

## BASICS OF GAS ULTRASONIC DIAGNOSTICS

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### Abstract

This paper discusses basic diagnostics, this term is somewhat misleading as what was once thought to be the basics have now been expanded to include several additional values which are based on simple calculation but are very powerful indicators of overall measurement uncertainty. We will review the basics plus advanced diagnostics that are part of the latest rewrite of AGA-9 which will be release later this year and includes a “USM Commissioning and Verification Checklist” which has been include in the appendixes as an informative guideline.

### Introduction

In 1999 the first edition of AGA-9 was released, and it exponentially increased the use of Gas Ultrasonic Meters (GUSMs) in custody transfer applications. At the time, there were some basic diagnostics that were used to ensure the meter was functioning properly. These included but were not limited to:

- Status
- Performance, number of accepted pulse firings
- Automatic Gain Control (AGC or just Gain)
- Inter chord or path Speed of Sound (SOS) and Velocity comparison
- Signal to Noise ratio (SNR)

These were very good indicators of overall meter functionality and will be expanded on throughout the paper. As good as these are they are limited to just being a simple indicators of a meter’s basic operation. As more and more meters were installed it became apparent that there was much more information available that showed what was going on inside the meter and its associated assembly. Custody transfer quality GUSMs were defined in AGA-9 as a meter with more than one path, this ensured that at least two paths would be present to measure. Manufacturers and end users realized that the more paths that were present the more information would be available to evaluate the overall performance of the meter and the installation. This prompted manufacturers to develop meters with multiple paths, initially these included the British gas (Rosemount), Westinghouse (Sick) and Stork (Honeywell) designs. For the sake of simplicity this paper will examine both basic and advanced diagnostics for chordal meters (Sick & Rosemount) as they both measure at the same points throughout the meter diameter. The main difference between the BG and Westinghouse designs is the crisscrossing of the paths in the BG meters as shown below.

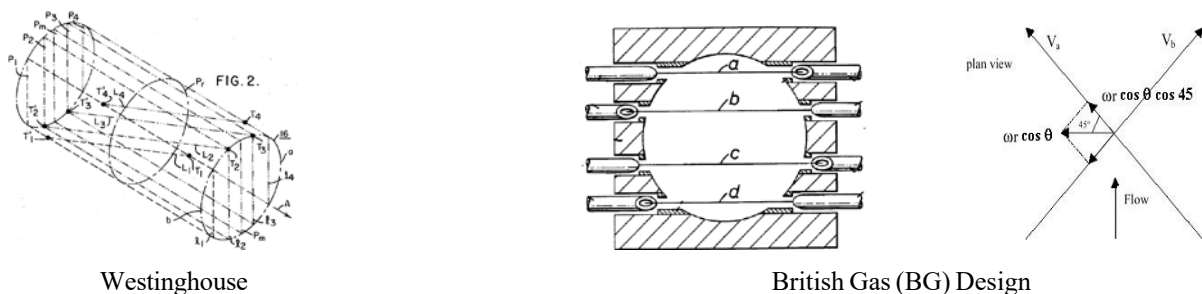


Figure 1

**Diagnostic**

As we look at these diagnostics it is important to remember that there is no single value that can be monitored to ensure proper meter assembly operation, each diagnostic point monitors a specific part of the meter’s operation or the internal process. All the diagnostic parameters must be monitored to ensure optimal performance and a good rule of thumb is change is not good, the meter is trying to continually repeat the measurements, if something changes it will become more difficult to repeat.

As previously stated diagnostics have been grouped into three categories:

**Functional Diagnostics**

Is the Meter (electronics, transducers and cabling) showing any signs of degradation or failure?

- Path and System Status
- Performance
- Gain
- SNR
- Inter chord SOS comparison

**Process Diagnostics**

Are the conditions in the meter assembly stable and suitable for custody transfer measurement?

- Profile Factor or Flatness Ratio
- Symmetry
- Turbulence
- Cross Flow (BG only)
- Swirl Angle

**System Performance Diagnostics**

Is the entire metering system performing as designed, are all readings from secondary instrumentation make sense?

- Theoretical SOS vs Meter SOS comparison (not part of this discussion)

**Functional Diagnostic**

**Path and System Status**

These points are influenced by many factors many of which are manufacturer dependent. They are the simplest diagnostic points and should be looked at as a starting point as it shows basic operation using a simple go no go indicator.

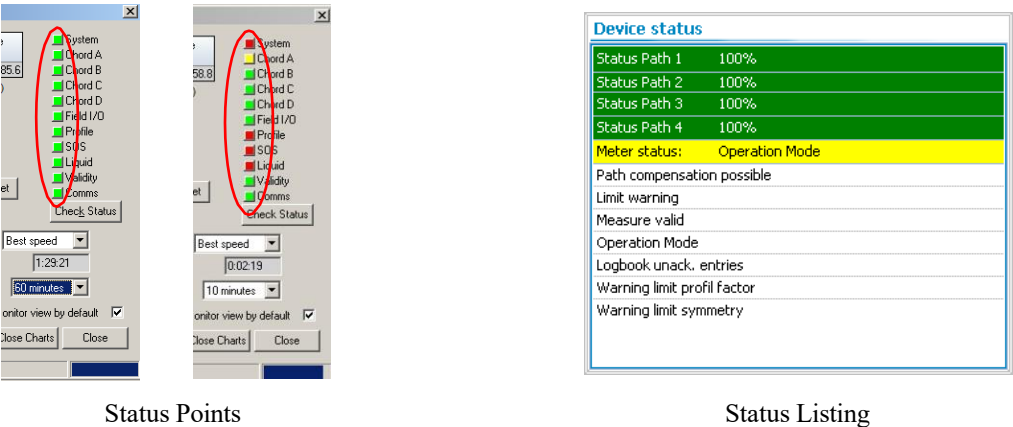
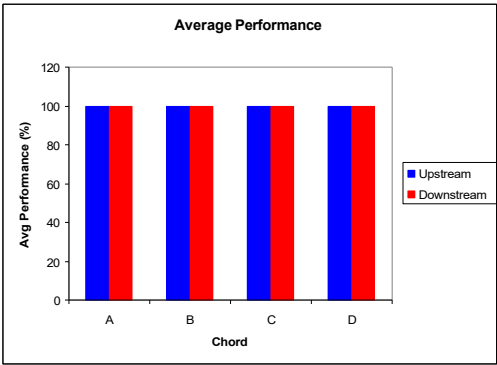


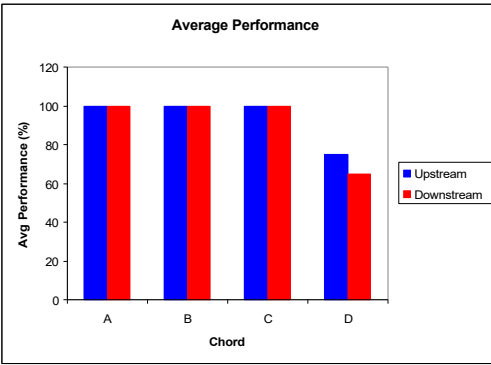
Figure 2

Performance (Signal Quality)

Every second multiple ultrasonic signals are sent and received going through the gas stream, as these signals are received they are put through several tests that all have an acceptance criteria to ensure the signal is intact and can be used for calculating transit times. As an example, if 20 signals are sent in a second and all pass the tests and are accepted performance would be 100%. If for any reason a signal is rejected the performance value would be reduced to 95%. Some factors that can cause signal rejection are ultrasonic noise, transducers degradation, exceeding meter velocity limits, debris or liquids in the line and/or electronics failure.

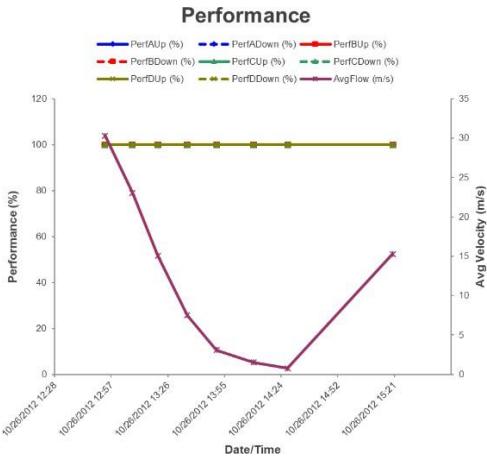


Good 100% Performance

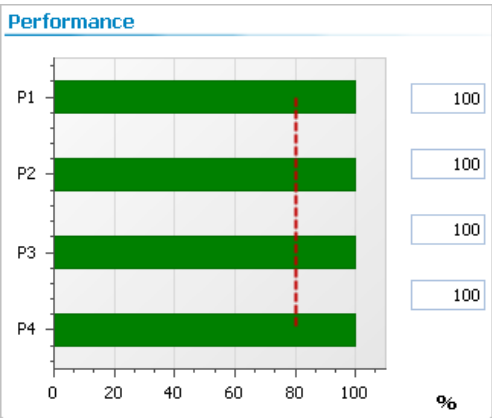


Poor Performance on Path D

Figure 3



100% throughout the meter's velocity range



100% Performance snapshot

Figure 4

Gain (AGC)

When an ultrasonic transducer is excited, it creates a finite signal that is transmitted across the gas stream, when the signal is received the amplitude is checked and if it is below the expected energy levels it is passed through an amplifier and the energy added to the amplifier is the basis of the gain value. Numerous factors contribute to the gain values, increases in pressure normally reduces gain values, increases in velocity will normally increase gain values. Transducer degradation, build up and liquids will all effect gain readings.

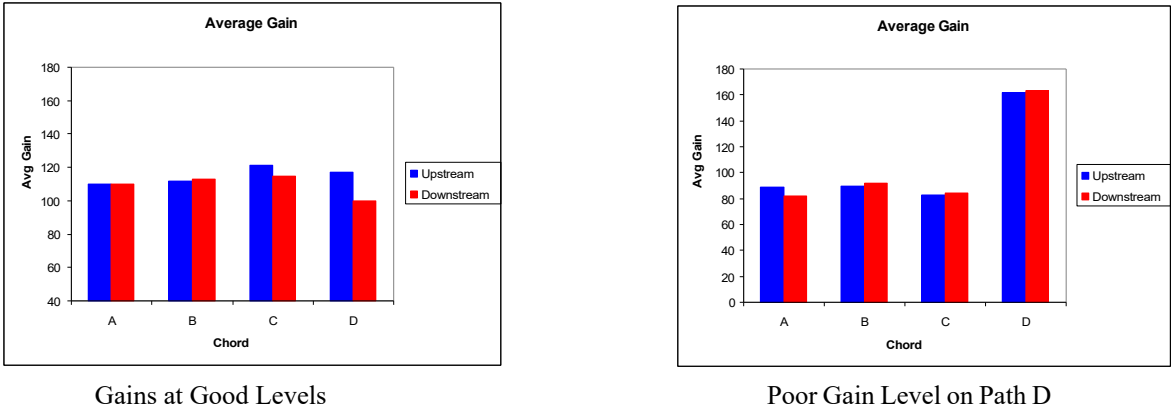
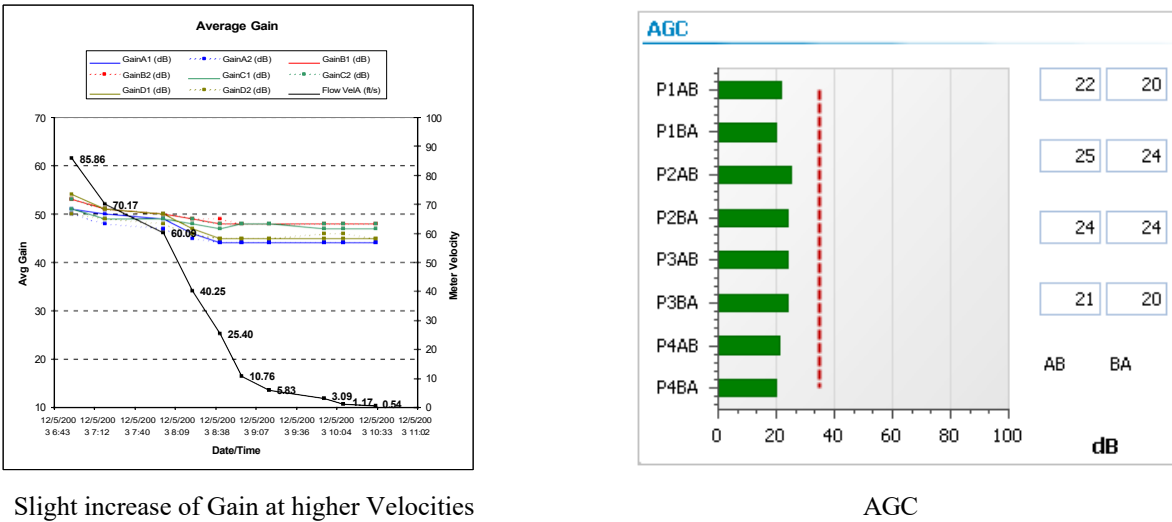


Figure 5



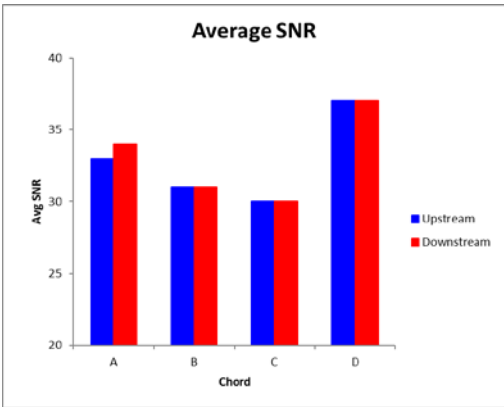
Slight increase of Gain at higher Velocities

AGC

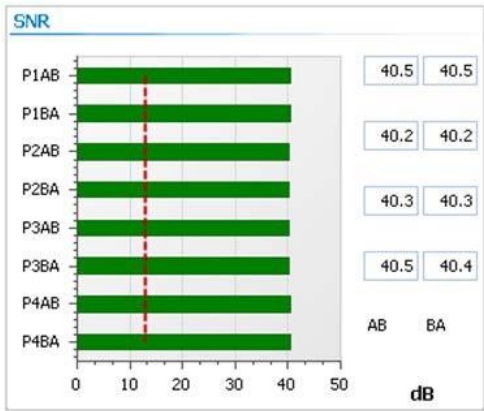
Figure 6

**Signal to Noise Ratio (SNR)**

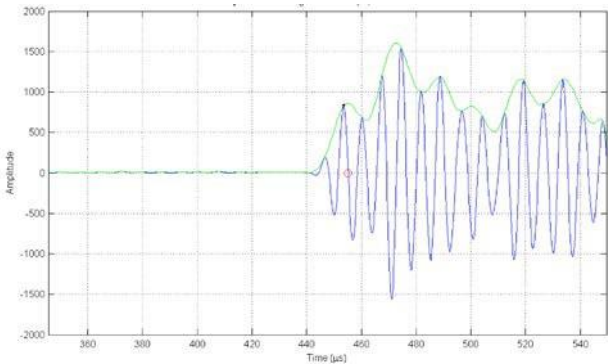
This is a simple comparison of the signal energy divided by the noise energy, if the signal strength decreases and the noise energy remains constant the SNR will go down. If the noise energy increases and the signal energy remains constant the SNR will also be lower.



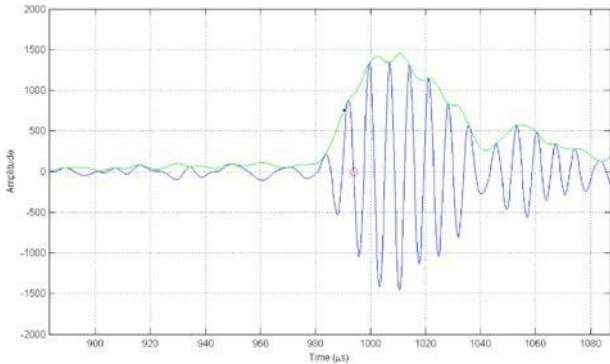
Average SNR



Real Time SNR



Waveform with no noise High SNR



Noisy Waveform lower SNR

Figure 7

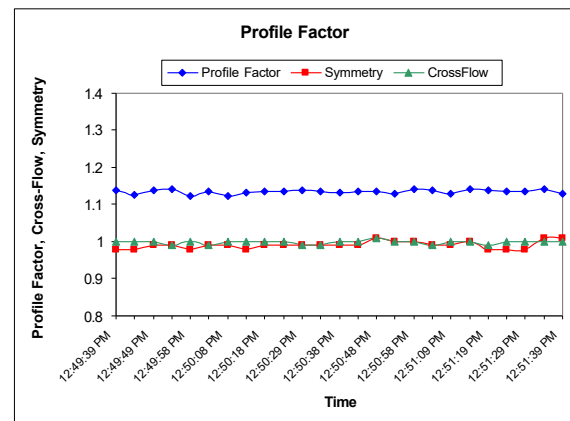
## Process Diagnostics

Once all the functional diagnostics are confirmed correct proceed to these:

The following section will describe what have been come to be known as process diagnostics, these have evolved over the years as more and more data has been collected and user experience and knowledge has grown. Even though these diagnostics are commonly referred to as Advanced, they have become part of the fundamental values that are observed to ensure the lowest possible uncertainty. These diagnostics use path velocities, transit times and delta times in simple equations to give valuable insight into what's going on in the meter assembly. When used conjunction with the Functional diagnostics they help ensure metering assemblies continue to operate at their lowest possible uncertainty. As with the functional diagnostics change is bad and there is not one specific point that can be monitored, all values must be within manufacturer specified sanity limits. It is important to baseline or fingerprint a meter when it is initially installed, this will allow for any fixed installation affects to be taken into consideration and basically zeroing these values out so that only process changes will shift the diagnostic values as the meter operates.

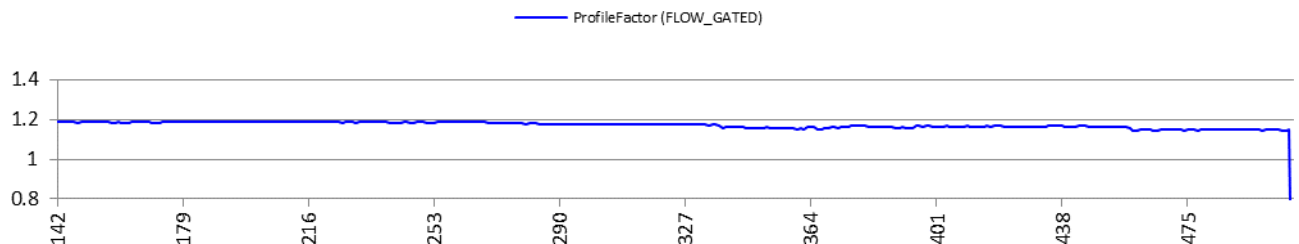
### Profile factor - Flatness ratio

The Profile Factor (PF) compares the sum of Raw Gas Velocities (RGVs) of the middle two paths with the sum of the outer RGVs. This comparison will show if the meter is become dirty as the drag on the pipe wall will slow the outer paths while the inner paths must accelerate to get the constant volume through the reduced conduit. This shift will cause the PF to increase as the sums of the inner paths will increase while the outer path sum will decrease. If the pipe walls become coated with liquids or smoother due to abrasive movement the PF value will decrease since the pipe wall drag will decrease allows for the outer RGVs to increase and the inner values to decrease. PFs for chordal meters that have paths at .309r and .809r should be about  $1.17 \pm 0.05$ , these values will differ depending on manufacturer, line size and any fixed affects from the installation. As previously stated, an initial PF should be recorded and used to compare to readings taken once the meter is in full operation.



$$\text{Profile Factor} = \frac{V_B + V_C}{V_A + V_D}$$

Figure 8

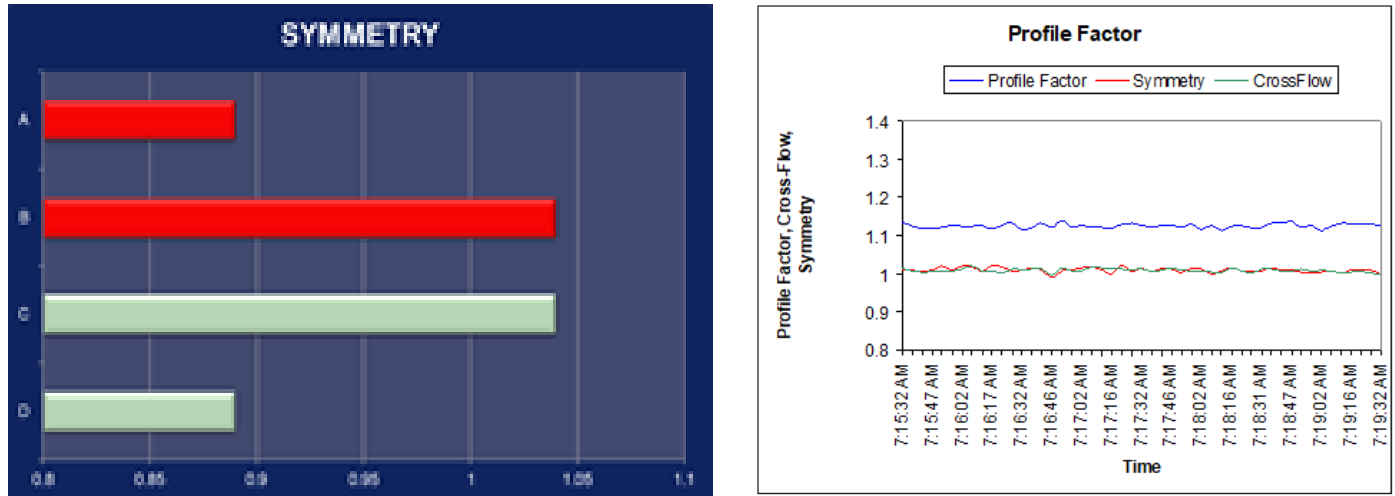


Long term PF shift over 365 days

Figure 9

## Symmetry

This value again uses the RGVs to monitor the symmetry of the flow going through the meter. It takes the sum of the upper two paths RGVs and divides by the sum of the lower path RGVs. If the flow is moving through the pipe the value will be around 1 as the flow should mirror itself from top to bottom. If for any reason there is a blockage in front of the meter, usually in the flow conditioner the symmetry will indicate a problem. Slow gradual changes in symmetry normally indicates build up on the bottom of the meter assembly piping, abrupt changes to Symmetry is a very good indication of a blockage.

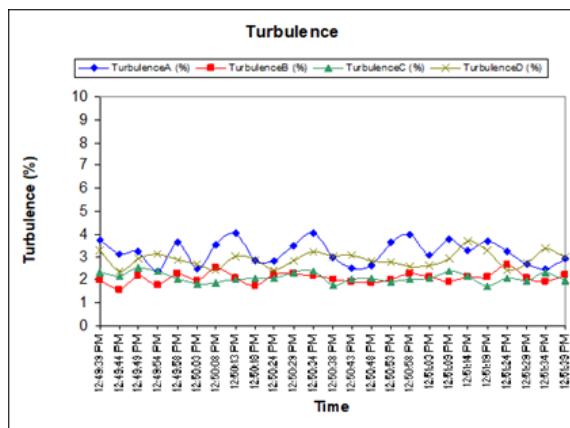


$$\text{Symmetry} = \frac{V_A + V_B}{V_C + V_D}$$

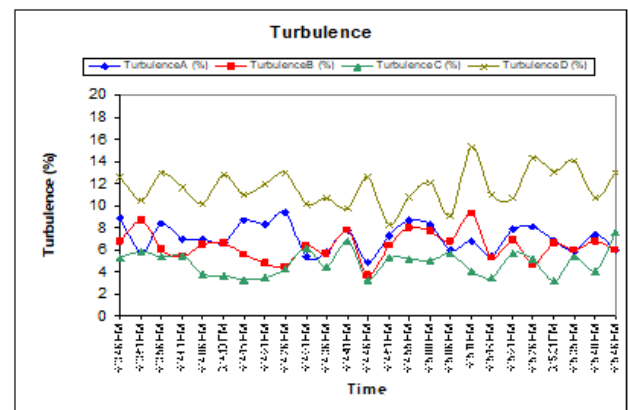
Figure 10

## Turbulence

The stability of the flow in the metering assembly is very important, the transit time measurements will be adversely effected if there are constant deviations in the gas velocities. Instability or turbulence can have numerous causes, pulsations caused by compressors or modulating piping components are common causes of turbulence. Blockages in the flow conditioner will also cause turbulence values to increase as will liquids or particles flow through the meter. If the instability is random it will normally be averaged out of the transit times and not cause any major uncertainty. If the deviations are synchronous there may be serious effects, this is particularly true if the frequency matches or is close to the sampling rate of the meter. The Nyquist theorem states that the sampling rate for digitally sampling an analog signal should be at least 2 times the frequency of the analog signal. The majority of modern GUSMs sample at rates much larger than those generated by most compressors, as the normal signal structure would be low frequency with higher amplitudes from reciprocating compressors and high frequencies at lower amplitudes for axial units. The equations for turbulence differ slightly depending on the manufacturer but it normally includes Transit Time Standard Deviations and the Delta Times (the difference in upstream and downstream transit time) multiplied by 100 to make it a percentage. For chordal type meters using the .309r and .809r path distribution the inner paths should have a turbulence value of around 2-3% and the outer paths around 4-6%.



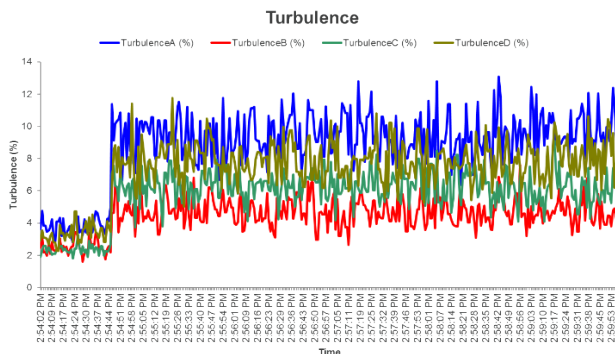
Normal Turbulence values



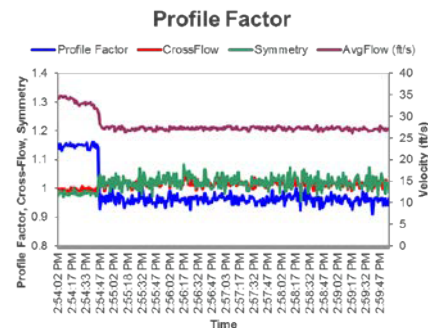
High Turbulence on Path D caused by blockage

Figure 11

Blockages in flow conditioner also cause shifts in turbulence, this can be used as a secondary confirmation of a blockage as Symmetry will normally be the initial indicator, once a shift in symmetry is confirmed looking for increased Turbulence on the opposite side of the pipe will confirm if a blockage exists.



Turbulence shift caused by piping components



Other Velocity Diagnostic shifts

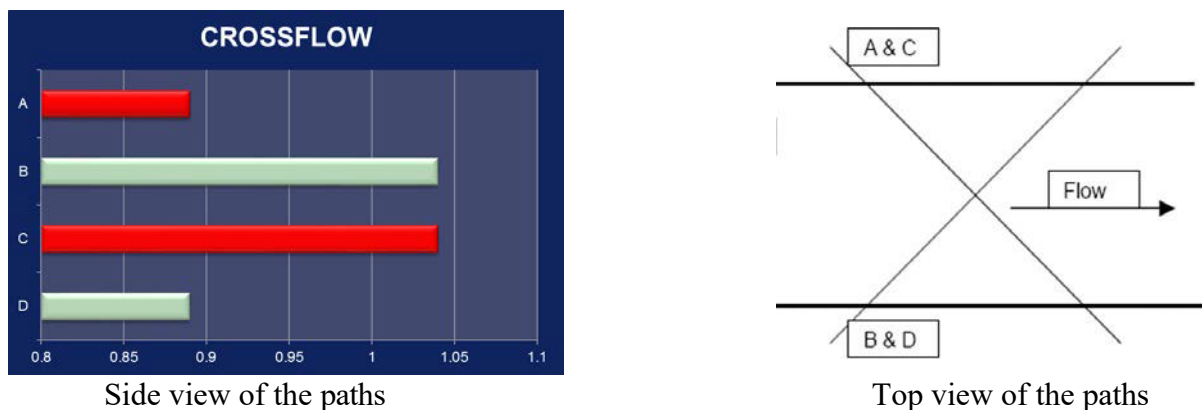
Figure 12

## Turbulence (Cont'd)

One more common cause of Turbulence is piping configuration, specifically the use of tees for either noise attenuation or for clean outs. There have been numerous cases of flow being stable until a certain velocity is reached at which point several of the process diagnostic indicators move out of range. Examples of the shifts in turbulence and the velocity diagnostics are shown in Figure 12.

## Cross Flow

Cross Flow (CF) is found in chordal meters that have crisscrossing paths, BG design. As symmetry is an indicator of the shape of the vertical velocity of the pipe, cross flow shows the horizontal velocity relationships. As with symmetry if the flow is moving straight down the pipe the value will be around 1, if there are any blockages on the sides of the flow conditioners cross flow will indicate the horizontal misbalance. To calculate CF the velocities of the 2 paths that cross the meter in the same plane are summed up and divided by the sum of the 2 paths that cross in the second plane.



$$\text{Cross Flow} = \frac{V_A + V_C}{V_B + V_D}$$

Figure 13

## Conclusion

Initially just simple basic functional diagnostics were used and widely accepted as a way to determine proper meter operation, it was quickly discovered that if the meter was correctly functioning that was only a partial indication of overall meter assembly integrity. The basic diagnostic term has expanded to include diagnostics that are referred to as advanced or process but are basically as important as the functional diagnostics. It is also very important to remember that there is not one diagnostic value that can be looked at to determine proper operation. All of the values needed to be used to first determine overall meter health and then move to the process information to evaluate overall meter operation.