

Introduction

Liquid ultrasonic flow meters are not new to the measurement of crude oil, over the last decade technological improvements have enabled liquid ultrasonic meters to meet the higher accuracy requirements needed for custody transfer measurement. The transit time principle of measurement has opened the window to allow the observation and measurement of aspects of the flow stream that have never been visible to traditional measurement technologies such as PD meters and turbine meters but are critical to the proper operation of a liquid ultrasonic meter. This paper discusses the specific diagnostic capabilities of FMC Technologies Smith Meter® Ultra Series™ Liquid Ultrasonic Flow Meters and how diagnostic information can contribute to maintaining high accuracy custody transfer measurement.

Liquid Ultrasonic Measurement Theory

Custody transfer liquid ultrasonic flow meters as defined in API MPMS chapter 5.8 use the well-known principle of transit time measurement to infer the volumetric flow rate through the meter. In transit time measurement, a pair of ultrasonic transducers are used to send an ultrasonic sound signal through the flowing product at an angle to the flow stream. The transit time is the time it takes for the signal to travel from one transducer to the other. Because the signal is sent across the flow stream at an angle, the transit time is greater when the signal is sent upstream against the flow stream than when it is sent downstream with the flow stream. The difference

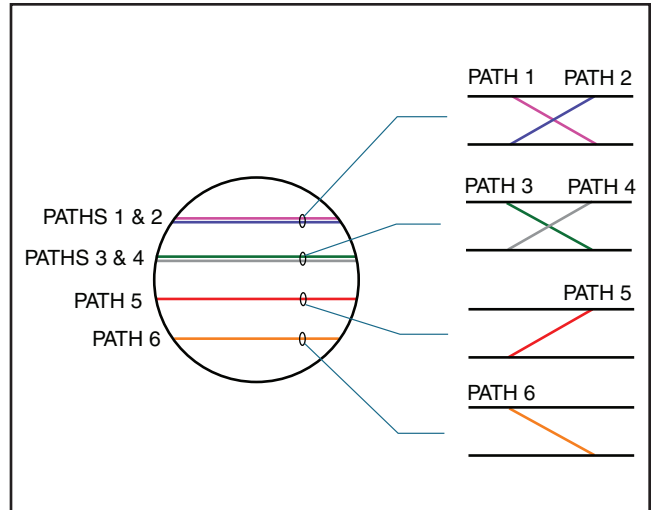


Figure 2 – Path Configuration

in the transit times, or ΔT is used to calculate the linear (axial) velocity of the fluid. The general configuration of this transducer pair is shown in Figure 1. In this case, the time from transducer B to transducer A (t_{BA}) will be greater than the time from transducer A to transducer B (t_{AB}).

The meter is configured to include transducer pairs located on multiple planes spaced across the cross-section of the flow stream. Typical configurations for custody transfer meters can range from 4 to 18 paths located on different planes across the flow stream. Figure 2 shows a diagram of a meter that has transducer pairs located on four planes across the flow stream. In this case, the

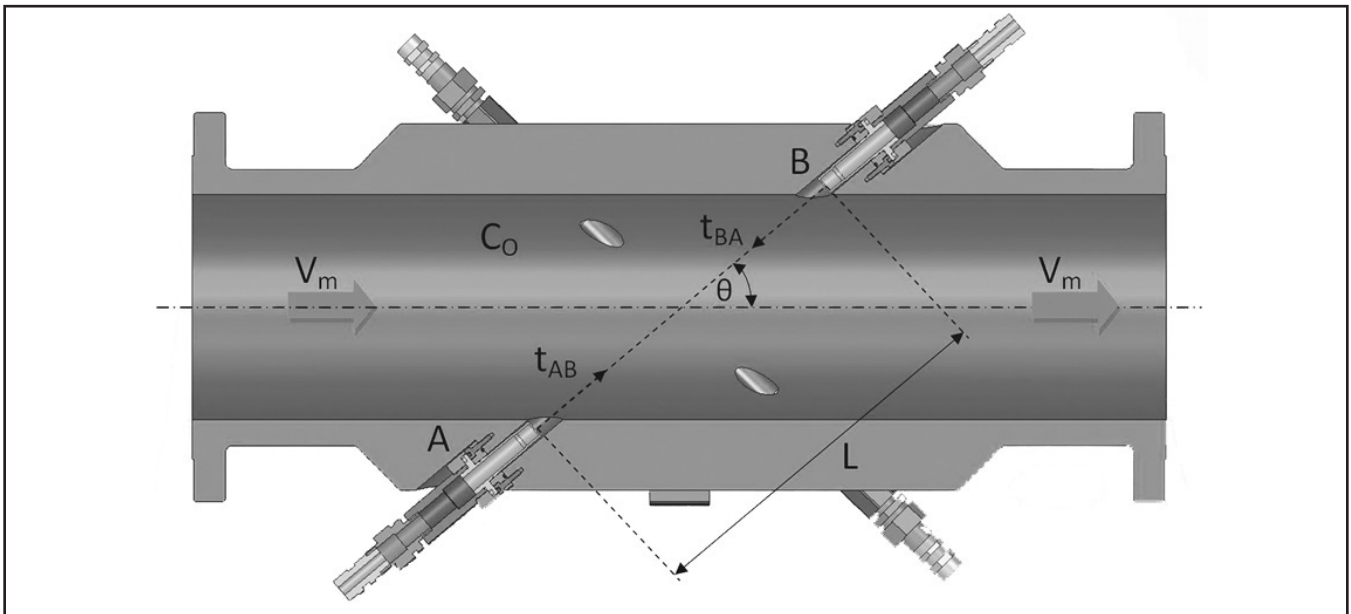


Figure 1 – General Configuration of Transducer Pair to Flow Stream

top two planes have two paths per plane for a total of six paths located on four 4 planes. Figure 3 shows the six path FMC Technologies Smith Meter® Ultra⁶ Liquid Ultrasonic Meter which employs this principle.

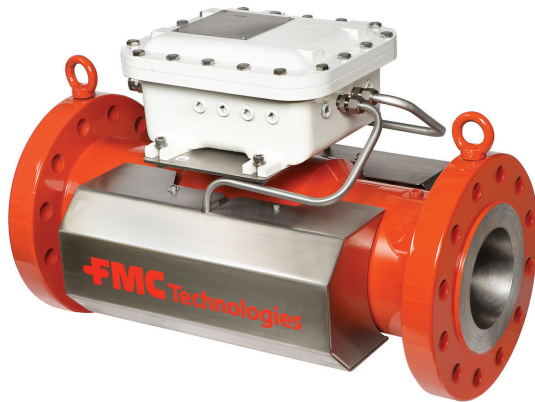


Figure 3 – Smith Meter® Ultra⁶ Meter

Calculating the axial velocity of the fluid on multiple planes allows the velocity profile of the flow stream to be determined empirically.

By employing 2 crossing paths on a plane, not only can the axial velocity of the fluid be calculated, the transverse component of the velocity can be calculated as well. This allows the presence of swirl and/or crossflow to be determined empirically in addition to the axial velocity profile as shown in Figure 4.

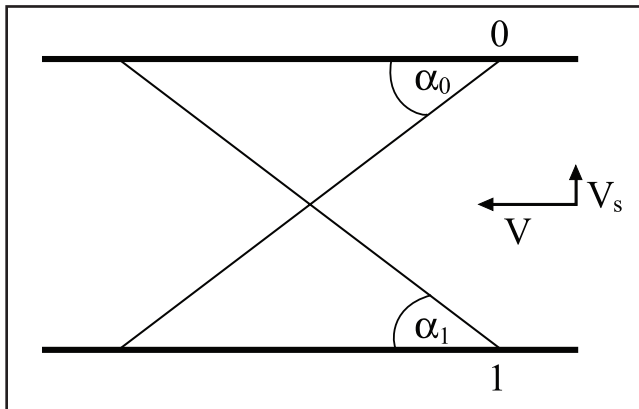


Figure 4 – Axial Component V and Transverse Component V_s

Liquid Ultrasonic Diagnostics

As already mentioned, Liquid Ultrasonic Flow Meters (LUFM's) employing the transit time method enable observation and measurement of aspects of the liquid flow stream that are critical to the proper operation of LUFM's but are not visible to other types of traditional metering equipment. These parameters can not only be used to quantify the liquid flow stream, but can be used to set limits to define if there is an aspect of the flow stream that is abnormal and may impede measurement accuracy. Each of these parameters has a limit that can be programmed into the meter's software to trigger an alarm condition. These alarms can turn on an alarm output to a supervisory system to provide instant notification or they can be monitored via communications by reading the values in the appropriate modbus registers.

The Smith Meter® Ultra Series uses a Windows based software program Winscreen to interface with the meter. This software can be used to monitor current data, program the meter, access historical data and run diagnostics on the meter. Figure 5 shows the measured values window within Winscreen which displays current data read from the meter.

The Measured values screen shows the current combined average values of all paths, the current individual path values, a graphic representation of the current axial and transverse flow profiles and a rolling display of flow velocity and velocity of sound (VOS).

The data shown on the Measured values screen can be grouped into two categories, flow profile parameters and signal parameters. Table 1 shows the flow profile parameters for the Smith Meter® Ultra⁶ six path flow meter. These parameters are normally listed as a percent from normal, for example, a profile symmetry value of 0% means that the flow is equally balanced between the top two planes and the bottom two planes (a symmetrical profile).

A reference profile can be entered into the database as individual limits for each of these parameters when the meter is calibrated. Whenever the meter is in operation, as long as these parameters are within the programmed limits, the current flow profile matches the reference profile. If the deviation between the current profile and the reference profile is larger than allowed by the programmed limits, an alarm condition will be triggered.

Profile Flatness	Describes the amount of flow on the outer paths compared to the center paths. This measure quantifies how parabolic the flow profile is.
Profile Symmetry	Describes the amount of flow on the top planes compared to the bottom planes.
Swirl Flow	Describes the amount of transversal flow that is rotating in the pipe. (Typical flow profile after a double elbow out of plane.) A positive number means that the swirl flow is clockwise if you look downstream.
Cross Flow	Describes the amount of transversal flow that is generating a double swirl pattern with individual vortices in the top and bottom of the pipe. (Typical flow profile after a single bend.) The sign of the number indicates the direction of the cross flow.
Turbulence	The turbulence level describes the stability of the flow measurements on each path. Variation in the measured flow velocity on each path is created by turbulence in the flow. If the level of this variation increases from its normal level it can be a sign that the time detection of the ultrasonic signals is not stable.

Table 1 – Flow Profile Parameters

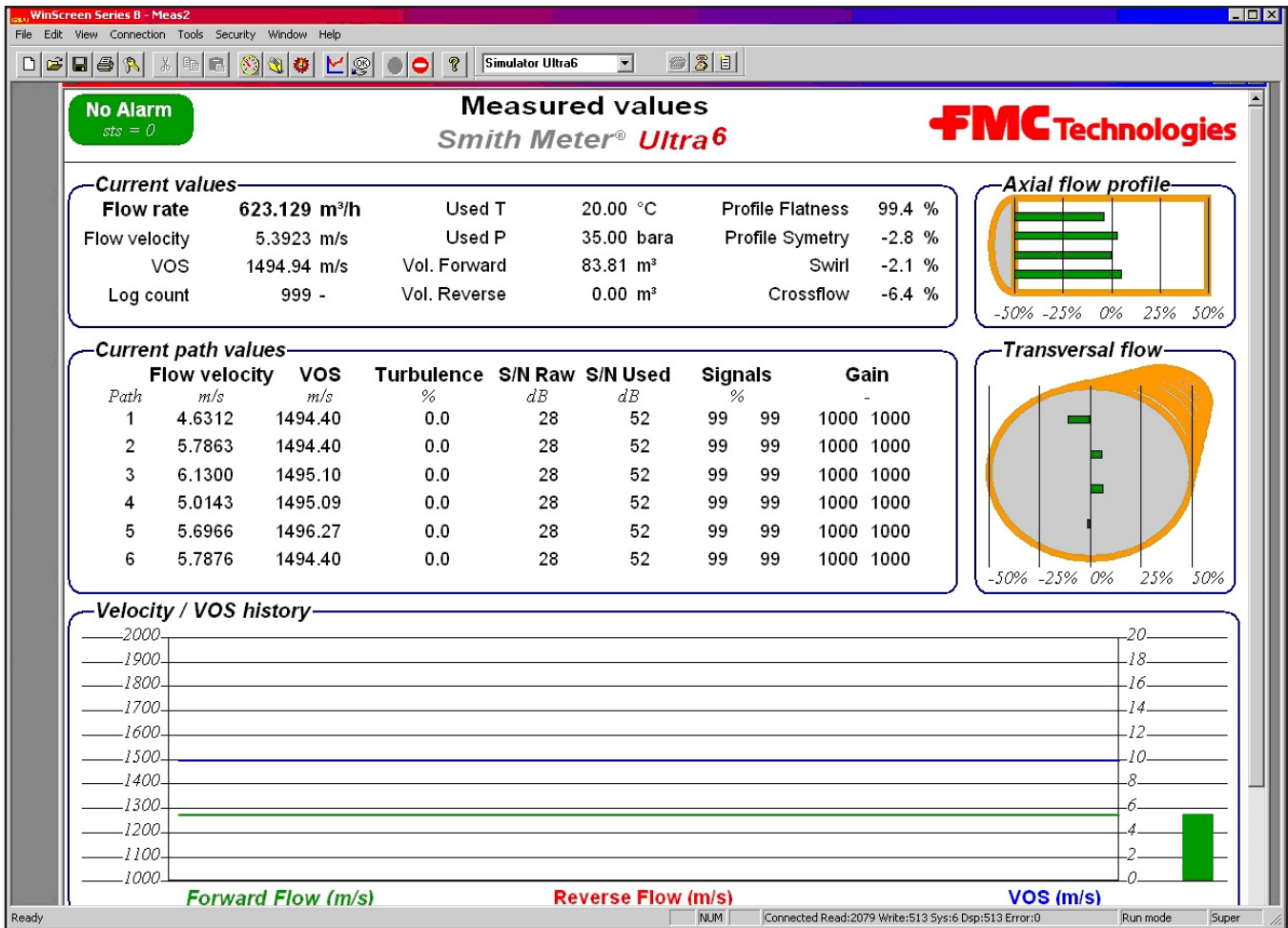


Figure 5 – Winscreen Measured Values Display

Velocity of Sound (VOS)	<p>Velocity of sound is measured together concurrently with the velocity of the flow. Since the two values are calculated from the same transit time measurement (the travel time of the ultrasonic signal), the correctness of the velocity of sound will also indicate the quality of the flow measurements.</p> <p>A check of the transducer health on each path can be made by comparing the velocity of sound measured on the different paths. Since each path has an individual VOS measurement and they are measuring the same liquid, the VOS should be the approximately the same for each path.</p>
Gain	<p>The gain is a measure of how much amplification is being applied by the electronics to effectively detect the transmitted ultrasonic signal. This is controlled by the automatic gain control (AGC) function built into the software. The AGC tries to keep the received signal level constant. The amplification needed to achieve this is represented by the gain value. This value is displayed for each individual transducer, both upstream and downstream for each path. A high gain is an indication that the signal strength may be too low for proper measurement.</p>
Signals %	<p>This value describes how many of the ultrasonic signals are acceptable to be used for custody transfer flow measurement. The value is displayed as a percentage indicating how many of the transmitted signals are being used.</p>
Signal to Noise Ratio (S/N)	<p>The signal to noise ratio is monitored both on the sampled signal and the processed signal. The S/N ratio is calculated by measuring the RMS (Root Mean Square) value of both the received signal and the ambient ultrasonic noise. A low S/N ratio is an indication that the signal is being attenuated by the product.</p>

Table 2 – Signal Parameters

If an alarm condition is present on one of these parameters, it indicates that something has caused a change to the flow profile. This change could be caused by many different conditions such as a significant change in fluid viscosity, a damaged flow conditioner or excessive accumulated debris in the strainer upstream of the meter run.

Table 2 shows the signal parameters for the Smith Meter® Ultra⁶ six path flow meter. Like the flow profile parameters, limits can be set on each of these parameters to indicate a deviation from the reference condition.

If an alarm condition is present on one of the signal parameters, it indicates that something is causing the ultrasonic signal to degrade as it is transmitted through the product. Some causes of this signal degradation could be entrained air or particulates in the product, a damaged transducer or cabling or debris fouling in the meter.

Naturally, any alarm condition needs to be investigated to correct the root cause of the problem. Isolating the cause of the alarm to specific flow profile or signal parameters will assist in quickly identifying the problem.

Winscreen also includes higher level diagnostic functions that can be used to identify the root cause of the problem. One such diagnostic function is the Signal Analyzer window. Figure 6 shows a sample of the signal analyzer window.

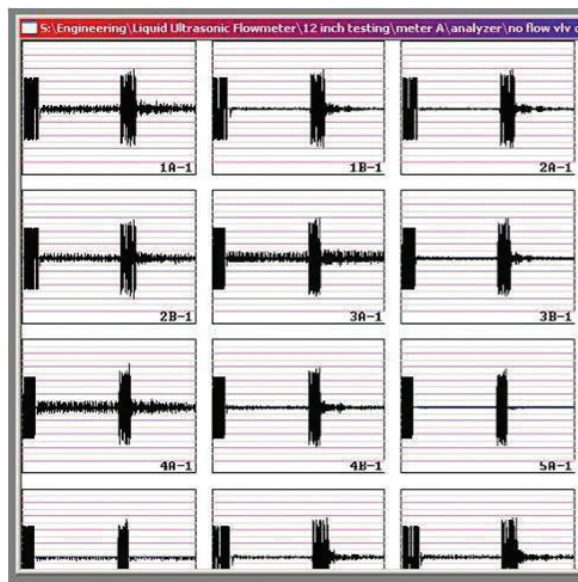


Figure 6 – Winscreen Signal Analyzer Window

The Winscreen Signal Analyzer Window (Figure 6) shows the transmitted and received signals for each of the 12 transducers that make up the six paths in the meter. Each of these windows can be view individually and further expanded to analyze the signal in detail to help in identifying the root problem.

Remote Diagnostics

The Winscreen software also gives the user more options for quickly accessing the meter even if it is installed in a remote location. The meter has an Ethernet port and is networkable by assigning it a unique IP address so that it can be accessed by any PC that is on the same network. Likewise, if the customer provides access to the network on which the meter is installed, factory technicians can monitor and diagnose the meter via the internet.

Even if direct access to the meter is not granted, the customer can use Winscreen to gather data files that can be sent to factory technicians who use simulation software to recreate the actual operation of the meter to monitor its operation.

Conclusion

As discussed, proper operation of liquid ultrasonic flow meters is dependent on aspects of the fluid flow stream that have never been visible using traditional metering technology. These flow profile and signal parameters can be used not only to verify proper operation of the meter but also to identify changes in the flow stream that could lead to inaccurate measurement. By properly using the diagnostic capabilities of LUFM's, the user can be assured that highly accurate custody transfer measurement is being achieved.

Acknowledgement

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