Selecting Flowmeters to Provide Accurate Measurement of Biogas Flow and Composition

New technology overcomes measurement challenges

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With the increasing interest in renewable energy, more and more plants are being built to produce biogas from fermentation of biomass. Measuring biogas flow has historically been challenging, due to the gases' low pressure and water saturation, and the presence of corrosive hydrogen sulfide (H_2S). Now, new flow measurement technology is available, which provides the accurate measurement of biogas flow and composition necessary to promote efficient energy production.

Increasing interest in biogas

In the past, biogas was traditionally produced from digestion of wastewater treatment plant sludge and decomposition of landfill waste into landfill gas. Recently biogas has begun to be produced at a larger scale from other bio feedstock, for example, food waste, and agricultural (animal and plant) waste.

The biogas produced is generally used in combined heat and power (CHP) plants, providing heat that can be used for the fermentation process and electricity that can be fed into the grid. For example, by 2012, Germany had 7215 biogas installations, for a total of 2904 megawatts of electric power – about 3 percent of the nation's electricity. This figure is expected to rise around the world.

Biogas flow measurement requirements and challenges

Biogas contains 50-70 volume percentage of methane (CH_4), depending on the bio feedstock and process. The remaining volume includes carbon dioxide (CO_2) (30-50 percent), along with small amounts of H_2S, oxygen (O_2), and nitrogen (N_2). Biogas temperature ranges from slightly above ambient temperature up to 50°C (122°F). Pressures are typically 50-60 millibar (gauge) (mbar (g), or 0.73-0.87 pounds per square inch (psi).

Multiple flow measurements may be needed, for example, before and after the storage tank. To ensure the measurements are comparable, the volume must be converted to standard conditions. Temperature and pressure can vary slightly among measurement locations.

The producer must know the CH_4 content of the gas, because smooth and efficient gas engine operations in a CHP plant can only be guaranteed if the biogas has the right minimum CH_4 content. Since the CH_4 content of biogas can vary greatly, plant operators rely on continuous and reliable information about the biogas composition.

Flow measurement of biogas provides several challenges:

- The gas typically runs at low pressure. In general no pressure drop is allowed in the pipelines, so flow meters must be line size. Further downstream in the system the gas may be compressed to 100 mbar (1.45 psi).
- The biogas is saturated with water after the fermentation process. When the gas cools down after leaving the fermentation tank, 5-6 volume percentage of free liquid water may appear in the pipeline.
- Due to its molecular structure, H_2S is corrosive when dissolved in water, while CO_2 provides a strong damping to acoustic signals.
- Scaling of bacteria may occur in the flowmeter, generally <1 millimeter (mm).
- Process conditions can be variable. For example, when measurement is done directly after fermentation, sudden temperature drops can occur when new sludge is fed into the fermentation tank.

Options for biogas flow measurement

Demanding measuring parameters associated with biogas applications have definitely created a measurement challenge. Several technologies are available, including thermal mass, mechanical, vortex, and ultrasonic technologies. Orifice plates are generally not used because of the pressure drop they deliver.

Thermal mass flowmeter technology has historically been used for gas measurements. The problem with using thermal mass flow metering for biogas is that biogas is wet; when water is introduced, it skews the results, creating the potential for large measurement errors.

Mechanical meters are not really suited for the types of measurement needed for biogas. They tend to have turndown issues because the flows are so low; in addition, the need to measure gas and water together tends to throw mechanical metering off. This measurement is very pressure sensitive, and with mechanical instrumentation, there is substantial pressure loss.

Vortex metering has been more successful. However, one must be careful of how the frequency is picked up if the vortex device uses a membrane; water soaking the membrane shortens the life of the vortex measurement device. While there is little pressure drop, turndown issues must be considered. In addition, one cannot obtain a CH_4 content measurement with a vortex meter alone.

Ultrasonic measurement technology is particularly well suited to biogas applications because it guarantees a full transit without loss of pressure or any other negative effect on the flow, and it can cover a wide measuring range. Another advantage is that it can measure the CH_4 content, which can be calculated from the velocity of sound and the biogas temperature. This provides a better overview of the fermentation process, allowing for better control of the biogas. By connecting an additional pressure transmitter, the standard volume of the gas can also be calculated. This enables the gas volumes to be balanced through different stages in the process.

Ultrasonic flowmeters have traditionally been challenged by high damping of the acoustic signals by the CO_2 and by high water content. These factors, in combination with a high price tag, have limited their application with biogas in the past.

New technology shows promise

One new technology that shows promise is the KROHNE OPTISONIC 7300 Biogas, an ultrasonic measurement solution that enables online measurement of CH_4 content in biogas and landfill gas with 2 percent accuracy. The flowmeter can accurately measure biogas with high CO_2 content, saturated with water, or with free condensation water present. The meter's all stainless steel flow sensor body and titanium transducers resolve the problem of H_2S corrosion.

Figure 1 New OPTISONIC 7300C features integrated pressure and optional temperature sensor

The technology was recently applied on biogas at several wastewater plants, at which anaerobic digestion in biodigesters produces biogas, removes biochemical oxygen demand (BOD) from sewage, conserves nutrients (especially nitrogen compounds), and reduces pathogens. The biogas produced can be used as a supplemental heat or power generation energy source. Depending on the influent and the treatment facility's size and design, the resulting biogas flowing conditions can vary greatly from season to season and from plant to plant.

One example is the Ara Region Bern, ag (arabern) wastewater treatment plant in Switzerland, which generates renewable energy from biogenic waste and sludge. Using a CHP, the operator converts a portion of this biogas into electrical energy, producing 24 percent of its own power requirements. The heat energy released in the process is used to generate thermal energy. Another portion of the biogas is converted to natural gas quality biomethane in a treatment plant, which is then injected into the public gas grid.

The biogas mixture released in the process contains 65 percent CH_4. Other components include CO_2 (> 25 percent) and water (5-7 percent). Immediately following production, the biogas runs through various filters and is transported through a pipeline system to a gas storage tank, which then supplies the CHP's motor with energy.

Arabern needed reliable and accurate biogas volume measurement of the biogas flow from the digestion tower to the storage tank. This was a challenge, due to the very high moisture in the gas flow and its low pressure (about 35 mbar (0.5 psi). The application allows virtually no pressure loss, and also requires approval in accordance with the ATEX directive on protection against explosion (Zone 1).

Arabern reviewed several options for the measurement. Mechanical measuring devices could not be used, due to the gases' low pressure. The measurement stability of other ultrasonic devices was negatively affected by the moist gas and the high CO_2 content. They eventually opted for the OPTISONIC 7300 F flowmeter to measure the biogas. To increase the biogas mixture's flow velocity, the stainless steel pipeline was reduced from DN200 (8-inches) down to DN150 (6-inches) when installing the flow meter. The free measuring tube means no loss of pressure. The measuring instrument was provided in Ex-version, in accordance with ATEX.

Arabern also uses a KROHNE GFM 700 ultrasonic device for a bypass measurement. Another is installed in front of the flare stack, where it measures the flow of the CH_4 gas that is burned when the CHP is switched off.

The flowmeter provides precise flow measurement of the biogas produced on-site. The integrated calculation of the methane content in the biogas allows the operator to accurately determine the wastewater plant's energy production. The device provides reliable measurements in a pressure-sensitive environment and independent of the gas composition.

Another example is the Burghausen public utility company in Germany, which operates a sewage treatment plant and connected CHP plant fueled by digester (CH_4) gas. Sewage sludge is transported from the treatment plant to the digestion tower, where the residual solids are partially decomposed by microorganisms. The methane released in the process is then supplied to the biogas plant as an energy source.

To obtain accurate energy production information, the operator requires continuous measurements of the volume and energy flow of the gas transported from the digestion tower to the CHP plant. Despite two water separators installed in the pipeline, the exhaust gas was still very wet. The pressure of the gas was initially very low, 65 mbar (0.94 psi) and decreased over time to 20 mbar (0.29) psi, and then to an average of just 7-8 mbar (0.10-0.11 psi) with the installation of a low pressure system. The gas was also exposed to seasonal temperature fluctuations, which affected gas density.

The sewage treatment plant operator had already tried using a differential pressure device but stopped using it due to faulty measurements. They were skeptical about finding a measuring principle that would work with the existing parameters. They eventually tested a KROHNE OPTISWIRL 4070 C vortex flowmeter, a 2-wire device with integrated pressure and temperature compensation and conversion into energy. They reduced the pipeline from its original size of DN 50 (2-inches) to DN 25 (1-inch) to accommodate the recommended flowmeter size. The vortex device measures the operating pressure, temperature and volume flow, and then automatically calculates the CH_4 mass and energy flow. The instrument has a shut-off valve, so the pressure sensor can be replaced if necessary, even during operation – and without process intervention.

With the vortex flowmeter, the operator of the Burghausen sewage plant can now accurately test and demonstrate the sewage treatment plant's performance and energy production. Even though the system pressure following the conversion decreases to 7 mbar (0.10 psi) or even lower, and the gas is extremely wet, the device still measures continuously and provides accurate measuring results. The device has been running without interruption or maintenance for more than three years, and has measured more than 620,000 cubic meters (near 22 million square feet) of digester gas.

New ultrasonic and vortex flowmeters currently being installed

New ultrasonic technology, including the OPTISONIC 7300, developed by KROHNE, Inc., can now provide the kind of reliable and accurate flow measurement needed to advance biogas as an important strategic energy source. Test results indicate the technology can be used for biogas with a diameter up to DN200 with a CO_2 content up to 35 percent, and up to a diameter of DN150 with a CO_2 content up to 50 percent. Further testing is focusing on larger diameters. The technology is currently being installed on biogas applications at several additional sites in the Netherlands, Sweden, and Austria.

Now that the meter has received full compliance approvals for North America hazardous areas, including Class 1, Division 1 ratings, several customers there are deploying the products.

For additonal details on this meter click here:

https://krohne.com/en/products/flow-measurement/flowmeters/ultrasonic-flowmeters/optisonic-7300-biogas/

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