

Fiscal Measurement – *How much?*

Fiscal Measurement should 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.

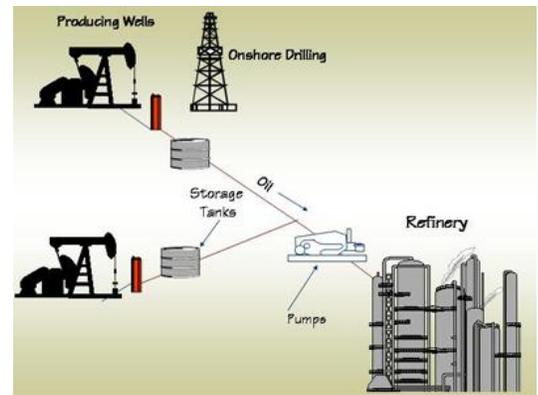
Custody transfer flow measurement can take place anywhere along the process value chain from the wellhead to delivery or sale location. The dynamics of where these transactions are actually located can be influenced by a number of factors with the two primary ones being regulation and commercial arrangement. 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 most favorable conditions that flow measurement devices can operate predictably and repeatably.

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 and loss/gain balance. All of them 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 – Oil

Petroleum or crude oil is a naturally occurring flammable liquid consisting of a complex mixture of hydrocarbons of various molecular weights and other liquid organic compounds, which is found in geologic formations beneath the Earth's surface. As fossil fuel, it is formed when large quantities of dead organisms are buried underneath sedimentary rock and undergo intense heat and pressure. In its strictest sense, petroleum includes only crude oil, but in common usage it includes all liquid and gaseous, hydrocarbons. At surface pressure and temperature conditions, lighter hydrocarbons (such as methane, ethane, propane and butane) occur as gases, while pentane and heavier ones are in the form of liquids or solids. However, in an underground oil reservoir the petroleum exists as a homogeneous fluid which, depending on the subsurface conditions, exists as gas or liquid.

Petroleum is recovered mostly through drilling of wells into the subsurface reservoirs. This comes after the study of structural geology (at the reservoir scale), sedimentary basin analysis, and reservoir characterization (mainly in terms of porosity and permeable structures) and estimation of the recoverable quantities in place. After extraction petroleum is then processed, most easily by boiling point, into a large number of consumer products, like gasoline, diesel, jet fuel, heating oil, lubricants, asphalt and chemical reagents used to make plastics and



pharmaceuticals. Gathering lines transport crude oil from several nearby wells to the treatment plant or processing facility. Today, major refined product pipelines currently move 100-120 distinct products compared with only 10-20 products in the 1960s.

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 measurement of the flow rate)
- Metering lines that can include control valves to limit the capacity per line
- Oil samplers to provide information on quality and composition
- Chemical injection systems to improve oil characteristics for transportation
- Proving systems for the periodic check of the meters
- A data management and control system

A large amount of instrumentation is associated to 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.

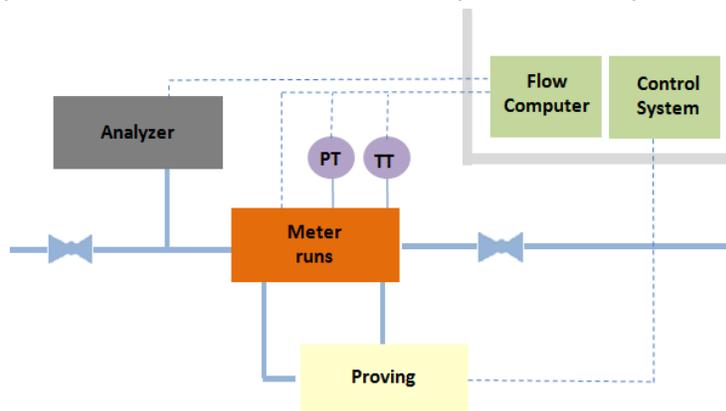
Measurement Uncertainty

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

- **Accuracy** is matching the meter output a known standard or reference and will include associated terms like error, 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.

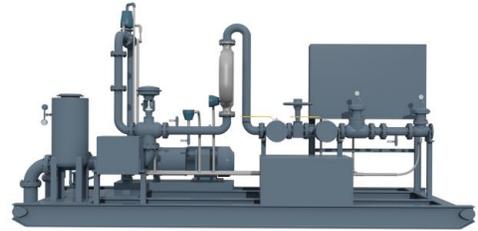
Fiscal measurement systems are typically driven by regulation (tax, royalty, etc.) and generally follow the same principles as a custody transfer system. A standard oil measurement system uncertainty is $\pm 0.25\%$ of Standard Volume; therefore to get within this value the other system components that combine to generate a Standard Volume figure must be better than this. Standard Volume is a volume at a known reference temperature and pressure; in the US this is normally 60 DegF and 14.73 psi.

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



'Automatic Custody Transfer' units (LACT Units)

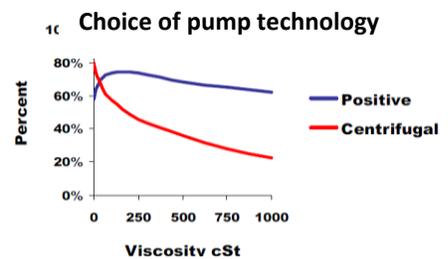
Automatic Custody Transfer units, also called Lease Automatic Custody Transfer or LACT units in some countries, are the final point of product transfer prior to pipeline transportation. Once the oil has been fully processed, it can be sold based on volume, oil grade, and quality. These 3 factors require that each parameter be considered in the design and operation of the LACT unit.



Since oil is sold as a net barrel there must be a meter to register volume and a device to measure temperature so the volume can be corrected back to a reference temperature. The quality of the oil is determined by sampling at set intervals and analyzing the sample to determine API gravity and basic sediment and water (BS&W) content. The corrected volume adjusted for S&W equate to what is called Merchantable Oil or Net Oil. Online BS&W monitors are often used to provide continuous monitoring of oil quality to provide data between samples.

Pumping Stations

Liquid products are propelled by pumps sited at the pumping stations, one at the origin and the others distributed along the line. There are several technologies that can be used, two of the most common ones are centrifugal and positive displacement pumps. The choice of the technology will depend on many factors, one of the most important is fluid viscosity; an accurate measurement of oil viscosity will help to choose the right pump and so to reduce the power consumption of the system, that is the largest pipeline operating cost.



The capacity of a pipeline can be increased by installing additional pumping stations along the line to raise pressure.

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 [Turbine](#) meters and [Ultrasonic](#) meters; [Coriolis](#) meters are an example of mass flowmeters.

These are just some examples of the many technologies available for oil fiscal measurement; even if it's true that each technology will most certainly work at all given conditions, it is also true that not 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, fluid composition and quality, accuracy and redundancy desired, component and installation cost, maintenance cost, required foot print and so on. It's 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 fluid or noise in the system, etc.

A complete knowledge of oil flow conditions must be understood before the fiscal measurement can be decided and the meter station design can proceed.

Back pressure Systems

Downstream of the flowmeter, relief valves or back pressure valves are usually installed to avoid overpressure problems in the line and to reduce the potential for cavitation through the meter.

Oil Sampler System

Knowing the correct liquid composition is an important factor in fiscal measurement as it gives the quality of the fluid, normally determined by a combination of API gravity, water and sulphur content and boiling point curves. In addition to that, it's necessary to know if there is presence of salt, sediments, sulphur, and general contaminants that can impact pipeline integrity, so their monitoring can be combined with energy measurements for complete custody transfer analysis.

Another important parameter for oil measurement is the water content: the quantity of sediment and water in crude oil must be established accurately as part of the custody-transfer process. Purchasers pay only for the crude oil received and want to minimize the quantity of sediment and water they must handle. Consequently, monitoring the sediment and water content is performed at the production site to prevent excessive amounts entering the pipeline system. How much a pipeline operator is willing to accept into its system depends on geographic location, market competitiveness, and its ability to handle the sediment and water in the system. Each pipeline publishes the quantity it will accept. Most pipelines require that LACT units be equipped with a basic sediment and water (BS&W) monitor, typically in a vertical rise of pipe. Most of the BS&W monitors in use are capacitance devices and generally detect only the amount of water present. BS&W monitors based on microwave technology are generally accepted as the optimum devices for this application,

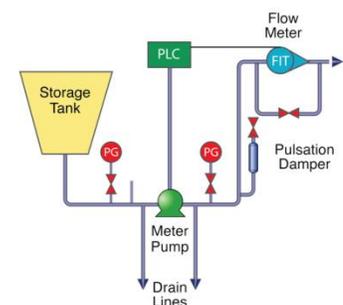
Usually a sample of the fluid is collected from the flowing line for transportation to a laboratory for analysis. There are also devices that vaporize the components and then analyze them like in a gas chromatograph (GC), normally for lighter fluids condensate like Natural Gas Liquids (NGLs) etc. To ensure that the sub sample is representative of the flow fluid, the sample location may have mixing equipment installed upstream of the sampling probe.

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 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. In addition to these parameters, the measure of viscosity is a very important unit for liquid transportation; a high viscosity can make the movement of the fluid in the pipe very slow and cause pressure drops due to high friction losses. Also, it's already been said that the correct viscosity will greatly help in the selection of the correct technology for pumping system, helping to reduce the total power consumption and reduce ownership costs.

Chemical Injection

When handling fluids with high values of viscosity, there are special components that can be added to the system to help reduce the viscosity and achieve the maximum capacity from the system. For example, it's possible to blend the fluid with a lighter, less viscous one to meet density and viscosity requirements, or add drag reducing agents (DRA). In both cases, the friction losses will be reduced and flow rate can be increased up to 100%. For pipelines where there is acidic conditions present from the dissolution of Carbon Dioxide in water corrosion inhibitors may be added.



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, density and viscosity), 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. Meter factors have huge impacts on company profits and operations: adjustments for incorrectly metered product are a cumbersome accounting procedure that is best limited by the selection of a meter which can show the least effect on its accuracy overtime.

A largely used method to check meters performance is Proving, which is based on the principle that to verify a meter throughput this must be compared with a known volume; the meter volume is then compared to the meter throughput and a meter factor is provided. Different meter factors will be established for each fluid type transported. Block valves are critical for meter calibration and calibration of prover unit; usually they are equipped with remotely operated electrical actuators with failsafe “stay in position”. There shall be automatic monitoring of the flow diverter valve in the prover unit.



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 the accumulated flow amount at 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 and a meter factor introduced if necessary.

Meters can also be sent to external laboratories that 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 meter k-factor correction within the flow computer.

Proving/Calibration of meters is a costly operation, but necessary to ensure the high performances required from 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 can 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 gas, accumulations of solids, 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, 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: metering, filters, chemical injection, remote control and proving systems. Civil works and electric plants are 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 fluid 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 flow for all types of meters. In volumetric flow measurement, the different types of meters will read different fluid characteristics; the FC will receive a signal from the meter plus temperature and pressure. In most cases an algorithm is required to convert the raw meter reading into a flow rate.

In addition to providing volumetric and mass flow data, the flow computer can also provide flow control signals and handle meter proving. Other parameters like intermediate calculations and date and time stamping of the instantaneous, hourly and daily data are all handled within the FC. The flow computer typically stores date/time stamped data records of the key parameters 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

Oil pipeline companies have customers on both ends of the pipeline - the producers and processors that input oil into the pipeline, and the consumers that take oil out of the pipeline. In order to manage the oil that enters the pipeline, and to ensure that all customers receive timely delivery of their portion of this oil, sophisticated control systems are required to monitor the oil as it travels through all sections of what could be a very lengthy pipeline network. To accomplish this task of monitoring and controlling the oil that is traveling through the pipeline, centralized control stations collect, assimilate, and manage data received from monitoring and pumping 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 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 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.