

CUSTODY TRANSFER SYSTEMS FOR NATURAL GAS AND CHALLENGES IN ITS MEASUREMENT AND HANDLING

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ABSTRACT

In Natural gas application, predominantly used technologies for custody transfer flow measurement systems are: - (i) Differential pressure (DP) (ii) Turbine (iii) RPD (iv) Ultrasonic. Perspective of DP based Orifice flow meters, Turbine Flow meters, RPD flow meters & USMs has been presented in this paper with emphasis on their operating principle, their limitations, challenges and technological advancements that evolved to mitigate these challenges. One of the major challenges in measurement & handling natural gas based custody transfer applications is under such harsh environments such as wet, rich and / or dirty gas applications. Latest evolution technology-wise in natural gas metering with the best possible accuracy so far that can cater to the redressing of various persisting challenges in natural gas metering has been the Ultrasonic Flow Meter technology. To counter such hostile conditions such as wet, rich and / or dirty gas applications, USM transducer probes which are designed for wet gas are in vogue. Also relocating the transducers to the upper side of the meter (in case of USM) to avoid their contamination due to their positioning at bottom, techniques to

eliminate acoustic interference through filtering of USM frequencies from external noise are some of the advancements made to improve USM metering performance. So, objective of this paper is to primarily outline the challenges in various natural gas metering systems along with mitigation criteria for the same & to finally drive out the conclusion that challenges in metering systems are inevitable which can be mitigated through employing best industrial practices & advanced technological solutions.

KEYWORDS

Orifice flow meter, Turbine flow meter, RPD flow meter, Ultrasonic flow meter, limitations, challenges

1.0 INTRODUCTION

Custody Transfer in the oil and gas industry refers to the transactions involving transporting physical substance from one operator to another. Custody transfer in fluid measurement is defined as a metering point (location) where the fluid is being measured for sale from one party to another. In Natural gas application, predominantly used

technologies for custody transfer flow measurement systems are: - (i) Differential pressure (DP) (ii) Turbine (iii) Rotary Positive Displacement (iv) Ultrasonic. Unlike Simple volumetric flow measurement technology is not the only consideration because the ultimate measurement—and what the customer pays for—is energy delivered. For this reason, accurate and repeatable measurement of natural gas flow requires simultaneous measurement of several other variables, including pressure, temperature, density, and gas composition.

2.0 DP BASED FLOW METERING FOR NATURAL GAS

DP meters measure volumetric flow through a calibrated orifice (generally a flow plate), are inexpensive, and simple in concept. Orifice flow meter works on the principle that when there is a flow restriction in a pipe, a differential pressure results which can be related to the volume flow rate through the restriction. They are accepted broadly and are not limited in line size. While not the most accurate instruments available, they are acceptable for the purposes for which they are used, and the calculations for correcting to standard conditions are widely known.

2.1 Limitations in DP Based Flow Metering

DP meters measure only differential head. To measure either mass or volumetric flow, they must be corrected for density (mass) or temperature, pressure, and gas composition to obtain a standard reading. They have low turndown unless the orifice plate is changed. In addition, they are subject to fouling, which can partially obstruct the orifice plate and cause the meter to read high. The only way to counter fouling in a DP meter is to send someone out periodically to inspect the orifice plate, which is expensive in terms of labor and can mean an interruption in production. In

addition, DP meters are sensitive to flow profile and require either a fairly long straight run or an upstream flow conditioner. They also generate a medium-to-large pressure loss, and they are not as accurate as other technologies, such as gas turbine or ultrasonic gas meters.

2.2 Challenges in DP Based Flow Metering

Typical abnormal conditions that cause inaccuracy of orifice measurement but are not limited to:

- Rough upstream pipe wall: Gas flow is slower along pipe walls due to friction causing the entry flow profile to be more arrow shaped
- Improperly designed or installed flow conditioner: Entry flow profile is not developed properly and may be altered by abnormality
- Swirling gas flow pattern challenges
- Partially closed valves or other similar type condition upstream of meter tube
- Liquid in meter tube
- Valve 'noise' or pulsation
- Orifice with damaged bore
- Obstruction in orifice bore
- Meter tube shorter than AGA 3 specifications
- Orifice not centered in tube per AGA 3 specifications
- Protrusions in upstream piping

In case of conventional orifice based metering systems - paddle type orifice plates designed to be used with orifice flanges, the often encountered challenge is orifice plate alignment and eccentricity issue with regard to orifice plate i.e. ensuring the concentricity of the plate with respect to meter tube & possibility of plate deflection. With the evolution of single chamber & dual chamber orifice fittings, this challenge has become addressable. Orifice plate alignment is one of the most significant factors in reducing measurement

uncertainty. Orifice plate holder which carries the orifice plate is concentrically

designed such that it reduces measurement uncertainty. (Refer fig.1)



Figure 1: Orifice plate holder

- Single Chamber Orifice fittings: Allows quick and economical inspection and replacement of orifice plates with minimum downtime. The single-chamber fitting is engineered

to make plate changing quick and easy at installations where line movement from flange spreading is undesirable. (Refer fig.2)



Figure2: Single chamber orifice fitting

- Dual Chamber Orifice fittings: Allows easy orifice plate replacement with no down time. It provides fast and

simple method of changing orifice plates under pressure without flow interruption. (Refer fig. 3)



Figure 3: Dual Chamber Orifice Fitting

3.0 TURBINE & RPD FLOW METERING FOR NATURAL GAS

Turbine flow meters & RPD flow meters are used to measure gas flow, particularly for clean, medium-to-high steady flow of low-viscosity fluids. The turbine meter measures volumetric flow based on fluid flowing passed a free-spinning rotor, with each revolution agreeing with a specific volume of fluid. PD meters differ from turbine meters in that they handle medium and high-viscosity liquids well. In the case of RPD meter, two figures "8" shaped lobes, the rotors(also known as impellers or pistons), spin in precise alignment. With each turn, they move a specific quantity of gas through the meter. The rotational movement of the crank shaft serves as a primary flow element and may produce electrical pulses for a flow computer or may drive an odometer-like counter. Compared with orifice-type meters, PD meters require very little straight upstream piping since they are not sensitive to uneven flow distribution across the area of the pipe.

3.1 Limitations in Turbine & RPD Flow Metering

Certainly, both the turbine and RPD meters have moving parts which is always a limitation, and the user needs to consider the cleanliness of the gas. There is also the chance of damage because of over-speeding these meters.

3.2 Challenges in Turbine & RPD Flow Metering

- In both Turbine & RPD flow meters, measurement accuracy and life expectancy can be impeded by excessive deposits of dirt or other type of foreign material present in the gas stream. Proper oil level and cleanliness

have the greatest effect on meter life expectancy. Meter oil change frequency will depend upon cleanliness of the gas being measured. Oil has to be changed when the color darkens or when the level increases, indicating an accumulation of moisture.

- A change in the meters internal resistance can affect the rotary meter accuracy. Any significant increase on the meter's internal resistance to flow will increase the pressure drop between the inlet and outlet of the meter, thus increasing the differential. Therefore, the meter differential pressure appears as a prime indicator of meter condition. Establishing base line curves – developing an original differential or baseline curve is recommended at the time of meter initial installation. At least 3 test points are required at gas flow rates between 25% to 100% of meter capacity. Plot the points on a graph and then connect the points to form a curve. This provides baseline data for comparison to later tests.
- In case of both Turbine & RPD meters, operating flow below Q_{min} can lead to increased measurement errors; operating flow above Q_{max} can be detrimental to the metering system. This challenge can be meted out through appropriate sizing of metering system with due emphasis on process conditions.
- Turbine & RPD flow meters which are flanged end-to-end & misalignment during installation can pose critical issues such as zero shift. This challenge can be mitigated by ensuring proper flange-to-flange alignment.

The technological advancements achieved in these meters are:

- Increased life span by using an oil system that not only refreshes the oil in the bearings and lubricates all moving parts, but also flushes out all the dirt and dust.

- Reduced sensitivity to severe gas conditions by improved protection of the main bearings against dirt and dust.

Technological advancements sought in TFM & RPD metering systems will be to know friction of bearings used.



Figure 4: 4 inch size Turbine flow meter



Figure 5: 2 inch size RPD flow meter

4.0 ULTRASONIC FLOW METERING FOR NATURAL GAS

An ultrasonic flow meter takes advantage of the principle that an ultrasonic pulse travels faster with the gas flow than against the flow. The larger the difference between the upstream travel time versus the downstream, the more gas has passed through the meter. The advent of high speed computer processors has made it possible to detect very small time differences between the upstream and the downstream travel times. Because ultrasonic meters do not depend on the kinetic energy from the field, very low flows can be detected. Other advantages include standard volume flow accuracy of 0.35% to 0.5%, with 0.25% available, as well as negligible pressure drop and high turndown capability. The high turndown makes them useable in applications subject to wide variations in flow, which means that a single ultrasonic meter can replace multiple other meters

4.1 Limitations in Ultrasonic Flow Metering

Limitations of ultrasonic meters include its high initial cost and the need for sufficient straight-run upstream or a flow conditioner. Because the accuracy of an ultrasonic meter depends on the accuracy with which the flow profile inside the instrument is known, ultrasonic meters for custody transfer applications generally use a minimum of four paths.

4.2 Challenges in Ultrasonic Flow Metering

Ultrasonic flow meters have historically been installed at custody transfer points in natural gas transmission and distribution pipelines known for clean dry natural gas composition. Today, with new sources of natural gas entering the value chain, gas quality managers are working hard to maintain quality natural gas in the pipelines.

Despite such initiatives, due to some of the operational issues such as liquid carryover from wells along with natural gas, operating under such harsh environments such as wet, rich and / or dirty gas applications pose significant challenges in Ultrasonic Flow Metering. Some of the technological advancements that evolved to mitigate these challenges in USM metering are:

- Transducer probes which are designed for wet gas application; they offer benefits such as – resistance to liquid borne dirt, more tolerance to corrosive fluids, robust electrical connection & less sensitive to process conditions.
- Development of path failure compensation routines in some USMs which compensate for failure path based on path relationships deduced under normal operating conditions.
- Relocating the transducers to the upper side of USM to avoid their contamination due to their positioning at bottom.
- Technique for filtering of ultrasonic frequencies from generated external noise to reduce and eliminate acoustic interference. Regulating valves create line noise whose frequencies often fall in a meter's ultrasonic range. Part of the energy created during pressure reduction is transferred into acoustic energy, which can lower the meter signal-to-noise ratio and resulting measurement accuracy.
- Intelligent self diagnosis with Condition Based Maintenance (CBM) functionality. CBM provides a single point of critical system information to help operators monitor and manage the performance of multiple metering stations and system devices simultaneously, delivering diagnostic information to predict maintenance requirements, reduce measurement uncertainty and maximize system uptime.
- In case of USMs that use bouncing path technology, along with improved flow

profile and swirl information, the reflective path matrix provides diagnostic information about inside pipe diameter condition. Changes in path-length caused by build-ups in pipe can be alarmed by diagnostics.

SNR ratio, path performance etc. are featured in the USMs to evaluate metering performance. The same are elaborated below:-

4.3 Gauging of Ultrasonic Flow Metering Performance

An important feature of many ultrasonic meters is their built-in diagnostics, which enable them to detect the presence of liquids (two-phase flow), dirt buildup, blockage, and other problems. Various performance gauging indices such as profile factor, swirl angle, symmetry, turbulence,

4.3.1 Symmetry

Symmetry is a dimensionless measure of the flow symmetry comparing the upper chords to the lower chords. The symmetry represents the path velocity ratios of upper to lower paths. A change of the symmetry value may be caused by contamination, blockages or deposits in the line that change the symmetry of the flow profile. Ideally the Symmetry should be 1.0.

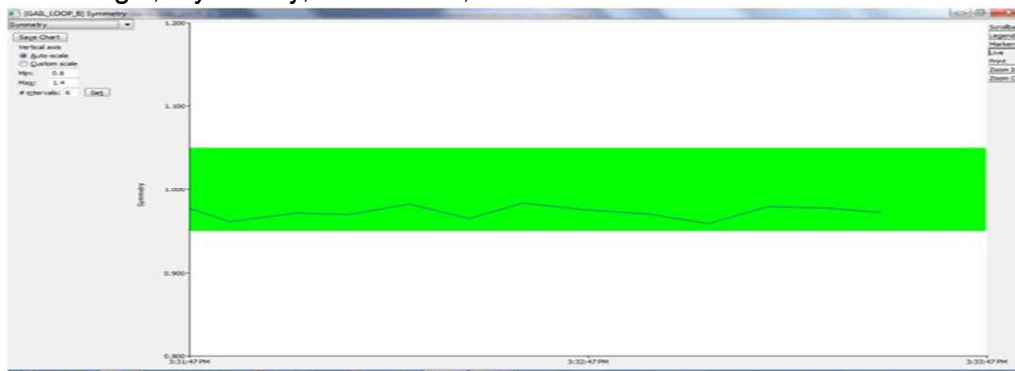


Figure 6: symmetry plot of USM

4.3.2 Cross-Flow

Cross-Flow is a dimensionless measure of the flow symmetry comparing the chords on

one side of the meter to the chords on the other side. Ideally the Cross-Flow should be 1.0.

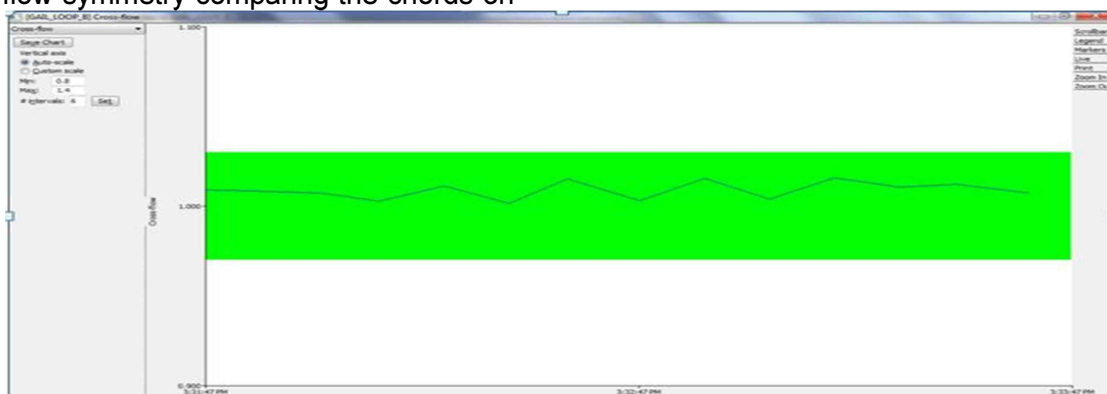


Figure 7: cross-flow plot of USM

4.3.3 Turbulence

Chord Turbulence is an estimate of the turbulence (percentage) at a chord location. A value is calculated for each active chord. A value of 0% indicates no appreciable turbulence. A change in the path turbulence

indicates changed flow conditions (e.g. a blocked flow conditioner). A change of the turbulence value may be caused by contamination, blockage or deposits in the line that change the symmetry of the flow profile.

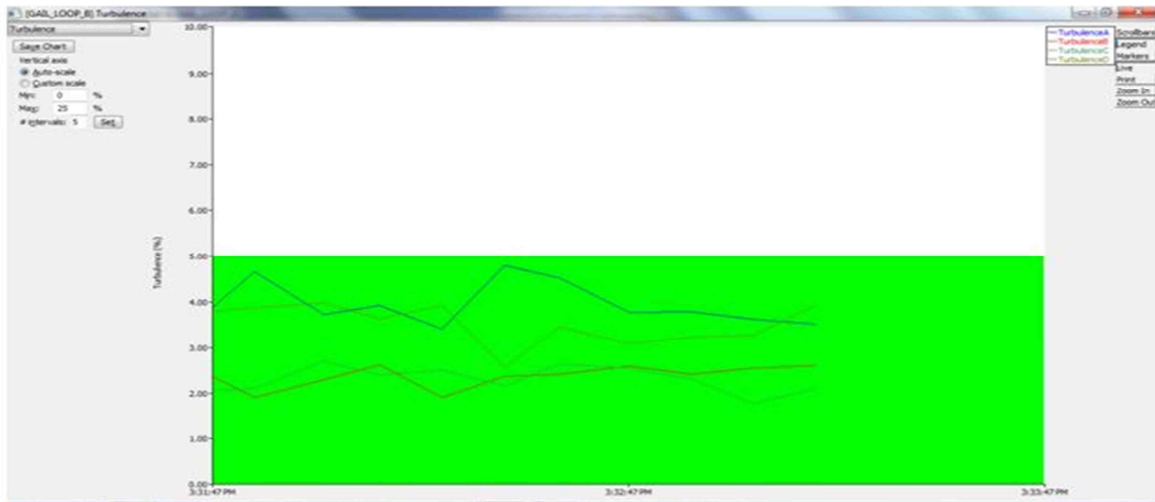


Figure 8: Turbulence plot of USM

4.3.4 Profile Factor

The profile factor represents the path velocity ratios of inner to outer paths. In other words, it is a dimensionless ratio of the inner chord velocities to the outer chord

velocities. A change of the profile value may be caused by contamination, blockages or deposits in the line that change the shape of the flow profile.

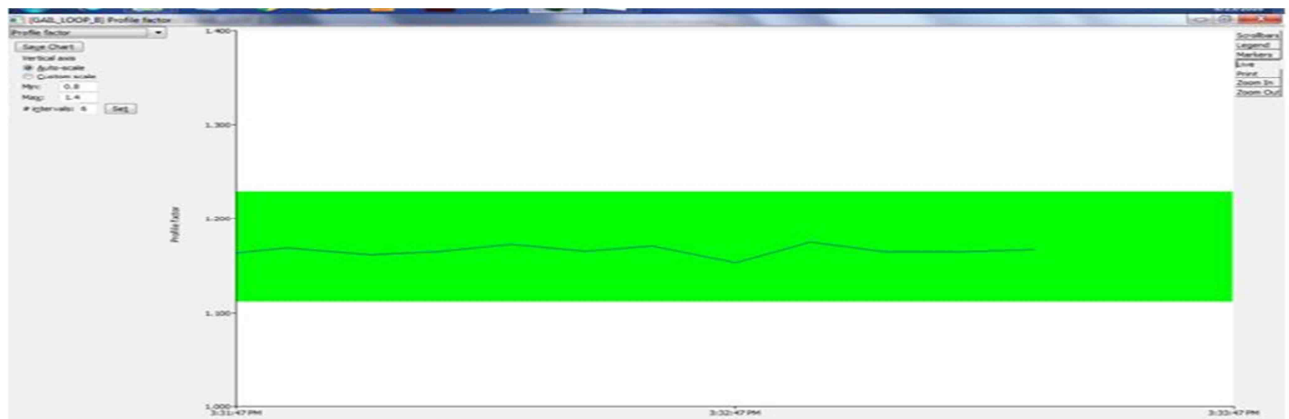


Figure 9: Profile factor plot of USM

4.3.5 Swirl Angle

The Swirl Angle is an estimate of the swirl (to the nearest degree). It is calculated as a

function of the meter body style and Profile Factor. A value of 0 degrees indicates no appreciable swirl.

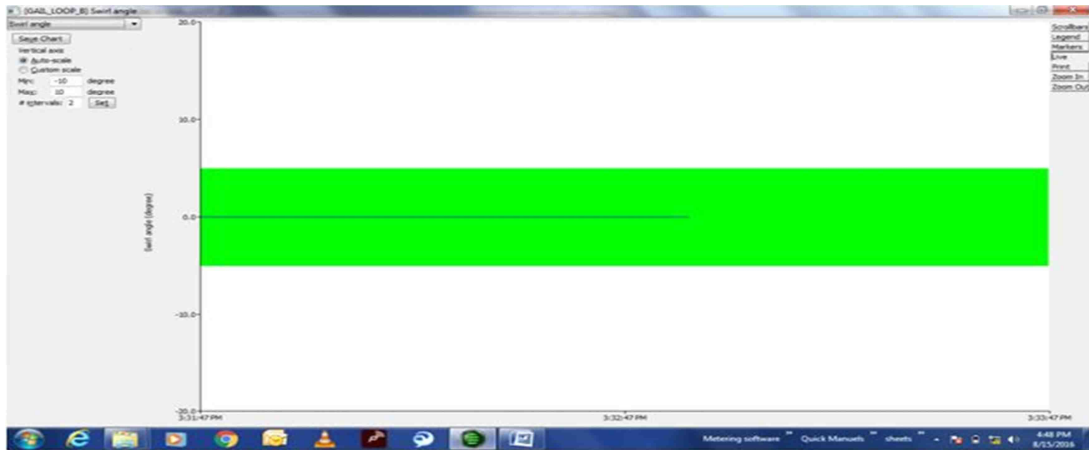


Figure 10: swirl angle plot of USM

4.3.6 SNR Ratio

A measure of the signal “goodness” is the signal-to-noise ratio (SNR). The higher the SNR, the better the signal. Interfering noise caused by fittings in

the pipeline, valves that are not fully open, sources of noise near the measuring location, or defective ultrasonic transducers may affect the signal-to-noise-ratio.

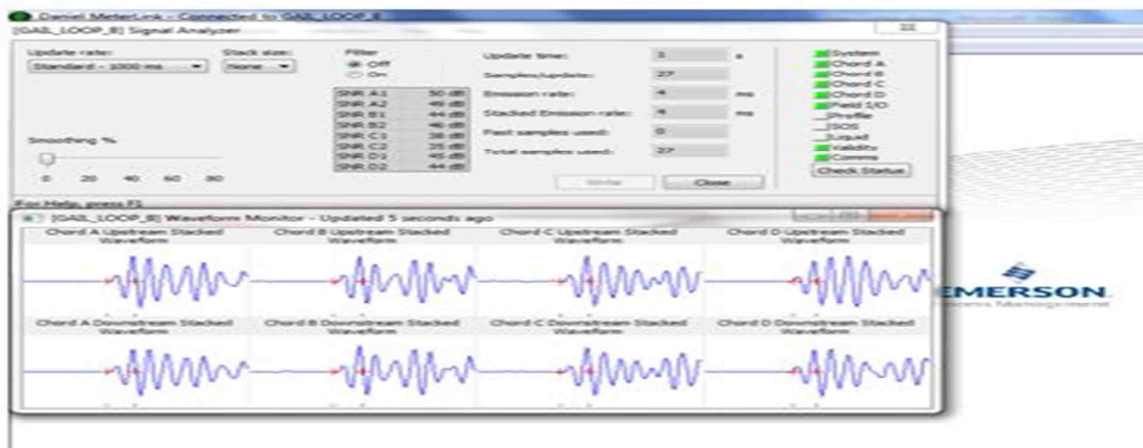


Figure 11: SNR plot of USM

4.3.7 Path Performance

The performance is the percentage of valid received ultrasonic signals for each path. That means, if 5 of 100 transmitted signals do not meet the acceptance criteria for a signal analysis, then the performance of this path is only 95%. The performance of each path should be very close to 100%. Due to signal attenuation on

the way from the transmitting to the receiving sensor or due to acoustic noise, also caused by very high gas velocity, the performance can be significantly lower. A change in performance at comparable process conditions can indicate a potential transducer problem (e.g. contamination). A visual inspection of the ultrasonic signals and the transducer itself is required.

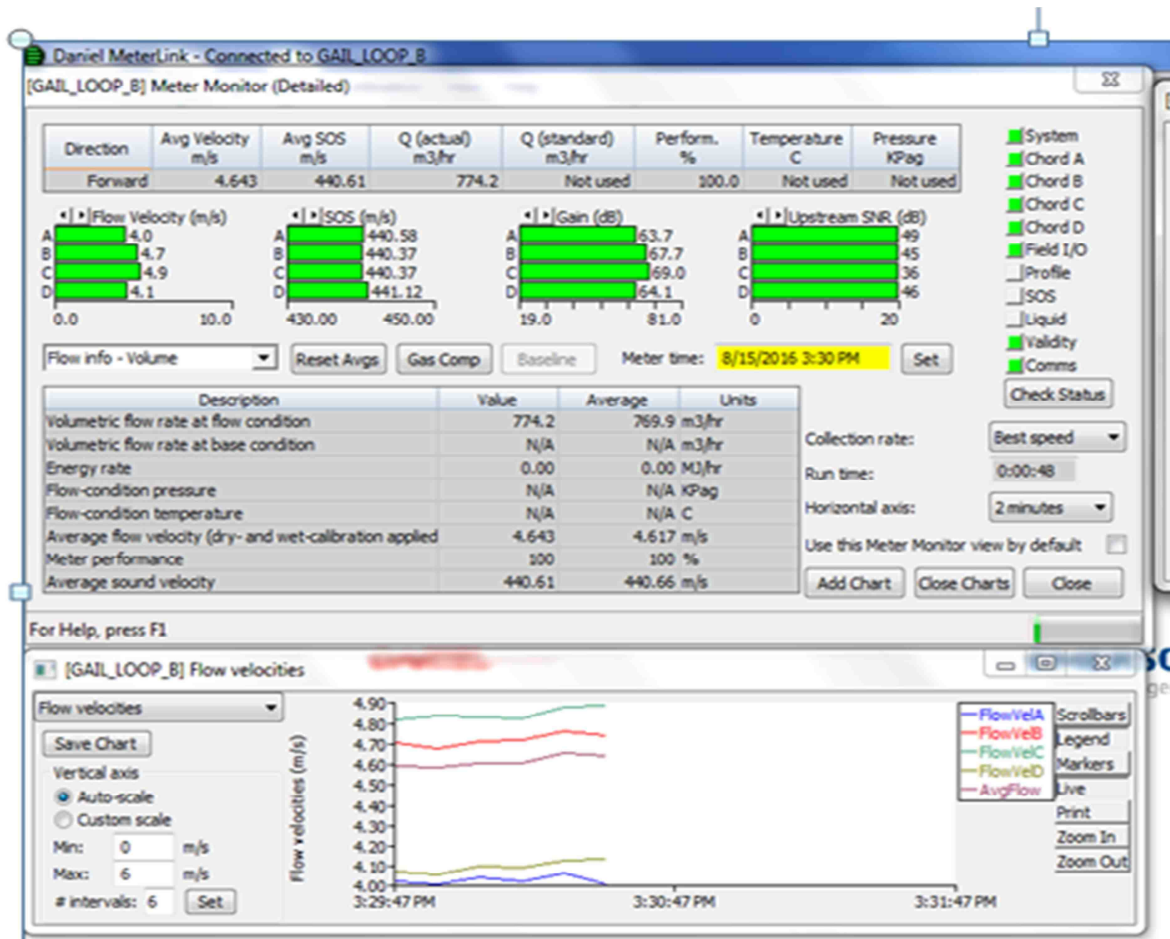


Figure 12: Snap of USM diagnostics

Summary of comparison of technologies & challenges for upgradation for Custody transfer measurement & handling:

DP Based Flow Meters	Turbine & RPD Flow Meters	Ultrasonic Flow Meters
Inexpensive & simple	Accurate measurement for clean & medium to high steady flow	Most accurate, Negligible pressure drop & high turndown
# Limitations:		
1.This measures volumetric flow, must be corrected for density	1.Having moving parts	1.Expensive
2.Low Turndown & Generates medium to large pressure loss	2.Change in meter internals can affect accuracy	2.Flow conditioner required
3.Requires periodic inspection , sensitive to flow profiles & Requires long straight runs	Deposition of dirt or foreign material ,affects performance	
# Challenges :		
1.Errors due to rough upstream pipe wall & damaged bore , improper design of profiler & Swirling gas flow pattern	1.Reduced life span due to deposition of dirt	1.Liquid carryover, wet ,rich & dirty gas
2. Meter tube , Plate eccentricity & alignment issues	2. Errors due to deposition of foreign particles	2. Noise
# Upgradation in Technology		
1.Orifice plate holder: Ensures alignment	1.Use of lubrication enhances life span	1.Transducer probes designed for wet gas
2.Compact flow profiler design: Reducing straight length	2.Improved protection of main bearing	2.Path failure compensation
3. Single chamber: Inspection with less downtime		3.Relocation of transducers on upper side to avoid contamination
4. Double chamber design: Inspection without flow interruption		4.Noise filtration, Condition based Maintenance & built in diagnostics
# Technological advancement required		
1.Automatic cleaning mechanism for deposition on orifice plate	1. To know bearing friction to ensure accuracy	1.Automatic cleaning of probes in case of deposition
2.Compact design	2. To restrict entry of foreign particles to avoid damage to rotor	2.Proving & validation requirements

5.0 CONCLUSION

Hitherto, with regard to challenges as highlighted in this paper in case of various Metering Systems being employed for natural gas, whatsoever the type of metering system employed in natural gas applications, high moisture/H₂S content in gas can have adverse impact which could internally erode / corrode the meter run causing pitting, denting the surface roughness levels of the meter run rendering it non-conformant to relevant AGA standards. Also carbon dust depositions & also debris which get stuck to inner side of metering system in place & that of piping would impact the metering systems. This would significantly contribute to measurement errors. This challenge can be dealt with by carrying out periodic meter tube inspections along with cleaning of meter run, meter body & profiler plate, checking their conformity to relevant AGA governing standards & carrying out buffing of meter tube as deemed required. So, challenges in metering systems are inevitable which can be mitigated through employing best industrial practices and advanced technological solutions.

6.0 FUTURE PERSPECTIVE / SCOPE

In the years ahead, it is expected that natural gas flow metering technology to continue to evolve, with greater use of microprocessor technology. It is foreseen that more on board diagnostic capabilities to be added to the various flow metering types

to provide better tracking of meter performance problems in a timelier manner. More optimizations could take place in the metering technology with more robust methodologies for flow calculations rendering very lean possibility for occurrence and recurrence of measurement errors. Also, new sensing technology will likely allow for integrated metering packages that measure energy rate rather than gas flow rate and gas composition (or heating value) independently. Scope for further improvisation is sought in USM metering arena for use in low pressure metering applications. The applicable metering standards will continue to be updated to reflect changes in technology, although those documents inherently lag behind the latest technological developments.

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