Understanding Gas Ultrasonic Meter Diagnostics

Advanced

WGMSC

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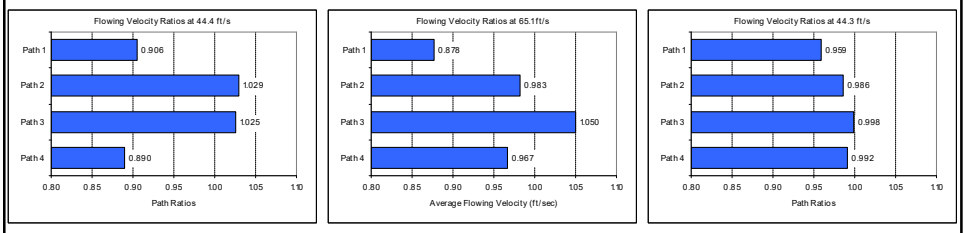
John Lansing
Lansing Measurement Services, LLC



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Advanced Diagnostics Indicators

- Most USMs provide additional (advanced) diagnostics
- Advanced diagnostics include:
  - Profile Factor
  - Symmetry
  - Crossflow
  - Turbulence
  - Swirl Angle
- Advanced diagnostics permit a more detailed analysis of process conditions
- Most meters today have advanced diagnostics
- This presentation is primarily on 4 & 6-path USM diagnostics

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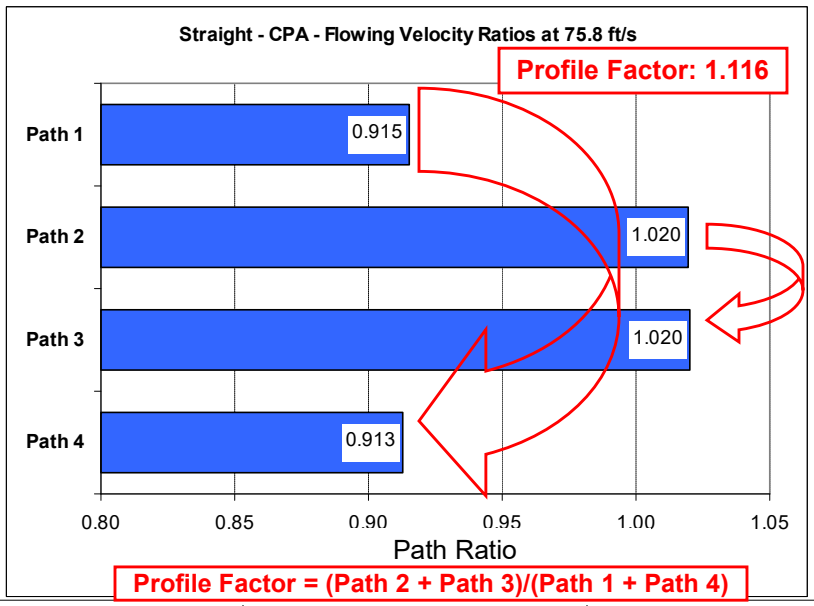
Profile Factor Definition

- Profile Factor (PF) is a summary of the path ratios
- Definition is defined as (Path 2 + 3) / (Path 1 + 4)
- Since Path Ratios for 2 & 3 are larger than Paths 1 & 4 for a 4-path Chordal meter, the Profile Factor greater than 1.00
- Typical profile factor for a 4 or 6 path Chordal meter is between 1.11 and 1.18 (depends upon the manufacturer)
- PF is a simple method for identifying changes in the profile
- PF is generally stable from 3-5 fps up to meter capacity

Path Ratios – 4-Path Meter – Profile Factor



Distorted Profile from Elbows and Tee

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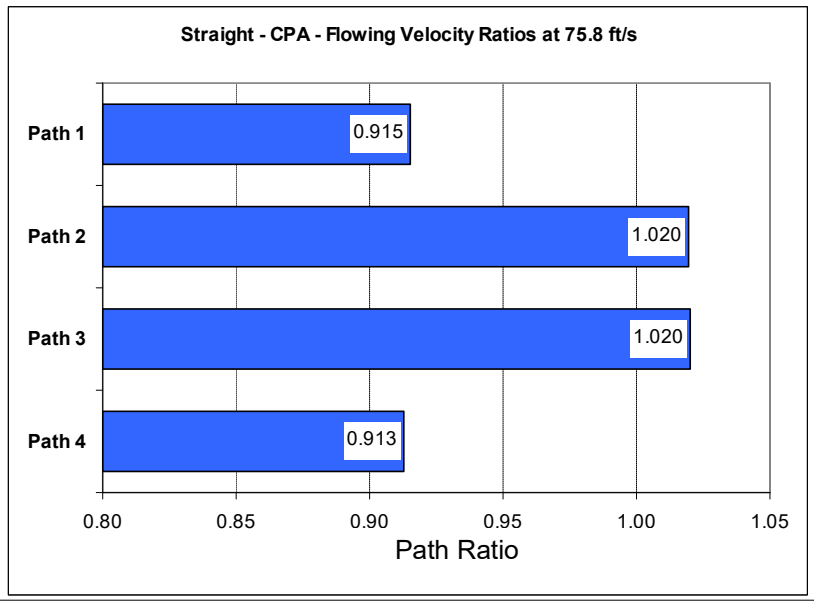
Path Ratios – 4-Path Meter – Normal Profile



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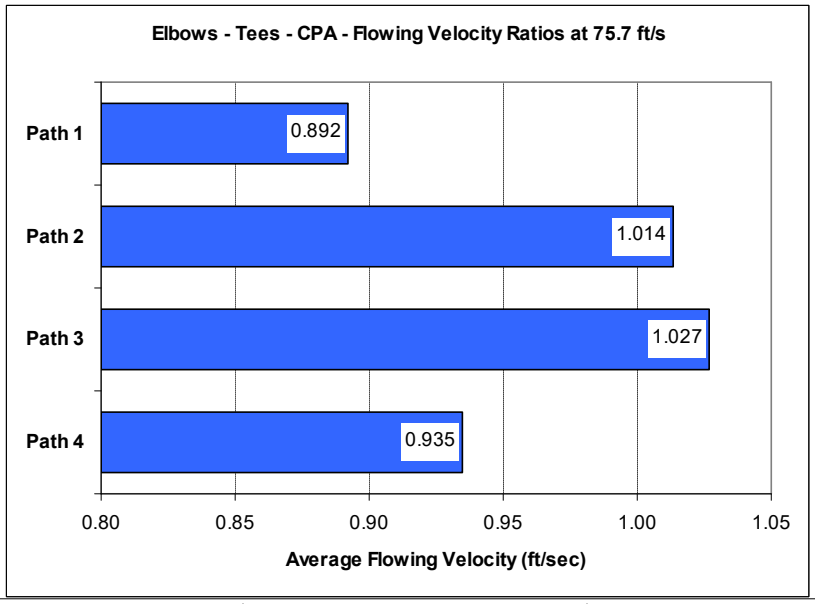
Path Ratios with CPA, Elbows & Tees



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Symmetry Definition

- Symmetry is a summary of the path ratios similar to Profile Factor
- Definition is defined as (Path 1 + 2) / (Path 3 + 4)
- If the velocity profile is symmetrical from top to bottom on a Chordal meter, the Symmetry value should be 1.00
- Distorted profiles will cause the Symmetry value to either be above or below 1.00, depending upon the distortion
- This additional diagnostic parameter helps verify consistent profile
- It is possible to have a correct Profile Factor, but have a distorted profile – Symmetry provides a second check

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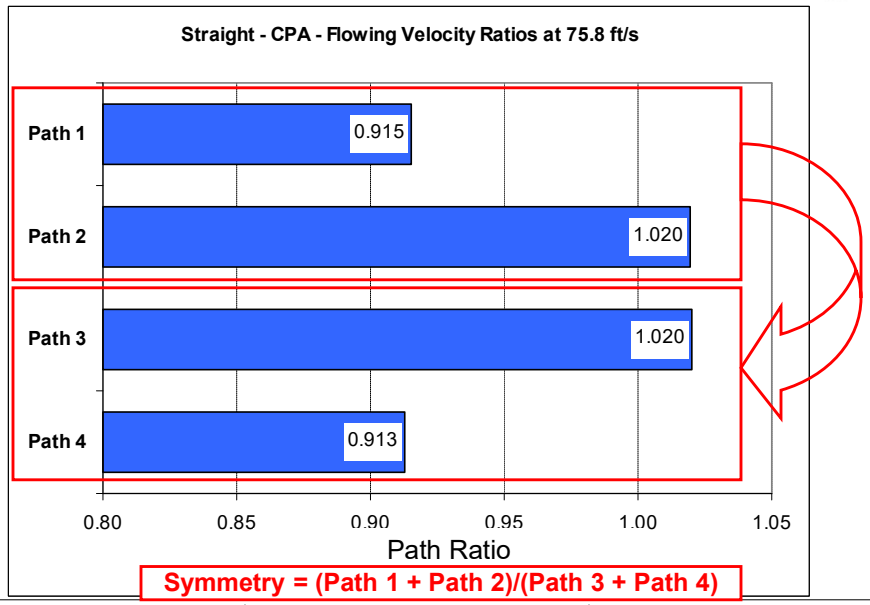
Path Ratios – 4-Path Meter - Symmetry



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40% Blocked CPA Flow Conditioner

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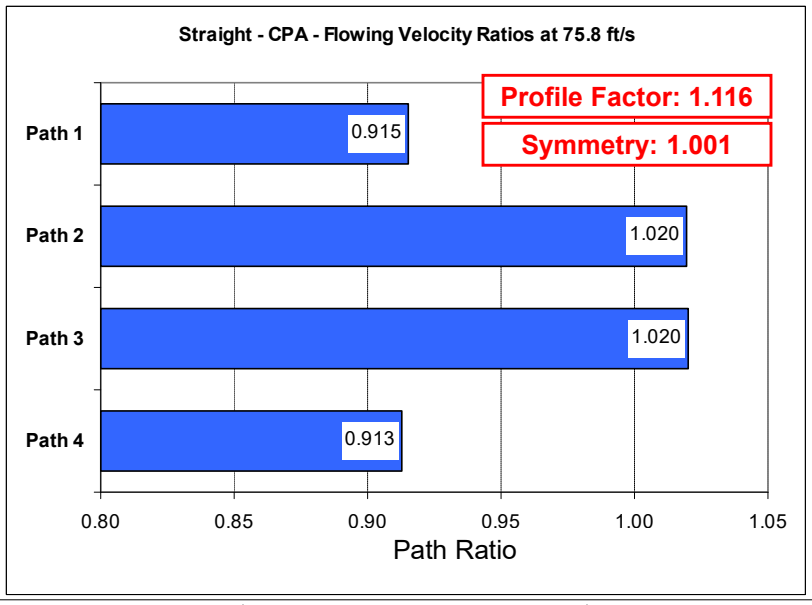
Path Ratios, 12-inch CPA, No Blockage



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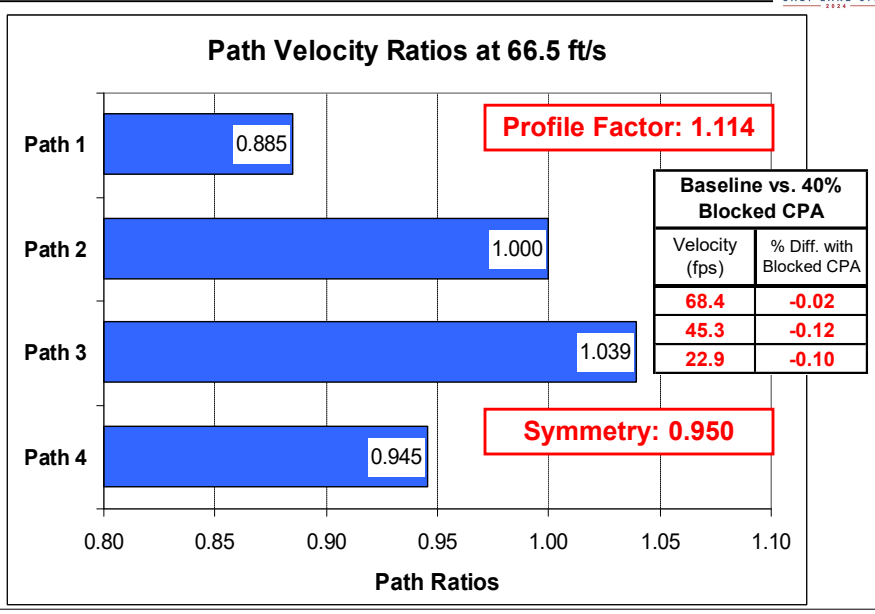
12-inch, 4-Path Path Ratios, CPA, 10D + 10D



Baseline vs. 40% Blocked CPA	
Velocity (fps)	% Diff. with Blocked CPA
68.4	-0.02
45.3	-0.12
22.9	-0.10

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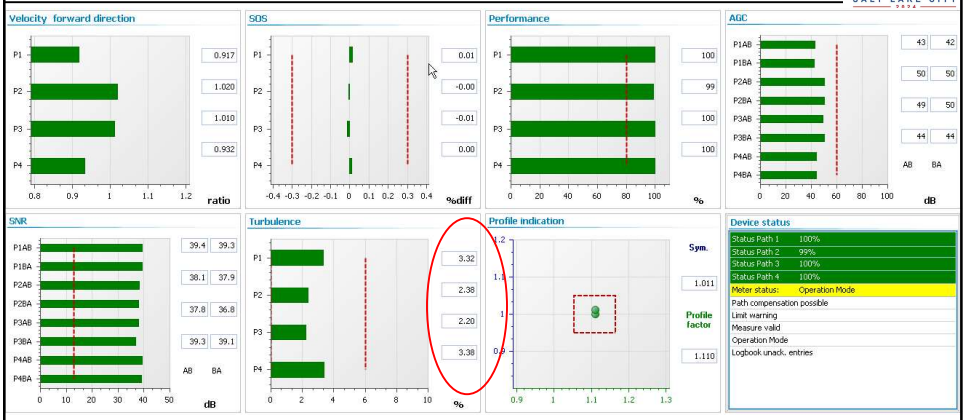
Turbulence

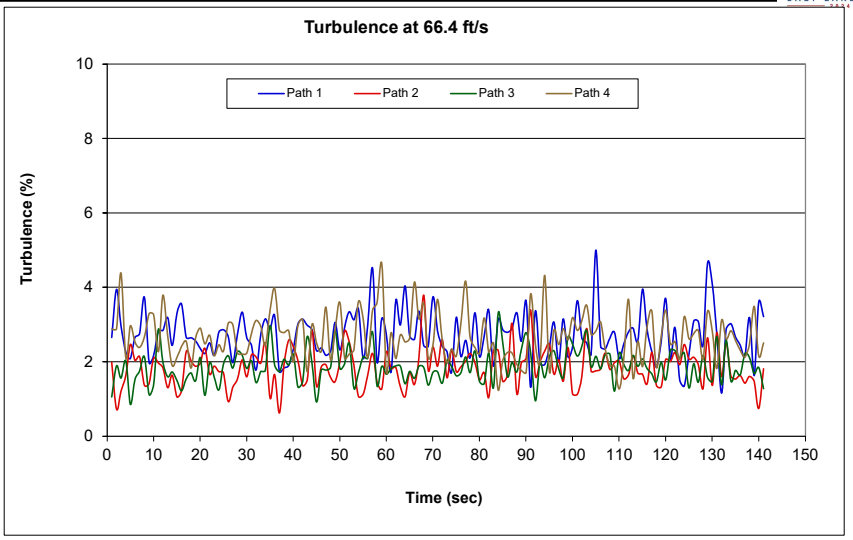
- USMs sample each transducer pair several times per second
- The average transit time of many samples is used to compute the flow rate
- Each transit time measurement for the sampling period has some variation
- The variability of these samples, when compared to the average, provides in indication of the velocity stability
- This variability is called **Turbulence**
- Think of this as a measure of the gas profile stability
- Maybe the easiest way of identifying flow conditioner blockage
- Useful for identifying many other abnormal conditions

Turbulence Diagnostic - Normal



Turbulence is typically 2-3% on Path 2 & 3, and 3-4% on Paths 1 & 4

4-Path Turbulence – Normal



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40% Blocked CPA Flow Conditioner

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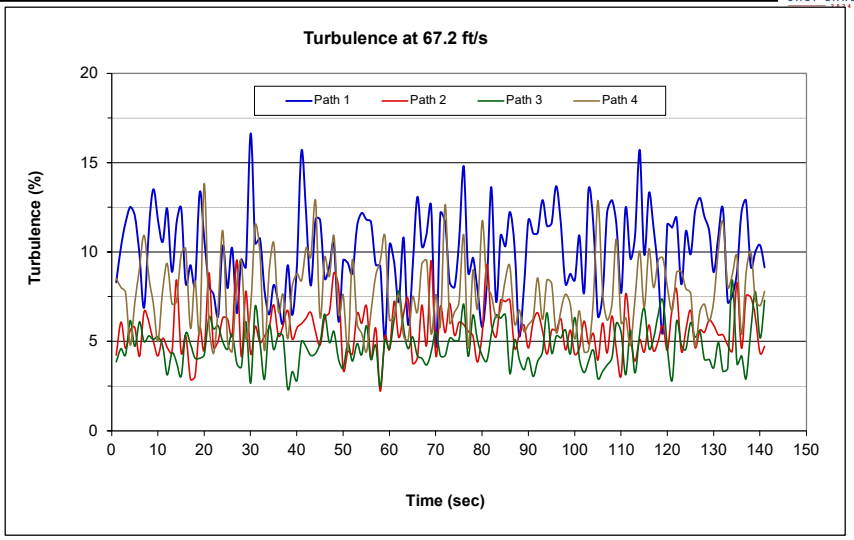
4-Path Turbulence with 40% Blocked FC



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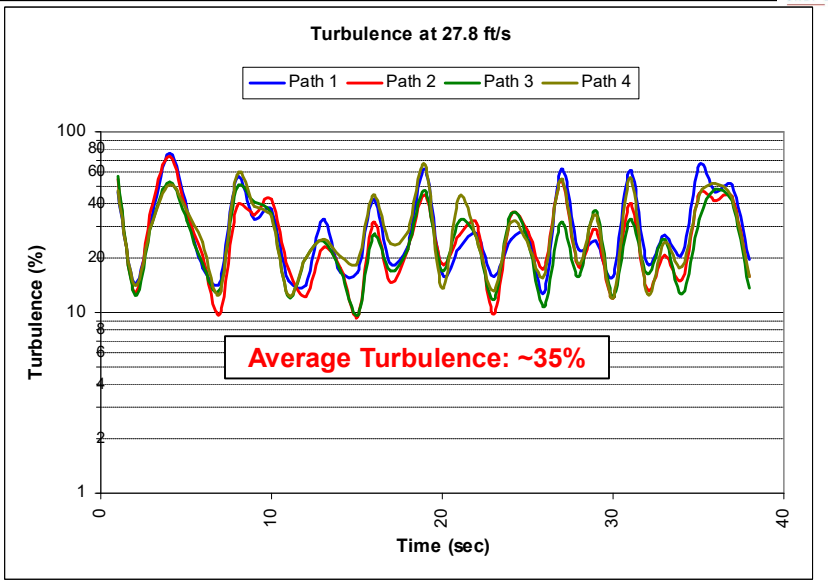
Turbulence – 15 Hz Pulsation



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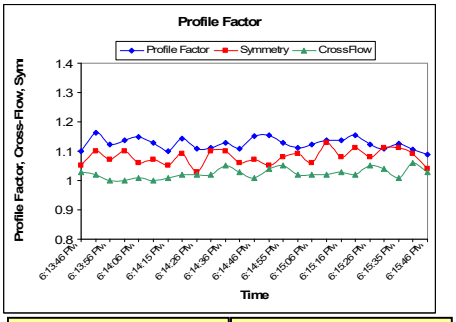
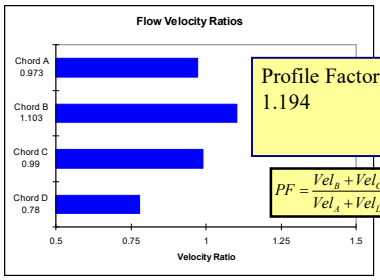
Advanced Diagnostics – Abnormal Conditions

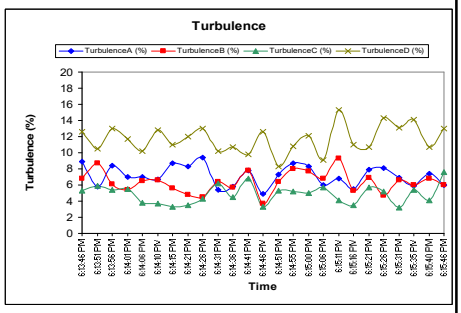
Software Diagnostics report high values for symmetry, flow profile, and turbulence indicating that there is a blockage.





Profile Factor = 1.194

$$PF = \frac{Vel_B + Vel_C}{Vel_A + Vel_D}$$



Symmetry = 1.098

Crossflow = 1.051

High Turbulence on all chords

$$Sym = \frac{Vel_A + Vel_B}{Vel_C + Vel_D}$$

$$CrossFlow = \frac{V_A + V_C}{V_B + V_D}$$

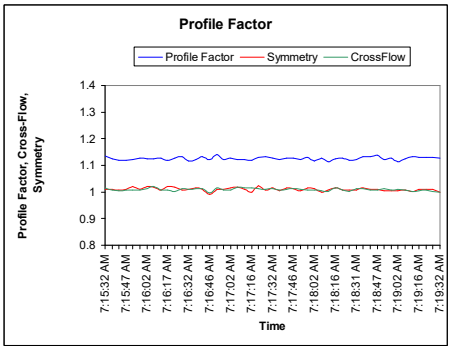
12-inch Flow Conditioner Blockage

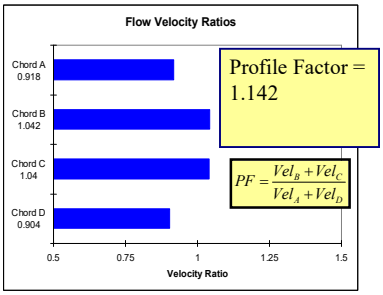
Customer Value:

- Pipeline debris is recognized with advanced diagnostics
- Recognized changes in symmetry and flow profile

Advanced Diagnostics – Normal Conditions

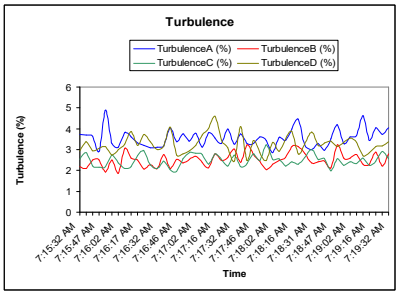
CUI Diagnostics report normal values for symmetry, flow profile, and turbulence.





Profile Factor = 1.142

$$PF = \frac{Vel_B + Vel_C}{Vel_A + Vel_D}$$



Symmetry = 1.010

Crossflow = 1.010

Normal Turbulence
2-3% on A & D chords
3-4% on B & C chords

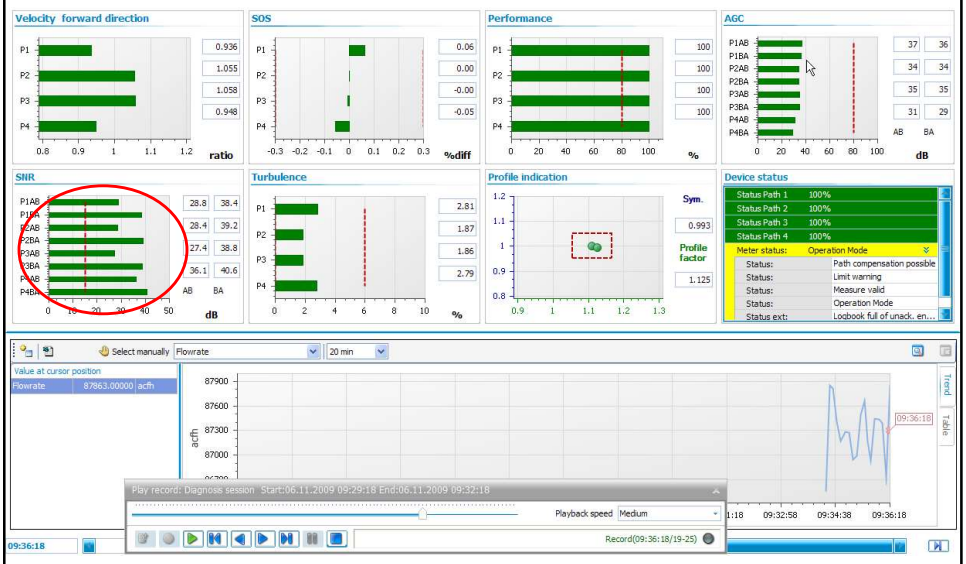
$$Sym = \frac{Vel_A + Vel_B}{Vel_C + Vel_D}$$

$$CrossFlow = \frac{V_A + V_C}{V_B + V_D}$$

Real World Regulator Noise – 12-inch Meter

- This is a 12-inch meter with regulation upstream
- Bi-directional design but flow primarily in one direction
- Pressure drop during this session file was 350 PSI differential
- Regulator has downstream header (two change of directions)
- No noise attenuation tees incorporated
- Pressure at meter about 800 PSI and data about 40 fps
- Let's look at the installation and review a Maintenance Report

Real World Regulator Noise – 12-inch Meter



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Wet Gas Testing

- Wet Gas testing has been performed at the CEESI Nunn facility
- 4-inch testing done at 3 pressures: 13, 33 & 55 Bar (300, 500 & 800 psi) [March 2010]
- GVFs tested included: 100, 99.9, 99.5, 99.0, 98, 97, 96 & 95%
- All testing included a CPA 50E flow conditioner located at 10D upstream of the USM
- The dual-chamber orifice meter had a 19-tube bundle and was located downstream of the USM

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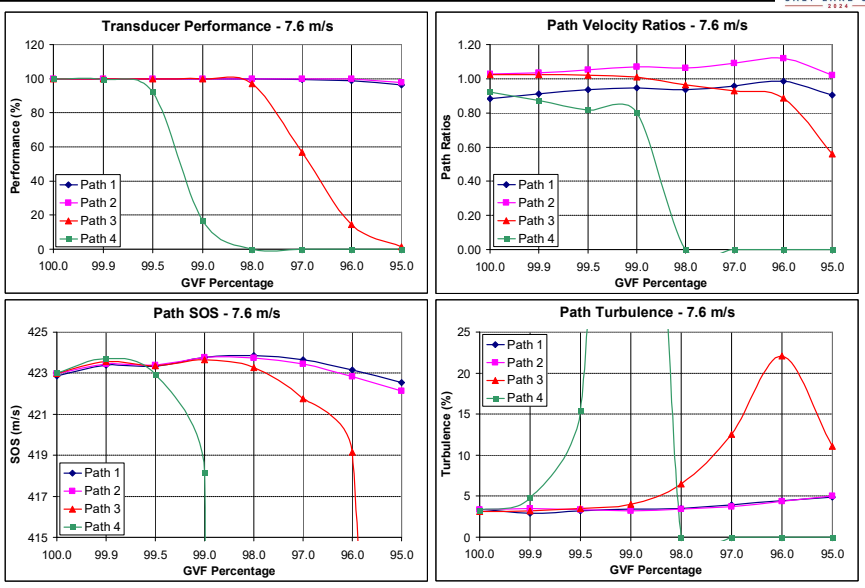
4-inch Meter Diagnostics – Wet Gas – 25 fps



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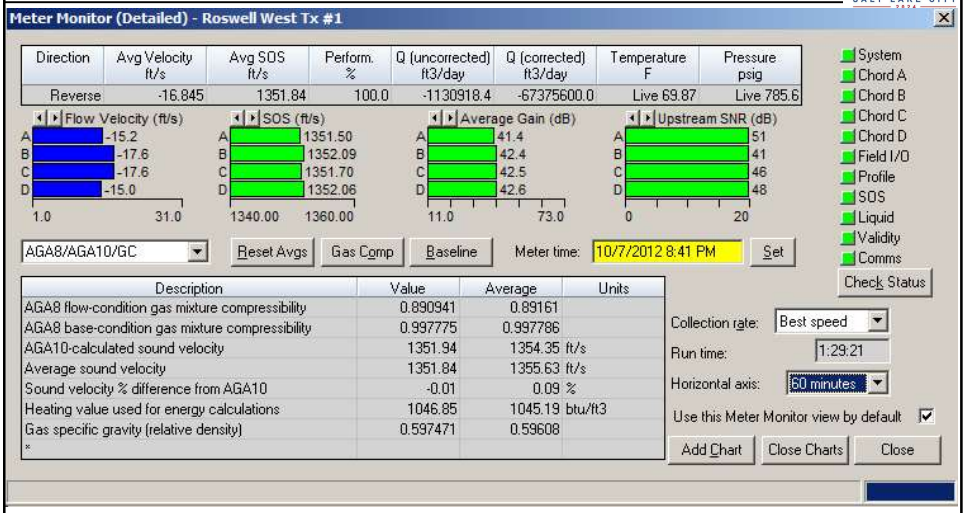
Example Chordal Meter Operating Correctly



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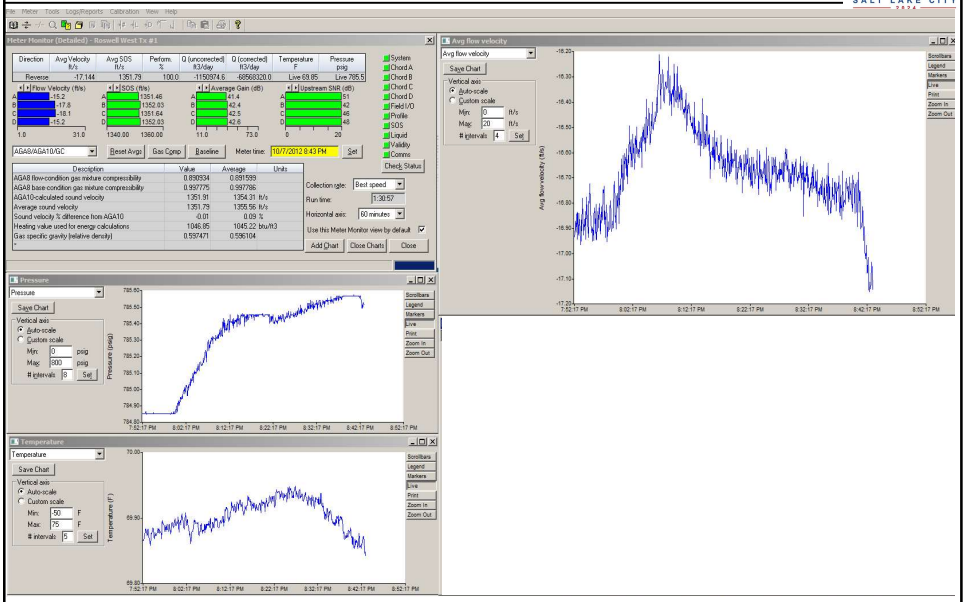
Example of Changing Gas Composition Problem



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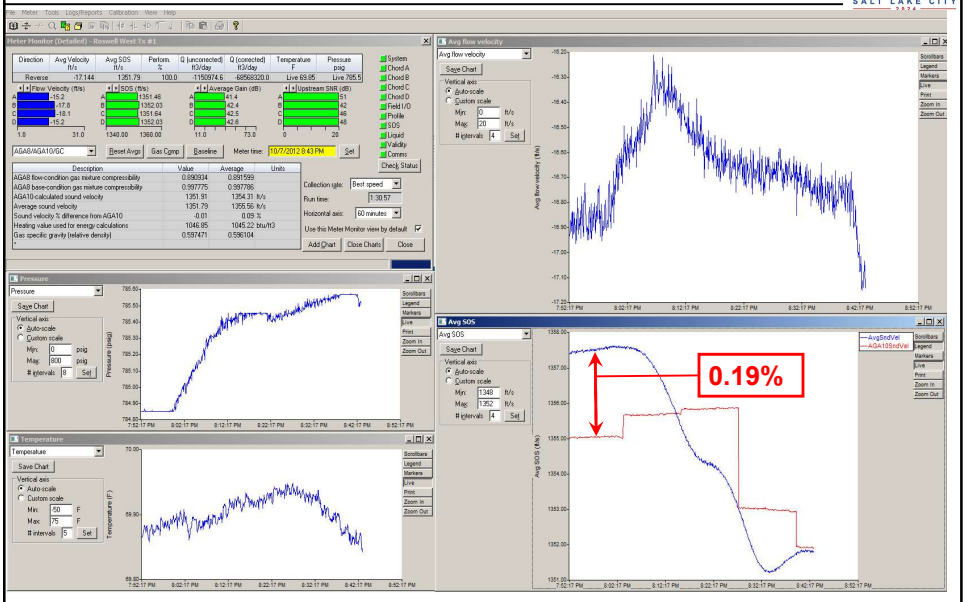
Example of Changing Gas Composition Problem



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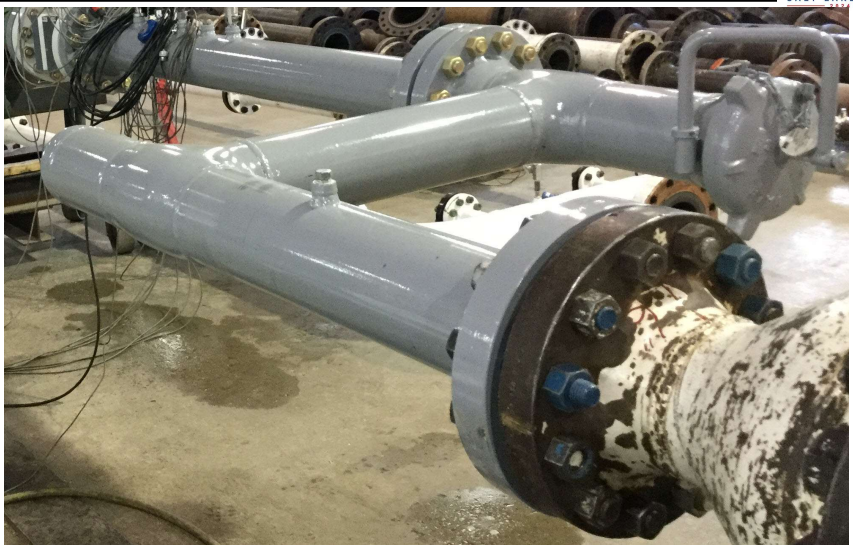
Elongated Tee Used for Testing



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Elongated Tee and Swirl at the SICK Meter

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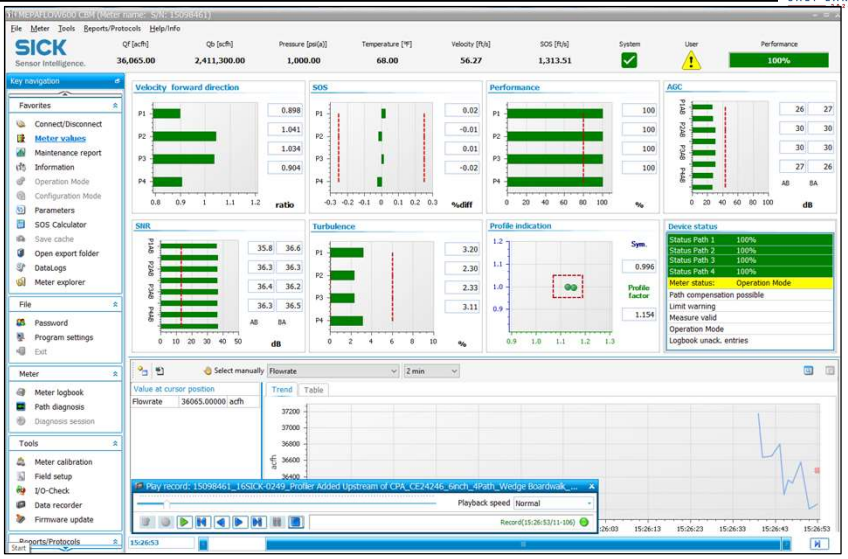
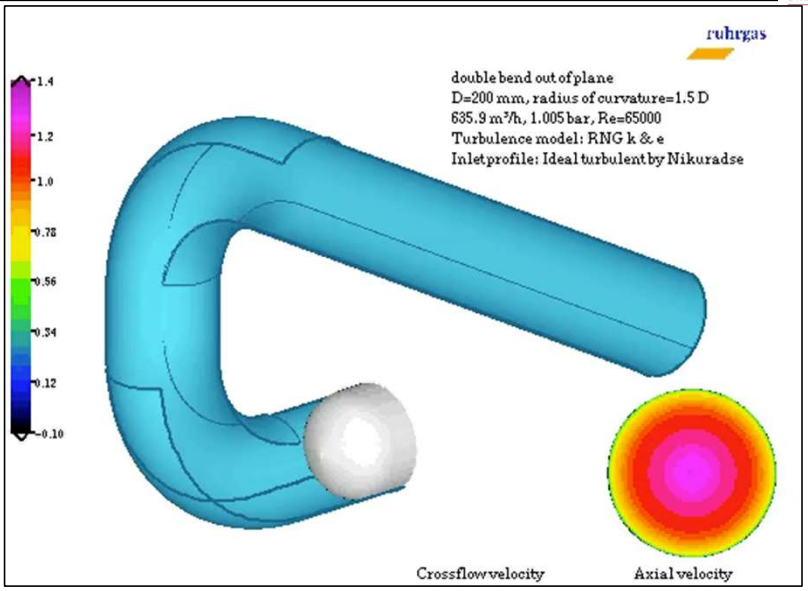
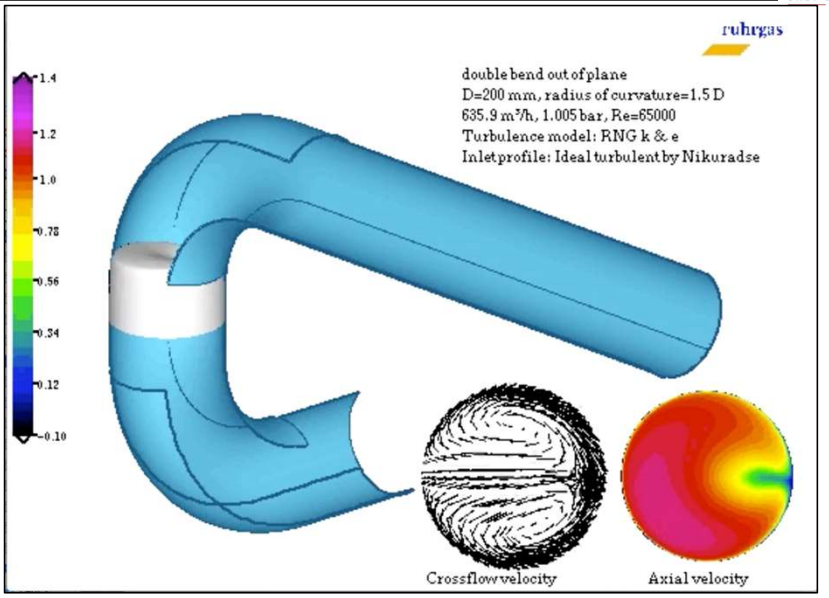
Elongated Tee and Dual Flow Conditioner Results



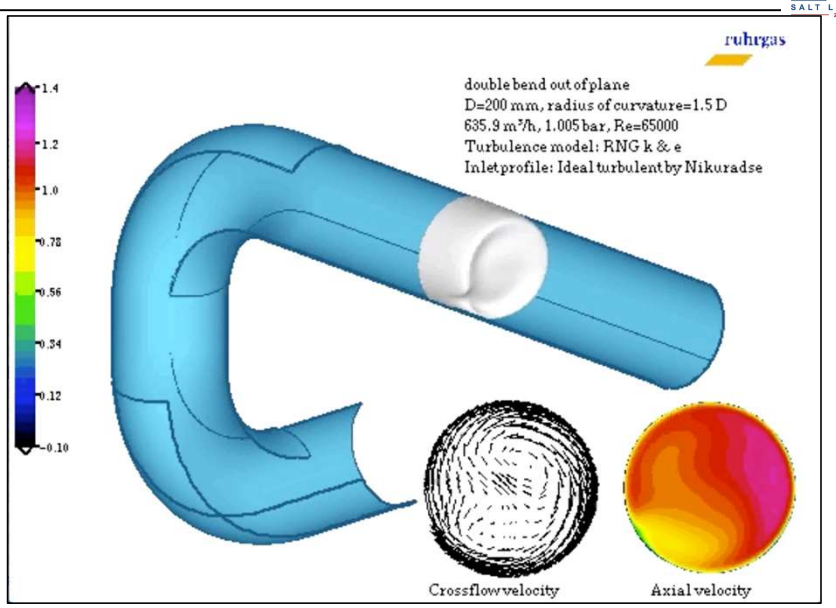
Crossflow & Swirl Discussion



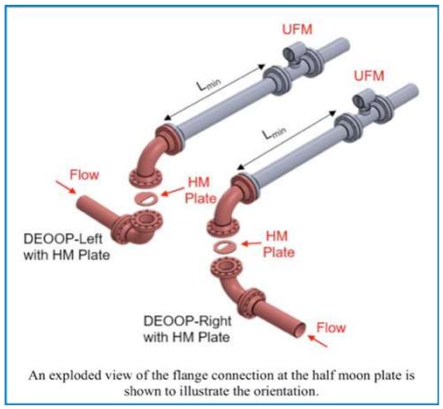
Crossflow & Swirl Discussion



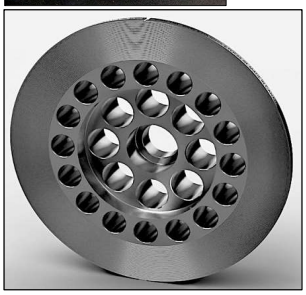
Crossflow & Swirl Discussion



OIML Installation Effects with / without CPA 55E



An exploded view of the flange connection at the half moon plate is shown to illustrate the orientation.



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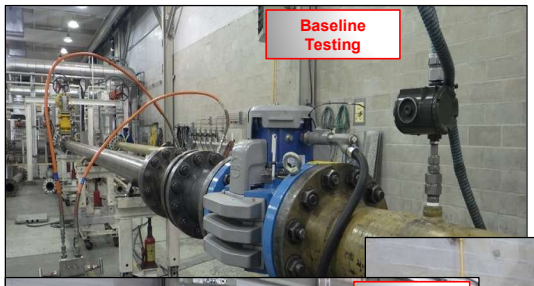
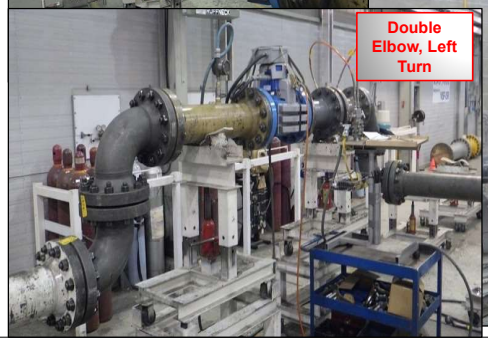
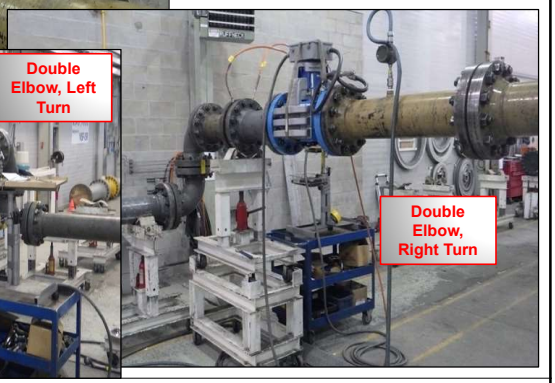
CPA 55E 3 ND Installation Effects







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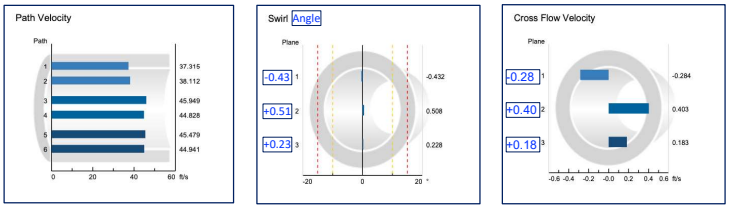
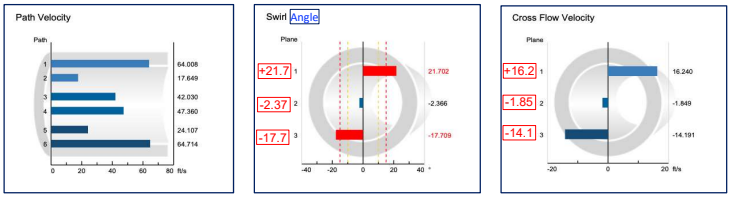
Meter Diagnostics with / without CPA 55E (45 FPS)

Discussion on Crossflow and Swirl Angle



Diagnostics with the CPA 55E, DBOOP RT HMP

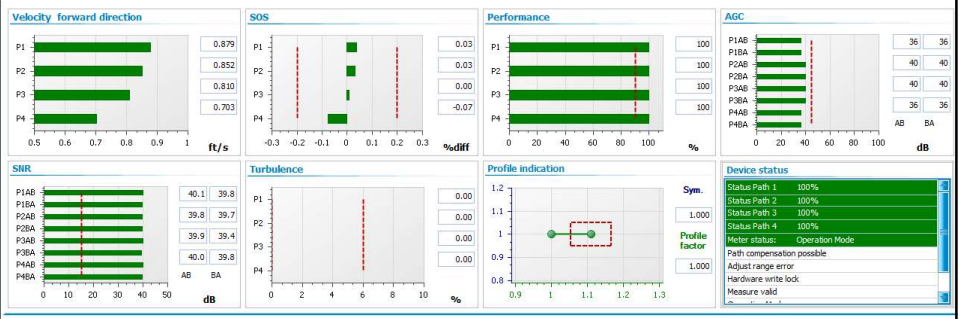


Diagnostics without the CPA 55E, DBOOP RT HMP
Significant Swirl & Crossflow Components

Thermal Stratification Discussion

- At lower velocities it is possible to have significant heat transfer between the gas and the atmosphere
- Chordal meter designs exhibit a path by both SOS separation from top to bottom when this occurs
- As the SOS is sensitive to changes in temperature, this is easily identified by monitoring the SOS spread from top to bottom
- Stratification won't occur until the velocity is low enough to allow for less mixing of the gas and more time to stratify
- Depending upon the difference in gas temperature to ambient, stratification MAY begin to occur around 3-5 fps
- The velocity point where this phenomena begins depends a lot on the temperature difference and amount of upstream piping
- The effect on the USM uncertainty is generally not significant

Meter Diagnostics – Some Thermal Stratification



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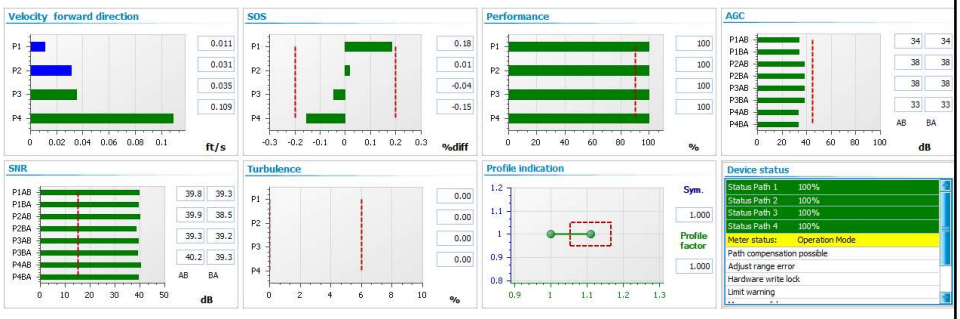
Meter Diagnostics – More Thermal Stratification



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Summary – Advanced Diagnostics

- Advanced diagnostics include Profile Factor, Symmetry, Crossflow, Turbulence and Swirl Angle
- Turbulence best diagnostic to identify blocked flow conditioners, pulsation and one indicator for liquid detection
- Symmetry, combined with Profile Factor, helps validate the gas velocity profile has not changed
- Small changes (<5%) in Profile Factor / Symmetry may only constitute a minor increase in measurement uncertainty
- Pulsation or cyclic flow both have a different diagnostic signatures the swirl
- Liquid slugs can cause a meter to totally stop working very quickly vs. some “free running” liquids

Summary – Advanced Diagnostics (Cont.)

- Turbulence is very helpful in identifying a number of issues:
  - Blocked flow conditioners
  - Liquids in the pipeline
  - Pipeline contamination
  - Pulsation
- Sometimes several diagnostic parameters are required to identify the problem
- It is often important to know the station design to diagnose problems
- Troubleshooting “Real World” issues much easier when using Advanced Diagnostics
- It is imperative to understand and utilize the manufacturer’s software to verify the USM is operating correctly

Any Questions?