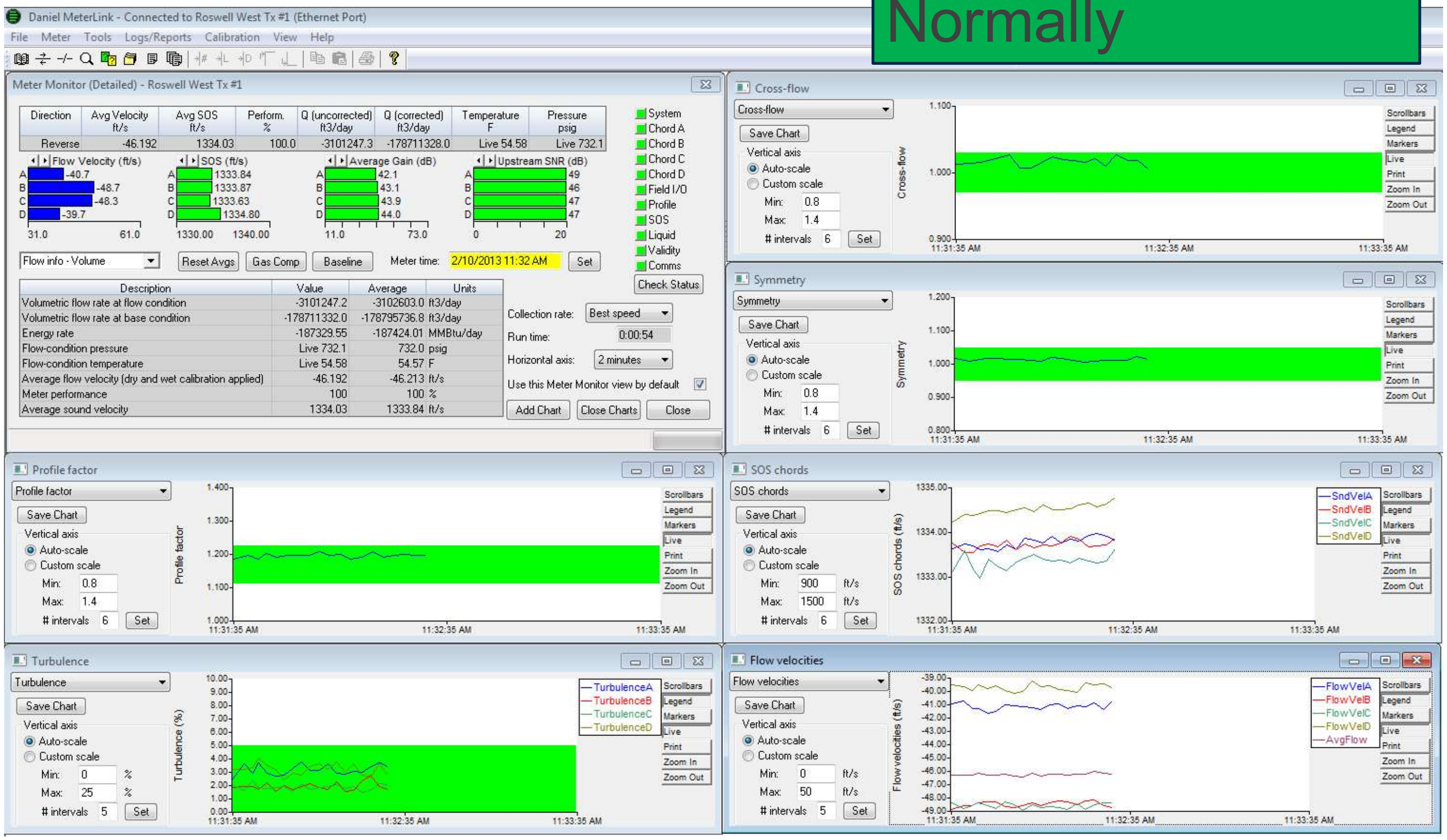
Is this Data Good?

Status Indicator Legend

- No Alarm
- Warning
- Alarm

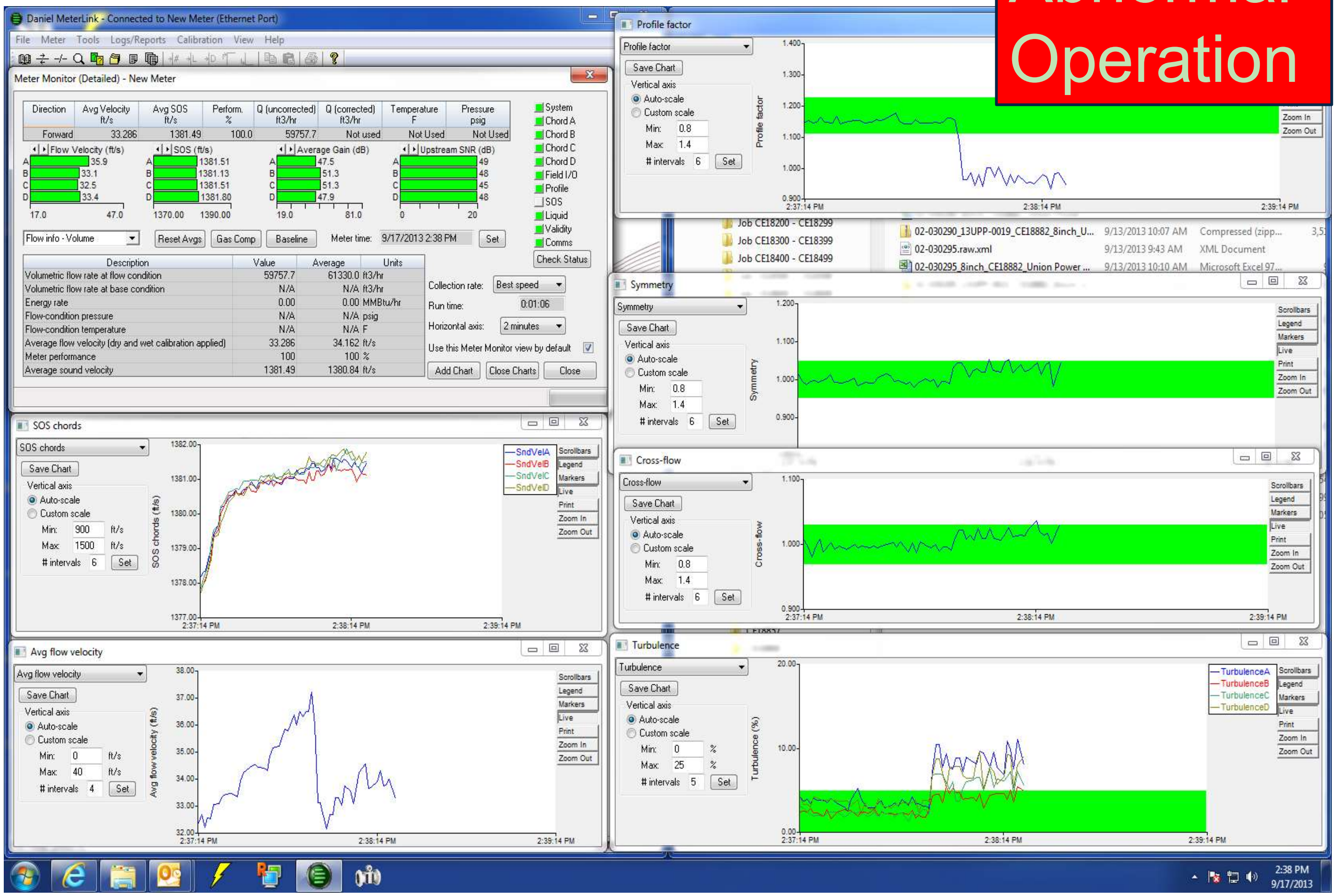
Monitor page

Meter Operating Normally



Monitor page

Abnormal Operation

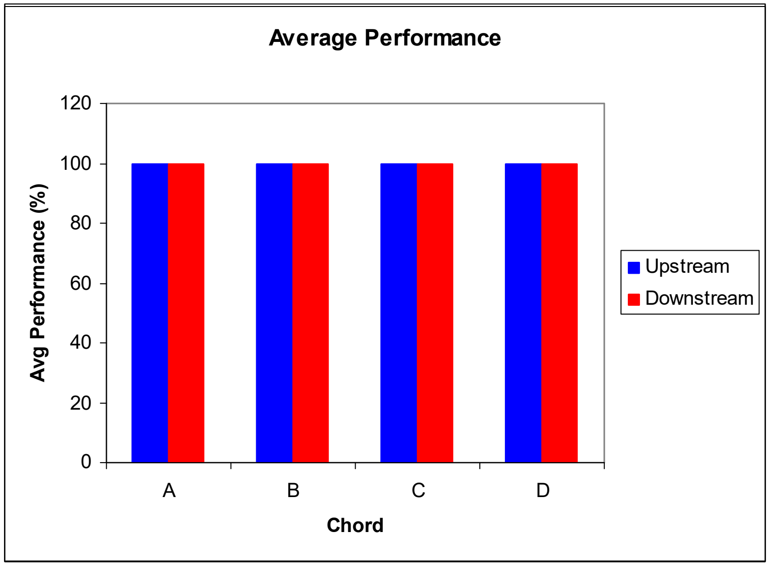


Understanding Diagnostics

- Our experience over the years has led us to form 3 distinct categories of diagnostics

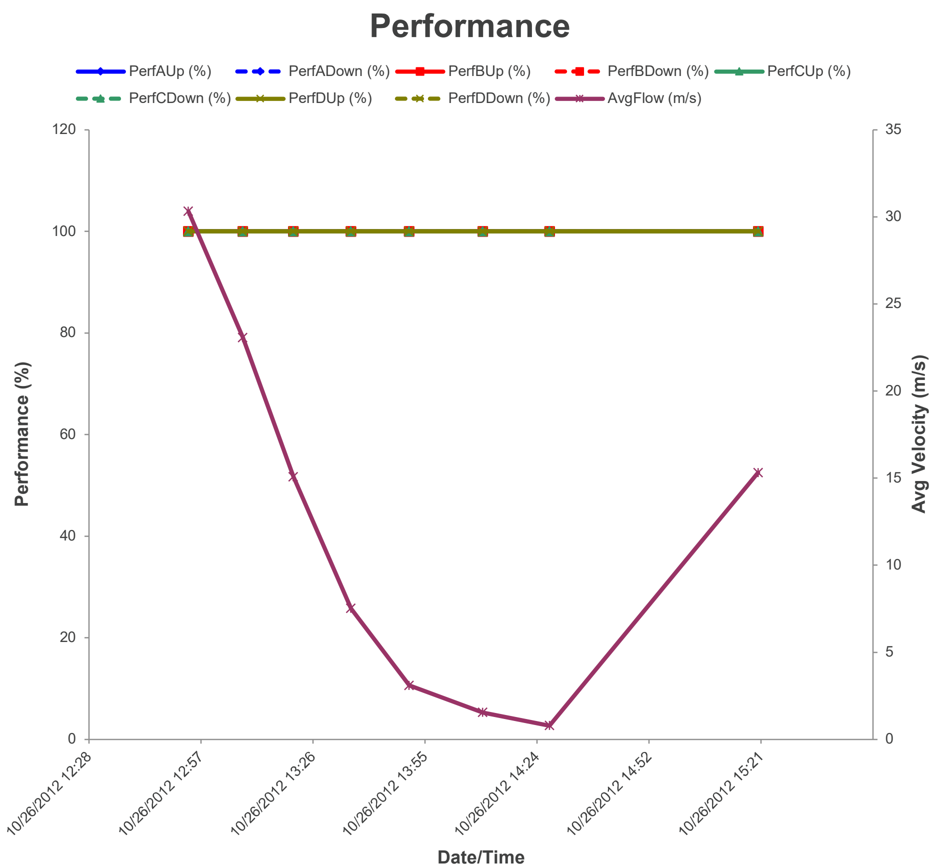
1. **Functional diagnostics (Basic)**
    - Is the meter (electronics, transducers & cabling) showing any signs of degradation / failure ?
2. **Process Diagnostics (Advanced)**
    - Are the conditions in the pipeline stable, and suitable for Custody Transfer measurement ?
        - Is there any evidence of wall roughness changes? Contamination? Blockage? Swirl? Asymmetries?
3. **System Performance Diagnostics**
    - Is the metering system performing as designed?
    - Do all the readings from the secondary instrumentation make sense?
        - Doesn't matter how accurate the USM is if the pressure let down system is altering the gas composition !

Functional Diagnostics – Is my meter OK?

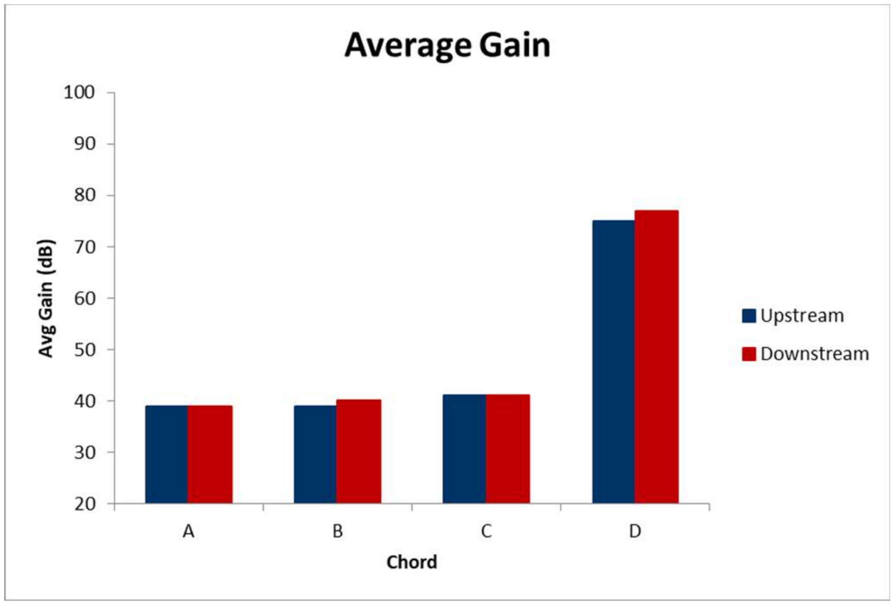


- Performance
  - % of received signals which pass all the suitability checks applied by the meter electronics prior to being used for a time measurement
  - Confirms healthy signals
  - Alerts operator to failing transducer or contamination

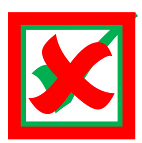
Transducer Performance in a Healthy Meter at High Velocity



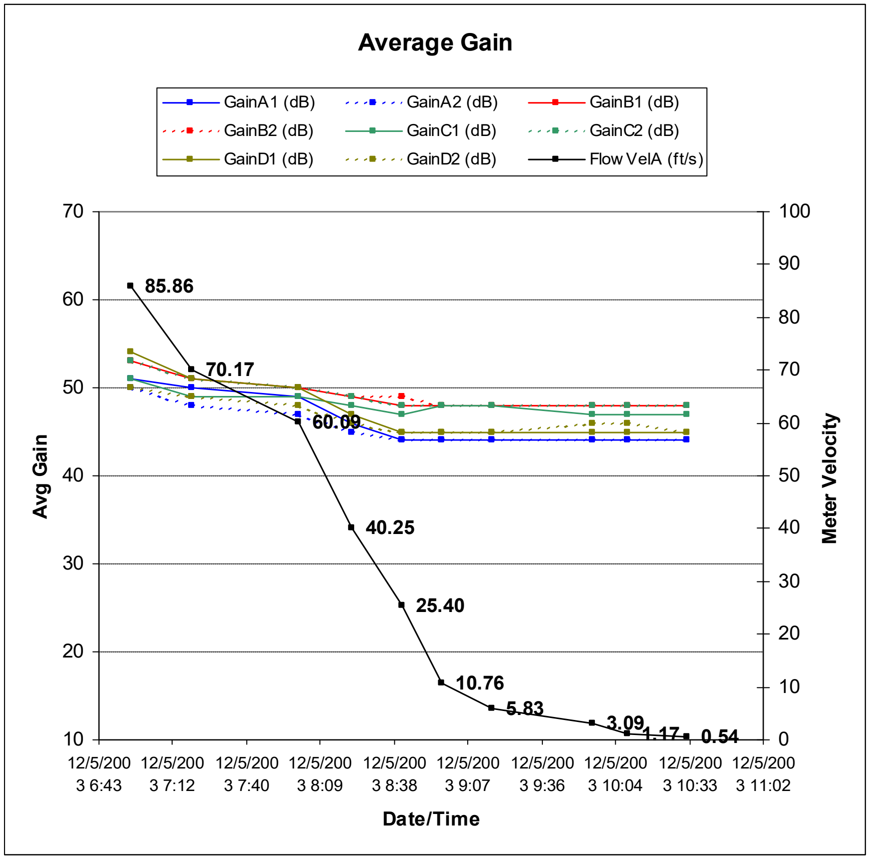
Functional Diagnostics – Is my meter OK?



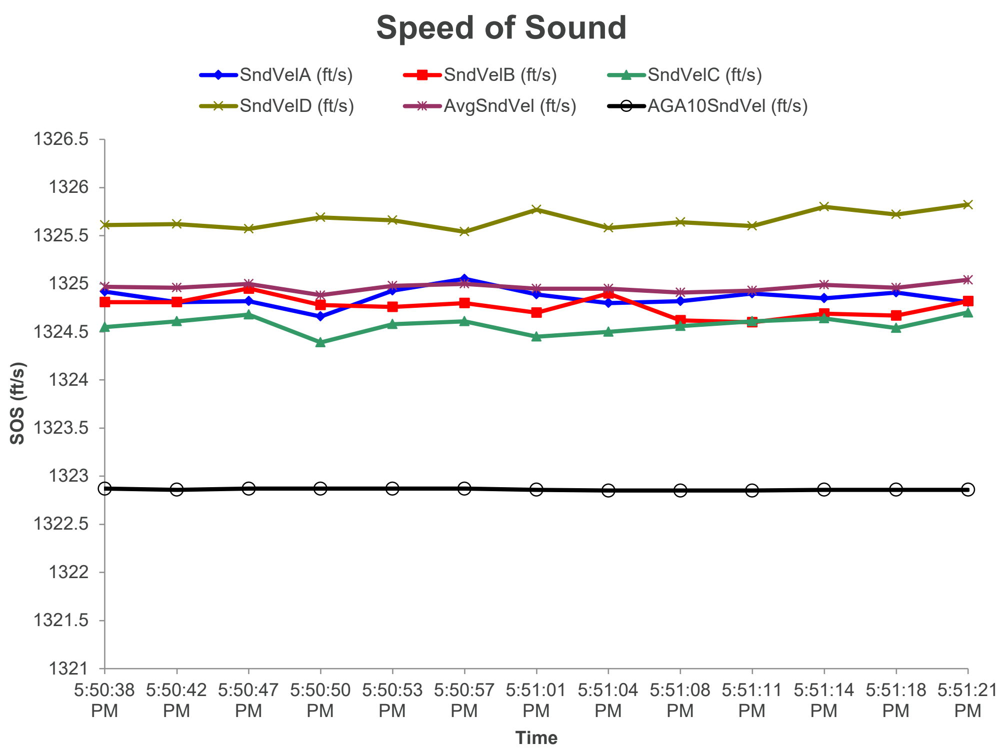
- Gain (AGC)
  - Amount of amplification applied to received signal by Automatic Gain Control in meter electronics
  - Confirms healthy signals
  - Alerts operator of failing / degrading signals
  - Preventative maintenance possible



Gain Changes with Meter Velocity



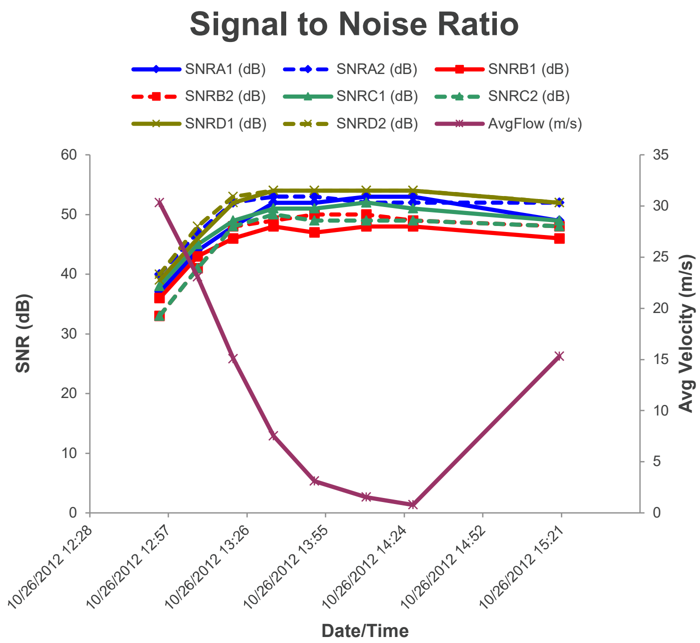
Functional Diagnostics – Is my meter OK?

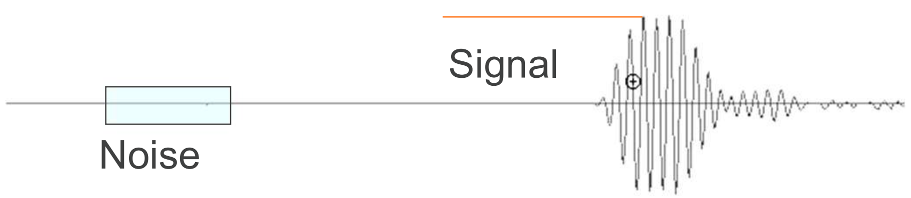


- SOS
  - When gas is flowing above 3 fps the per path Should be within .3% of maximum
  - Confirms healthy signals
  - Alerts operator of failing / degrading signals
  - Preventative maintenance possible

Functional Diagnostics – Is my meter OK?

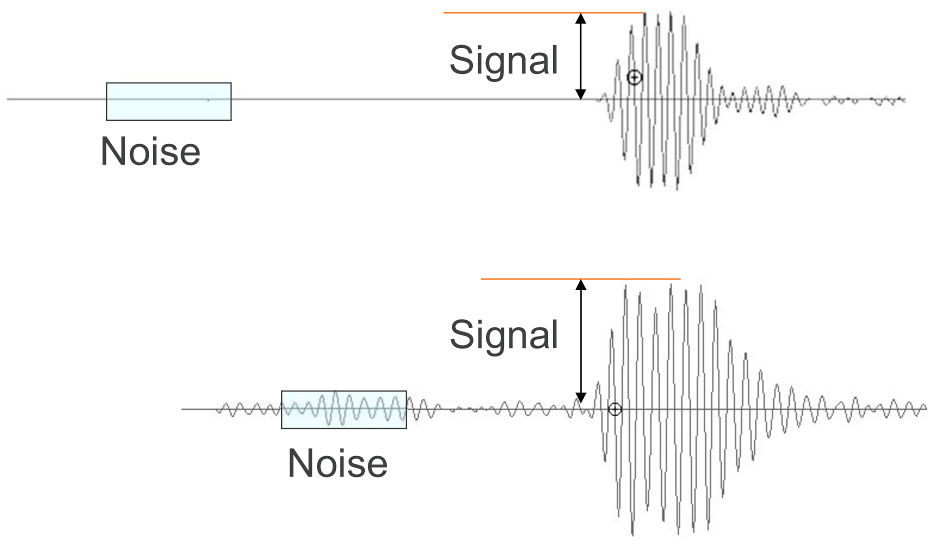
- Signal to Noise Ratio
  - Compares maximum signal energy to average noise energy
  - Confirms healthy transducers and signals
  - Alerts operator to failing transducers / electronics or external noise (e.g. FCV)





Signal-to-Noise Ratio

- Provides information on background noise
- Measured between transmitted pulses



Summary – Basics

- Meter designs and path layouts vary considerably, but the basic fundamentals of Transit Time Measurement remain constant throughout
- The addition of paths and secondary meters in the same body has greatly improved and simplified the uncertainty validation
- Basic Diagnostics are somewhat universal as the fundamental operation of all meters requires that these values are constant and correct
- Validating any meter must start with the Basic or Fundamental diagniostics before moving to the Advances trouble shooting
- It is imperative to understand and utilize the manufacturer's software to ensure the USM is operating correctly

EMERSON.

Questions?

Thank you for attending today!

Please feel free to connect with me if you have any more questions or connect with me on LinkedIn to see all the latest information on Emerson solutions.

You can also visit our site on Emerson.com
[Rosemount Ultrasonic Flow Meters]

Flow.support@emerson.com

1-800-522-6277




Martin Schlebach
Martin.schlebach@emerson.com
+1-403-615-7429

Thank You!

Martin Schlebach

EMERSON