An innovative approach to increase diagnostic sensitivity in ultrasonic flow meters

by

Daniel Heinig, SICK
Agenda

- Motivation
- Literature study
- Introduction of the „Condition based indicator“ (CBI)
- Summary
- Next steps
Motivation

- Goals for operators of gas metering stations
  - *Reduce* initial *uncertainty* budget to a (reasonable) minimum
  - Ensure *long term stability* of operation
  - Overall: *reduce financial risk / unaccounted-for gas*
Motivation

- Typical influencing factors for USM uncertainty after commissioning:
  - Installation effects (e.g. flow profiles from headers, elbows, etc.)
  - Pressure & Temperature measurement, gas composition
  - Control valve noise
  - Pipe corrosion and build-up
  - And others …

Source: Wim Volmer, „Metrological Reliability“, EFMWS 2013
Motivation

• Several tests & researches were performed in the past to determine impact of corrosion and wall roughness to USM uncertainty

• Papers have addressed USM diagnostic capabilities to detect changes in wall roughness and build-up

• Additionally check meter for verification recommended (master-check-meter concept)

➔ This paper discusses an innovative approach on how to increase diagnostic sensitivity for a direct path USM without adding additional hardware (Sensors / Electronics).
Time for Literature Study
Dirty vs. Clean USM performance, Lansing, ISFFM 2002

Two main impacts on USM performance:
- Change in Diameter → Over reading
- Change in flow profile → adding uncertainty
- Errors up to 0.5% observed
- Flow profile diagnostics potentially identify corrosion & build-up
Technical Paper 2
Two different Path Layouts, 2007

- Relevance of two different path layouts“ Lansing/Herrmann/Dietz, NSFMW, 2007

THE RELEVANCE OF TWO DIFFERENT PATH LAYOUTS FOR DIAGNOSTIC PURPOSES IN ONE ULTRASONIC METER

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1. ABSTRACT
During the past several years the use of ultrasonic meters (USMs) has gained world-wide acceptance for fiscal applications. The many benefits of USMs have been documented in several papers at virtually every major conference. As the cost of gas continues to increase, the importance of knowing that the ultrasonic meter is operating accurately has never been more important. The use of diagnostics to help identify metering issues has been discussed in several papers over the past few years [Ref 1 & 2].

- First introduction of Fiscal + „sensitive“ Check meter for advanced diagnostics
- Relative comparison of measured volume
- Changes in wall roughness or FC blockage can be detected by check meter before the fiscal meter reacts
- Some details …
Two different Path Layouts
4+1 Meter Design

4-Path Transducers

Single-Path Transducers
Two different Path Layouts
Flow Conditioner Test Program

- 8, 10, 12 inch USM tested with
  - Blocked FC (one hole, 3 holes, 40%)
  - Dirty FC – particle
Two different Path Layouts
Flow Conditioner Test Program

• Testing at CESSI back in 2006, 2007 and 2009
Two different Path Layouts
Some Results

- 12 inch, 4-path, 1 hole blocked
Two different Path Layouts

Some Results

- 12 inch, 1-path, 1 hole blocked
Two different Path Layouts
Some Results

• 12 inch, 4-path, 40% blocked
Two different Path Layouts
Some Results

- 12 inch, 1-path, 40% blocked
Two different Path Layouts
Some Results

- 12 inch, 4-path, clean vs. dirty meter

<table>
<thead>
<tr>
<th>Velocity</th>
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12-inch, 4-Path Dirty and Clean Piping Results
Two different Path Layouts
Some Results

- 12 inch, 1-path, clean vs. dirty meter

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12-inch Single-Path Dirty and Clean Results

- As Found Dirty CPA & Meter Run
- Clean CPA & Meter Run
Technical Paper 3

Finger Print

- Diagnostic fingerprint”, Schäfer/Dietz/Herrmann/Peterka, NSFMW, 2010

- Introducing finger print concept based „gas flow classes“ to improve evaluation of diagnostics
- Changed perspective from actual data to trend analysis
- Calibration vs. commissioning vs. actual condition
Technical Paper 4
Influence of Wall Roughness

- "Consideration on the influence of changes in wall roughness on USM accuracy" Horst/Jakschik/Dietz/Riezebos/Herrmann, NSFMW, 2011

Meter & pipe corrosion testing
Changes in wall roughness can be identified by diagnostics
Recommendation: Equip meter with corrosion protection, e.g. nickel coating
Some details...
Technical Paper 4
Influence of Wall Roughness – Test Program

Use case 1 – new meter

CS pipe – “new”
CS pipe – “marginal corroded”
CS pipe – “smooth”
CS pipe – “completely corroded”

FLOWSIC600 2plex (4+1) – “brand- new”

Use case 2 – Corroded meter

CS pipe – “new”
CS pipe – “marginal corroded”
CS pipe – “smooth”
CS pipe – “completely corroded”

FLOWSIC600 2plex (4+1) – “corroded”
Technical Paper 4
Influence of Wall Roughness – Test Program

Use case 1 – new meter

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FLOWSIC600 2plex (4+1) – “brand- new”

4 Paht-System 4-inch 2-Plex-Meter (brand-new)
20bar KEMA Groningen (as found)

Delta 4 Path to 1 path-System 4-inch 2-Plex-Meter (brand-new)
20bar KEMA Groningen (relative)
Technical Paper 4
Influence of Wall Roughness – Test Program

Use case 2 – Corroded meter

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FLOWSIC600 2plex (4+1) – “corroded”

4 Paht-System 4-inch 2-Plex-Meter corroded (used-corroded)
20bar KEMA Groningen (as found)

Delta 4 Path to 1 path-System 4-inch 2-Plex-Meter (used corroded)
20bar KEMA Groningen (relativ)
Technical Paper 4
Influence of Wall Roughness – Conclusion

• Protect meter from corrosion is key to reduce uncertainty impact
• Nickel coating as the solution for LTCS meters
• If meter corrodes, uncertainty bias due to:
  – Diameter change, leading to over reading at small size meters
  – Wall roughness
    ➔ This impacts ALL meters
• 1 path systems detects changes in wall roughness before it effects meter accuracy
• Diametric path layout is most sensitive to flow profile changes
Summary of Literature Study
Publications on USM & Wall Roughness / Corrosion

• Many research done on effects on accuracy for USM & effect of corrosion
• Diagnostics is powerful for pre-indicating corrosion & build up
• Sensitive check meter systems help to improve diagnostic indication

Dirty vs. Clean Ultrasonic Gas Flow Meter Performance
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TOM MOONEY, Business Development Manager, Gas Products, Strinor, Scotland, UK

1 ABSTRACT
The use of ultrasonic meters (USMs) for measuring gas flow has increased at a remarkable rate over the past 15 years. A large number of publications have documented over the past few years [Ref 1 & 2] the many benefits of USMs when compared with traditional methods. As the cost for installing USMs is comparable, the advantages on both benefits and acceptance for fiscal applications are often considered major. The use of USMs has become more popular as the need for precise measurement requirements have been evident. To date, several papers at virtually every major conference have been presented on the benefits of USMs. The use of USMs in the oil and gas industry, for example, has increased significantly during this period. As the benefits of USMs are well known, the importance of knowing the ultrasonic meter’s performance and the associated piping and equipment changes is critical. This new study will focus on the importance of USM performance and the associated piping and equipment changes. This new study will focus on the importance of USM performance and the associated piping and equipment changes.

The Relevance of Two Different Path Layouts for Diagnostic Purposes in One Ultrasonic Meter
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MR. TORALF DIETZ, SICK AG, Reutlingen, Germany

1. ABSTRACT
During the past several years, the use of ultrasonic meters (USMs) for measuring gas flow has increased at a remarkable rate. The use of USMs has become more popular as the need for precise measurement requirements have been evident. To date, several papers at virtually every major conference have been presented on the benefits of USMs. The use of USMs in the oil and gas industry, for example, has increased significantly during this period. As the benefits of USMs are well known, the importance of knowing the ultrasonic meter’s performance and the associated piping and equipment changes is critical. This new study will focus on the importance of USM performance and the associated piping and equipment changes.

Diagnostic Fingerprint – A New Method for Fully Automated Accuracy Monitoring in Ultrasonic Meters
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Toralf Dietz, SICK AG, Reutlingen, Germany
Thomas Horst, SICK AG, Dresden, Germany
Ing. Konrad Peterka PMSc, OÖ, Ferndorf, Austria
Dr. Volker Herrmann, SICK AG, Reutlingen, Germany

1. Introduction
Due to their advantages, advanced ultrasonic gas meters are being used on a steadily increasing scale, and they stopped being perceived as exotic devices. The multitude of diagnostic information that can be derived from ultrasonic meters provides significant benefits. However, the user is often not able to benefit from this rich information if they do not have specialist assistance in evaluating the data. Therefore, a solution is needed to make this variety of information controllable for the end user.

Considerations on the influence of deposits or changes in wall roughness on the validity of the calibration and long-term accuracy of ultrasonic gas flow meters
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Alexander Jakusch, SICK AG, Dresden, Germany
Toralf Dietz, SICK AG, Dresden, Germany
Henk Riezebos, KEMA Nederland BV, The Netherlands
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1. Introduction
Due to refined diagnostic capabilities and the lack of moving mechanical parts, ultrasonic flow meters (USMs) provide excellent reliability and long-term stability. These properties lead to high accuracy and low costs of operation in the field. Recent studies [2] have shown how meter performance changes when electronics or transducers are replaced. This demonstrates the high precision of time-of-flight measurement with up-to-date components. Nevertheless, some installation parameters relevant to meter accuracy may change after a long period of operation. For instance, in many situations in the field, inner pipe wall corrosion and contamination can occur. These changes in the inner pipe wall may influence the geometrical parameters and/or wall roughness of the pipe and consequently the shape of the flow profile.
The Time Line

- 2006: Software supported Condition based Maintenance (CBM)
- 2007: Introduction 4+1 concept (main and diagnostic check meter)
- 2010: Introduction Fingerprint concept for USM diagnostic
- 2016: New generation USM with CBI – Condition Based Indicator
Condition Based Indicator (CBI)

How does it work?

- 4-Path system, Westinghouse Design
  - P1 … P4

Condition Based Indicator (CBI)*
- Measurement of diametric path
- Path velocity comparison to average VOG of 4-P system
  - \( P_x = \text{CBI 1} \)
  - \( P_y = \text{CBI 2} \)
  - Sequential firing @ 10/s measurement rate

\[
CBI \left( \frac{m}{s} \right) = f(VOG_{px}, VOG_{py}, VOG_{avg})
\]

*Patented technology
Condition Based Indicator (CBI)

How does it work?

- Transducer design with wider path angle
- Electronics with improved signal gain
Condition Based Indicator (CBI)

How does it work?

- CBI: single path measurement with same number of transducers & hardware!
- Applicable in 4/8-path meters
- CBI has high sensitivity to Reynolds number and flow profile changes
- Linear over flow range ($Q_{t}…Q_{max}$)
Condition Based Indicator
CBI vs. 1-path Correlation

- Easy verification test with blocked FC (1 m/s … 6 m/s)
- Good correlation between 1P System and CBI
Condition Based Indicator

Field Data

- Bi-directional installation of FLOWSIC600 and 600-XT in natural gas underground storage
- Commissioned in November 2015 and running for over 12 month
- Calibrated metering package ensures direct comparison over installation time
Condition Based Indicator
Field Data

Graph showing condition based indicator vs. velocity of gas (m/s) with data points for reverse and forward directions.
Condition Based Indicator
Field Data – Evaluation of 12 Months Operation

Separation in VoG classes

Reverse | Forward

Condition based indicator vs Velocity of Gas [m/s]

- CBI Nov2015 - Mrz2016
- CBI Aug2016 - Okt2016
Condition Based Indicator
Field Data – Evaluation of 12 Months Operation

Separation in VoG classes
Fingerprint:
Reference values per class

Warning limits
Condition Based Indicator
Trending and Finger Print

- CBI is part of the diagnostic fingerprint
- CBI is continuously recorded in the diagnostic archive
- Easy comparison between initial commissioning and life time
- Innovative additional diagnostic indicator for flow profile changes
- It helps to judge whether or not a re-calibration / inspection is required
Summary

• Corrosion and build-up: impact on measurement uncertainty

• Sensitive diagnostic systems enable ultrasonic meters to indicate changes in wall roughness & build-up

• Corrosion protection of flow meter (nickel coating) recommended to fully leverage the diagnostics
Summary
Condition Based Indicator (CBI)

• … an innovative approach to increase diagnostic sensitivity in a standard 4-path meter – without adding hardware

• … correlates to a physical 1-path measurement through the diametric path

• … can identify changes in wall roughness, build-up or blockage of flow conditioners

• … is a valuable additional flow profile indicator – next to symmetry and profile factor – that helps to estimate when calibration or meter inspection is required
Next Steps
Condition Based Indicator (CBI)

• Observation of the CBI in **field applications**
• Correlation to **re-calibration** results & prediction using CBI data
• Correlation to other diagnostic indicators
• Implementation for complete **application range**
  – Line size above DN400/16 inch
  – Other gases than natural gas
  – Pressure above 110 bar
  – Velocity above 36 m/s