CONTAMINANT ACCUMULATION EFFECT ON GAS ULTRASONIC METERS
Class #1340.1 0000

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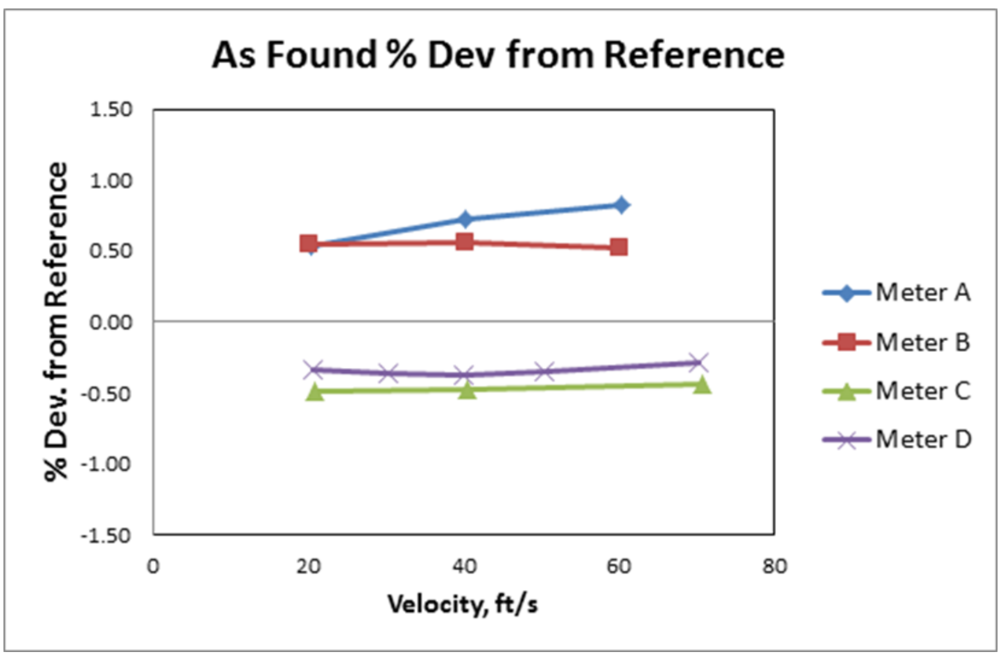
Introduction

The following paper discusses the effects of accumulation on natural gas ultrasonic meters. The paper uses four meters, two Daniel meters and two Instromet meters that were recalibrated at the CEESI Iowa facility. From CEESI's experience with recalibrations of contaminated meters, the results of these four meters are typical. Due to the relative newness of the other brands of meters in the US market, CEESI does not have recalibration data available for this paper and thus other brands are not included.

The four meters discussed in the paper are labeled meters A through D. Meters A and B are Instromet Q3 meters. Meter A is an 8" meter and B is a 10" meter. Meters C and D are Daniel SeniorSonic meters. Meter C is a 10" meter and D is a 12" meter.

The recalibration work consisted of collecting as found data, cleaning and repairing the meters as needed, and recalibrating. Repairs consisted of replacing a transducer on the C meter and replacing all the transducers on the D meter. The data also includes the effects of debris in front of the flow conditioner on the B meter.

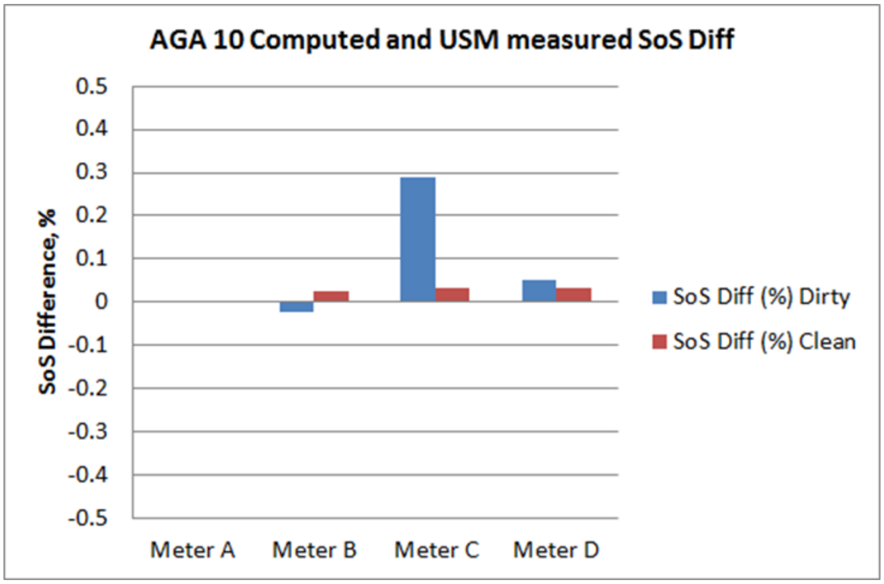
Graph 1 illustrates the as found results for all four meters. The data shows that meters A and B over-registered by approximately 0.5% to 0.8% while meters C and D under-registered by about 0.2% to 0.5%. These results are typical. The contamination in the meters was similar and typical to contamination regularly observed on recalibration projects. The contamination could be described as light, uniform buildup, with material buildup, either totally covering or partially covering the flow conditioner and transducer faces.



Graph 1: Typical As Found Results

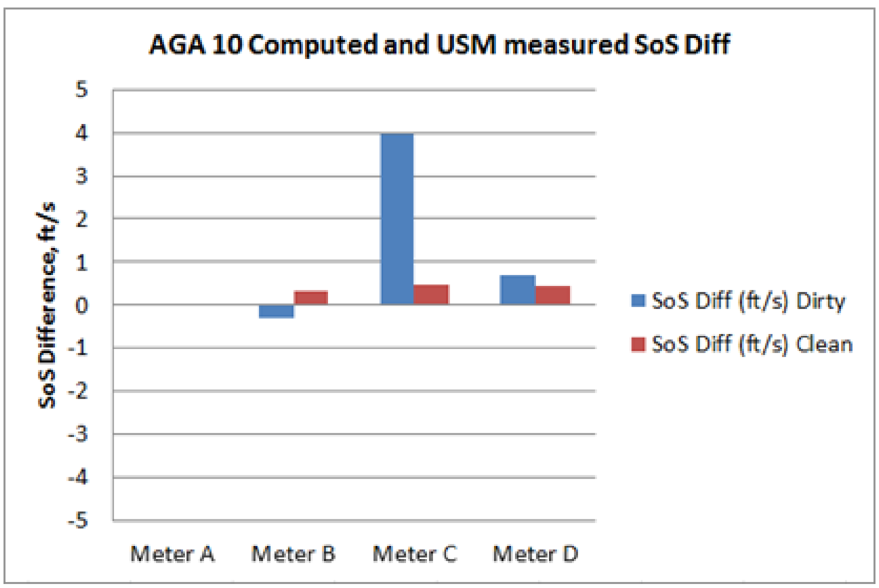
Speed of Sound Deviation

A common practice recommended in AGA9 and practiced by the industry is the comparison of the Average Speed of Sound measured by the meter to a Speed of Sound calculated using AGA10. The data from the meters show that this comparison is not a good indicator of contamination. Many users use a 0.2% deviation limit or a 2 ft/s limit in their measurement practices. Graph 2 illustrates the % deviation for meters B, C, and D (data was not available for meter A). The graph shows that meters B and D where well within the 0.2% deviation.



Graph 2: Average SoS % Deviation

Graph 3 illustrates the same data in feet per second.



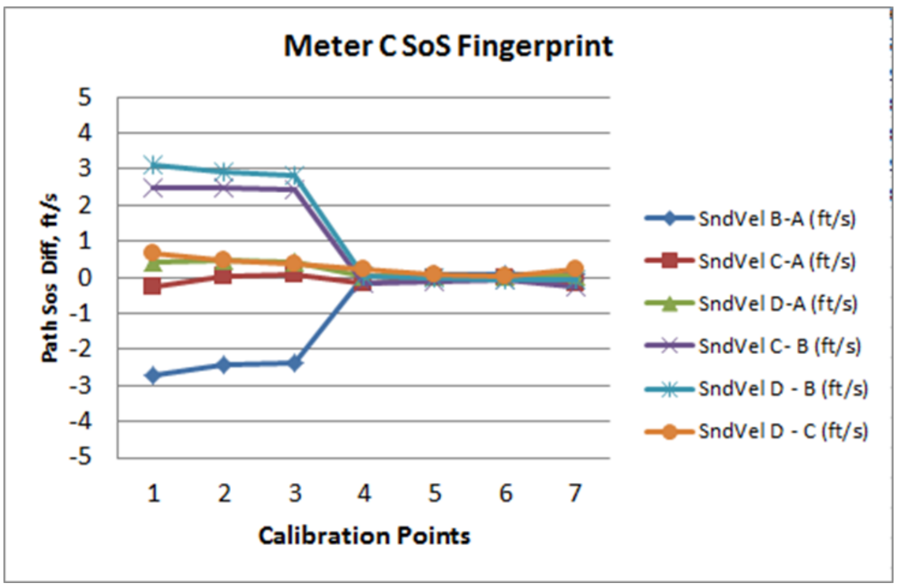
Graph 3: Average SoS % Deviation

Speed of Sound Fingerprint

The Speed of Sound deviation results are the first step in evaluating possible contamination. The second step is to evaluate the Speed of Sound Fingerprint. The Speed of Sound Fingerprint is the relationship between the individual path Speed of Sound measurements. Ideally, the relationships should not change with time. Many times the relationship is illustrated by differences between each path's Speed of Sound measurement and the average Speed of Sound calculated by the meter. For most analysis this method is adequate, but a more thorough approach is to compare each of the path speed of sound relationships independently.

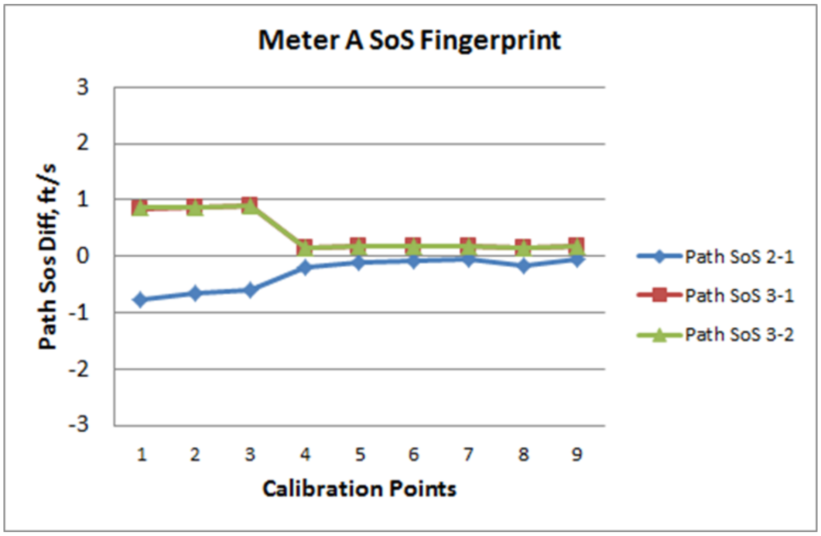
For example, for a Daniel SeniorSonic meter there would be six possible relationships, the relationships between paths A and B, A and C, A and D, paths B and C, B and D, and paths C and D. For an Instromet Q3 meter there are three relationships, paths 1 and 2, paths 1 and 3, and paths 2 and 3.

Many users set the maximum speed of sound difference between any two paths at 2 ft/s. Graph 4 illustrates the Speed of Sound Fingerprint for Meter C, the meter which had the greatest Average Speed of Sound deviation was 0.29%. The first 3 points on the graph illustrate the Speed of Sound Fingerprint when the meter was dirty. Points 4 through 6 illustrate calibration data when the meter was clean. Examining the graph shows that Path B had shifted compared to the other paths by approximately 2.5 ft/s. The path B transducers were replaced and the meter's average delay times on all paths were adjusted per the Daniel procedure. Points 4 through 6 illustrate the results of the work.



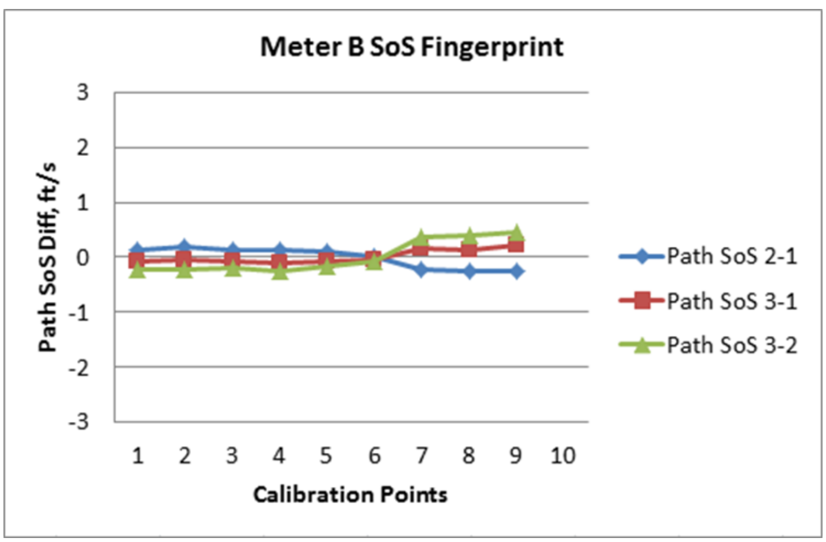
Graph 4: Meter C SoS Fingerprint

Graph 5 illustrates the SoS Fingerprint for Meter A. Like the previous graph, the first three points illustrate the SoS Fingerprint when the meter was dirty and the last six points illustrate the fingerprint after the meter was cleaned. The graph shows that the cleaning improved (tightened) the SoS Fingerprint.



Graph 5: Meter A SoS Fingerprint

Graph 6 below illustrates the results for Meter B. In Graph 6 the first 6 points illustrate the SoS Fingerprint of the dirty meter while the last three points illustrate the Fingerprint of the clean meter. In this graph the clean Fingerprint appears worse than the dirty Fingerprint; however, the change is small. This graph points out that the SoS Fingerprint must be monitored closely to detect contamination. The SoS Fingerprint should not be used as a single indicator of contamination, but a shift in Fingerprint warrants investigation.



Graph 6: Meter B SoS Fingerprint

Gas Profile Ratios – Profile Factor

So far the Speed of Sound has been examined, first the Average Speed of Sound, and then the SoS Fingerprint. The Speed of Sound works as an indicator of buildup because the signal is affected when it passed through or bounces off of contamination. Contamination effects the gas velocity measurements in two ways.

First, it reduces the cross-sectional area of the meter. Thus, to pass the same amount of gas in a contaminated meter, the velocity must increase. Second, the contamination causes drag. This drag slows the gas down towards the pipe wall. Thus, overall the gas towards the center of the pipe is sped up while the gas towards the outside is slowed down by contamination.

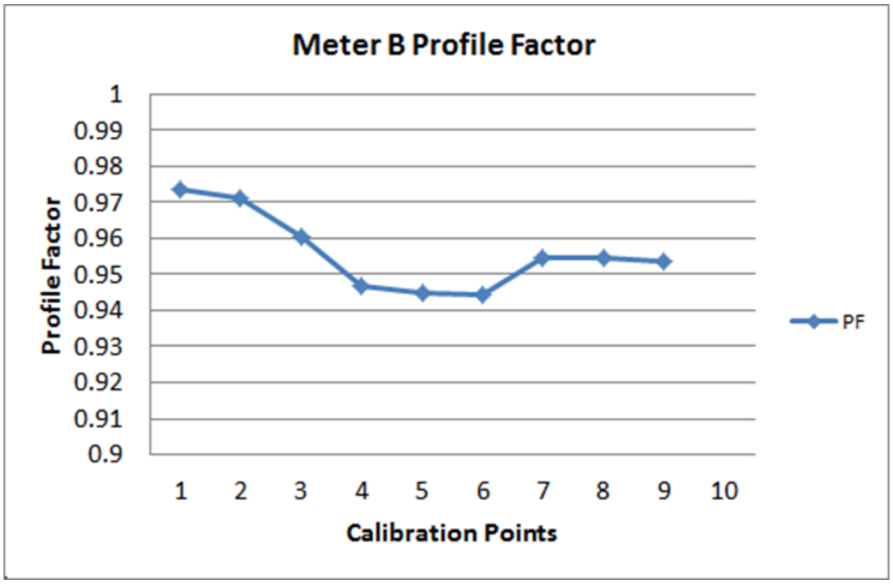
This affects meters differently according to their geometry. Because the outer paths, paths A and D, on a Daniel meter are located close to the pipe wall, drag caused by contamination significantly slows the gas velocity measured by the paths. The inside paths are sped up, but because of the larger area the paths sample, the effect is much lower on paths B and C. The overall result is that the Daniel meter generally under-registers as Graph 1 illustrates.

The Instromet meter is affected differently, but because the swirl paths on the Instromet meter are not as close to the pipe wall as the Daniel meter, the swirl paths do not register as significant of a velocity reduction due to the contamination drag as the Daniel meters. Thus, the overall result on the Instromet meter is that it over-registers roughly proportional to the reduction in cross–sectional area of the meter body.

This Profile Factor (PF) can be observed to monitor the effect. For the Daniel SeniorSonic meter, the Profile Factor is the ratio of the inside path velocities to the outside velocities, PF = (Vel B + Vel C)/(Vel A + Vel D). Since the paths B and C sample the gas in the center of the pipe the paths should measure faster velocities than paths A and D. Thus, for the Daniel meter the PF should be greater than 1 and is generally observed to be in the 1.14 to 1.16 range. The baseline PF should be established during the meter's flow calibration.

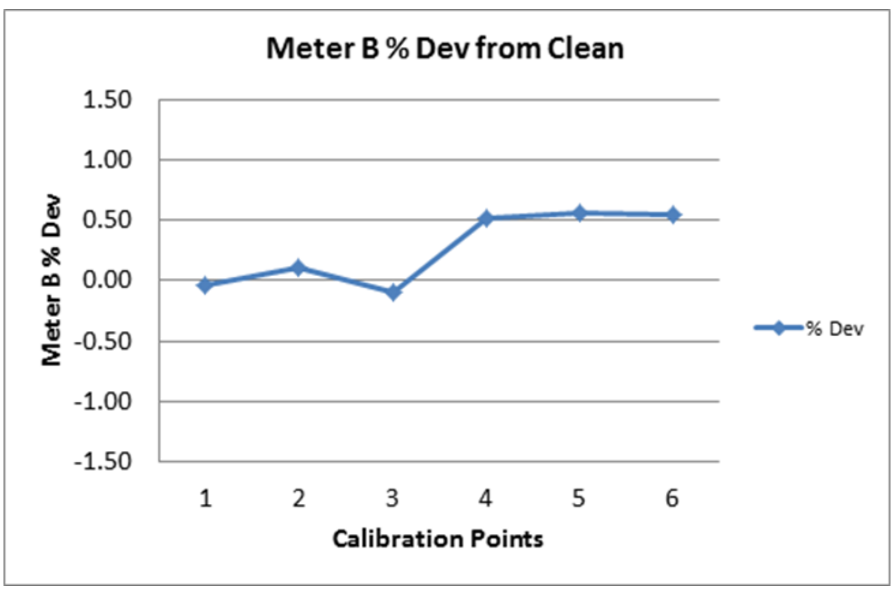
For the Instromet meter the PF is the ratio of the average of the swirl path velocities and the axial path velocities. Thus, for a Q3 meter the PF = ½(Vel 1+ Vel 3)/Vel 2. This ratio places the faster velocities in the denominator and thus the ratio is always less than one and is generally in the 0.95 to 0.97 range. Again, the baseline PF should be established during the meter's flow calibration.

Graph 7 on the following page illustrates the Profile Factor for Meter B. The graph illustrates a total of 9 calibration points. The first three illustrate the PF when the meter was dirty and there was an obstruction in front of the flow conditioner. Points 4 through 6 illustrate the PF after the obstruction was removed; however, the meter remained contaminated. Points 7 through 9 illustrate the PF when the meter was clean. The PF is as expected in points 7 through 9 and the downward shift illustrated in points 4 through 6 illustrate buildup. Points 1 through 3 show how a problem such as a blocked flow conditioner can mask the buildup in the Profile Factor.



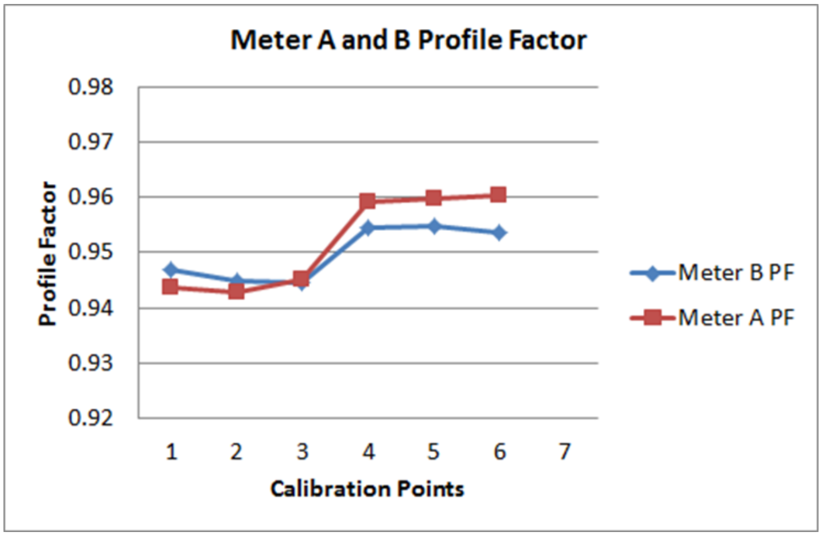
Graph 7: Meter B Profile Factor

Graph 8 illustrates the % Deviation of Meter B from the clean calibration results. The first three points illustrated the deviation while the meter was contaminated and there was a blockage in front of the flow conditioner. Points 4 through 6 illustrate the deviation after the blockage was removed, but with the contamination still in place. The graph shows that while the blockage was in front of the conditioner the meters output did not significantly deviate from the clean results. This is an unusual result in as much as the blockage was creating error in the opposite direction of the contamination and of about the same magnitude. Once the blockage was removed, points 4 through 6 shows that the contamination caused the meter to over-register by about 0.5%.



Graph 8: Meter B % Deviation from Clean

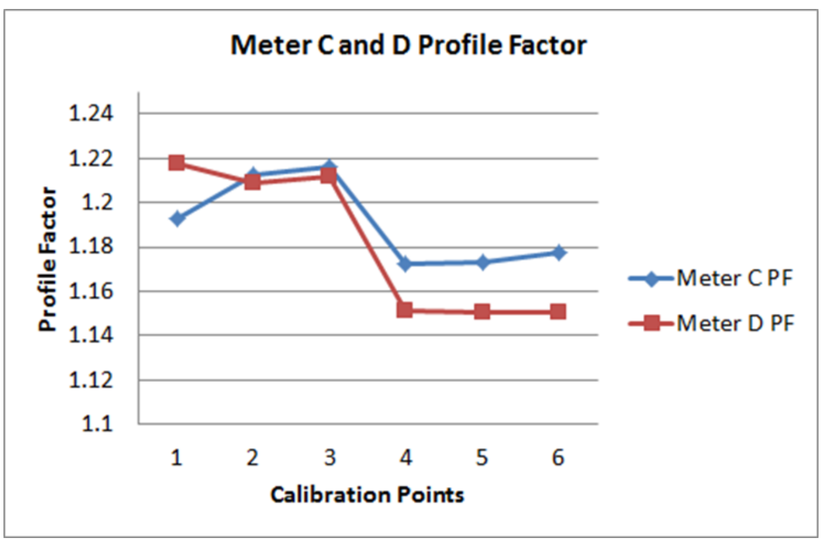
Graph 9 below illustrates the Profile Factor for both the Instromet meters, Meter A and Meter B. The first three points illustrate the PF while the meters were contaminated and points 4 through 6 illustrate the clean results. The PF shifts similarly on both meters on the order of 1% to 1.5%.



Graph 9: Meter A and B Profile Factors

Graph 10 below illustrates the Profile Factor for the two Daniel meters, Meter C and D. Like graph 9 above, the first three points illustrate the PF while the meters were contaminated and points 4 through 6 illustrate the clean results. However, due to the difference in the method for calculating the Profile Factor between the two brands, the PF shifts down on Graph 10 as compared to the upward shift in Graph 9.

Either the Daniel or the Instromet Profile Factors can be displayed as the inverse of the typical calculation. What is important to understand is which calculation is used and what values the user should expect.



Graph 10: *Meter C and D Profile Factors*

Summary

Typical pipeline contamination causes ultrasonic meters to miss-measure. The direction and the magnitude of the miss-measurement appears to be not only a function of the contamination, but also the meter geometry and path design. Meter diagnostics can help to identify meter contamination. From the data, the combination of the Profile Factor and the SoS Fingerprint in combination identified contamination, with the Profile Factor being the stronger indicator except for when other conditions are present such as blocked flow conditioners.