Gently down the stream

Flow measurement in the upstream, midstream and downstream oil and gas markets

by Jesse Yoder, Flow Research

The oil and gas industry, along with the chemical and water and wastewater industries, is one of the largest areas in which flowmeters are used. Both oil and natural gas need to be measured at many points within the process stream that starts with drilling and ends with the delivery of refined products to customers. There is also a need for many other types of instrumentation, including temperature and pressure transmitters and sensors, analytical equipment, level products and other types of measurement and control equipment.

Upstream

The oil and gas industry is sometimes divided into upstream, midstream and downstream segments. The upstream segment involves finding and locating oil and natural gas, drilling for oil and natural gas, and physically separating the components of the drilled fluid into oil, gas and water. Geologists use many techniques to detect the presence of oil and natural gas reservoirs. These include seismic surveys and testing, both on land and subsea. Other methods include collecting and analysing rock samples and the use of satellite imagery.

Once petroleum reserves are located with reasonable certainty, oil wells are drilled to locate the oil reservoir. Drilling rigs are used for this purpose. A drilling rig contains a rotating shaft that drills what is called a borehole into the ground and down to the desired depth. As the drilling occurs, steel pipe known as casing is used to prevent the sides of the well from caving in. This casing is held in place with cement. Drilling a well is a very complex process that requires serious attention to safety issues, due in part to the high pressures that exist underground.

Not all wells are equally productive. There are over one million oil and gas wells drilled in the world, with more than half of these in the US. However, many of these are low producing wells located on land. Subsea wells such as those located in the Gulf of Mexico are more expensive to drill but typically have higher flow rates, which means they produce more oil than their land-based counterparts. The Middle East doesn't have nearly as many wells as the US, but their wells are much more productive. For example, Saudi Arabia's Ghawar oil field has famously produced five million barrels of petroleum per day for decades, a figure which may never be surpassed.

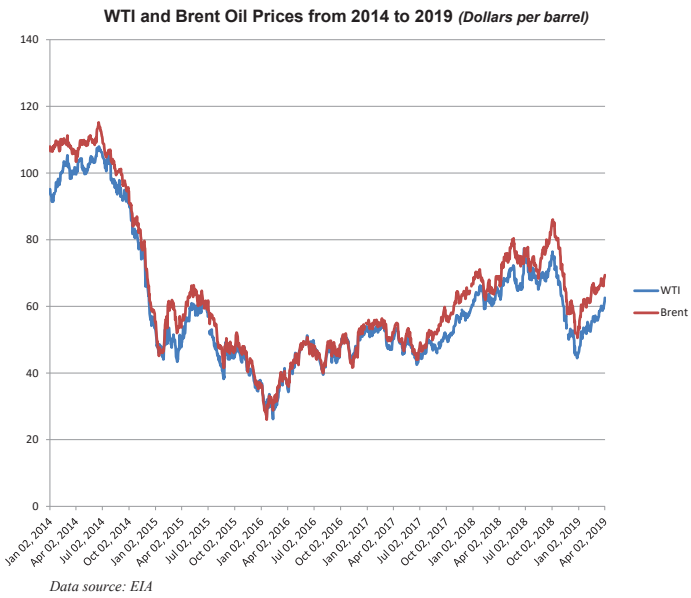
Once an oil well is completed and production begins, the fluid containing the oil is pushed to the surface by underground pressures. The fluid that reaches the surface of the well is typically a mixture of oil, gas and water. Once it reaches the surface, it is guided through a series of test separators and production separators that are designed to physically separate the oil, gas and water, and to send them to different destinations.

There are many opportunities for flow measurement in the upstream oil field. In some cases, multiple wells feed into a common flow stream and the amount of fluid from each well has to be measured. This can be an opportunity for custody transfer measurement, depending on the ownership of the different wells. Fluid is measured as it enters the separators and also as it leaves the test and production separators. Often these measurements are made with ultrasonic, differential pressure, or turbine meters. Coriolis meters can also be used for upstream measurements, but they perform better with liquids than gas and also have line size limitations.

Oil tanks near an oil field outside of Houston, Texas. Credit Flow Research

Midstream

The midstream section of the oil and gas process stream is where oil and gas is transported from the upstream oil field down to a refinery or gas processing plant. This can be done by pipeline, or by truck, railcar or ship. It also refers to the



West Texas Intermediate (WTI) and Brent Oil prices from 2014 to 2019

storage component of the process. Often crude oil that leaves an upstream oil field is not yet ready to be transported, so it's stored in large oil tanks until it is needed. One of the most famous storage areas for crude oil is in Cushing, Oklahoma, where about 90 million barrels of oil are stored.

Oil and natural gas pipelines are often the preferred method of transportation. Natural gas is transported from Canada by TransCanada through a vast network of natural gas pipelines to destinations in Canada and also to many regions in the US. These regions include many states in the northeast, with the pipelines extending south to the Gulf of Mexico.

Custody transfer of natural gas, especially for large natural pipelines, is one of the fastest growing niches within the flowmeter business. The main types of flowmeters used for this are ultrasonic, differential pressure and turbine. Ultrasonic flowmeters have been gaining market share because they are non-intrusive and they do not have moving parts. They are also highly accurate and typically meet industry guidelines for accuracy, provided they have three or more paths.

Crude oil and refined fuels often travel by truck or train to areas where pipelines are not available. Trains offer high speed delivery of crude oil throughout the US, although like pipelines, they don't go everywhere. With the advent of shale drilling and hydraulic fracturing, new areas such as North Dakota's Bakken region have been opened up for oil production. These are regions where pipelines may not already exist, or where it may not be possible to put in additional pipelines. Texas and North Dakota are leading the way for states using railcars to transport crude oil.

Trucks are also used because they can travel almost anywhere in the US, given the country's vast highways network. When it comes to refined fuels, trucks play a major role in delivering fuel to its point of use. Fuel oil is still typically delivered to businesses and homes that burn oil for heat, since it is often the only practical method of delivery available. Both positive displacement and Coriolis meters are used on these delivery trucks as part of an integrated system that includes pumps and valves.

Besides pipelines, trains and trucks, ships are playing an increasingly important role in the delivery of crude oil and refined products. Oil tankers carry crude oil to destinations that cannot be reached by pipeline or other means. Often oil tanks carry crude oil to refineries. Many ships from the Middle East pass through the Strait of Hormuz on their way to the US, Western Europe, Japan and China. The Panama Canal is another critical channel through which ships transport crude oil from the US to other destinations in North America and to Latin America.

Crude oil and refined fuels do not have a monopoly on the shipment of petroleum products by ship. Transportation of

A pumpjack in an oil field near Houston, Texas. Credit Flow Research

Large liquefied natural gas (LNG) carrier with 4 LNG tanks

liquefied natural gas (LNG) by ship is a rapidly growing and increasingly important part of the world's natural gas supply. To send natural gas by ship, it must first be transformed into liquid form, creating LNG. This is done through liquefaction, which cools the gas down to -162° C. During this process, the natural gas is reduced to 1/600th of its previous volume. The liquefaction takes place in a liquefaction plant and the natural gas is generally delivered by pipeline to the plant.

Liquefaction is a complex process and there are many occasions for flow measurement. The natural gas is measured as it enters the plant. Measuring the LNG at cryogenic temperatures places special requirements on flowmeters. The meter should have low pressure drop to avoid LNG vaporisation. It needs to be able to perform at cryogenic temperatures and should have no moving parts. In addition, an LNG meter needs to have custody transfer accuracy and its accuracy needs to be provable. The two types of flowmeters that most consistently meet these requirements are Coriolis and ultrasonic.

While many liquefaction plants are located on land, there are also floating LNG (FLNG) ships that contain onboard liquefaction plants. They are typically anchored offshore and produce LNG onboard that is ready to be shipped or transferred to land. These ships contain complex transfer hose systems that enable them to offload the LNG. One advantage of FLNG ships is that in a busy harbour without additional real estate, the vessel can anchor offshore and produce LNG without taking up valuable land space.

Once the LNG is transferred to a ship for transportation, it is stored in insulated tanks to maintain its low temperature. The ships are built using a double-hulled construction. Sometimes ships use the LNG they are carrying as a source of energy. Once the ship reaches its destination, the LNG is warmed to atmospheric temperature, turning it back into natural gas. This process is called regasification. Once the LNG has been regasified, it is often transferred to a pipeline. Alternatively, it may be transferred to a storage area. Just as liquefaction plants exist offshore on vessels, so regasification plants can exist offshore on barges or on land.

It is hard to overstate the importance of the growth in LNG transportation. China, Japan and many parts of Asia have very limited natural gas and oil resources. At the same time, the US, Russia, Western Europe and the Middle East have vast amounts of both oil and natural gas. Some countries are islands and simply cannot be reached by pipelines. While China has limited volumes of oil and gas, it does have vast coal reserves, but its use of coal has had severe environmental effects. Many Asian countries are consequently turning to natural gas as a source of fuel that is cleaner than coal and safer than nuclear energy. This is where LNG ships come into play. Qatar is the world's leading exporter of LNG.

Downstream

The downstream element of the oil and gas process stream is located downstream from a refinery or gas processing plant. Crude oil comes to a refinery via pipeline, railcar, truck or ship. At the refinery, the crude oil is converted into many different refined petroleum products, such as gasoline, diesel, kerosene, fuel oil and jet fuel. In many cases, these refined products are transported via pipeline to their next destination point. Trucks typically take over at the end to deliver the products to their point of use. This is often the case with gasoline and fuel oil.

Refineries offer many opportunities for flow measurement. There are many points of measurement within the refinery as the crude oil goes through the distillation process and is converted into various types of refined fuels. Much of this is intra-plant measurement, so custody transfer accuracy is not required. Ultrasonic, differential pressure, turbine and vortex meters are all used for flow measurement inside refineries. In some cases, steam measurement is required, which favours differential pressure and vortex meters. In addition, the crude oil entering the refinery needs to be measured and the refined fuels leaving the refinery are also measured. These are typically custody transfer measurements.

Natural gas processing plants form a parallel example to refineries. Instead of using crude oil as feedstock, they use natural gas. A gas processing plant 'cleans' the natural gas by stripping out the impurities and non-methane hydrocarbons to produce 'pipeline quality' natural gas. As part of this process, certain valuable natural gas liquids (NGLs) are recovered, such as ethane, butane and propane. These NGLs are sold separately and have a variety of uses, including enhanced well recovery.

Large liquefied natural gas (LNG) carrier with 4 LNG tanks

Industrial gases are composed of elements, compounds or mixtures. Common examples include nitrogen, oxygen, hydrogen and carbon dioxide. They are manufactured by a limited number of companies, including Air Products and Chemicals, Praxair and Air Liquide. Industrial gases are often delivered by truck or pipeline. Many are delivered in cylinders to the healthcare and retail markets. They are also used in manufacturing plants.

Natural gas processing plants offer many opportunities for flow measurement, as well as for temperature and pressure measurement. Natural gas is measured as it enters the plant, typically by means of a custody transfer measurement. As is the case with a refinery, many in-plant measurements do not require custody transfer standards. Flowmeters that perform well with gas flow, such as thermal, vortex, differential pressure and turbine, are likely candidates for in-plant flow measurement. Similar opportunities exist in plants that manufacture industrial gases.

What it all means

There are many opportunities for flow measurement in upstream, midstream and downstream oil and gas. This helps to explain why the flow measurement market declined in 2016, when oil prices went from over $100 per barrel in 2014 to under $30 per barrel in 2016. Many oil exploration and production projects were cancelled or put on hold, while the more expensive subsea projects were drastically curtailed. Oil and gas is one of the largest industries for flow measurement, so when these projects were cancelled or postponed, it resulted in fewer sales of flowmeters.

The reasons for the decline in oil prices are complex. Oil prices started declining in August 2014. The Organization of Petroleum Exporting Countries (OPEC) usually tries to keep prices relatively high by controlling production. In November 2014, however, OPEC decided not to cut production and let the market determine prices. The result was an oversupply of oil, relative to demand, and oil prices plummeted.

Oil prices remained relatively low for two years until OPEC met again in November 2016. This time the organisation agreed on production cuts with Russia. Oil prices then stabilised and began rising again in 2017. This helped the flowmeter market, but it seemed to take longer than anticipated for the positive effects to be felt in instrumentation. By comparison, in 2018 oil prices were in the $60–70 per barrel range and the flowmeter market had a banner year. This strong performance appears to be continuing into 2019 and will hopefully remain. While the end of the year appears somewhat uncertain from a macroeconomic point of view, 2019 is likely to be another strong year for the flowmeter market.

For more information:
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