

Fiscal Measurement – Natural Gas

Fiscal Measurement – *How much?*

Fiscal Measurement must not be confused with Custody Transfer; in fact, fiscal measurement is a more general term meaning “measurement for money” that includes both allocation and custody transfer flow measurement.

- **Allocation** is the numerical distribution of products between parties according to their equity share.
- **Custody transfer** is contract driven: that means that there is a contractual obligation between buyer and seller which may require adherence to accuracy, repeatability, linearity or uncertainty standards as defined by measurement standards such as API, GOST (Russian equivalent to API), etc. Custody transfer need not imply change of ownership.

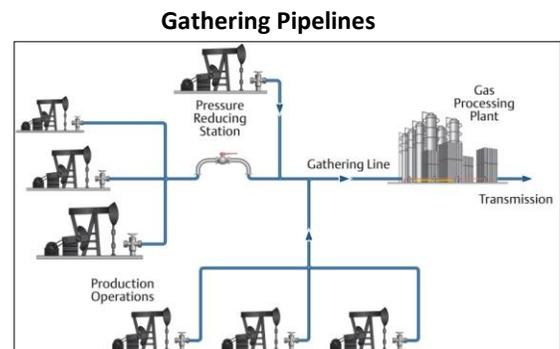
Gas custody transfer flow measurement can take place anywhere along the process value chain from the wellhead to delivery or sale location. The dynamics of where these transactions are actually located can be influenced by a number of factors with the two primary ones being regulation and commercial arrangement. However for the lowest uncertainty in measurement, custody transfer generally takes place at stable, predictable single phase locations or physical discrete hand-over points (e.g. platform/production exit location, pipeline entry/exit, terminal entry etc.). These locations generally provide the favorable conditions that flow measurement devices can operate predictably and repeatability.

In the recent years the importance of flow measurement has grown, not only because of its widespread use for accounting purposes due to escalation in material values, but also because of its application in several other aspects of upstream and pipeline operation such as leak detection systems, batch operation (for liquids only) and loss/gain balance. All of these applications constitute key elements for the operator who wants to maximize pipeline efficiency, and requires a very strict correlation with accurate and reliable flow measurement.

Background information – Natural Gas

The natural gas delivered to consumers is composed almost entirely of methane (CH₄). However, natural gas found at the wellhead, although still composed primarily of methane, is by no means as pure. Once separated during initial processing it commonly exists in mixtures with other hydrocarbons; principally ethane, propane, butanes, and pentanes. In addition, raw natural gas contains many other compounds such as water vapour, hydrogen sulphide (H₂S), carbon dioxide (CO₂), nitrogen etc.

Gas gathering systems and major transportation pipelines impose restrictions on the composition of the natural gas that can be shipped into the pipeline. Although not exclusive gas gathering systems usually focus restrictions on the amount of water and other contaminants such as H₂S, benzene, mercury, arsenic. Gas transportation systems, as these are post some processing, generally focus restrictions on quality factors such as CO₂, N₂ and overall Wobbe Index etc. This normally determines the location of a primary Custody transfer point as quantity and quality must be measured to determine these requirements.



Flow Measurement – General information

A complete measurement system is usually composed of many different parts:

- Pressure reducing lines with overpressure protections (it is important to stabilize the pressure and maintain it at a constant value to optimize the measure of the flow rate)
- Metering lines that can include control valves to limit the capacity per line
- Gas sampler or gas chromatograph (GC) to provide information on gas quality and composition
- Proving/calibration systems for the periodic check of the meters
- A data management and control system.

A large amount of instrumentation is associated with the various steps of the measurement process, and accuracy and reliability are very important to ensure that the overall system Uncertainty agreed within the contract can be achieved and maintained.

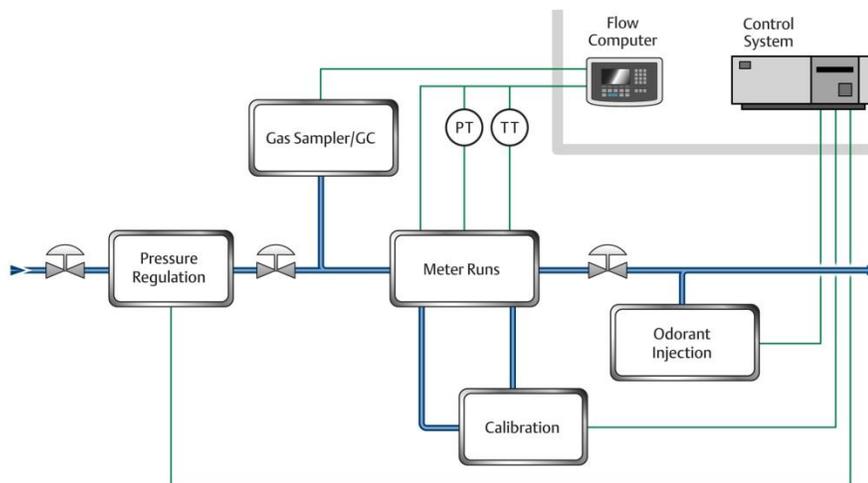
Measurement Uncertainty

All meters and metering systems are subject to uncertainty and it is a common mistake to mix accuracy and uncertainty as they are subtly different.

- **Accuracy** is matching the meter output to a known standard or reference and will include terms like bias, readability and precision, this can be considered the best estimate according to the scale of the measurement.
- **Uncertainty** is more related to repeatability and is an estimate of the limits where the true value is expected to lie for a given confidence level.

Fiscal measurement systems are typically driven by regulation (tax, royalty etc) and generally follow the same principles as a custody transfer system. A standard natural gas measurement system Uncertainty is $\pm 1\%$ of Energy, therefore to get within this value the other system components that combine to generate an Energy figure must be better than this.

To summarize with a simple schematic, these are the main components of a gas measurement system:



Compression Stations (Upstream production)

Natural gas is highly pressurized as it travels through a pipeline; as gas is a compressible fluid, the trend is to increase the pressure in the pipelines so more gas can be transported keeping the pipeline size constant. To ensure that the natural gas flowing through any one pipeline remains pressurized, compression of this natural gas is required periodically along the pipe. This is accomplished by compressor stations, usually placed at 40 to 100 mile intervals along the pipeline. The natural gas enters the compressor station, where it is compressed by either a turbine, motor, or engine. Siting is dependent on terrain, and the number of gas wells in the vicinity; frequent elevation changes and a greater number of gas wells will require more compressor stations.

In addition to compressing natural gas, compressor stations also usually contain some type of liquid separator, much like the ones used to dehydrate natural gas during its processing. Although natural gas in pipelines is considered 'dry' gas, it is not uncommon for a certain amount of water and hydrocarbons to condense out of the gas stream while in transit. The liquid separators at compressor stations ensure that the natural gas in the pipeline is as pure as possible, and usually filter the gas prior to compression.

Compressor station



Pressure Reducing

For delivery to the consumers the gas in the main trunk lines is depressurized to manageable levels. Usually metering lines are installed downstream of pressure reducing stations. This was mandatory years ago when flow computer technology was not so advanced; a constant value of pressure could greatly help to ensure a stable correction of the signal sent by the meter. Pressure reducing lines (usually at least two lines are present, one main line and one back-up) are composed by a main pressure regulator that will reduce the inlet value of pressure to a fixed value, and other equipment to ensure overpressure protections: monitor regulators, relief valves, slam shut valves. The choice of the devices to use to protect equipment and pipeline from overpressure problems can be regulated by national standards, or by customer internal procedures.

Pressure reducing lines usually includes filters and heat exchangers to improve the gas characteristics, eliminating dust, particles and hydrates that could damage downstream equipment.

Pressure reducing station



Meters

There are many different flow measurement technologies available in fiscal measurement; one of the first differentiators is measurement in volume or in mass. Volumetric measurements are called inferential as these types of meters can calculate the capacity by measuring another parameter, like for example the fluid velocity. Examples of volumetric meters are [Orifice](#) fittings, [Turbine](#) meters and [Ultrasonic](#) meters; [Coriolis](#) meters are an example of mass flow meters.

These are just some examples of the many technologies available for gas fiscal measurement; even if it's true that each technology will most certainly work at all given conditions, it is also true that not of all of them will give the maximum performances. The choice of the right technology to be used will depend on many factors: pressure, temperature, flow rate and range, gas composition and quality, accuracy and redundancy desired, component and installation cost, maintenance cost, required foot print and so on.

It's also necessary to take in consideration other important aspects linked to the characteristics of each meter; pressure loss, rangeability, requirements for flow conditioning, ability to deal with dirty gas or noise in the system, etc.

A complete knowledge of gas flow conditions must be understood before the right meter technology can be chosen and the meter station design can proceed.

Gas Custody Transfer meter



Odorant injection

Natural gas has no odor so it's mandatory to have it odorized in the event of a leakage as smelling of gas is one of the simplest leak detection systems. Odorant injection systems vary from simple and manual ones (i.e. absorption type) to complex and completely automated units where concentration ratio is ensured by a microprocessor based control unit, that will keep track of the liquid actually injected and automatically adjust the injection rate to keep the odorant ratio constant.

Gas Composition

Knowing the correct gas composition is an important factor in fiscal measurement: it is used to determine the latent energy content of the gas (that is the amount of energy that we will get when we will burn it), that is the final scope of the metering system. In addition to that, it's necessary to know if there is a presence of sulfur compounds, hydrogen sulfide and mercaptans (both natural and added as odorants); contaminants can reduce pipeline integrity, so their monitoring can be combined with energy measurements for complete custody transfer analysis. The physical properties are required for measurement so that quantity can be reported in the required units. Finally, gas characteristics are important to select all station main components, like filters, heaters, regulators, meters etc.

There are mainly two components installed on the field that can be used as an aid in determining gas composition: gas samplers, that collect a sample from the flowing line for transportation to a laboratory for analysis, and on line gas chromatographs, which separates the compounds in the system and reports the results.

A sampler is normally used where many lines are present, a lab is readily available and cost is an issue. A gas chromatograph is normally located on large gas stations with dedicated buyer use. The output may interface with the flow computer or HMI.

Gas Chromatograph



Instrumentation

In a measurement system many different instruments are installed; the more insight that is possible to have into the operating conditions of the system, the more accurate the fiscal measurement can be and less time and money will have to be spent in troubleshooting and maintenance. Accurate and reliable measurements of gas density, temperature, static and differential pressure will help the operator to make the right choices in the selection of the main equipment, to maximize the efficiency of the complete system and to localize better and faster possible malfunctioning or problems.

Proving / Calibration

A periodic calibration of the meter is necessary, as its performance can be affected by many things: change in physical properties (pressure, temperature, flow rate), mechanical wear, obstructions in the pipe, product build up and encrustations and so on. For all these reasons, meter performance must be regularly verified to make sure that repeatable results are consistent and traceable to an external reference. Meter calibration validates consistent meter accuracy, meter trending and provides traceable evidence of meter performance.

The simplest and cheapest ways of calibration is to ensure mechanical tolerances are compliant with the standard, i.e. Orifices Plate.

Another way of calibrating a flow meter is to put it in series with another flow meter of higher accuracy and to compare their readings. Calibrated master meter may be used to measure the flow in a pipe and to calibrate other meters. To achieve a check on the performance of a master meter they are often used in pair, either in series, so that the consistency of their readings is continually checked, or in parallel when one is used most of the time and the second is kept as a particularly high precision meter for occasional checks. After accumulated flow amount of standard flow rates, test results are calculated by comparing the reading of master meter and meter on test. Therefore, the performance of each meter could be determined.

Meters can also be sent to external laboratories that can provide calibration services. The 3rd party calibration facility will normally provide detail of the offset from the reference standard for the meter over the calibrated flow range. This known offset can then be applied as a correction within the flow computer.

3rd Party Calibration of gas volume meter is a costly operation, but it's necessary to ensure the high performances requested to the meter and to ensure that the system Uncertainty agreed can be achieved. Usually calibrations are scheduled at fixed periods (i.e. once per month), but there are cases in which an unplanned calibration seems necessary. It's important to reduce these needs as much as possible, as they are time and money consuming; one of the tools that can help in this is meter advanced diagnostic.

Troubleshooting

Flowmeters with advanced diagnostics, a feature that is now available for some meters, help the operator to be aware of potential problems in the meter and in the sensors (equipment wear, damage), but that's not the only outcome; they actually help with a number of other events that can occur during operations, in both fluid conditions or the pipeline itself. As an example, the operator could deal with entrained liquids, liquid accumulations, blockage (i.e. in the flow conditioner), pipe coating and so on.

Advanced diagnostics, together with the possibility to set actionable alerts once a specific problem has been identified, will help tremendously by offering an operational insight into pipeline parameters and measurement system health between two consecutive calibrations. No process shutdown will be required, so the customer won't deal with interrupted delivery.

Turnkey Solutions

As previously stated measurement stations can include many components: filtering, heating, pressure reducing, metering, odorizing, remote control. Civil works and electric plants are also often included.

There are many considerations to make during the design of a metering skid: available space (underground stations), spare lines, overpressure protections, automation and remote signals, different materials and technologies depending on gas quality, operating conditions etc.

In order to ensure the best performance of the whole measurement system in all its components, the solution for the customer would be to have one supplier for the design, manufacturing and supply of the complete system, thereby avoiding having to deal with many different sources. This will help to optimize the entire process without dealing with uncertain responsibilities in case something goes wrong.



Flow Computers

For custody transfer applications, flow computers (FC) are usually mandatory; they measure, monitor, and may provide control of gas flow for all types of meters. In volumetric flow measurement, the different types of meters will read different gas characteristics; the FC will receive a signal from the meter plus gas temperature and

pressure. In many cases, an algorithm is required to convert the reading into a flow rate. Since gas is compressible and affected by temperature, the gas temperature and pressure must also be monitored and compared to a specified standard temperature and pressure within the algorithm.

Next we need to calculate mass flow based upon the density of the gas. Since a natural gas stream contains a mix of various hydrocarbon gases of different densities and also some inert gases like nitrogen and carbon dioxide, the gas flow computer will require the entry of mole percentages for each gas component. Mole percentages must be determined via a gas sample analysis.

Based on accurate mass flow calculations it becomes possible, based upon the energy content of each gas component, to calculate energy flow, since each gas component contains different energy content. Energy flow metering is the ultimate goal, since this is where the true value is for the client. Also, these mineral reserves are taxed based upon energy content.

In addition to providing volumetric, mass and energy flow data, the gas flow computer also provides date and time, instantaneous, hourly and daily data. The gas flow computer typically stores date/time stamped volume records for up to 35 days in order to provide sufficient time for a host system to retrieve the records as well as to allow time for human intervention if this retrieval fails to occur.

Data Management & Control

Natural gas pipeline companies have customers on both ends of the pipeline - the producers and processors that deliver gas into the pipeline, and the consumers and local gas utilities that take gas out of the pipeline. In order to manage the natural gas that enters the pipeline, and to ensure that all customers receive timely delivery of their portion of this gas, sophisticated control systems are required to monitor the gas as it travels through all sections of what could be a very lengthy pipeline network.

To accomplish this task of monitoring and controlling the natural gas that is traveling through the pipeline, centralized gas control stations collect, assimilate, and manage data received from monitoring and compressor stations all along the pipe.

Most of the data received by a control station are provided by Supervisory Control and Data Acquisition (SCADA) systems. These systems are essentially sophisticated communications systems that take measurements and collect data along the pipeline (usually in a metering or pumping stations and valves) and transmit it to the centralized control station. Flow rate through the pipeline, operational status, pressure, and temperature readings may all be used to assess the status of the pipeline at any one time. These systems also work in real time, meaning that there is little lag time between the measurements taken along the pipeline and their transmission to the control station.

The data is relayed to a centralized control station, allowing pipeline engineers to know exactly what is happening along the pipeline at all times. This enables quick reactions to equipment malfunctions, leaks, or any other unusual activity along the pipeline. Some SCADA systems also incorporate the ability to remotely operate certain equipment along the pipeline, including pumping stations, allowing engineers in a centralized control center to immediately and easily adjust flow rates in the pipeline.

