National Measurement System

# GUIDANCE NOTE

## Application of Ultrasonic Flow Meter Diagnostics

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## Introduction

Improvements in digital signal processing techniques have enabled large amounts of data to be processed and stored in real time. Manufacturers of modern flow meter devices such as ultrasonic meters (USMs) have taken advantage of these improvements and are now using diagnostic parameters to perform a 'health-check' of the meter when in operation. This can help the diagnosis of potential problems with the measured fluid or the measurement system.

A typical ultrasonic flow meter incorporating diagnostic parameters will have 4 signal paths set up as chords as shown in Figure 1. However, it should be noted that this is not the only configuration of USM available.

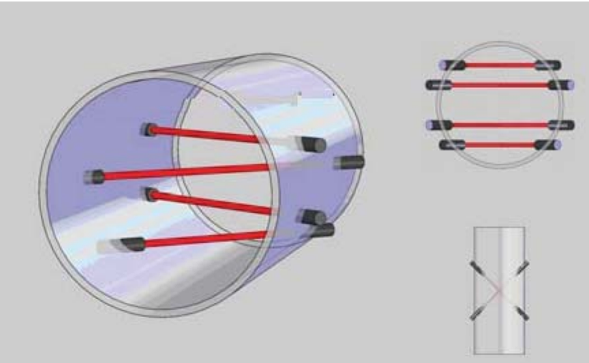

***Figure 1. Transducer position in a 4-path USM***

The diagnostic parameters generated are derived from changes in the ultrasonic signal of each path and the relationship with other paths. For instance, in the top path, the ultrasonic signal passes from the transmitting transducer, through the fluid, to the receiving transducer. During this traverse, the signal will lose energy due to a number of factors such as velocity of the fluid flowing in the pipe, noise interference, attenuation of the ultrasonic signal by the fluid, presence of a second phase, etc. Monitoring the small changes in signal amplitude, waveform and transit-time of the ultrasonic signal created by these influencing factors enables different signal property parameters to be recorded. Data is recorded for each path shown in Figure 1 and this enables a meter 'health-check' to be performed. If any parameter falls out with 'normal' values then this is indicative of a problem within the measurement system.

## Diagnostic Parameters

Numerous diagnostic parameters are recorded for each path and emphasis on a specific parameter may vary from manufacturer to manufacturer. Table 1 lists the diagnostic parameters common to most ultrasonic flow meters.

**TABLE 1 - DIAGNOSTIC PARAMETERS**

| Parameter | Description |
|---|---|
| **Flatness ratio or profile factor** | This parameter compares the amount of flow on the outer paths to the centre paths. It quantifies how peaked or flattened the flow profile is. |
| **Profile symmetry** | Profile symmetry compares the amount of flow on the top planes to the bottom planes. |
| **Swirl** | Swirl describes the amount of transversal flow that is rotating in the pipe. Typically this describes flow profile in a pipe after an out of plane double elbow. A positive number means swirl flow is clockwise looking downstream. |
| **Crossflow** | This parameter describes the amount of transversal flow that is generating a double swirl pattern with individual vortices in the top and bottom of the pipe. Typically this describes flow profile after a single bend. The sign of the number indicates the direction of the crossflow. The crossflow compares velocities in the chords in one plane to velocities in the plane at right angles. In good flow conditions the ratio should be close to unity. |
| **Turbulence** | The turbulence level describes the stability of flow measurement in each path. |
| **Speed of sound (SoS)** | Speed of sound (SoS) is calculated from transit-time measurements. The calculated value is compared to a theoretical value or a value calculated using AGA-10 standard equation. The SoS should be approximately the same for each path. |
| **Automatic Gain** | Gain is a measure of how much amplification is being applied by the electronics to the transmitted ultrasonic signal to ensure an effective level at the receiver. This is controlled by the automatic gain control (AGC) function built into the software. The AGC function is programmed to maintain a constant amplitude of received signal. The amplification needed to achieve this is represented by the gain value. |
| **Performance or signals percentage** | This value describes how many of the ultrasonic signals are acceptable to be used for flow measurement. The value is displayed as a percentage indicating how many of the transmitted signals are being used. |
| **Signal to noise ratio (SNR)** | The SNR is the ratio of the amplitude of the received ultrasonic signal to the amplitude of the background noise. The signal amplitude should be significantly greater to ensure good measurement. |

Detail on how each parameter is calculated can be found in the further reading documents which contain more comprehensive information.

## Application of Diagnostics

The diagnostics capabilities of USMs can be classified into three main groups:

1. **Functional diagnostics** - These are used to check that the USM is operating correctly and there are no signs of degradation. The following parameters are normally checked:
   - Gain (dB)
   - Signal to Noise Ratio (SNR)
   - Performance (%)

2. **Process condition diagnostics** – These are used to check that the conditions of the flowing fluid are stable and suitable for measurement. The following parameters are normally checked:
   - Turbulence (%) or velocity fluctuations for each chord
   - Profile factor/Flatness ratio
   - Symmetry
   - Crossflow
   - Swirl angle

3. **Measurement integrity diagnostics** – check that the measurement system is operating within the design specifications:
   - AGA-10 comparison for SoS
   - Comparison of measured & calculated density
   - Independent gas chromatography, temperature and pressure checks.

The diagnostics parameters described above are normally monitored in order to ensure optimum performance and combinations of these may serve as the basis of an expert system. An example of common problems often associated with USMs is shown in Table 2 (from ISO 17089-1:2010) alongside the diagnostic parameters that would indicate their presence.

**TABLE 2 - RELATIONAL DIAGNOSTIC DIAGRAM**

| Relational diagnostics diagram | Performance | Automatic Gain Control (AGC) (per path) | Signal to Noise Ratio (SNR) (per path) | Speed of Sound (SoS) (per path) | Flow velocity (per path) (Symmetry/ Crossflow etc) |
|---|---|---|---|---|---|
| Transducer failure | X | X | | X | X |
| Detection problems | X | X | | X | X |
| Ultrasonic noise | X | X | X | | |
| Process conditions- Pressure | | | X | | |
| Process conditions- Temperature | | | | X | |
| Fouling | X | X | X | X | X |
| Changes in the flow profile | | | | | X |
| High velocity | X | X | X | | |

Table 2 is by no means complete and is simply given to demonstrate some common problems. As can be seen, changes in some diagnostic parameters can have multiple causes. This underlines the difficulty in diagnosing a problem particularly when detailed knowledge of fluid dynamics and the meter's software are often required. Often all diagnostic parameters have to be reviewed before a conclusion can be reached.

## Recommendations

Diagnostic parameters can provide large amounts of secondary information about fluid flowing in a pipe. In order to utilise this information properly, it is important to realise how the diagnostics data are generated and how they interact. For instance, if a problem is found with profile factors or flatness ratio then one could assume that there is a change in the flow profile within the pipe. However, it may be the case that analysing the other diagnostics show asymmetry, swirl or even the presence of a second phase within the flow.

It is therefore imperative when using diagnostics not to infer additional properties of the fluid flow on a single diagnostic parameter. All diagnostics must be consulted in order to fully understand what is happening in the pipe. As shown in Table 2, different metering problems can show similar diagnostic discrepancies. This is why diagnosing problems without full knowledge can be difficult.

For further help or advice please consult the reading documents below or contact NEL on info@tuvnel.com.

## Further Reading

Diagnostic Capabilities of Ultrasonic and Coriolis Flow Metering Technologies. Report No. 2010/262, 2010, NEL, East Kilbride, Glasgow

Exploring the Diagnostic Capabilities of Ultrasonic Flow Meters. Report No. 2011/301, 2011, NEL, East Kilbride, Glasgow

Testing the Diagnostics Capabilities of Ultrasonic Flow Meters. Report No. 2011/426, 2011, NEL, East Kilbride, Glasgow

ISO 17089-1:2010, Measurement of Fluid Flow in Closed Conduits – Ultrasonic Meters for Gas – Part 1: Meters for Custody Transfer and Allocation Measurement

AGA report No. 10, Speed of Sound in Natural Gas and other Related Hydrocarbon Gases, Jan. 2003.

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The purpose of this Guidance Note is to provide, in condensed form, information on measurement methods and technologies. It was produced as part of the UK Government's National Measurement System.

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