

Water Flow Monitoring and Measurement in the Oil & Gas Industries

Why is it Important to know the critical data when selecting a flow measurement device for your water flow application?

Background

To understand the importance of water flow monitoring in the oil and gas industry, we have to look into recent history. In 2002, Devon Energy acquired Mitchell Energy, which had drilled seven experimental horizontal wells. This signaled an acceptance of the new drilling practice: hydraulic fracturing. With the success of these wells, many other producers explored this new way of drilling and operations and began to shift from vertical drilling to horizontal drilling. In this article, we will explore two differences between vertical and horizontal drilling: the cost and the amount of water used. It is a significant issue, as, depending on the region and who is drilling a well, the cost can range from \$5 to \$9 million per well. A good portion of that cost is related to water.

In the article from OilPrice.com "*Fracking and Water: A New Way to Profit from the Industry's Biggest Problem*," written by Keith Schaefer, Feb. 14, 2013, the industry is using between 2 and 6 million gallons of fresh water per well and the industry cost of handling this water can and will run into the billions. In the Marcellus Shale, it cost \$3 per bbl to dispose of the water and \$ 7 to \$10 per bbl in handling fees. In the Eagle Ford, it is less at \$.80 per bbl to dispose of the water and \$3 to \$6 in handling fees. According to the EPA, based on the average of 35,000 wells being fractured each year in the U.S., the U.S. oil & gas industry fresh water consumption is estimated between 70 to 140 billion gallons per year. The industry spent more than \$18 billion in 2013 on produced water, making water transport, storage and produced water recycling a multi-billion part of the industry.

As the industry moved forward with horizontal drilling, the technology has improved on the down hole methodologies, thus improving the production capabilities as well as the life span of the well. It is now time for the industry to work on improving the topside and develop more efficient handling of fresh frac and produced water. This means more engineering, increasing efficiencies, decreasing costs, and a solid focus on safety, while maintaining stable productivity with minimum downtime. The question is: How this can be applied to the water side of the business? For years, the old saying in this industry "if it's not broke, don't fix it" became a standard of operation in the field. What that translates into is that many older technologies and processes remained in play in this ever-changing industry. Still today, you will see Turbine Meters used or using the pump rate for water flow monitoring. For produced water tanks, many still use the manual gauging standard in order to determine the amount of volume used.

Many companies are putting cost structures together and have determined that some of these outdated technologies and procedures to monitor and track the amount of water used or transported is not efficient enough. When companies hold fast to technologies past their prime they can expect to see water usage

accuracies of 5% to 10%. By implementing current technologies, companies will typically find that they can meet accuracies of water flow monitoring that are less than 1%.

When you consider the millions of gallons of fresh water consumed each year, this represents a substantial cost savings to the industry.

Areas to apply new technologies and procedures

Fracking a well

Most water used in fracking a well is fresh water. The water is taken from a natural resource (river, pond or lake) or impoundment. In many cases the natural resource or impoundment is close enough to the frac site that flexible lines are used with a mobile pump. The mobile unit pumps the water to the frac water storage tank or frac pit (similar to an impoundment) at the frac site. In this case, an electromagnetic flow meter is the technology best suited for this application, due to the ruggedness of the unit. Some manufacturers have incorporated battery-powered options while maintaining less than 1% accuracy, making the electromagnetic flow meter ideal mobile and remote applications.

From the frac water storage to the hydration truck, many regulate the amount of water used in each stage of fracking by monitoring the flow by pump rate or by a freight ticket provided at the time of delivery of the water. Electromagnetic flow meters or Coriolis flow meters can perform at very high accuracies, giving the operator better control and data of the amount of water actually used. This can assist the operator in offering superior inventory control of the water usage. This helps the operator to have better inventory control of the

water, so they can order a truck tanker just in time, avoiding the demurrage fees. These fees can be substantial depending on how long the truck stays on site waiting.

Produced Water Storage

A large cost of operation to a producer is the transport and handling of produced water. First, you have to know the interface between the water and hydrocarbon liquids. This is done through measuring the interface with technologies like Guided Wave Radar, Magnetic Restrictive Float, or can be measured by manual gauging. Once most of the liquid hydrocarbons are separated, the produced water is transported mainly by truck, rail or pipeline to an injection well site or to a water recycling facility. Money can be exchanged through several parties. Trucking companies, owners of pipeline, the owners of the injection well, recycling facility and the producer all have invested interest in ensuring the proper amount of produced water is transported. The question is: Which company has the best data? The company with the best data usually wins. For this reason, it is important for either party to protect themselves by using the most accurate technology to document the amount of produced water taken or delivered.

Interface and top level measurement with level instrumentation is very important for separation of the interface and level management of the produced water along with preventing overfills and cutting downtime. However, it can be tricky when calculating the volume of tank battery. If tanks are not properly maintained, sediment on the bottom can be several inches deep. This also changes the volume. Even more troublesome, the tank could become unlevelled from the shifting

of the foundation causing the tank to lean slightly to one side.

Manual gauging is not a proper way to calculate volume. Many issues come into play when converting a level measurement into a volume measure. Using a calibrated tape for manual gauging starts out with +/- 2" error, and, if the tape is not maintained it could be a lot worse. Every kink in the tape represents a 1/16" + in error. Temperature change alone can change the level of a static tank with expansion and contraction of the liquid and even the tank itself. Temperature change also changes the density of the produced water. To know the actual density of the produced water is virtually impossible without some type of instrument to measure the density. The density of the produced water can differ from well to well.

When looking to measure by volume or mass, one needs to have the correct technology for mass flow and volume measurement. Ultrasonic flow (also known as clamp-on), electromagnetic flow, and Coriolis flow all can provide high accuracy and are very low maintenance. The main difference between the three are slight variances in accuracy, functionality and price, but it does give a person the flexibility to choose the best technology based on their application, budget and other factors specific to their needs and wants.

Water Recycling

In Pennsylvania, water recycling of produced water is leading the way for the oil and gas industry. Other states with large shale plays like Texas, Colorado and North Dakota are aggressively moving in a similar direction. However, most produced water is still disposed by way of injection wells. Currently, Pennsylvania can't keep up with only recycling and with limited

injection wells in the state. Millions of gallons of produced water are being transported to other states, increasing the operational cost to the producer. By all accounts this is going to be largest growing sub-industry of the oil and gas. The recycling plants returns water for fracking at less cost than purchasing the water directly from a natural source. According to a lead project manager for a major midstream company, his cost of \$.30 per barrel for recycled water is much more cost-effective than \$.80 per barrel for fresh water from the owner of the water source.

Since we can expect new construction of many of the recycling plants, the two technologies that should be considered are the electromagnetic flow meter and the Coriolis flow meter. For existing plants that are being retrofitted and upgraded to improved accuracy of the plan, a project manager should consider the ultrasonic clamp-On flow meter if budgeting, downtime or time restraint is an issue.

Technology Comparison

There are many challenges to making a proper choice between technologies. An incomplete understanding of the capabilities and differences between flow technologies can make it a challenge for the decision maker. It is only human nature to choose what you're comfortable with. Budget can influence a person to select a technology based on pricing. The goal is to make sure whatever technology is selected qualifies as the best solution for the application. Once that is determined, other considerations will need to be addressed, such as maintenance, safety, ease of use, ease of installation, post sales service and warranty, and, of course, pricing. It begins with an

understanding of the available technology.

Turbine Meter: Inferential Technology

Used widely for years within the oil and gas industry for flow measurement. It is a very simple inferential technology. A liquid such as fresh or produced water impinging on the blades of the turbine cause the blades to rotate and with magnets fitted in the rotor assembly, and a flow reading is provided. In order to calibrate to the liquid being measured a K-factor of the liquid is entered into the operating parameters of the unit. For the unit to remain repeatable to this liquid the viscosity must remain constant. For fresh water, the viscosity remains constant; with produced water, a slight change in viscosity occurs causing errors in measurement.

Pros:

- Low purchase cost.
- Operators are very comfortable using this technology
- Accuracy +/- 0.2% to 0.5% and repeatable at +/- 0.5% to 1% if maintained properly
- Easily repairable
- Easy setup and calibration

Cons:

- Preventive maintenance is key to maintaining accuracy and repeatability
 - Maintenance may not be needed at the time of scheduled maintenance
 - Keeping an inventory of replacement parts is required
 - An improperly maintained unit will have increased inaccuracies that will go unnoticed, causing loss revenue

- Mechanical moving parts are subject to wear from particulates in water
- Unsuitable for dirty liquids
- Long inlet/outlet sections (10D/5D) required

This technology is suitable for fresh water applications but should not be considered as the best technology unless the source of fresh water is free of particulates. Due to sand, paraffin and other particulates found in produced water the Turbine Meter is not the best technology for measuring flow of produced water. The biggest benefit of using an inferential technology such as turbine meters for frac & produced water is the initial cost of the unit. However, the resources and inventory of repair kits to effectively maintain this technology negate the low cost benefit. If not maintained properly, the loss of accuracy and repeatability negates the benefit of accuracy.

Electromagnetic Flow Meters

The Electromagnetic flow meter is a proven technology and is the primary flow element for the Water and Wastewater Industry. It is now aggressively growing in the Oil and Gas industry frac water and produced water applications. With the addition of battery-operated electromagnetic flow meters, sensors can now be applied in very remote and harsh locations, while still providing the accuracy required. The base of the technology is Faraday's law. The coils in the sensor generate a consistent magnetic field. The liquid flowing through the sensor induces a voltage proportional to the flow velocity. With no moving parts the technology is virtually maintenance-free. At times, build-up may occur where pigging the line is necessary, but the flow meter does not have to be removed while pigging the line.

Pros:

- No pressure drop
- Short inlet/outlet sections (5D/2D) or less
- Insensitive to flow profile changes (laminar to turbulent)
- Accuracy of better than $\pm 0.2\%$ of actual flow over full range. Battery operated units are slight greater at $\pm 0.6\%$ but still remain well below any industrial or regulation requirement.
- No recalibration requirements. The verification of the flow and calibration can be done in the field without interfering with the process
- Bi-directional measurement
- No taps or cavities
- No obstruction to flow
- Not limited to clean fluids
- High temperature and harsh environment conditions: Ideal for remote locations
- High pressure capabilities
- Volumetric flow
- Typical battery-operated units can run 6 to 10 years without replacement of batteries

Cons:

- If coil or electrodes fails or does become damaged, the unit is beyond repair and will have to be replaced.

The long life span and the ability to maintain accuracy at a low cost of operation makes this technology best suited for measuring frac and produced water. However, since not all manufacturers are the same, some of the pros and cons may vary. For example, not all manufacturers carry an integrated battery-operated unit.

Coriolis Flow Meters

The Coriolis flow meter is a proven technology for hydrocarbon liquids and gas measurement, and is critical point of measurement for custody transfer. For water applications, the Coriolis effect does provide a higher accuracy than most other technologies. The largest advancement is the compactness of the unit, allowing the unit to be mounted in tight areas and on skids. The largest disadvantage is the cost of unit compared to other technologies.

Pros:

- Direct, in-line and accurate mass flow measurement of both liquids and gases
- Accuracies as high as 0.1% for liquids and 0.1% for gases
- Mass flow measurement ranges cover from less than 5 g/m to more than 350 tons/hr
- Measurement is independent of temperature, pressure, viscosity, conductivity and density of the medium
- Direct, in-line and accurate density measurement of both liquids and gases
- Mass flow, density and temperature can be accessed from the one sensor, and can be used for almost any application irrespective of the density of the process

Cons:

- Expensive; the larger the size, the greater the price difference between electromagnetic and turbine meters
- Many models are affected by vibration
- Current technology limits the upper pipeline diameter to 400 mm; and secondary containment can be an area of concern.

In simple, fresh frac water flow applications and flow measurement to and from produced water storage tanks, the Coriolis flow meter is not the most economical choice. With produced water recycling, there are a number of new and existing processes where the additives, treatments and conditioners in the water are measured. The Coriolis flow sensors have been proven in industries like water and waste water, petro-chemical and pharmaceutical, making the Coriolis flow meters the most logical choice due to the critical nature of accuracy and performance required for these produced water recycling applications.

Ultrasonic Clamp-on Flow Measurement

The Ultrasonic Clamp-on flow meter is a technology developed in the 1960s. The two technologies used in Ultrasonic Clamp-on flow metering are Doppler and Transit-time, allowing for the measurement of most liquids and gases. It is a non-intrusive technology that can be mounted for temporary or permanent measurement. Clamp-on flow meters are ideal for upgrading any water flow line without having to cut the line or stop the process to install.

Transit-time measurement is primarily used on 'clean' liquids that do not contain high percentages of solids or entrained air. Transit-time (or time-of-flight) meters are designed on the principle that sound travels faster when moving in the same direction as the flow and slower when traveling in the opposite direction. This technology measures the independent travel times of sounds transmitted in each direction between two transducers positioned upstream and downstream.

Doppler measurement, on the other hand, is used when gas bubbles or suspended solids are present in the fluid. The required concentration of gas bubbles or solids that dictate Doppler use will vary based on pipe size, particle size, and fluid velocity. This metering technique relies on the reflection of the sound energy off the bubbles or particles to create a Doppler shift in the fixed-frequency acoustic transmit signal. The frequency shift is proportional to the fluid velocity. For liquid applications that vary from clean to dirty due to process changes and pigging, one flow transmitter utilizing both Transit Time and Doppler transducers can be used to provide continual flow measurement during the process changes.

The advancement of Ultrasonic Clamp-On systems with Wide Beam Technology harmonizes the ultrasonic transducers to the pipe producing a stronger, stable, and coherent signal independent of the flowing medium and velocity providing improved accuracy and repeatability.

Pros:

- Easy installation; no need to cut pipe or stop flow
- Can be installed in harsh environments
- No pressure drop or energy loss
- Minimal maintenance; external transducers that do not require periodic cleaning
- Bidirectional flow
- Detects reverse flow and empty pipe
- Insensitive to outside noise with wide beam technology
- Field installation accuracy: +/- 0.5 – 3% of flow at <0.3 m/s (1ft/s) (Range dependent of Manufacture)
- Custody Transfer capability.

Cons:

- Not all manufacturers use Wide Beam Technology

The ultrasonic clamp-on technology could easily be used for fresh frac water and produced water applications. A dual channel transmitter including both transit-time and Doppler technology will ensure an uninterrupted flow measurement when particulates are present in the flow.

Conclusion

The oil and gas industry only consumes between 0.01% and 0.3% of fresh water in the U.S., but the transport, storage and recycling of the water has become big business and is becoming a large sub-industry of Oil and Gas. The question is what technology to use. A Coriolis meter can be 2 to 3 times higher in cost compared to electromagnetic flow measurement, but it can also provide a higher accuracy. On the other hand, due to some sediment and particulates in produced water, a flow line may need to be pigged, making the electromagnetic flow meter the better choice. With no moving parts in the line on an electromagnetic flow meter, the line can be pigged without shutting down the process to remove and reinstall the unit.

Other flow technologies are utilized in Oil & Gas for hydrocarbon liquids and gas, such as Vortex, orifice plates and V-cone. These technologies were not included in this article because for fresh frac water or produced water, these technologies are too expensive, are considered overkill, or do not provide a significant advantage of accuracy. Of the technologies that were presented, electromagnetic flow meters meet all the requirements of the industry and its regulations. They provide a lower operational cost and better accuracy (at less than 1%), and require less

maintenance. It has been an established, proven technology for billing; it is designed for remote locations and harsh environments, and can be configured to meet any corrosive condition of an application. The flow reading can be easily verified in the field and does not require recalibration. For these reasons, electromagnetic flow meters should be the primary choice when selecting a flow technology for fresh frac water and produced water applications.

For a company looking to upgrade or retrofit an existing flow line to gain accuracy and cut down maintenance without shutting down the production of the well, the Ultrasonic clamp-on flow meter is the right technology.

Sticking to the old field standard of "if it's not broke don't fix it" – and not utilizing the best available technologies - could actually be costing producers and other support companies millions of dollars. The best way to ensure you are using the best technology to meet all the requirements of the water flow applications and still provide a return on the investment is to evaluate the who, what, where, when and how's of the flow technologies. The best source to help in making the right choice is the manufacturer of these technologies, but do remember the same consideration is important for the manufacturers. Choose wisely.

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