Daniel Gas Ultrasonic Meter

Presented by:

Howard Brumbaugh

WGS Equipment & Controls, Inc.

Introduction To Ultrasonic Measurement Techniques

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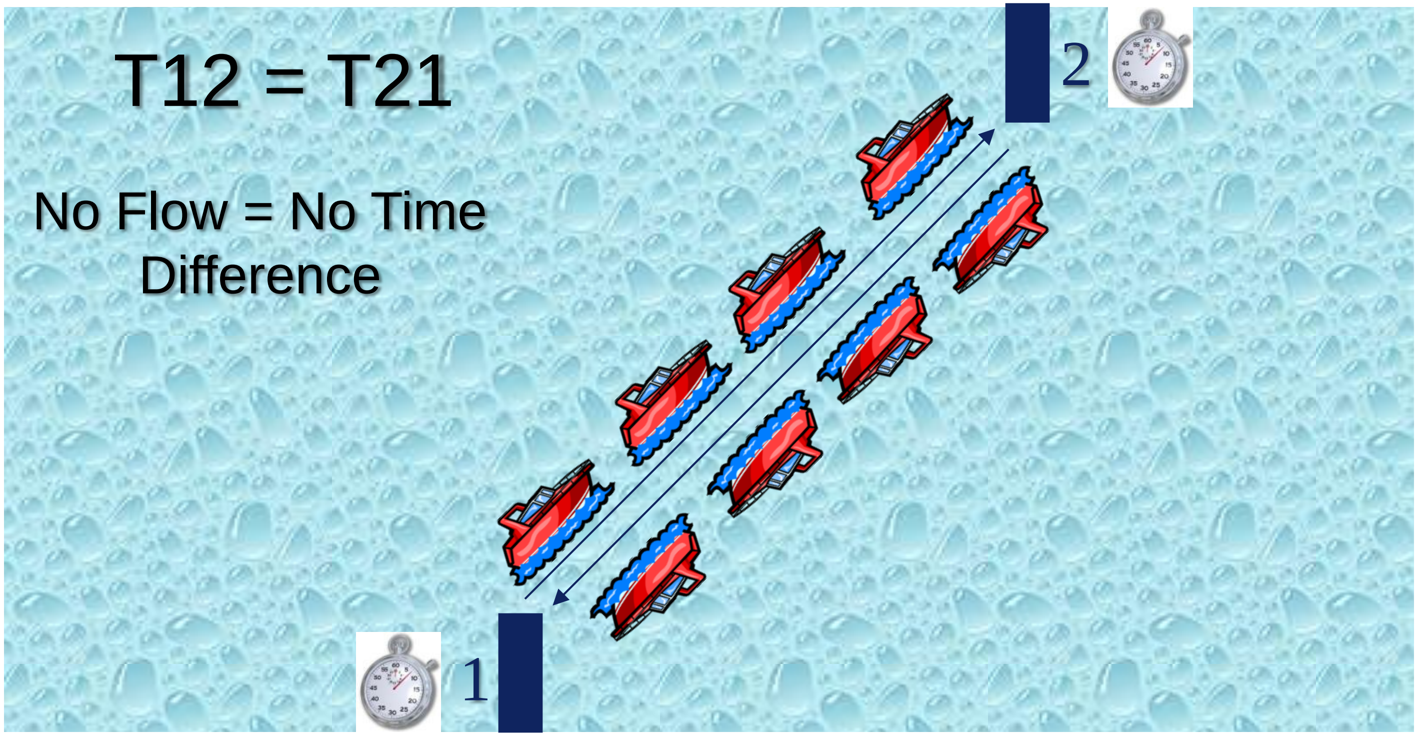
Daniel Ultrasonic Flow Meters

Basic Transit Time Theory of Operation

Theory of Operation - Transit Times

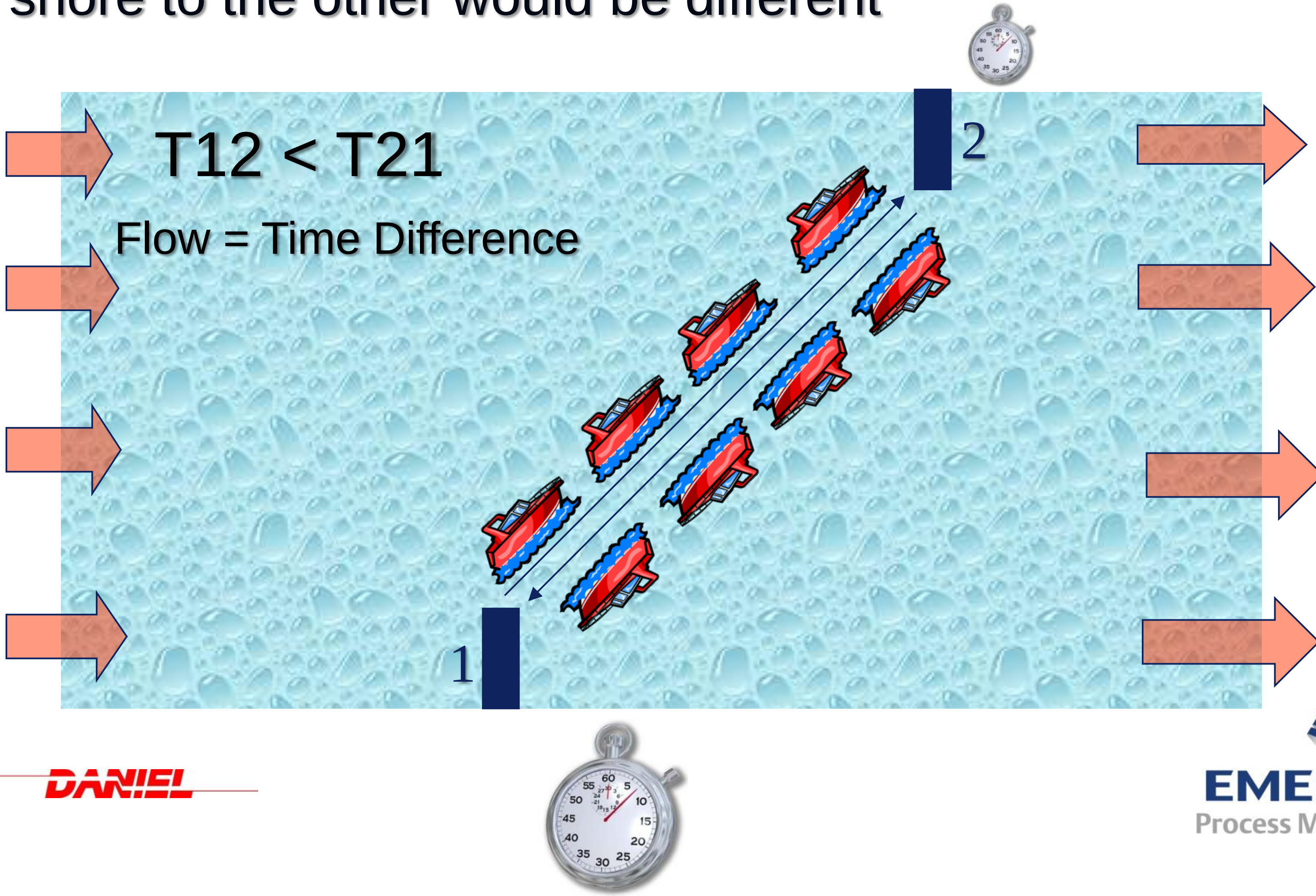
If we were to imagine a blocked river, where there is no flow

Travel time from one shore to the other would be identical



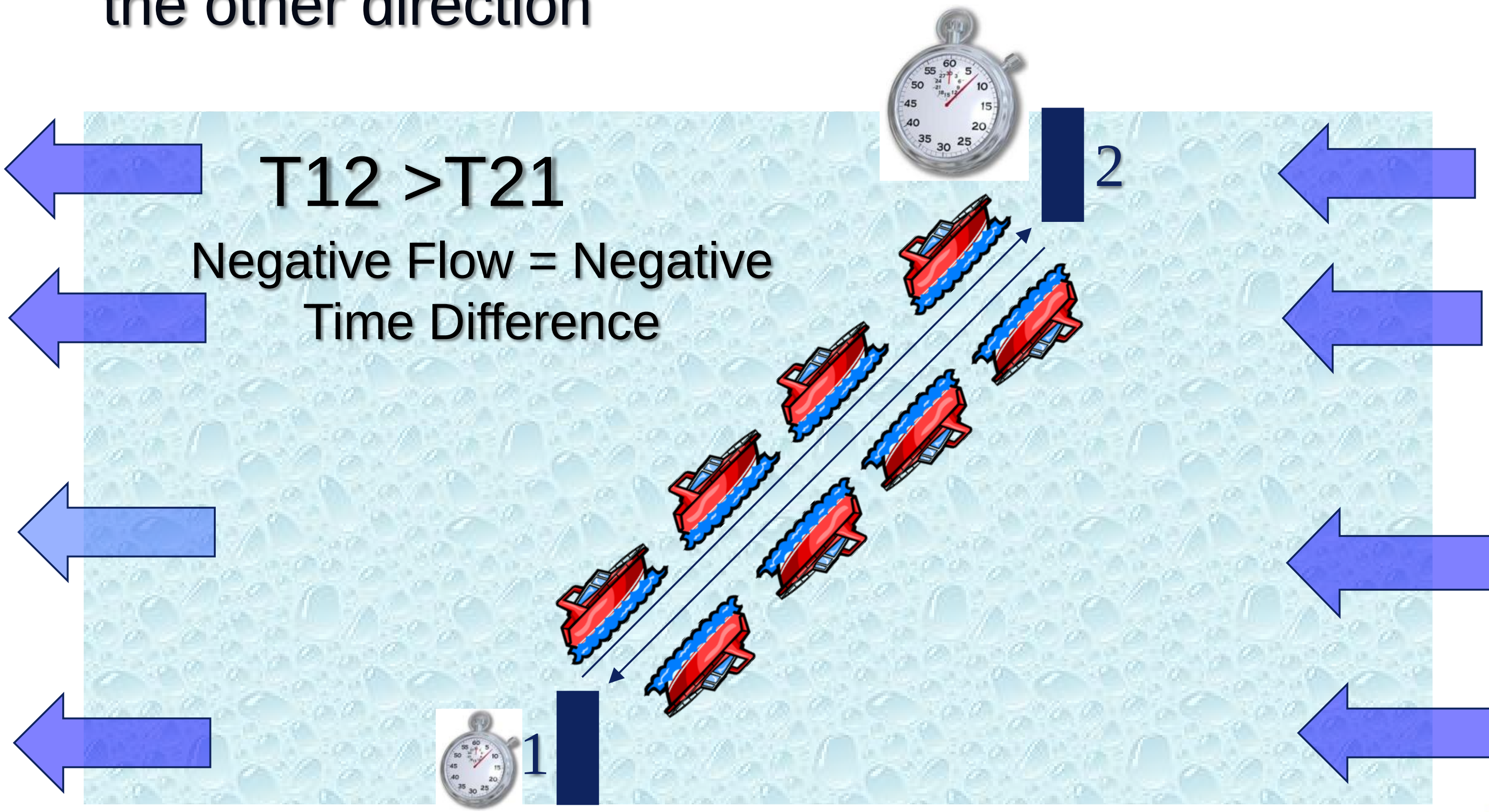
Theory of Operation - Transit Times

If we were to imagine a flowing river, travel time from one shore to the other would be different



Theory of Operation - Transit Times

If we reverse the flow, the time difference is created in the other direction



Daniel Ultrasonic Meters Are Inherently Bi-Directional

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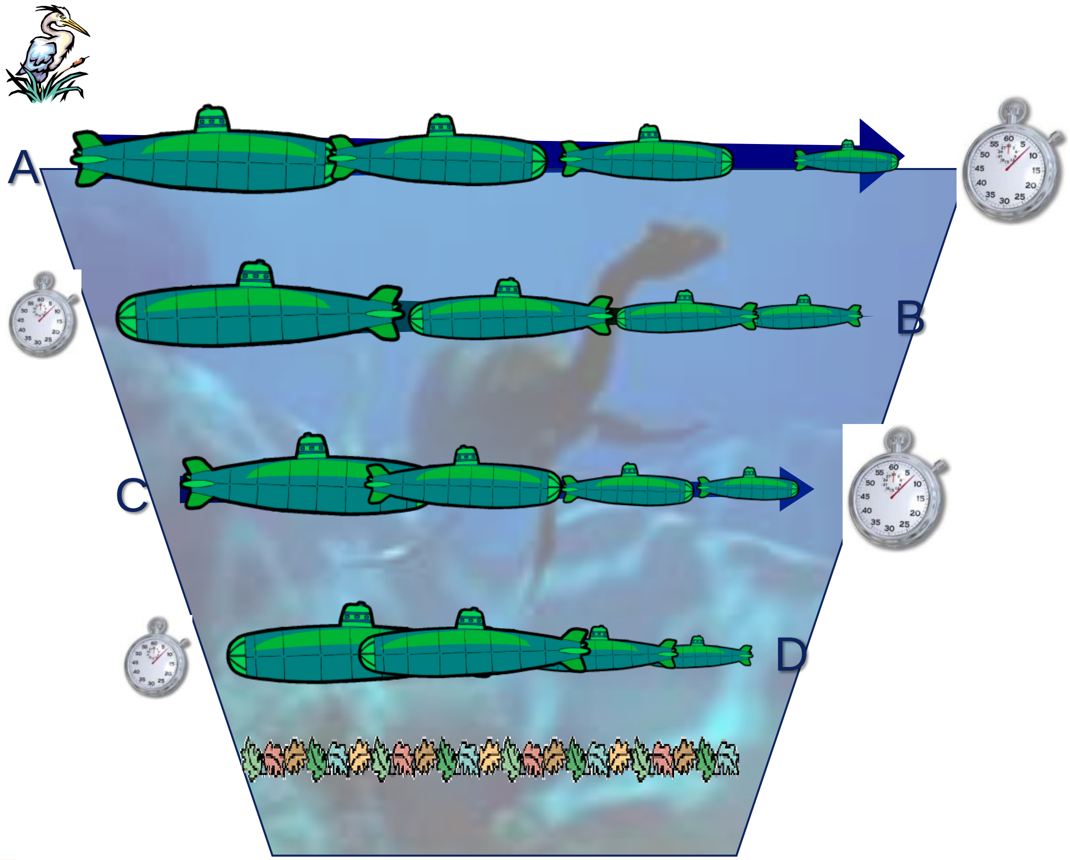
Theory Of Operation

From this we have established 3 basic points:

1. The presence of flow or not
   - Flow = A Time Difference
2. The direction of the flow
   - Using the “polarity” of the time difference
3. The magnitude of the flow
   - Small time difference = Small flow
   - Large time difference = Large flow

Theory of Operation - Transit Times

- Boat transit time theory is limited to the surface
- If we want volume information we need to take measurements at varying depths



Theory Of Operation

- The Daniel Senior Sonic and Junior Sonic meters use these time difference measurements as a basis for calculation of volumetric flow rate

- Instead of a river we have circular steel pipe
- Instead of water we have hydrocarbon gas
- Instead of boats we have ultrasonic sound waves

Daniel Ultrasonic Flow Meters

What is “Ultrasound?”

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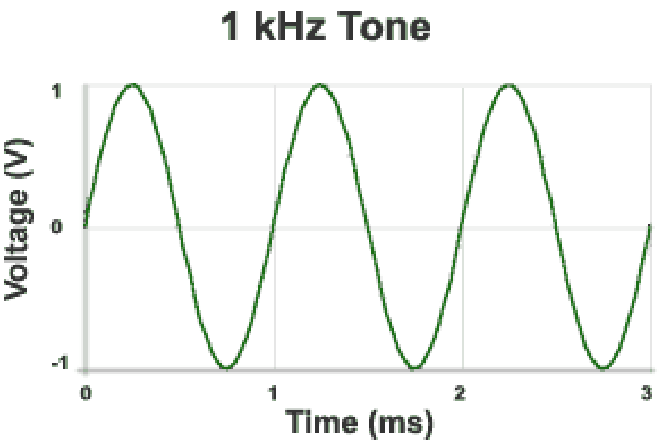
What is Sound?

- Sound waves are mechanical energy that is transmitted by pressure waves in a material medium
- Sounds waves are produced when a vibrating object comes into contact with a medium



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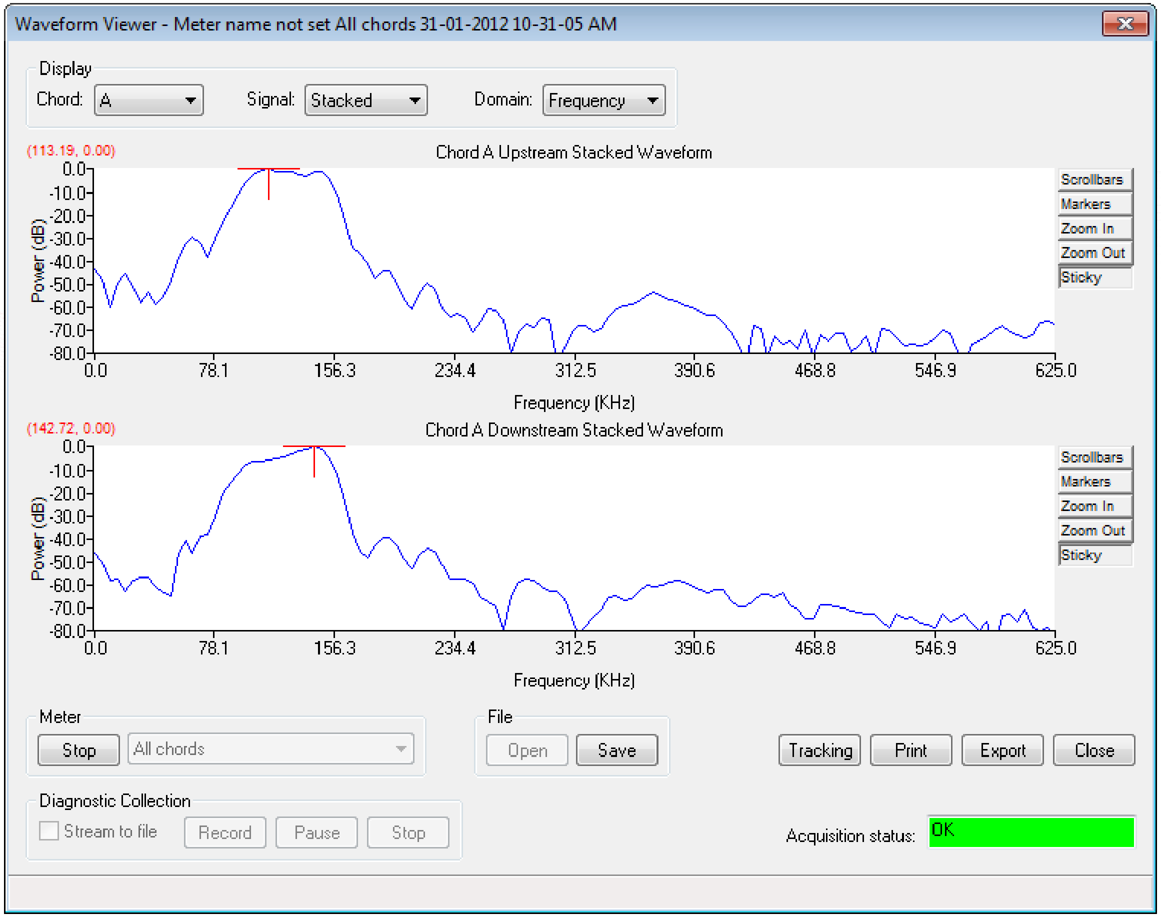
Speed Of Sound (SOS)

- The SOS (Speed of Sound) is the velocity at which the sound wave is propagated through the medium
- The power of the wave does not affect it velocity
- The frequency of the wave does not affect its velocity
- The SOS of a hydrocarbon gas is a function of its pressure, temperature, and composition

What is Sound?

- The rate at which an object vibrates is called its Frequency and is measured in the units Hertz
  - Hertz (Hz) = Cycles Per Second
- The audible frequency range for human hearing is between 20 – 20,000 Hz
- Any sound with a frequency above the threshold of human hearing is classed as ultrasound

Ultrasound

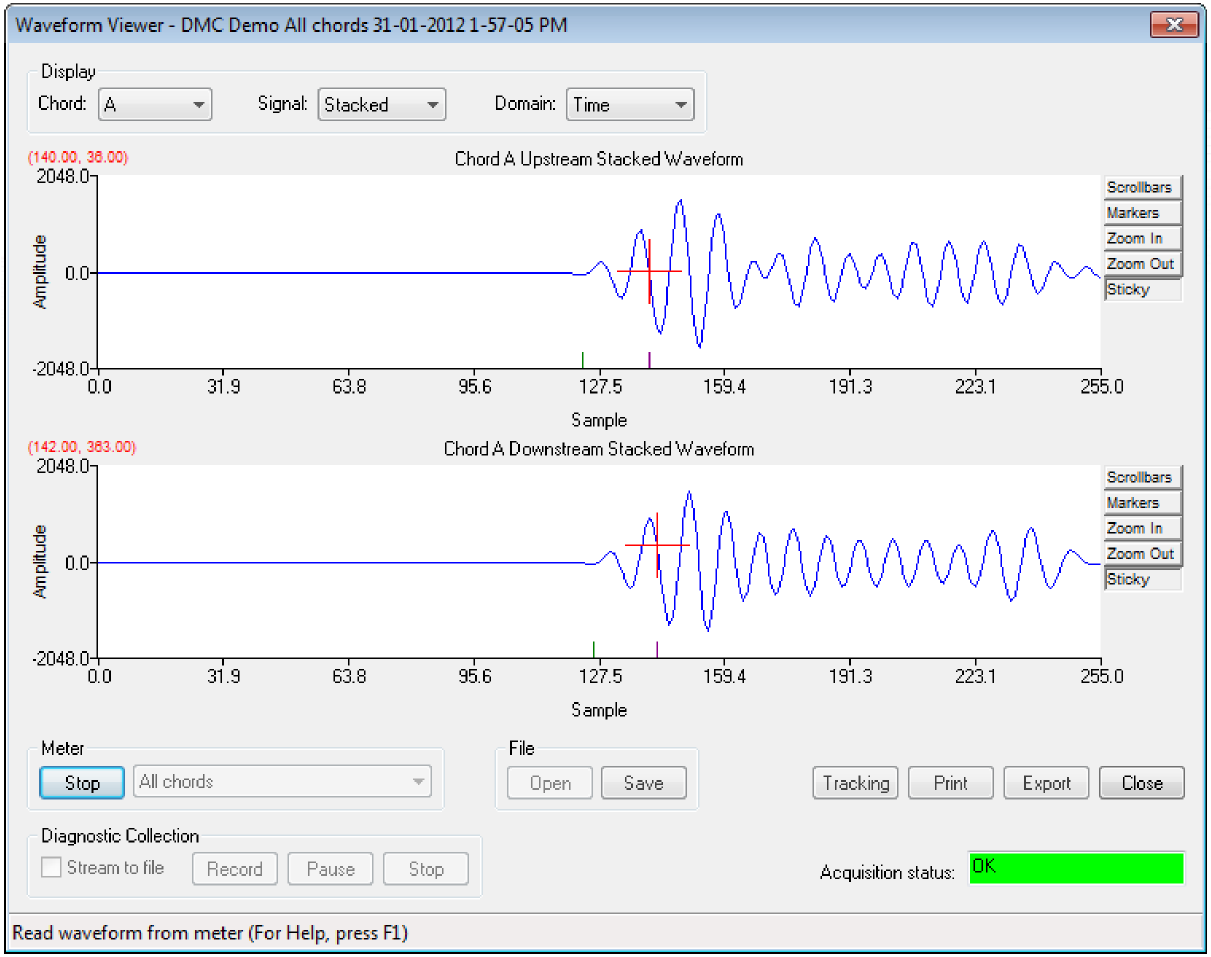


Daniel USM Transducers operate between 100-150kHz

(125 kHz)

Frequency Analysis of Transducer Pair

Ultrasound



In a typical hydrocarbon gas the SOS is approximately 400 m/s

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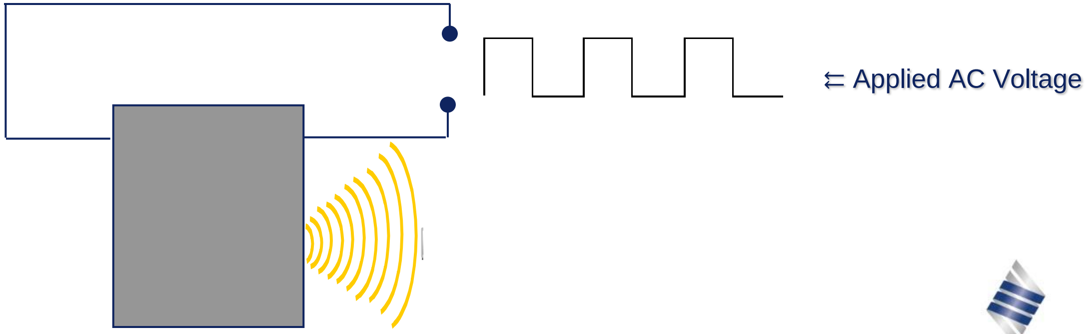
Producing Ultrasound

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

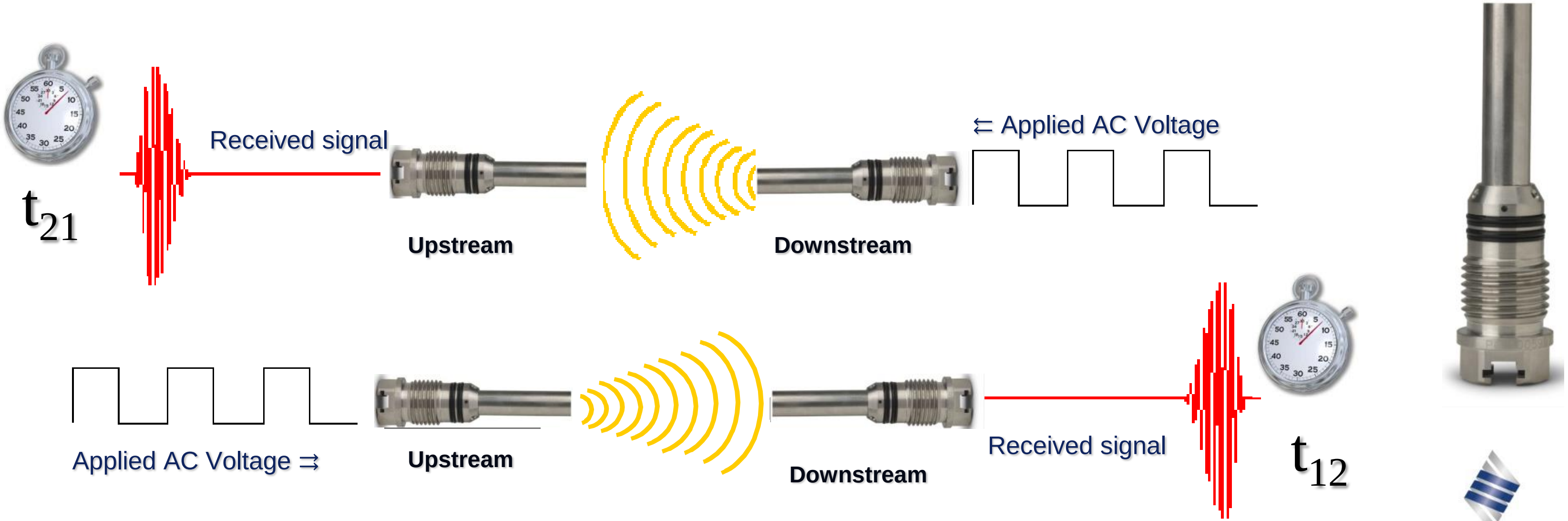


Daniel Ultrasonic Flow Meters

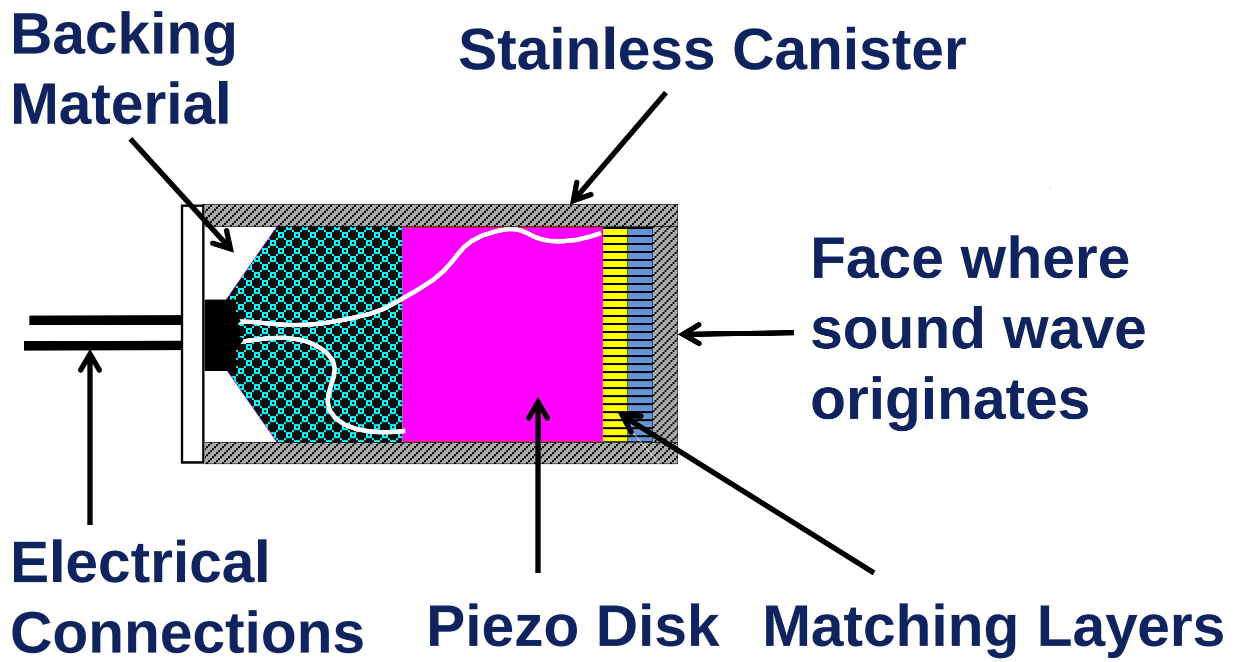
Practical Ultrasonic Applications

Practical Ultrasonic Meters

- Ultrasonic pulses are both transmitted *and* received using the piezo crystals mounted inside the transducer capsules
- The crystal (transducers) are always used in pairs
- The pairs from a “stopwatch”

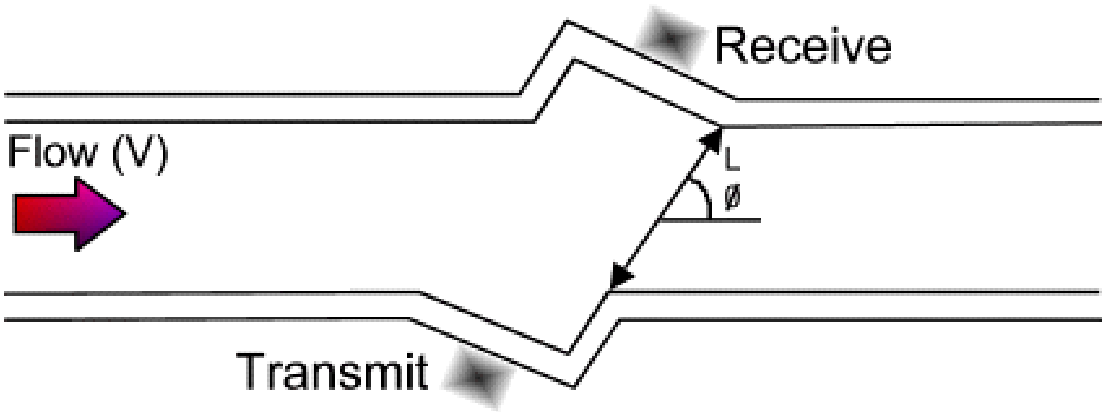


Transducer Assembly



Practical Ultrasonic Meters

- The effect is reversible, it can be used to determine transit time in both directions
- The crystal acts as both a loudspeaker and a microphone



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Daniel Ultrasonic Meter Training

Senior Sonic & Junior Sonic

Theory Of Operation

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Daniel Ultrasonic Flow Meters

Daniel Senior Sonic Meter

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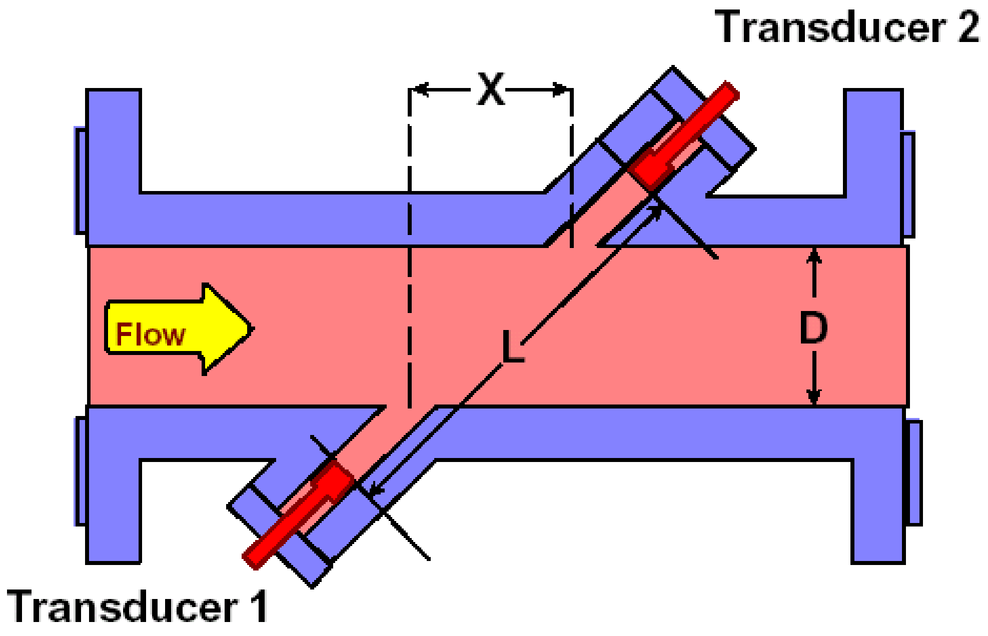
Flow Velocity Calculations

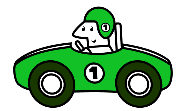
➢Transducer time measurements are combined with information from the dimensions of the meter body in order to calculate flow velocity

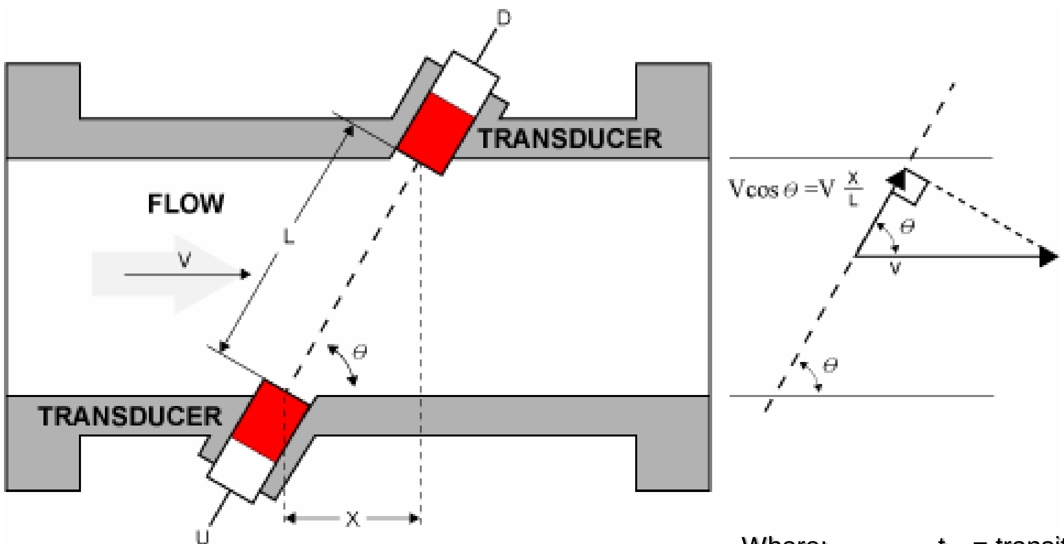


Flow Velocity Calculations

$$V = \frac{d}{t}$$

Where: t = Time
d = Distance
V = Velocity





$$t_{ud} = \frac{L}{C + V_i \cos\theta} \qquad \textbf{(Eq. 2)}$$

$$t_{du} = \frac{L}{C - V_i \cos\theta} \qquad \textbf{(Eq. 3)}$$

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

$$C = \frac{L}{2} \cdot \frac{t_{du} + t_{ud}}{(t_{ud})(t_{du})} \qquad \textbf{(Eq. 5)}$$

Where:
t_{ud} = transit time from transducer U to D
t_{du} = transit time from transducer D to U
L = path-length between transducer faces U and D
x = axial length between transducer faces
C = velocity of sound in the gas in still condition
V_i = mean chord velocity of the flowing liquid
θ = acoustic transmission angle

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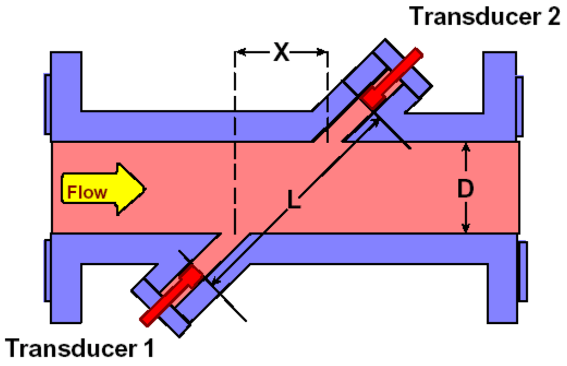
Flow Velocity Calculations

Inversion of these equations yields:

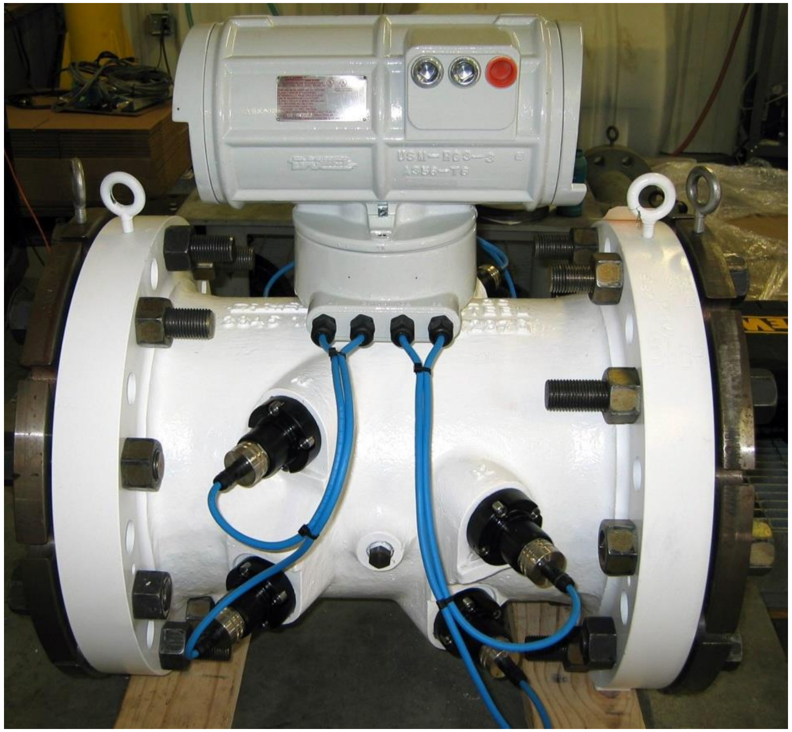
$$V = \frac{L^2}{2X} \cdot \frac{t_{21} - t_{12}}{t_{21} \cdot t_{12}}$$

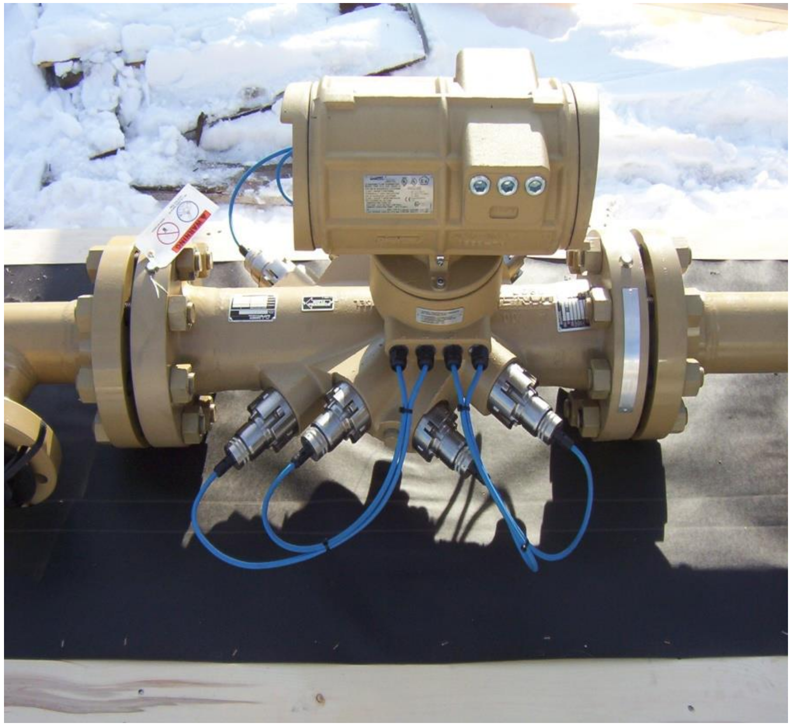
$$SOS = \frac{L}{2} \cdot \frac{(t_{21} + t_{12})}{(t_{21} \cdot t_{12})}$$



Senior Sonic Design

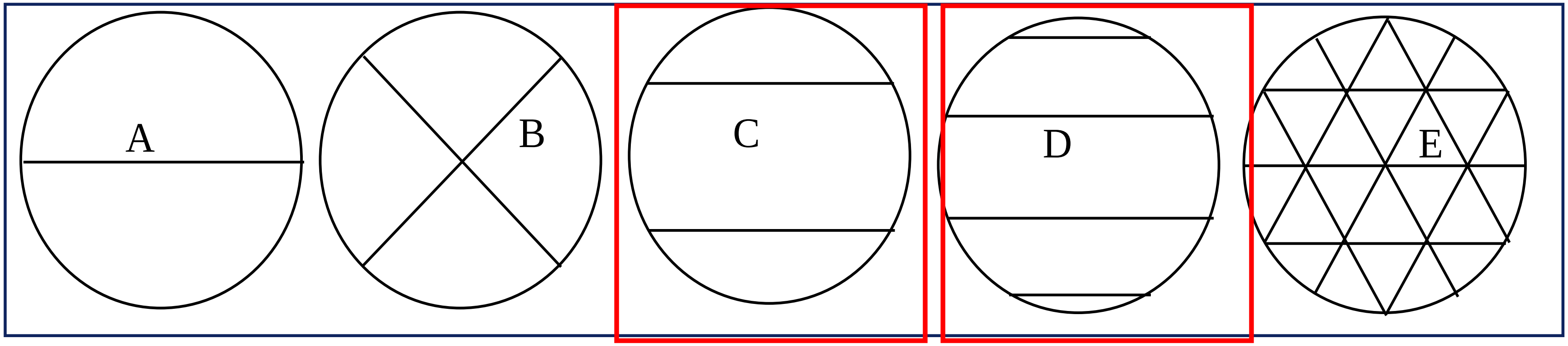
- British Gas Design – 8” & Larger Meters
- Dual “X” Design – 4” & 6” Meters



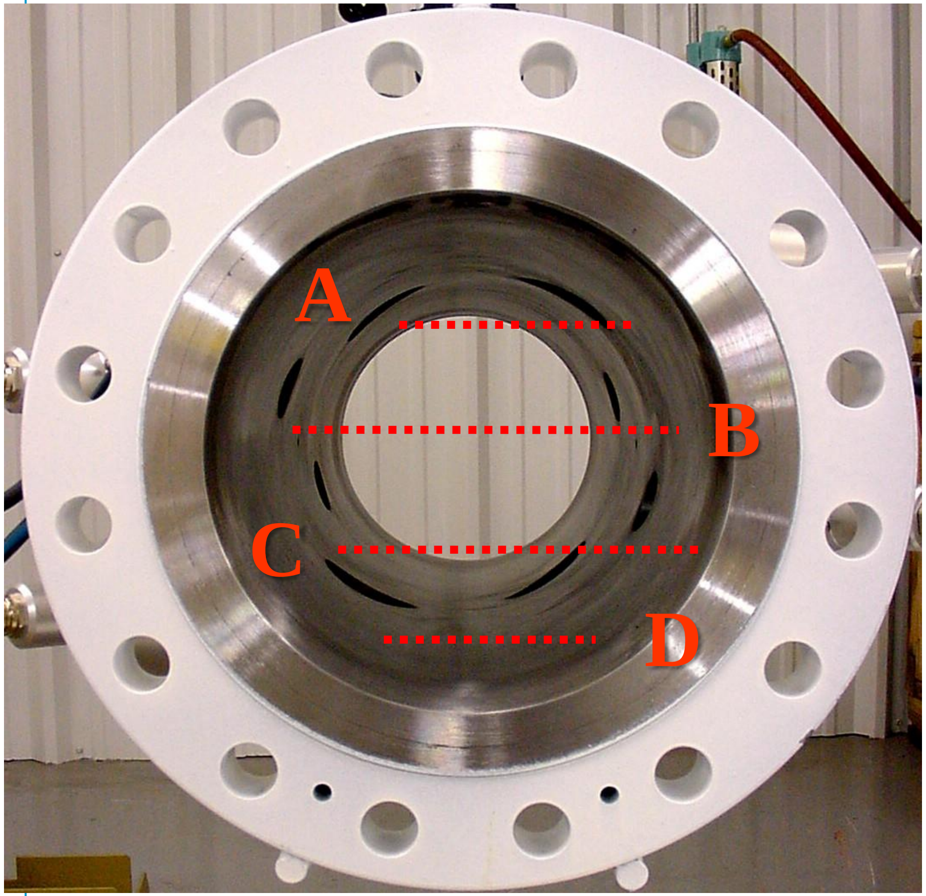


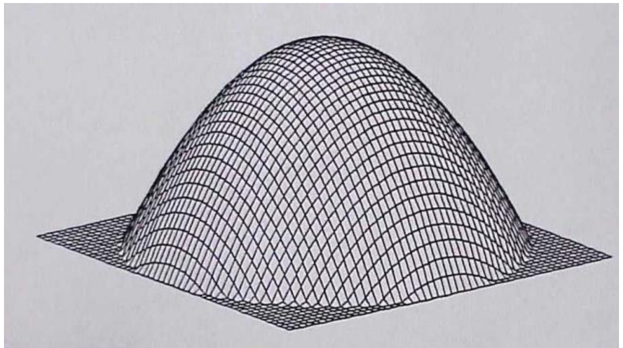
Senior Sonic Design

- Figure C shows the Dual-X design
- Figure D shows the British Gas (BG) design

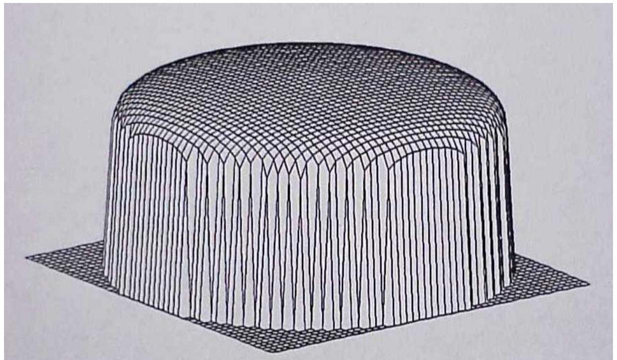


Chord Layout and Profile Considerations



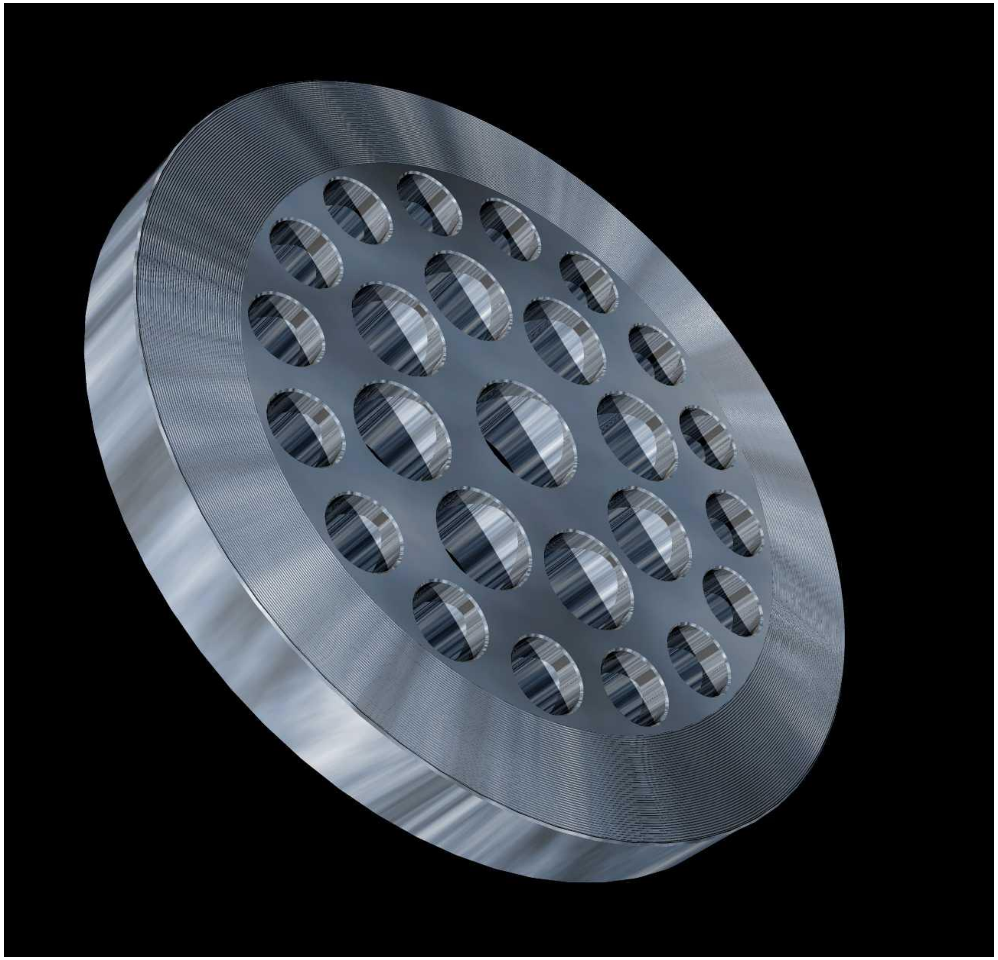


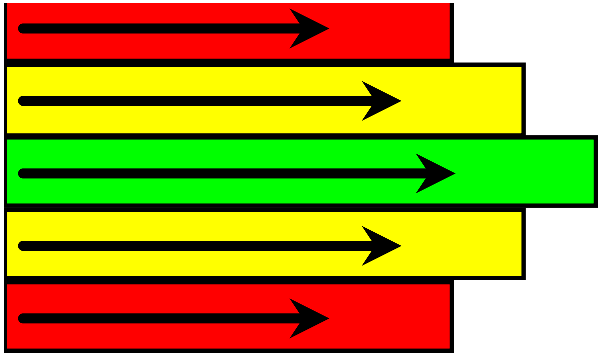
Re = 1,000, laminar

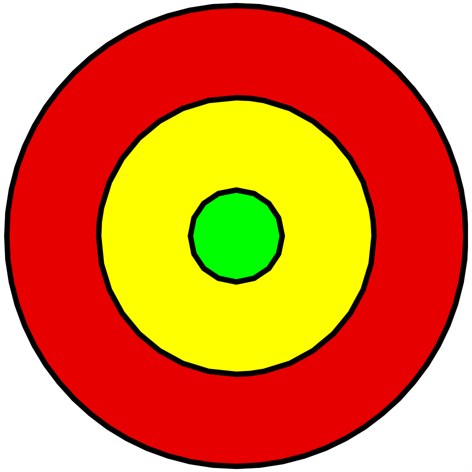


Re = 1,000,000, turbulent

CPACL Nova 50E Flow Conditioner







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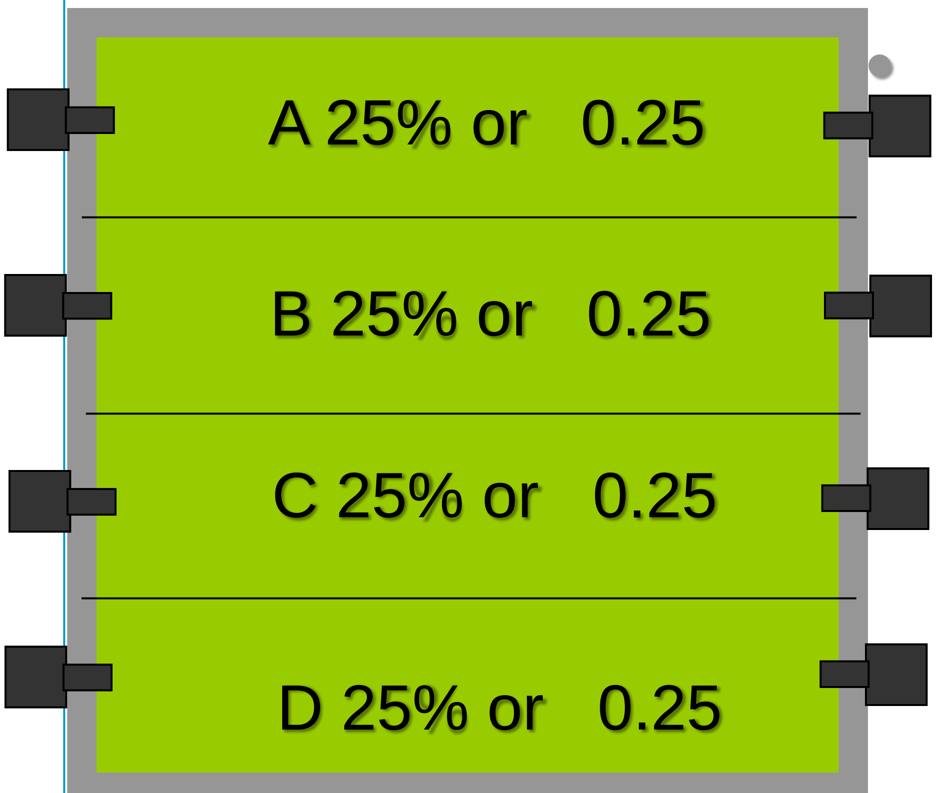
Chords – Contribution to Total Flow

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



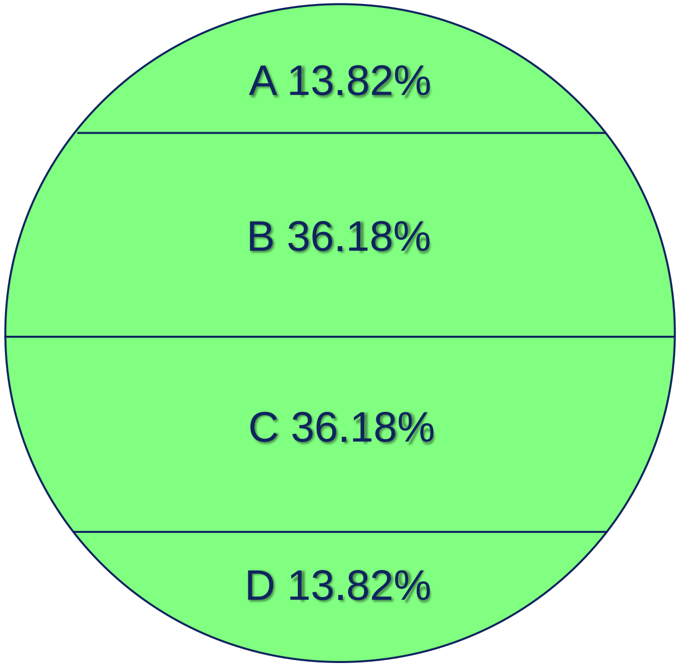
- If we had square pipes……

Chords – 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

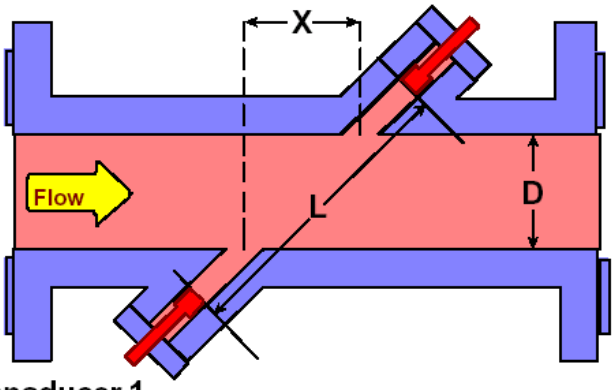
$$\overline{V} = \sum_{i=1}^{4} V_i(r_i)W_i$$



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= AV(Average)

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



Calculations - Acceptable Flow Units

- A final calculation from m3/sec to m3/hr is performed
- Q (Flow) x 3600 = Actual Volume Flow Rate (m3/hr)
- This actual flow rate can now be used for conversion to a standard rate with reference to the appropriate standard (AGA 8, ISO-5167, etc)
- This would require a suitable flow computer or internal in the MKIII with the Series 100 I/O Board

USM Calculation & Summary

1 - Measure Transit Times – (Up-Down & Down-Up)

2 - Calculate Individual Chord Velocities - (Velocities on ABCD)

3 - Weight Chord Velocities – (Round Pipe – Each Worth a %)

4 - Calculate Average Flow Velocity – (Average of All 4 Chords)

5 - Calculate Average Volume Flow Rate – (Avrg Velocity * Area = Flow Rate)

6 – Convert to Suitable Units (M3/Sec – M3/HR)

-The Ultrasonic Meter is using the timing of a sound wave over a know distance to measure velocity and then calculating a volumetric flow rate based on a know area

-Timing and distance are important!

-Timing = Transducers & "Stopwatch"

- Distance = "L" Chord Path – Transducer Face TO Face

Daniel Ultrasonic Flow Meters

Daniel Junior Sonic Meter

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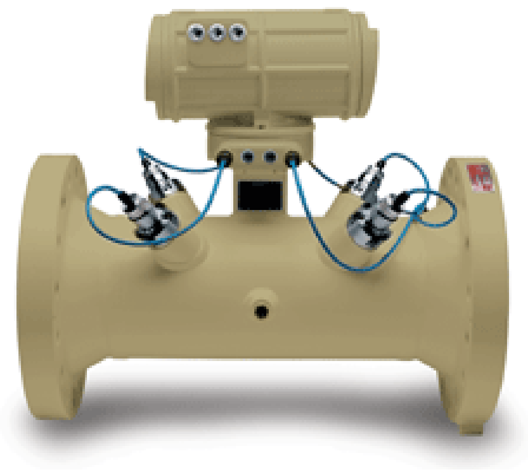
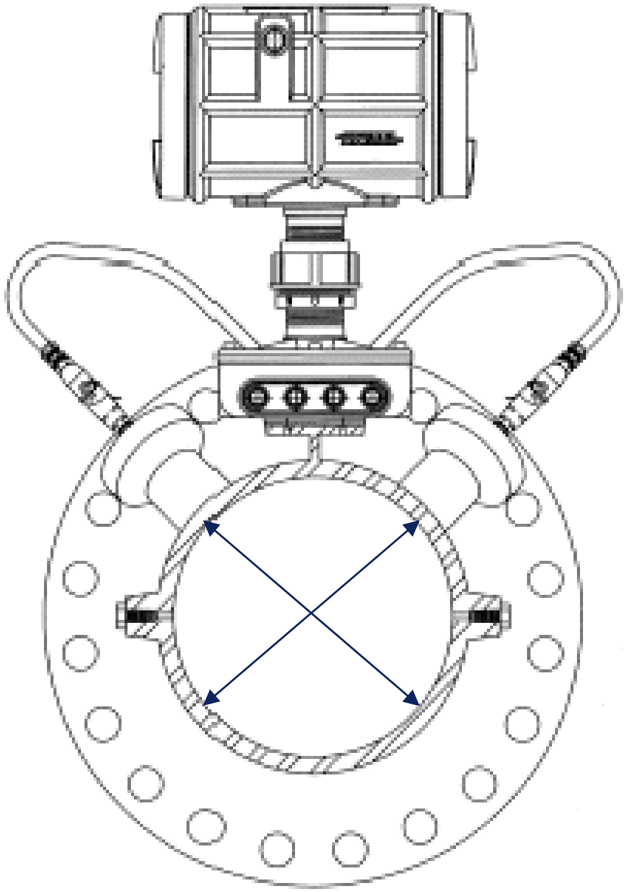
Junior Sonic

- 2 or 1Path Meter
- Uses Bouncing Paths
- Same Velocity Equation
- Requires Live Reynolds Number Correction





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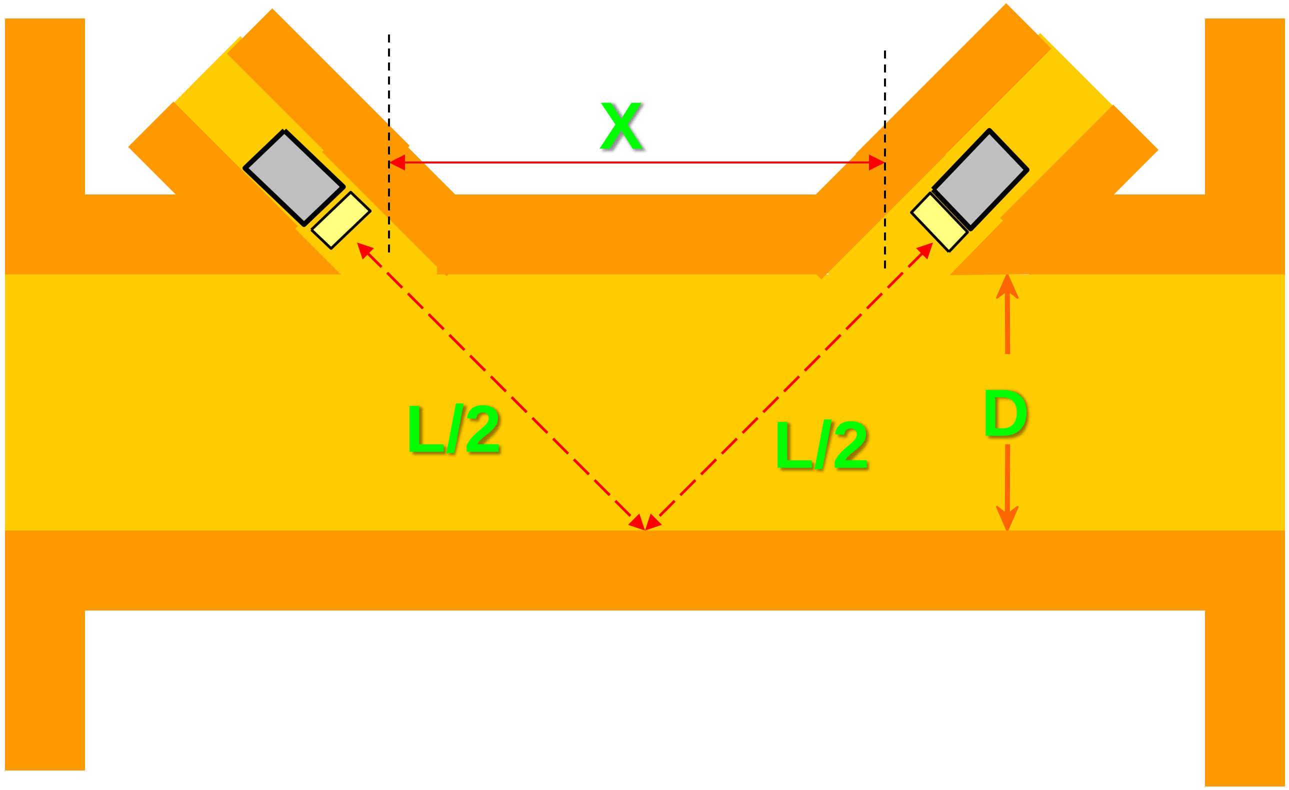
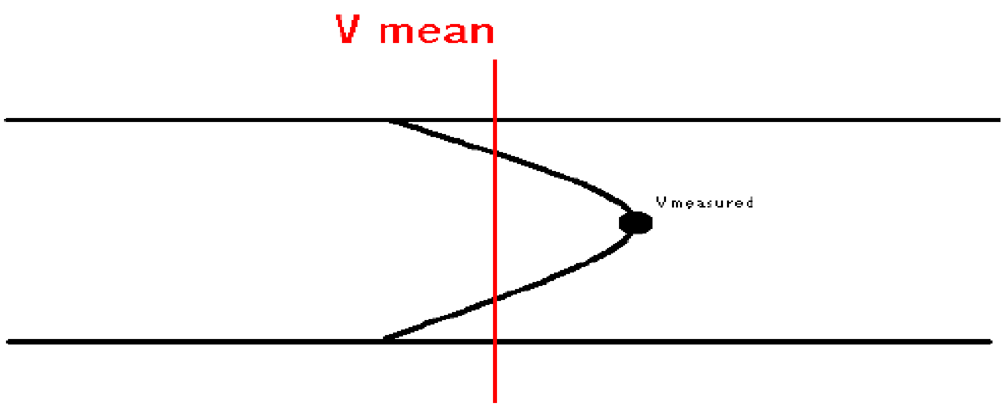
Flow Velocity Calculations

- Flow velocity calculations are identical
- X and L dimensions are as shown



Profile Factor Correction

- As both paths travel through the center line of the pipe they measure the velocity at its highest point on the flow profile
- The inherently "over measure" and as such must be flow profile corrected



Flow Velocity Calculations

- Calculations are done using the exact same formulas as the Senior Sonic only weighting factors are 0.5 and 0.5
- Both paths contribute equally to the flow total
- Once average velocity is calculated flow rate is then determined and the profile factor correction can be applied
- The profile factor correction can be live (dynamic) with pressure and temp, or set to fixed (0.95) is no press and temp is available

USM Calculation & Summary

1 - Measure Transit Times – (Up-Down & Down-Up)

2 - Calculate Individual Chord Velocities - (Velocities on ABCD)

3 - Weight Chord Velocities – (Round Pipe – Each Worth 50%)

4 - Calculate Average Flow Velocity – (Average of All 2 Chords)

5 - Calculate Average Volume Flow Rate – (Avrg Velocity * Area = Flow Rate)

6 – Apply Suitable Profile Correction Factor (0.95 or Dynamic)

7 – Convert to Suitable Units (M3/Sec – M3/HR)

Daniel Ultrasonic Meter

Daniel Ultrasonic Flow Meter Design

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Basics of Dry Calibration

- Dimensional measurement
- Meter electronics configuration
- Leak test at minimum of 200 psig on Nitrogen
- Zero flow verification
- Per-path speed of sound checks
- Documentation

Dry Calibration

During dry calibration pure nitrogen is introduced into meter

Speed of Sound is measured by meter and calculated using Pressure and Temperature measurements and physical properties of pure Nitrogen

Any disagreement between measured and calculated speed of sound must be due to path length inaccuracy or Average Delay Time Adjustment

Dry Calibration Key Points

- Required by AGA 9, PS-G-06 and ISO 17089
- Verification of Data from Measurements
- Documentation is provided to the customer
- Sometimes witnessed by customer

Meteorology Report

DANIEL MEASUREMENT AND CONTROL, INC.
ULTRASONIC FLOW METER
ZERO FLOW CALIBRATION REPORT
(All length measurements in inches)

Customer	Oneok Gas Transmission
Meter Size	8" 600#
Sale Order Number	213120
Electronic Housing S/N	06-393028
Base S/N	
Modbus ID	32
Meter Housing S/N	06-400231
CMM Bore Diameter (Actual)	7.9783

	Chord A		Chord B		Chord C		Chord D	
	S/N	Length	S/N	Length	S/N	Length	S/N	Length
Transducer 1	06-360142	1.7144	06-360131	1.7143	06-360129	1.7161	06-360057	1.7161
Stalk 1		0		0		0		0
Holder 1	06-280133	3.2502	06-280208	3.2515	06-280210	3.2516	06-280212	3.2516
Mount 1	06-330585	2.2503	06-330595	2.2507	06-330597	2.2502	06-330599	2.2506
Transducer 2	06-360170	1.7157	06-360076	1.7186	06-360093	1.7189	06-360114	1.7218
Stalk 2		0		0		0		0
Holder 2	06-280134	3.2501	06-280213	3.2516	06-280211	3.2514	06-280209	3.2514
Mount 2	06-330594	2.2504	06-330596	2.2503	06-330598	2.2507	06-330600	2.2503
Meter Housing		12.0334		14.7597		14.7575		12.0294
Chord Path "L" (inches)		6.6037		9.3247		9.3204		6.5894
Chord Path "X" (inches)		2.7026		4.3833		4.3784		2.7091
Average Delay time (µs)		20.979		21.451		20.83		21.119
Average Delta Time (µs)		0.013		-0.037		0.002		0.006

Calibrated By: ______________________ Date: ______________

Approved By ______________________ Date: ______________

ES-20794 REV. D
REV. D/ECO-195506

Wet Calibration

• Multi-point flow calibration cleans the meter of any intrinsic uncertainty and effects due to installation.

• The reference meters at CEESI, TransCanada Calibration (TCC), Westerbork and Pigsar are all turbine meters linked back to a primary standards.

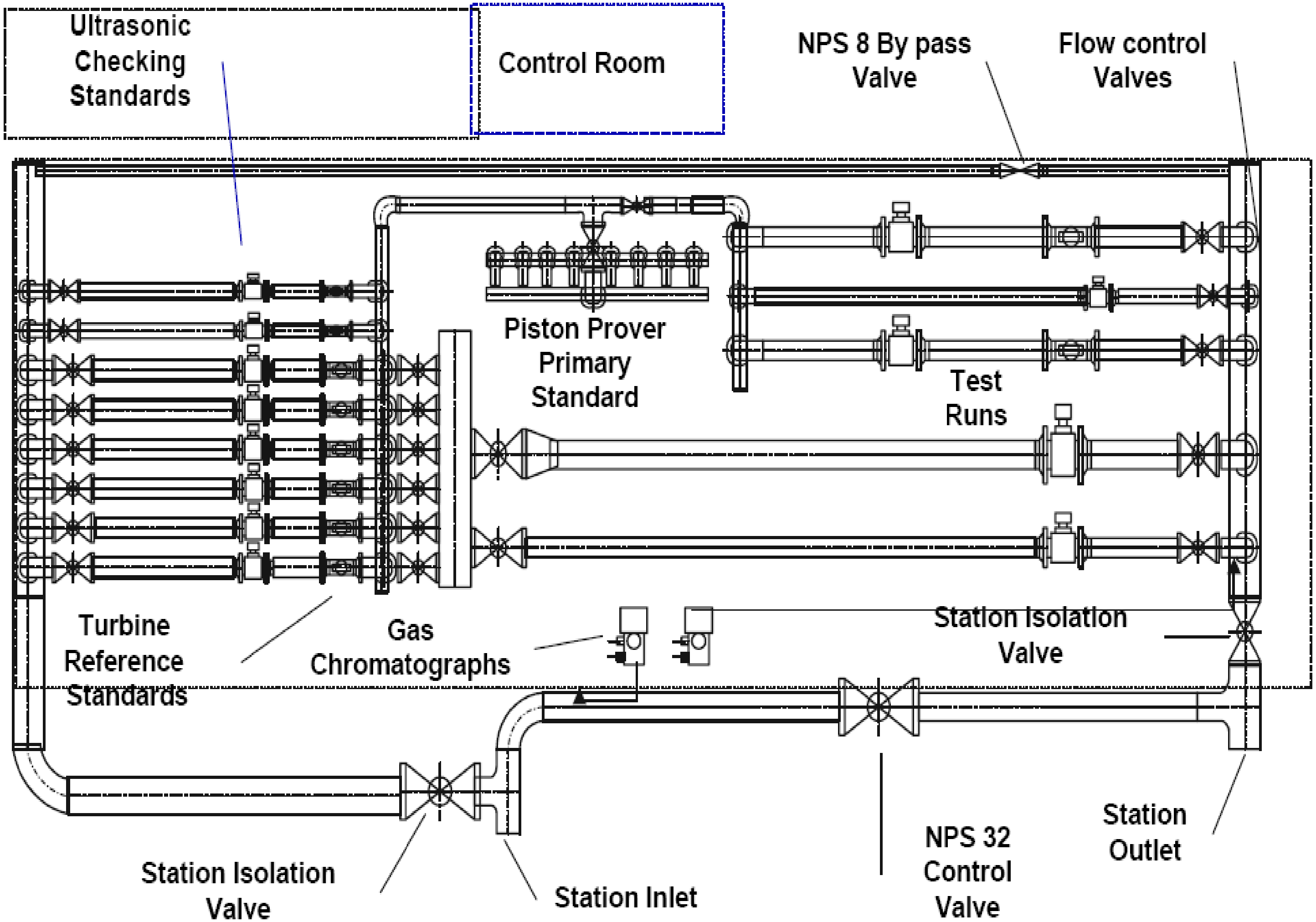
• Calibration facilities should hold ISO-17025 accreditation status

•All are traceable to some governing body, ie, NIST, NMI, PTB or NEL

• Only CEESI and TCC use Ultrasonic meters as statistical comparison meters.

• CEESI uses a single process control meter on facility discharge while TCC used a dedicated check USM for each reference turbine.

TransCanada Calibration Schematic



Transducer Assembly

- Transducer assembly consists of holder, stalk (optional), and transducer
- Each contains serial number and length etched on them

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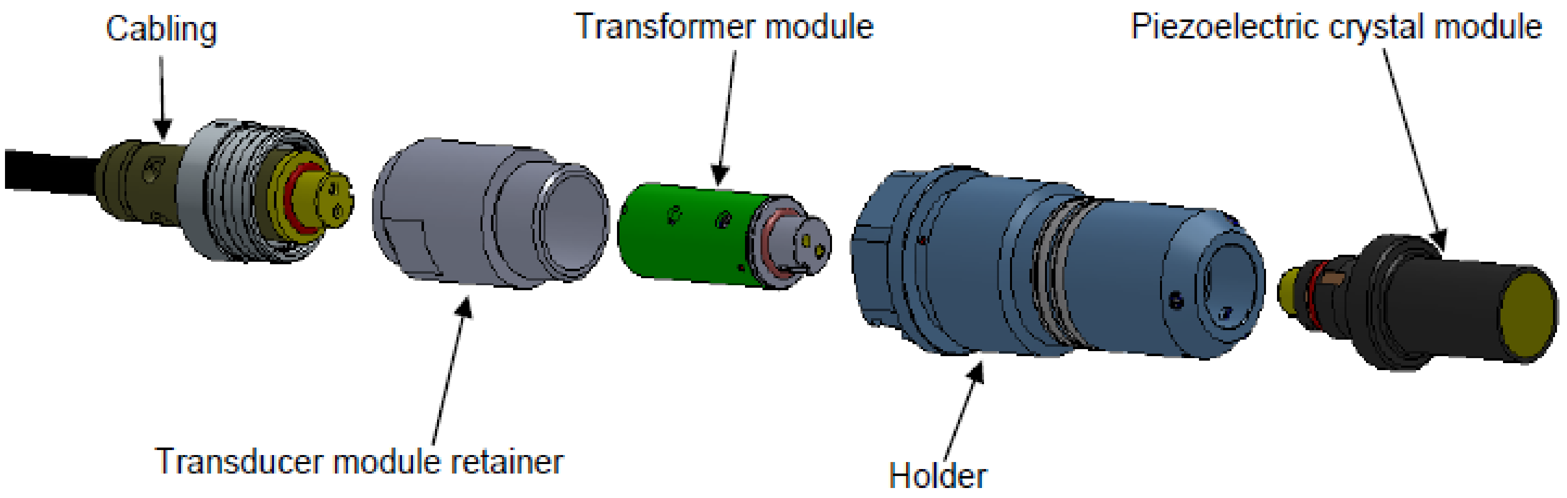
Mount

- Transducer assembly is threaded into mount which is attached to the meter body
- Unlikely to be removed over life of meter
- Double O-ring seal (Flat Backer, Round O-Ring)

New T21 and 22 Transducers



- Transformer has been moved outside of the process Fluid eliminating contact with potentially damaging gases
- Can be retrofitted to existing meters with blue screw in cable sets
- 10,000 PPM H_2S immunity in wet gas, higher in sour dry gas applications

Viewing Data: Meter Monitor Screen

Shows the velocities at each chord

Shows the speed of sound (SOS) at each chord

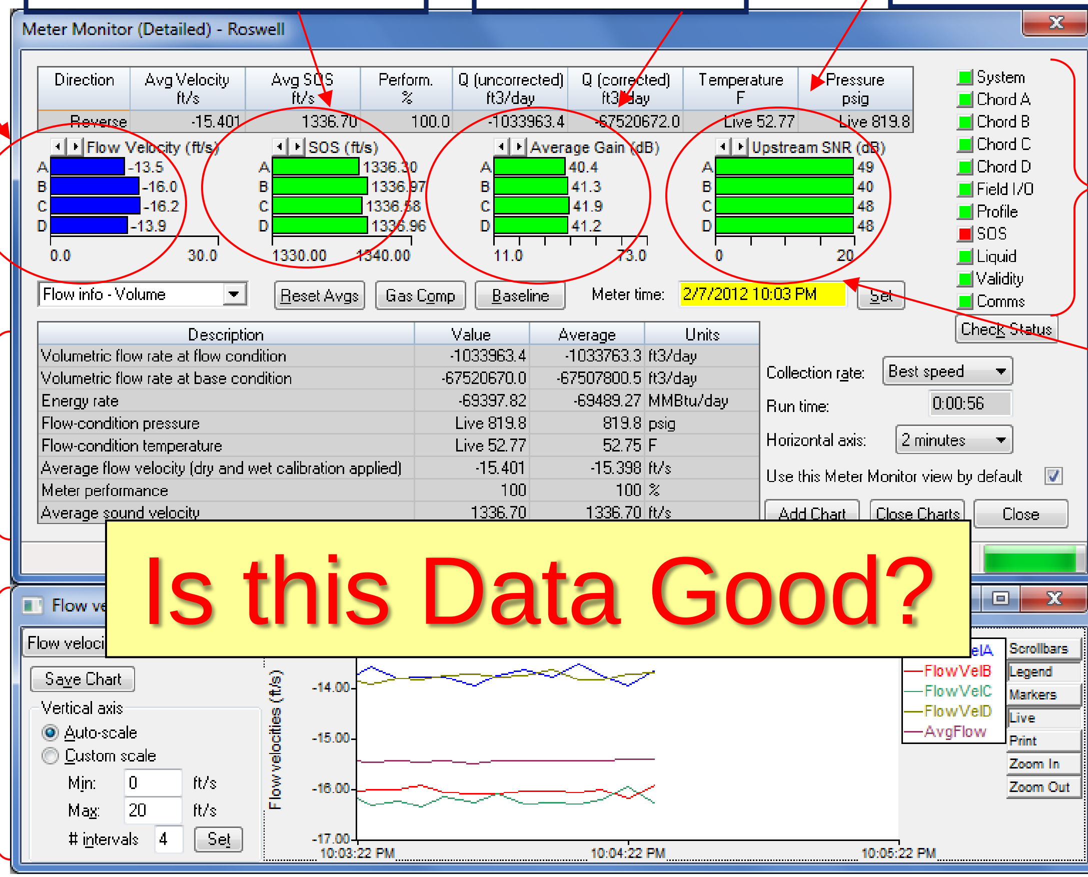
Shows the gain levels at each chord

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

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Future of the Gas Ultrasonic Meter

Dual-Configuration Meters

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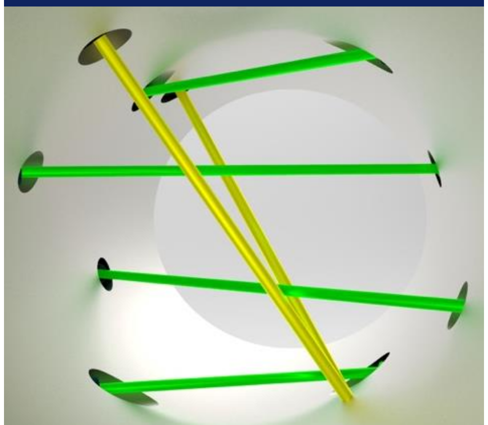
Three New Daniel Dual-Configuration Models

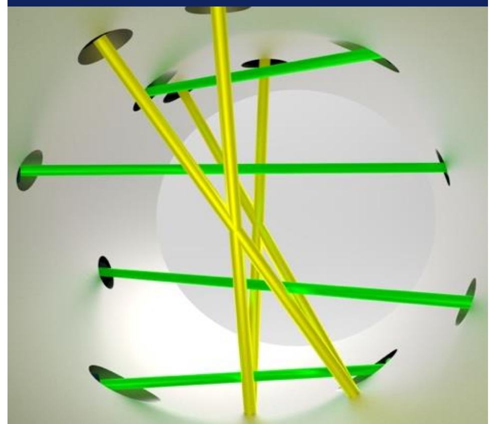
Additions to 3410 Series Gas Ultrasonic Meter Line

3415 (4+1)



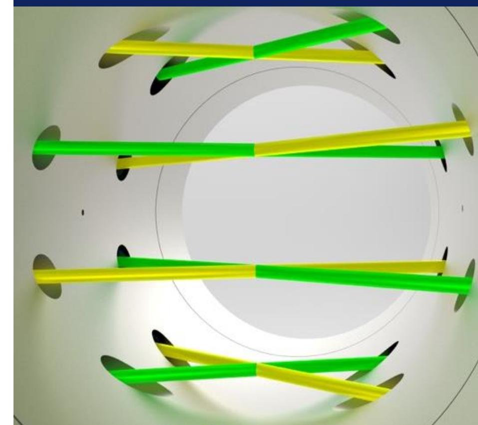
Primary	4-Path Chordal
Secondary	1-Path Reflective

3416 (4+2)



Primary	4-Path Chordal
Secondary	1-Path Reflective
Detection	1-Path Reflective

3417 (4+4)



Primary	4-Path Chordal
Secondary	4-Path Chordal

Verification

- Measurement verification with an integral check meter
- Provides early warning of process issues

Verification/Detection

- Measurement verification with an integral check meter
- Diagnostic path helps determine the cause of a shift
- Detects pipe bottom contamination

Reliability/Value

- Premium reliability with fully-redundant design
- Two independent fiscal/custody meters in one meter body

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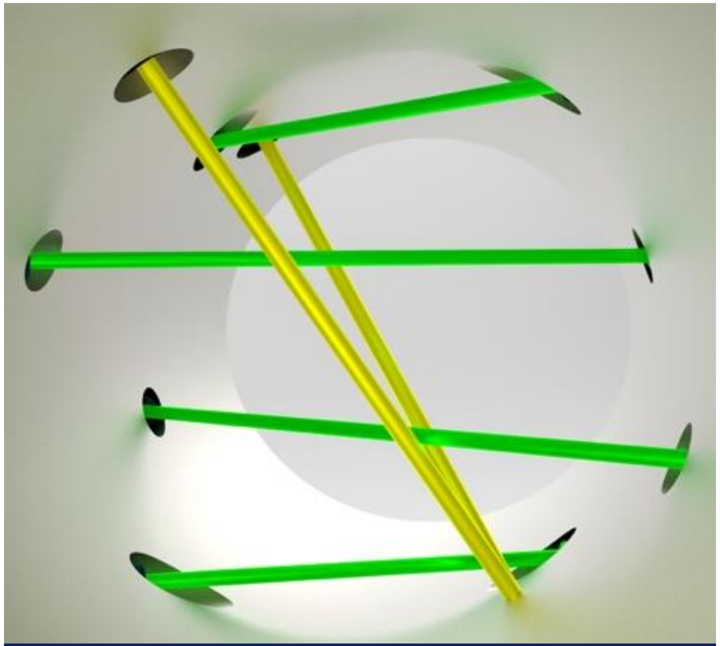
Daniel 3415 Gas Ultrasonic Meter

Integrated Check Metering



VERIFICATION

A Daniel British Gas custody meter and a single reflective path check meter in one body.

⇩

Verifies the custody measurement and detects a bias before it is critical.

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Key Features

- Two meters in one body – custody plus check
- Chordal and reflective paths – no common mode error
- Synchronized firing – no interference from check meter

Application and Measurement Sites

- Rich, dirty or wet gas (i.e. unconventional gas) measured at:
  - Gas processing plants
  - Gas transmission pipelines
  - Industrial interconnects

Value

- Prevents fiscal losses and damage to equipment
- Simplifies and prevents maintenance
- Provides backup measurement
- Eliminates secondary check meter

EMERSON
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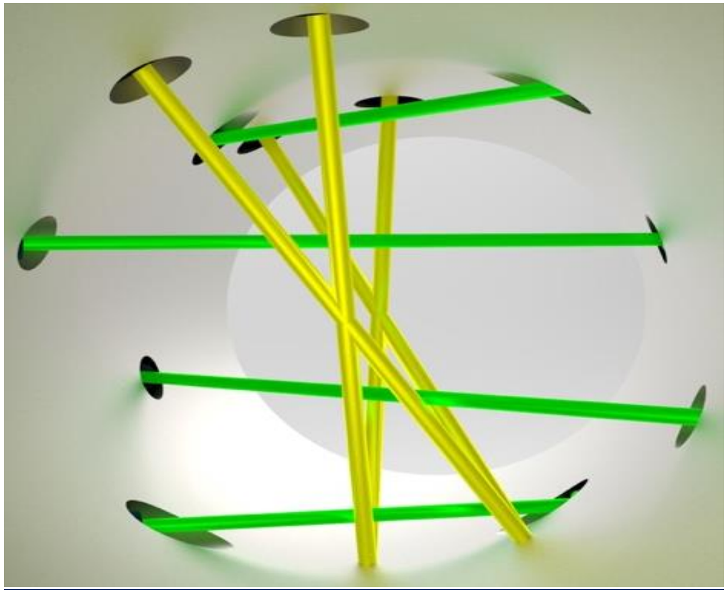
Daniel 3416 Gas Ultrasonic Meter

Integrated Check Metering Plus Liquid Detection



VERIFICATION/DETECTION

Daniel British Gas custody meter and a single reflective path check meter plus a single reflective bottom detection path

Verifies the custody measurement, detects a bias early and detects trace amounts of buildup or liquid on the bottom of the pipe

DANIEL

Key Features

- Two meters in one body – custody plus check
- Chordal and reflective paths – no common mode error
- Synchronized firing – no interference from check meter
- Vertical diagnostic path sees the bottom of the pipe

Application and Measurement Sites

- Rich, dirty or wet gas (i.e. unconventional gas) measured at:
  - Production and gathering
  - Gas plant inlets/outlets
  - Underground storage
  - Transmission Pipelines

Value

- Prevents fiscal losses and damage to equipment
- Simplifies and prevents maintenance
- Provides backup measurement
- Eliminates secondary check meter
- Detects liquid/buildup on pipe bottom

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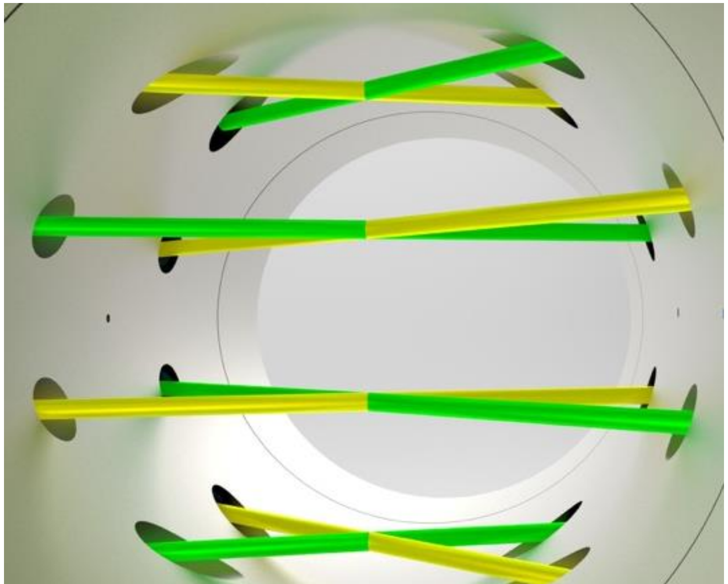
Daniel 3417 Gas Ultrasonic Meter
Fully-Redundant Custody Meter



RELIABILITY/VALUE

Redundant 4-path, Daniel British Gas meters in one body. The second meter is a mirror image of the first.

⬇

Ultimate reliability and reduced capital costs with two custody meters in one body.

Key Features

- Redundancy – two independent meters in one
- Synchronized firing – each meter fires 500x per second
- 3D view of flow: measures crossflow, asymmetry, swirl

Applications

- Pipeline interconnects (shared meter)
- Designs with no bypass
- Offshore and other remote sites
- Border stations
- Power plants
- Industry/city gates
- LNG regasification terminals

Value

- Continuous uptime; no critical maintenance
- Eliminate a meter run
- Share meter with a customer (buyer/seller)
- Extend calibration cycles

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Thank You!

Questions?