Rossella Mimmi, Emerson Process Management, USA, explains how the latest flow measurement technologies can help to provide more accurate and reliable custody transfer solutions.

Accurate flow measurement has grown in importance due to its widespread use for accounting purposes and in other upstream and pipeline operations. In addition to fiscal and custody transfer applications, correct flow measurement is required for production management, leak detection systems, batch operations and loss/gain balance. These applications constitute key elements for operators who want to maximise efficiency in production, transportation and storage facilities.

What is fiscal measurement?
Fiscal measurement is a term that commonly includes both allocation and custody transfer flow measurement. Allocation involves the assigning of aggregated product quantities back to owners, leases or individual source streams and is typically not governed by a buy/sell contract. Custody transfer is based on a change of
Ownership between a buyer and seller and is managed against a contractual obligation. Both require adherence to specified accuracy, repeatability, linearity or uncertainty values as defined by the appropriate owner policies, regulatory agencies and industry standards.

Fiscal measurement applications are everywhere in the oil and gas value chain and play an essential role in solving various industry challenges that customers face in each area. For onshore and offshore, fiscal measurement supports achieving real time product flow measurement data to optimise production and ensure regulatory compliance. In terminals and storage, use of the right flow measurement technology helps increase loading/offloading efficiencies. Finally, to ensure efficient product movement and maximise utilisation for pipelines and transportation, accurate flow measurement is key in leak detection systems, batch operations, loss/gain balance and throughput optimisation.

Oil and gas flow measurement accuracy and sustainability depends on many factors such as product quality, fluid properties and composition, operating parameters, maintenance practices and technology type. The selection and effective utilisation of newer measurement technologies are proven to minimise many of these factors, resulting in improved accuracy and reliability of fiscal measurement systems.

**Flow measurement accuracy and uncertainty**

All meters and metering systems are subject to uncertainty. It is a common mistake to mix accuracy and uncertainty; however they are subtly different. ‘Accuracy’ refers to matching the meter output to a known standard or reference (using terms like bias, readability and precision), and this can be considered the best estimate according to the scale of the measurement. ‘Uncertainty’ is related to repeatability and is an estimate of the limits where the true value is expected to lie for a given confidence level. Figure 1 gives an indication of flow measurement uncertainty levels that are generally required throughout the oil and gas supply chain.

The overall design objective of a measurement system is to continuously provide precise, reliable, and traceable volume measurement of the quantity of fluid or gas being sold. Given the maximum allowable uncertainty of the system, for example ± 1.0% of the actual reading, the other system components that combine to achieve this accuracy must provide measurement accuracy less than ± 1.0%. Selecting the right flowmeter technology with the best accuracy, in combination with other high accuracy components, helps ensure the overall measurement accuracy is consistently achieved. Inaccurate measurements can lead to increased fiscal risk, litigation and possible internal/external audits.

The measurement system is required to maintain the specified accuracy over the flow range, compliant with industry standards and regulations, provide the necessary fluid composition and ensure sustainable measurement...
performance between proving/calibration cycles. Overall system reliability is also a critical design element to minimise complex and frequent maintenance procedures. Other systems associated with gas measurement may include gas conditioning equipment for particulate and liquids removal, odorant injection and pressure control to stabilise the meter working pressure. The main components of a natural gas fiscal measurement system are shown in Figure 2.

Components of flow measurement systems
Referring to system components, it can be seen how each one contributes to the overall uncertainty of the total system.

Fluid composition
Manual samples and analysis or continuous analysers are used to provide information on fluid composition. For natural gas, this is associated with the fluid energy content, which determines the product value and price. For NGLs, it is required to determine component volumes at reference conditions. Inaccurate measurement of fluid composition and analysis can result in additional maintenance where contaminants are not detected.

Pressure control
A constant operating pressure can greatly help in the stable operation of some types of metering technologies and increase the measurement accuracy. Maintaining constant pressure is a prime reason why metering lines are usually installed downstream of pressure reducing stations.

Instrumentation
In measurement systems, a variety of pressure, temperature, density and viscosity instruments are used to help compensate for changing fluid properties that impact meter factors and correct fluid volumes to reference conditions. Inaccurate measurement, associated with any one of these components, will contribute to overall inaccuracy of converting flow measurement to reference conditions.

Flowmeter proving/calibration
One of the challenges faced in fiscal measurement is ensuring sustainable measurement performance over time. Meter performance can be affected by a change in fluid physical properties, mechanical wear in the meter, obstructions in the pipe and coating of the pipe wall. For these reasons, meter performance must be regularly verified against an external reference to ensure appropriate compliance to accuracy and repeatability requirements over time.

In addition to these challenges, undetected parameters associated with facility operations can occur on an intermittent or continuous basis and jeopardise measurement performance. For example, operators can encounter low volumes of entrained gas in a liquid stream, entrained liquids in a gas stream, or coating/obstruction of a flow conditioner. All of these conditions can impact the uncertainty of the flow measurement and may go unnoticed until the next verification event. It is clear that one of the main contributors to maintaining flow assurance is to detect factors that can potentially increase uncertainty before the next calibration.

New technologies bring higher accuracy, reliability and assurance
New technologies and solutions are now available to help optimise measurement systems. These include recent developments in flowmeter technology and advanced diagnostics, flow computers with the ability to pass through critical sensor information and diagnostics, and WirelessHART® to capture stranded device diagnostics. These technologies can also be incorporated to optimise integration and turn-key systems along with lifecycle services.

Flowmeters
Although there are a wide range of technologies that can be employed for fiscal measurement applications, ultrasonic and Coriolis are emerging as flowmeter technologies of choice for fiscal measurement systems, as demonstrated by their rapid adoption in the oil and gas industry. These devices are approved by the majority of industry bodies, such as GPA, AGA and API,
and national metrology standards such as OIML (International), NIST (USA), PTB (Germany), CMC (China) and GOST (Russia).

**Ultrasonic meters**

These provide volumetric flow rate. The meters measure flow rate via the transit-time method, where sound waves transmitted in the direction of fluid flow travel faster than those travelling upstream. The transit time difference is proportional to fluid velocity. The average axial velocity multiplied by the area of the pipe then gives the uncorrected volumetric flow rate through the ultrasonic flowmeter transmitter. Mass flow rates can also be determined in conjunction with densitometers. Ultrasonic meters (Figure 3) have negligible pressure drop, high turndown capability and can handle a wide range of applications, including natural gas and crude oil production, transportation and processing. The latest versions extend the temperature and viscosity range to address applications such as shale oil, LNG and heavy crudes found in oilsands.

**Coriolis flowmeters**

These provide direct mass flow measurement in both gas and liquid streams with high accuracy and repeatability over wide turndown ratios. The sensors maintain those qualities even when fluid conditions such as density, viscosity and composition frequently change. In a Coriolis meter (Figure 4), the material to be measured passes through one or more oscillating tubes; the rate of mass flow affects the oscillation of the tubes, and from this both mass flow and density can be determined.

Coriolis flowmeters do not require flow conditioning and mass calibration is valid on any fluid type, therefore they are a very good fit in both liquids and gas custody-transfer lines. Coriolis meters also work well in applications where fluid density is not stable, like critical phase ethylene, as well as slurry and high-viscosity products.

As such, these technologies can provide more sustained, accurate flow measurement under a wider range of application parameters than other flow metering technologies.

**Data and diagnostics**

The increased availability of diagnostic data for fiscal measurement systems and its ease of access and utilisation improve flow assurance by identifying potential accuracy deviations between proving or calibration. Outputs such as the real time speed of sound calculation and velocity profiles for the ultrasonic meter or drive gain/density curves for the Coriolis meter can be effectively used to detect pipe blockage or entrained gas in liquids.

Advanced in-situ diagnostics are becoming more prevalent in newer technologies. Ultrasonic meters utilise multiple path transducer velocity ratios to characterise meter performance under different flow rates and automatically alert operators of upstream piping conditions that degrade overall measurement accuracy. Some Coriolis meters have the ability to perform self-checks on the integrity of the flow tubes, sensor components and electronics without the need to remove the meter or interrupt flow measurement.

**WirelessHART**

The ability to access the added data, diagnostics, and information from measurement system components is enhanced through the use of wireless technology. All the system parameters and flowmeter data can communicate wirelessly with the control system, with countless advantages in terms of flexibility, ease of installation and start-up.

**Flow computers**

Centralised control stations collect, assimilate, and manage data received from all the instruments and devices present in the system, including flow computers and RTUs (Figure 5). The ability to access, assess and transmit flow rate, operational status, pressure, temperature and diagnostic information to central monitoring facilities is used to monitor the status of the measurement system at any time and provide early detection of any unusual behaviour. They can also incorporate the same information to provide actionable alerts indicating the possible root cause of degradation in measurement accuracy.

**Systems and lifecycle assurance**

New technologies can be very helpful, but they need to be well understood, in order to be properly used and integrated in a complete system (Figure 6). Experienced integrators and fabricators will have the skills and knowledge to properly design and engineer best practices associated with new technologies to enhance flow assurance, minimise maintenance intervention and enable remote information management.

Remote access to the system information enables collaboration with system fabricators, suppliers, subject matter experts and metrology services to improve lifecycle operability and reliability. Leveraging newer technology and expertise to augment or fill gaps in the lifecycle care programme will take this burden off the operator, who can then be confident in its system health throughout its lifetime.

**Conclusion**

Fiscal measurement systems are complex and, with regulatory requirements getting tighter, operators face more and more challenges on a daily basis. New technologies play an essential role in increasing overall accuracy, achieving consistent and reliable measurement, and providing better insight into system conditions. The result is improved overall fiscal flow assurance throughout the entire oil and gas value chain.