Back in full swing

Jesse Yoder, Flow Research, USA, explores various methods of flow measurement in the oil and gas industry.

Measuring the flow of oil and gas is one of the most important tasks of the many different types of flowmeters. Oil and gas is measured upstream as it comes out of the ground, and in pipelines on the way to refineries and processing plants. It is also measured in refineries and process plants, and then again in pipelines downstream from those plants and on the way to utilities that deliver it to consumers and industrial plants.

Benchmark crude oils

While it has become commonplace to talk about 'the price of oil,' in reality there are more than 150 different types of crude oil, each with its unique name and characteristics. These vary by location, API gravity, sulfur content, etc. Four of these have come to be known as 'benchmark' oils because of their central role in determining crude oil prices. These four oils are known as West Texas Intermediate (WTI), Brent crude, the Dubai/Oman 'basket,' and the OPEC Reference basket

WTI is traded on the New York Mercantile Exchange. It consists mainly of oils extracted from Texas and surrounding states. WTI has a low sulfur content, and is light and sweet. It is transported from US oilfields to Cushing, Oklahoma, where it is refined. The price of WTI is a benchmark for oil sold in the US. Brent, by contrast, is extracted from oilfields in the North Sea near the UK and Norway. It is both light and sweet, but is slightly heavier than WTI. Brent is the benchmark for oil sold in Europe, Australia, Africa, and some Asian countries.

Dubai/Oman oil is a basket of oils from Dubai, Oman, and Abu Dhabi. It is heavier than WTI and Brent oil, and is slightly sour. Dubai/Oman oil is traded as the average price of oils from Dubai, Oman, and Abu Dhabi. It has become a benchmark for oil shipped to Asia. The OPEC Reference basket is a blend of oils from most OPEC countries, including Saudi Arabia, Iran, Qatar and Kuwait. Its value is determined by the OPEC secretariat in Vienna, Austria.

Oil prices since 2011

Figure 1 illustrates the price of WTI from January 2011 to October 2018. The per-barrel price of WTI crude oil remained mostly between US$80 and US$100 from 3 January 2011 until August 2014. Beginning in August 2014, oil prices began a steady decline from the US$100 level, continuing down to the range of US$30/bbl in February 2016. While some of the fluctuations in prices were due to the Arab Spring uprising, hurricanes in Louisiana, and other events that temporarily affected oil prices, the main driving force behind this decline was supply and demand; when world oil supply exceeds demand, prices tend to decline. When oil demand exceeds supply, oil prices typically rise.

Why oil prices declined

August 2014 marked an important change in the supply/demand equation. From January 2013 until May 2014, world oil consumption exceeded world oil supply. During this time, oil prices averaged in the US$90 – US$100/bbl range. In May, June and July 2014, world oil supply and demand were closely balanced, but in August 2014, the supply began to significantly exceed the demand.

There are many reasons for the daily and monthly fluctuations in the price of oil. However, when considering the oil price chart in Figure 1, the high point and the low point can both be explained by the effect of two OPEC meetings. In late July 2014, the price of WTI stood at just above US$100/bbl. Beginning in August 2014, WTI prices began declining, mainly due to supply and demand considerations. OPEC held a meeting in late November 2014, at which it discussed the decline in oil prices. By this time, oil prices had fallen to almost US$70/bbl. While OPEC has previously stepped in to control oil prices, it decided at this meeting not to reduce production. This policy remained in place for two years, during which oil prices fell to just above US$26/bbl, hitting their lowest point in January 2016.

In 2016, there was a great deal of discussion among representatives of Russia, Saudi Arabia, and OPEC members about the low oil prices. OPEC attempted to come to an agreement on prices in April 2016, but was unsuccessful. In September, the outlines of an agreement on production cuts emerged, and in November 2016, both OPEC and selected non-OPEC countries agreed on a production cut of nearly 1.8 million bpd. Oil prices consequently rebounded from the US$45/bbl range to above US$50/bbl. Since this time, oil prices have seen a slow but steady increase until 1 October 2018, when they rose above US$75/bbl.

Figure 1. The price of West Texas Intermediate (January 2011 – October 2018) (source: US Energy Information Administration [EIA]).

Natural gas: an attractive alternative

Many countries have made commitments to significantly reduce greenhouse gas emissions, and a commitment to renewable energy is often part of this plan. The problem with renewable energy is that it is still quite expensive and research into renewable energy is still in its early stages. For these reasons, natural gas is seen as a cheaper and cleaner alternative to oil. Natural gas supplies around the world are plentiful, and LNG has been developed as a viable way to transport natural gas in ships across the ocean. While there is no single energy source that can solve all of the world's energy needs, the use of natural gas is growing rapidly. Natural gas is seen as a bridge to renewable energy.

Measuring oil and gas flow

There are ten main types of flowmeters. Of these ten, seven play a major role in oil and gas flow measurement. Each flowmeter type is used for different types of applications in energy measurement, and each type has its own advantages and disadvantages. The following paragraphs describe the main types of flowmeters used in oil and gas flow measurement.

Coriolis

Coriolis flowmeters operate by measuring the degree to which fluid momentum causes a vibrating tube to deflect. This enables Coriolis meters to measure liquids better than gases, since liquids are denser than gases. Coriolis meters are widely used in refineries and petrochemical plants, and also for downstream applications. They are used to measure billing and custody transfer applications of refined petroleum products; here they compete with positive displacement meters.

Coriolis meters are both highly accurate and very reliable. Their main limitation is line size; they become very expensive and unwieldy in line sizes above 4 in. Despite their line size limitation, some Coriolis suppliers are now producing Coriolis meters for line sizes from 6 – 16 in. The large Coriolis meters are mainly designed for custody transfer applications in oil and gas, and compete with ultrasonic, differential pressure, and turbine flowmeters in these applications.

Ultrasonic

Ultrasonic meters measure flow by comparing the time it takes an ultrasonic signal to travel across a pipe when it travels with the flow, as compared to its travel time against the flow. Like Coriolis meters, ultrasonic meters are highly accurate and reliable, and they do not have moving parts. Inline models are used for custody transfer of both liquid and gas. Inline custody transfer meters have three or more ultrasonic paths or 'beams' that measure flow with high accuracy. These are called multipath meters. The most common multipath meters have four, five, or six paths, though some companies also make 8-path, 12-path, and even 18-path meters.

Besides inline meters, some companies also offer clamp-on ultrasonic meters. These have the advantage that they measure flow without cutting the pipe or interfering with the flow in any way. Ultrasonic transducers are clamped on to the outside of the pipe and send an ultrasonic signal through the flow to the other side of the pipe. While clamp-on meters cannot be used for custody transfer applications, their versatility makes them valuable for check metering and for temporary flow measurement. Flexim and Siemens are two main suppliers of clamp-on ultrasonic meters.

Vortex

Vortex meters measure flow by placing a bluff body in the fluid and then counting the vortices the bluff body generates. They are among the most versatile meters, in that they can measure liquid, gas, and steam with equal ease. Vortex meters are widely used for steam flow measurement, since they can tolerate both the high temperature and high pressure of steam applications. This makes them popular in the power industry, but they are also used in the oil and gas, refining, chemical, and other process industries.

Thermal

Thermal flowmeters measure flow by injecting heat into the flowstream, and then measuring how quickly this heat dissipates. They are almost exclusively used for gas flow measurement, though some are used to measure liquid flows. One main application for thermal flowmeters is measuring stack gas flows. Some measure flow at a single point, however, multi-point thermal flowmeters have been developed that measure flow at multiple points. These became necessary due to the large size of some of the smoke stacks whose flows they measure. Multipoint thermal flowmeters are often used today to measure greenhouse gas emissions.

Differential pressure

Differential pressure (DP) flowmeters measure flow by placing a constriction called a primary element in the flowstream. A DP transmitter is then used to compute flow based on the difference between upstream and downstream pressures. Orifice plates are the most common type of primary element. Others include Venturi tubes, flow nozzles, Pitot tubes, cone meters, wedge meters, and other types. DP flowmeters are probably the most studied and tested type of flowmeter. Their introduction in the early 1900s gave them a jump on getting industry approvals, especially for custody transfer of oil and gas.

DP flowmeters are relatively stable, but some of their primary elements such as orifice plates and Pitot tubes are subject to clogging. They also cause significant pressure drop, since they must create a pressure drop in the flowstream in order to measure flow. Venturi tubes and flow nozzles are used to measure high speed flows, including air flows. Despite their limitations, suppliers have introduced some important innovations in primary elements. These include multiple types of orifice plates, averaging Pitot tubes, and cone meters. McCrometer pioneered the cone meter with its V-Cone, but other companies are now producing them as well. DP flowmeters have a very large installed base, and will be around for years to come.

Positive displacement

Positive displacement meters operate by capturing the fluid in small compartments of known quantity, and then

Figure 2. An ultrasonic flowmeter installed in a line at the CEESI flowlab in Colorado.

Figure 3. A DP flowmeter installed in an oilfield near Traverse City, Michigan.

measuring how many times this is done. Types of positive displacement meters include oval gear, spur gear, rotary piston, diaphragm, nutating disc, and helical. They are used for residential, commercial, and industrial applications. Both diaphragm and rotary meters are widely used for gas flow measurement.

One main application for positive displacement meters is in downstream measurement of petroleum liquids, where they are used for custody transfer and billing applications. Here they are often part of a measuring system that goes on trucks to measure and dispense different types of fuel, but Coriolis meters are making some inroads in these applications. In terms of line size, positive displacement meters top out at 16 in., though most have line sizes of 10 in. or less.

Turbine

Turbine meters measure flow with a spinning rotor that spins in proportion to flowrate. They are approved for custody transfer of both natural gas and petroleum liquids. Like ultrasonic meters, they come in large line sizes of up to 42 in. and above. Both turbine and ultrasonic meters excel in measuring high speed gas flows, and both are widely used to measure the flow in large natural gas pipelines. Here ultrasonic meters are gaining an advantage because they do not have moving parts. The rotor in turbine meters is a mechanical device that is subject to wear. It can also be knocked out of calibration by impurities in the flowstream.

For large line sizes, some end-users choose insertion turbine meters over inline turbine meters. Insertion turbine meters are very effective in measuring flow in large pipes, but generally do not have the same accuracy as inline meters. They also have the disadvantage of measuring flow at only one point in a large pipe, which helps limit their accuracy. Even so, insertion turbine meters can be a very effective choice for non-custody transfer applications that do not require extremely high accuracy.

How oil prices affect the flowmeter market

All of the above flowmeter types are widely used in the oil and gas industry, but they are also used in the chemical, food and beverage, power, water and wastewater, and other process industries. Despite their wide use in all the process industries, oil prices have had a significant impact on the sales of all these types of flowmeters. Many of these flowmeter markets either declined or experienced very slow growth in 2015 and 2016 when oil prices dipped below US$30/bbl. This is because many oil and gas projects were either cancelled or put on hold, resulting in a reduced need for instrumentation. The market seemed to have recovered in 2017, though the recovery was uneven. In 2018, with oil prices in the US$70/bbl range, the flowmeter markets were back in full swing. It looks like 2019 will be a very good time for growth in the flowmeter market.