WHITE PAPER

REDUCING UPSTREAM LOST AND UNACCOUNTED FOR GAS

SICK
Sensor Intelligence.

Historical Ultrasonic Measurement

Today, one could make the case that every molecule of gas that ends up at the burner tip has been measured at least once, if not multiple times, by an ultrasonic meter. Various ultrasonic meter technologies have been applied to measure the flow of liquid and gas streams since the 1960s.

FLOWSIC600XT

Although very early patents, like the Westinghouse meter design, were filed in 1968 and granted in 1971 (US3564912A), ultrasonic meters for commercial natural gas measurement didn't gain a foothold in the gas measurement market until the late 1990s. Up until the last few years, ultrasonic measurement for custody transfer has been confined primarily to gas transmission (i.e. larger volumes of relatively dry, clean gas). This reality arose primarily due to technology limitations on signal processing and transducer size, as well as cost benefit at the time.

FLOWSIC600 Classic

By the beginning of the 2000s, ultrasonic meters had replaced mechanical meters as the principal gas measurement device for pipeline transmission applications, both custody transfer AND system balancing. Leading the technology race is SICK's FLOWSIC600XT and its predecessor, the FLOWSIC600 (Classic). Both have become well known front runners in the transmission gas measurement market.

SICK's continued technological advancements, brought by a dogged investment in research and development, has yielded increased processing capabilities, more robust materials, and component miniaturization. In addition, development has allowed SICK to test the envelope by developing better meters for harsher environments, pushing into upstream applications ever closer to the source of the gas stream - the wellhead.

Advantages of Ultrasonic Measurement

The truths that drove transmission companies to Ultrasonic technology in the 1990s and 2000s are the same truths that will be driving gas producers and gathers to employ its use now and into the future.

- **Low uncertainty (+/- 0.33%*)**
  - *as calibrated (total meter uncertainty = lab uncertainty + meter repeatability. Typical lab is +/- 0.23%, and meter
  - repeatability is +/-0.1%.)
- **Reduction of L&U**
  - As an example, consider a 6" meter flowing 50 MMSCF/D of rich gas being sold at $3.00/MMBTU. Even a modest reduction of 0.15% in measurement uncertainty for this one 6" field measurement point removes over $94,000 a year out of the L&U equation.
- **Huge turndown**
  - 100:1 (Qmax/Qmin)
  - Directly reduces the labor cost and environmental venting associated with plate changes
- **Non-mechanical, solid state**
  - No moving parts or wear surfaces as with mechanical meters such as rotary or diaphragm.
  - Minimizes maintenance cost and uncertainty in measurement, both improve the bottom line
- **Naturally bi-directional**
  - Frequently when the application requires measurement in both directions (well injection, storage wells, etc.) dual-meter runs of orifice meters or costly bi-directional orifice plates are used, which result in higher uncertainty. Because of their simple spool-like design, ultrasonic meters are naturally bi-directional.
- **Negligible pressure drop (pipe losses only)**
  - High pressure drop, such as may be experienced with orifice meters, directly impacts compression cost.
- **Advanced diagnostics**
  - The advanced diagnostic capability of the SICK FS600/FS600-XT ultrasonic meters provide benefits unmatched by other technologies and positively impact profitability.
    - Ultrasonic meters reduce ownership cost through reduced maintenance. By trending diagnostic values and identifying when maintenance is needed, they eliminate the need to schedule time based inspections. Unnecessary inspections directly translate into wasted time and, thereby, wasted money.
    - Ultrasonic meters help maintain the lowest L&U by providing information about the quality of the measurement, including the health of the meter, the meter run's integrity, and the integrity of associated measurement equipment. In some cases, FS600/FS600XT diagnostics are integrated into the information provided through the SCADA of a facility and contribute data into the overall performance and health of some of the facility's equipment in proximity to the meter run. This actionable information contributes to maintaining both good measurement and overall operational performance of a facility or system.
    - In some applications, an ultrasonic meter can identify events relating to compositional changes in the fluid stream, including the presence of liquids in forms from light mist to free liquids. Whether water or hydrocarbon based, both adversely impact gas measurement quality.

Bottom Line

Summing up all these advantages, ultrasonic measurement has been proven over the last few decades and through countless installations to increase bottom line profits by:

- Lowering overall L&U
- Lowering measurement maintenance OPEX
- Lowering environmental exposure

After reviewing the benefits that FS600/FS600XT ultrasonic gas flow meters have brought to transmission pipeline measurement, it is no wonder that some in the industry are now embracing the use of this proven, robust technology both further upstream and downstream from the transmission pipeline.

The Ultrasonic Future: Upstream and Downstream

SICK has been a trendsetter at applying its industry-leading ultrasonic sensor technology in both the upstream and downstream markets. In 2013, SICK introduced the FLOWSIC500 (FS500) to be used primarily in downstream, low-pressure, gas measurement applications - a space traditionally occupied by rotary and turbine meters. Since that time, the FS500 has expanded beyond gas distribution applications and may even be found on upstream low-pressure applications, such as compressor fuel gas measurement, vapor recovery, and hydrocarbon venting.

FLOWSIC500

Following the release of the FS500, SICK introduced the FLOWSIC600 Differential Replacement Unit (DRU). This meter is a variant of the SICK FLOWSICS600 Classic, but has unique features that make it ideal for applications upstream of the gas plant toward the wellhead. After the DRU's market introduction in 2014, it has seen steady acceptance by gas producers and gas gatherers.

Some in the upstream industry are now realizing the benefits of installing DRUs near well pads like their transmission industry counterparts have experienced for years with the installation of FS600 on their pipelines. Additionally, the DRU has a very comparative CapEx cost to the traditional orifice measurement. Further, as with the FS600, the DRU reduces OpEx cost over the life of the field measurement point due to the decrease in lost and unaccounted for gas (L&U) and significantly reduced maintenance costs. Therefore, it is no surprise that the DRU is the new rising star for upstream gas measurement applications.

FLOWSIC600 DRU-S

FLOWSIC600 DRU

The Key is the Transducer

So why might there be hesitation to use ultrasonic measurement in upstream, dirty, and/or wet gas applications? This is most likely traced back to early (and some cases current) transducer designs. Some older designs of transducers had equalization ports, others had connections exposed to the process, and others were constructed with "matching layers." In fact, some transducers had all three. Unlike other manufacturers of failure prone transducers, SICK set an industry best Mean Time Between Failures with a transducer design that has none of these issues.

- **Equalization ports:** Some early transducer designs did not use sealed transducers, which allowed process gas to equalize to the process pressure in the internal transducer resonance chamber. While, at the time, this design assisted in acoustic coupling and prevented damage under certain conditions, it also, unfortunately, served as an "open window," allowing for process gas and associated fluid to interact with the transducer's internals, frequently causing transducer failures. The transducer design of SICK ultrasonic meters do not have equalization ports and, therefore, have none of the transducer failures frequently associated with these other designs.

- **Matching layers:** Some wetted transducer designs utilize a matching layer to help overcome the rapid impedance change between the source of the ultrasonic sound (metal transducer membrane) and the gas medium. In this design, the matching layer is non-metallic and must be secured to the tip of the transducers by other means. Under certain conditions, such as the rapid depressurization of a blowdown, fluids and even compressed gas molecules may be forced into the bond of the matching layer causing it to separate. This leads to failure and necessitates replacement of the transducer(s). The transducer design of SICK Ultrasonic Meters does not employ the matching layer design.

- **Internal connections:** Similar to the contamination of transducer internals by the fluid stream, some competitive designs have transducer connections that were internal to the meter and exposed to the gas stream. These connections degrade over time in less than ideal gas quality leading to transducer failure. The connections within the transducer design of SICK Ultrasonic Meters is completely sealed away from the process.

SICK's sealed titanium transducer technology has none of these traps, is impervious to aggressive gases, liquids and condensates, and, by design, has no matching layers. As a result, the SICK ultrasonic meter design is uniquely qualified to be used in the harsh environment of many upstream applications, which is why we used the FS600 Classic design as the basis for our DRU.

The Commercial Impact: Don't Give Away Gas

Midstream gathering companies charge a transportation fee based on per mmbtu of gas. As a result, accurate measurement is critical to both sides of the transaction, the buyer (gatherer) and the seller (producer). While older gas gathering contracts had a 2% uncertainty target, many of today's contracts are written so that discrepancies – losses or gains which exceed 1% -- require the discrepancy to be investigated and resolved.

For gas producers, under measurement at the pad (i.e. the inlet to a gathering system) results in what is sometimes called "gaining" gas by the gatherer. This occurs when the inlet meter is compared to the next stop on the pipeline at a transmission meter station and the meter at the pad shows less gas measured than the downstream meters, meaning that the difference in measured gas volume - the "gained volume" rides the gathering line free of charge. This is a direct loss of revenue for the gathering company, which did not charge the producer for transporting that difference in gas.

Unlike transmission industry norms, commercial agreements between many midstream gathering companies and their producers, historically, do not contain language stipulating strict contractual remedies for over measurement. Conversely, typical lost and unaccounted (L&U) targets for gathering systems of as little as 1% have become common. As a consequence, over measurement by gatherers necessitates investigation as to the root cause, requiring extensive research, significant money, and, occasionally, leading to significant exposure.

Ultrasonic meters can greatly reduce or even eliminate over- and under-measurement situations, provide highly reliable measurement at a low level of uncertainty, and lower operating costs to contribute to higher profits. Like the transmission line operators before them, upstream field operations enjoy these benefits because of the inherent nature of ultrasonic measurement.

- Rangeability of a USM increases revenue by recapturing "lost" unaccounted flow
- Rangeability of a USM reduces maintenance costs by eliminating plate changes
- Rangeability of a USM means it's very difficult to "over range" a meter
- Diagnostics of a USM identify and lead to correction of upstream issues, such as:
  - over-registered flow
  - Meter run contamination from paraffin, scale, etc.
  - Upstream equipment issues such as separators, vapor recovery units, etc.
- The actual measured speed of sound is provided and can be used to validate the static gas composition in flow computer gas

A Case Study: One Company's Transition from Mechanical Measurement to the DRU

Now let's look at one gathering company's results when they methodically transitioned to the SICK FLOWSIC600-DRU from traditional orifice measurement. They first evaluated their entire system in order to establish a baseline system L&U for a portion of their system. An 8" dual chambered orifice site, one of five field measurement points in this area, was identified for the proof of concept and replaced by a 3" SICK DRU. The remaining four sites continued to be measured by their orifice meters. Each of these five measurement points fed into a single gathering pipeline that then led to a transmission pipeline.

At the beginning of the evaluation, all orifice meter runs at all five pads were inspected and cleaned. This section was then closely monitored for a baseline period, resulting in an uncertainty for all five of 3.5% gain. For the next phase, all flow for the section was directed to the single evaluation 3" DRU. After the totals were compiled, the results demonstrated that the replacement of the orifice measurement on just one of the five measurement points, reduced L&U from 3.5% to 2.7%.

Continuing the evaluation, all flow at the test pad was split evenly between the 3" DRU and the remaining four 8" orifice. As expected, the L&U resulting gain, was back to 3%. Thus, it was clear that measurement of gas, even by clean, inspected, calibrated orifice meters at this site negatively impacted uncertainty, causing a net gain in L&U and consequently, negatively impacted revenue. The lost revenue was a direct result of "free" gas being transported in the gathering system which was simply not being measured and therefore not being charged.

By replacing just one of the five measurement points in this system with a DRU, the uncertainty for that portion of the system dropped by 0.8% -- impressively, the ROI for this retrofit was then less than four months, based on the increased gathering revenues and decreased OPEX costs applied against the installation and materials cost. As a result, there was justification to proceed on a larger field wide meter conversion project.

During the period of the system field conversion, approximately 100 situations arose in which DRU diagnostics indicated needed maintenance. Of those, 15 were related to start up issues (debris in the system) and each of the remaining situations required some action to correct an issue with the system, meaning there were no false alarms or wasted trips to the field. The company SOP (Standard Operating Procedure) was rewritten for the SICK DRU so that inspections only occurred once per year— unless diagnostics indicated otherwise. This is consistent with AGA 9 -2017, Section 7, which outlines this condition based maintenance.

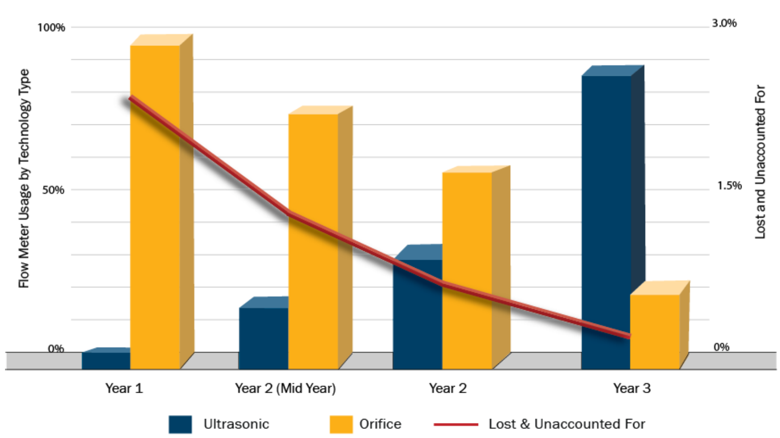
Finally, after the gathering system's complete conversion to DRUs, L&U data was demonstrated to have shifted in total from a gain of almost 2.5% to a loss of 0.1%. *NOTE: during the conversion period, all remaining orifice meters were still being cleaned monthly in order to provide the best orifice measurement possible.*

Below, the graph shows this improvement over time. With a system throughput of over 500BCF, 98% of measurement occurred through orifice meters. L&U at that time resulted in a 2.44% gain, even with a strict, monthly, routine, orifice run cleaning program. Years later, with a total system throughput now of over 850BCF, 80% of meters, those flowing greater than 5 MMSCFD, were converted or newly installed DRUs. The remaining 20%, all on sites of less than 5 MMSCFD, remained orifice meters. Because of this practice, the total amount of gas measured by orifice measurement was minimal, having very little effect on total system L&U. This result with the vast majority of the total volume measured by SICK DRUs improved by over 2% to a loss of 0.1% for the year.

Based on an industry average gathering charge and the ability to correctly charge for what once would have been unmeasured gas, results indicated additional revenue over $4.2M by Year 2. Additionally, maintenance costs fell precipitously as orifice meter inspection programs were replaced with a diagnostic based "as needed" program as indicated by the continuous data pulled from the DRU.

The customer increased revenue over $7.6M during the two year transition from orifice to ultrasonic measurement. Additionally, with the installation of DRUs, the customer was able to reduce OPEX through the elimination of monthly orifice field inspections. Approximately $100k was saved in OPEX expenditures on 72 operational CDPs (define CDP's) by the beginning of 2017. As an added benefit, capital expense was also reduced due to the increased rangeability of the ultrasonic meters, meaning smaller line sizes in comparison to orifice meter installations (8" to 3").

Lost & Unaccounted For Flow Variance vs. Measurement Technology



Conclusion

Ultrasonic meters are a proven technology and have been in use, primarily by gas transmission companies, for several decades. They are the undisputed choice for high volume transmission measurement points. A common notion for the 21st century is that because of their widespread acceptance and use, almost every molecule of gas being burned or otherwise consumed, has, at some point in its journey, been measured by an ultrasonic meter.

With the improved processing power, materials, and manufacturing techniques of SICK's Flowsic600-DRU, upstream producers and gatherers are finally able to realize the benefits of this low uncertainty, high rangeability measurement tool. The DRU is an AGA-9 compliant ultrasonic meter manufactured specifically to meet the demanding upstream environment at a very competitive price. As has been demonstrated by actual data from one gathering company's field conversion from orifice to DRUs, by installing these meters, the resulting increased revenue, decreased OpEx, and, in some circumstances, decreased CapEx, can directly deliver very positive results to an operation's bottom line.