INSTRUMENTS INC.
Complex Technology Made Simple

Application Note

# Biogas
# A Wet Gas Environment for Thermal Flow Meters

## A Stark Comparison Between Thermal Flow Meters

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# Summary

In a recent project and the subject of this paper, Kurz engineers conducted a study that lead to a unique, new design that allows thermal flow meters to perform accurately within a wet digester gas environment. The testing environment applies to landfill and digester applications.

Thermal mass flow meters provide excellent measurement capabilities in dry gas flows. They have proven durability, accuracy, and repeatability. However, thermal flow meters are sensitive to liquid droplets in the gas stream. For a thermal flow meter to work accurately in the digester environment, the probe must be placed far enough downstream so that the entrained water in the gas stream has condensed onto the pipe wall. Optimal placement is typically not an option and, in the real-world, probes are inserted very close to the digester. In this very wet environment, any condensing liquid (commonly referred to as mist or fog) contacting the sensor probes causes a high reading due to the liquid vaporizing on the heated portion of the sensor. As a result of this deficiency, digester measurements with conventional thermal meters are largely ignored when moisture levels rise because there is no confidence that the measurements are true.

Developing accurate flow rate data allows wastewater treatment facilities to more precisely manage digester production levels, enabling tighter controls on methane levels and flaring. This can make facilities more efficient in meeting peak flow and load conditions, which vary based on population changes or wastewater sources. It is also important to monitor the gas coming out of the digester to ensure the digester health levels are optimally maintained and that greenhouse gas emissions can be accurately reported.

A sensor used to monitor the biogas output can provide an indicator to efficiency of the digester. Gas production is one of the best measures of the progress of digestion. Total biogas production is estimated from the percentage of volatile solids reduction. However, gas production can fluctuate over a wide range, depending on the volatile solids content of the sludge and the activity of the bacteria in the digester. In addition, excessive gas production rates sometimes occur during startup that can cause gas to escape.

# Biogas

Sewage treatment involves removing contaminants from wastewater and sewage (human waste, food waste, soaps, and detergents) to produce a safe fluid waste stream and a solid waste suitable for reuse (typically as fertilizer). Two processes are predominantly used to break down the waste:

- Aerobic digestion uses bacteria in the presence of oxygen.
- Anaerobic digestion uses bacteria in the absence of oxygen.

Anaerobic digestion occurs in tanks called "digesters." Within the tanks, the sewage is digested in a thermophilic process where it is fermented at 131°F (55°C), or it is digested in a mesophilic process at 96.8°F (36°C). Mesophilic digestion is the most typically used anaerobic process in sewage treatment facilities, and the digesters used in the mesophilic process are the focus of this report.

The sewage within the digester is called "sludge." Bacteria is added into the digester where it breaks down the sludge. During this time, the sludge goes through four stages of reaction where complex proteins and sugars are broken down to form more simple compounds such as water, carbon dioxide, and methane:

1. Hydrolysis, where particulates are made soluble, and polymers are converted into monomers.
2. Acidogenesis, where the monomers are converted into volatile fatty acids.
3. Acetogenesis, where volatile fatty acids are converted into acetates, carbon dioxide, and hydrogen.
4. Methanogenesis, where acetates are converted into methane and carbon dioxide, while hydrogen is consumed. Variation in influent flow and organic loads can affect the balance between acid fermentation and methanogenesis.

Biogas from anaerobic digestion contains about 60 to 70 percent methane ($CH_4$), 25 to 30 percent carbon dioxide ($CO_2$), and small amounts of nitrogen ($N_2$), hydrogen ($H_2$), hydrogen sulfide ($H_2S$), water vapor, and other gases. The water vapor percentage depends on the gas temperature and is usually saturated or at 100% humidity.

The digester gas is collected, compressed, excess moisture is removed, and then further cleaned in a scrubber. The cleaned gas is sent to engines or fuel cells used for generating electricity and for heating the boiler jacket water (for steam or hot water). Many large sewage treatment facilities use digester biogas to run the facility, keeping their power use from the grid at a minimum.

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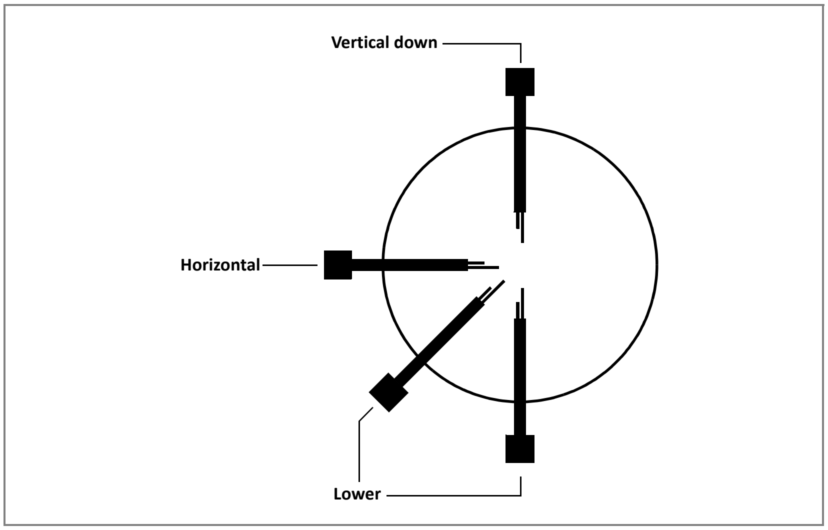
# Test Configuration

The tests were performed over several months using the Kurz 454FTB, Kurz WGF, and a constant power thermal mass meter (CPA) from a major manufacturer. Each meter was placed within a 6-inch pipe in the three primary installation locations:

- Vertical down position (from 12 o'clock)
- Horizontal position
- Lower position (45-degrees up or vertical up)



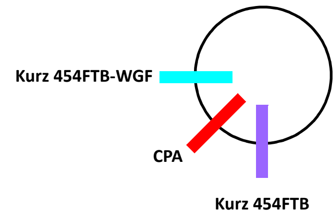

**Flow Meter Positions**

The sensors were calibrated to read volumetric gas flow in standard cubic feet per minute (SCFM). The probes were inserted close to the digester in a very wet environment.

In the following graphs:

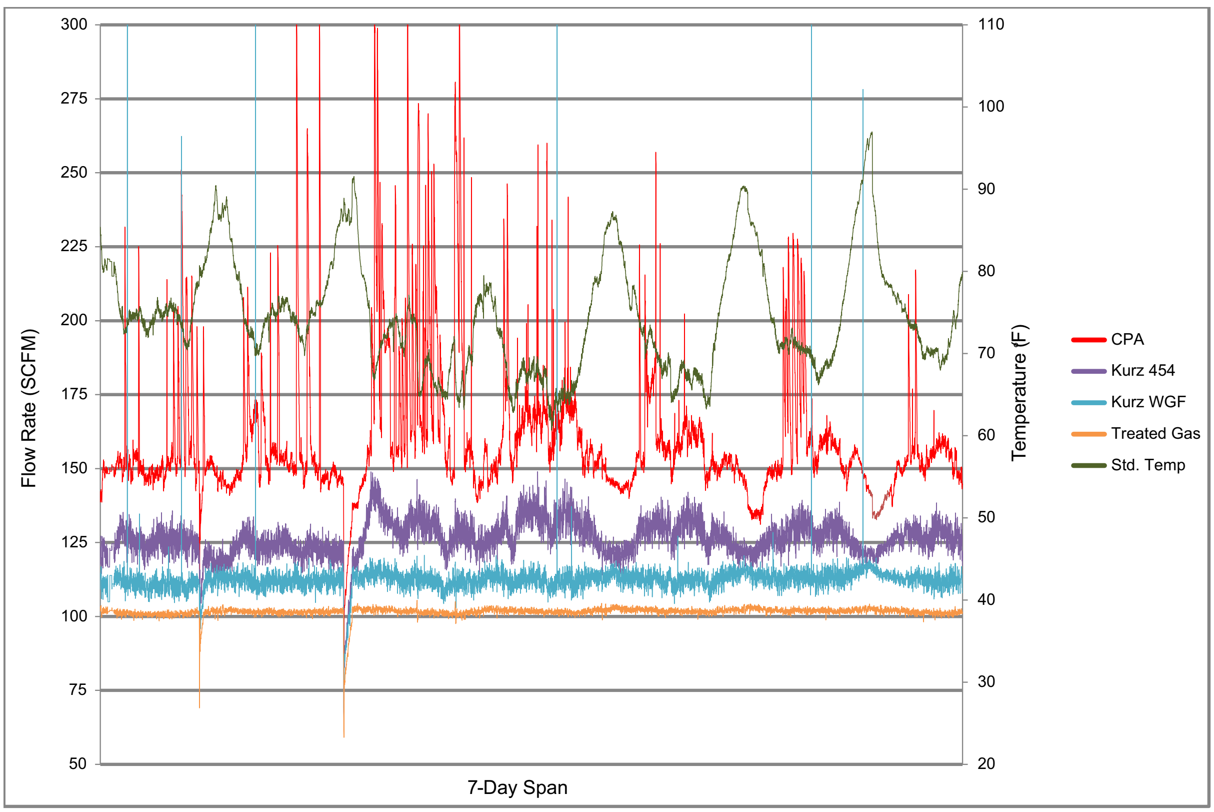
- Treated Gas has been cleaned to remove water vapor so the flow rate can be accurately measured as a dry gas. All other measurements are in a wet gas environment after the digester.
- Std Temp indicates the temperature sensed by the reference probe.

In the first test, the Kurz WGF was placed in the horizontal position, and the Kurz 454 and the CPA device were placed in the lower positions. The Kurz WGF maintained very steady measurements with only occasional spiking.




It was during this test that Kurz engineers determined that within the lower positions (45-degrees up and vertical-up) provide the optimal installation point. However, while the vertical-up position is the ideal location to avoid liquid migration onto the sensor, any corrosive gas constituents (such as $SO_2$) collecting at the bottom of the pipe can corrode the probe.

In the 45-degree up location, the probe support is outside the range of the wet flow stream buildup at the bottom of the pipe. The angle of the probe uses gravity to prevent liquid water from migrating to the sensor. As shown, the CPA device in the optimum location continuously spiked and provided a higher-than-true flow reading.



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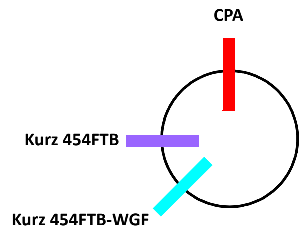
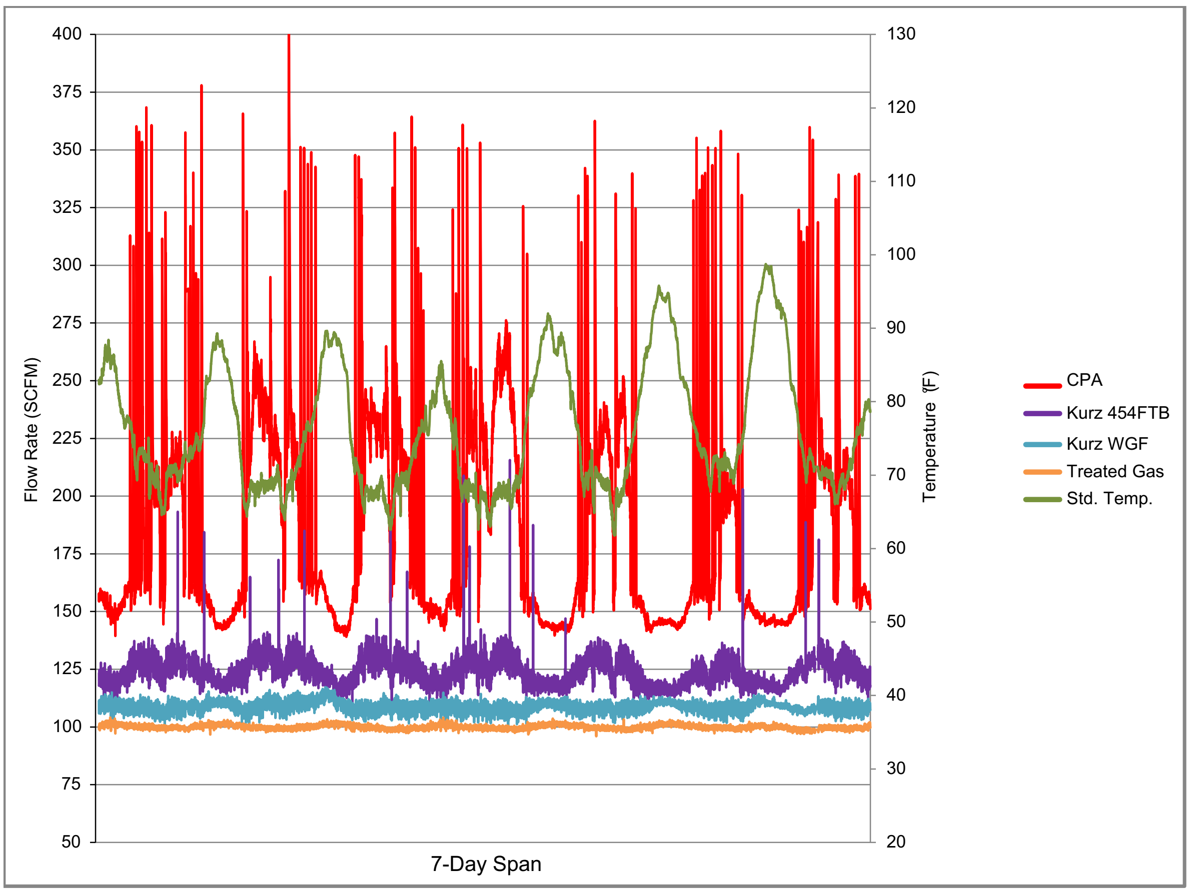
In the second test, the Kurz WGF was placed in the optimal lower position, the Kurz 454 in the horizontal position, and the CPA device in the vertical-down position. As expected, the CPA device in the vertical-down position performed extremely poor with spiking high flow readings. The Kurz 454 performed better in the horizontal position than when the CPA device was in the same position. The Kurz WGF outperformed all flow meters maintaining very stable measurements with no spiking.



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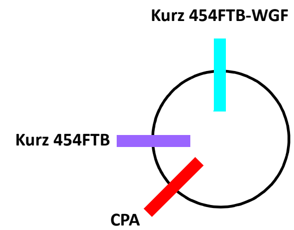
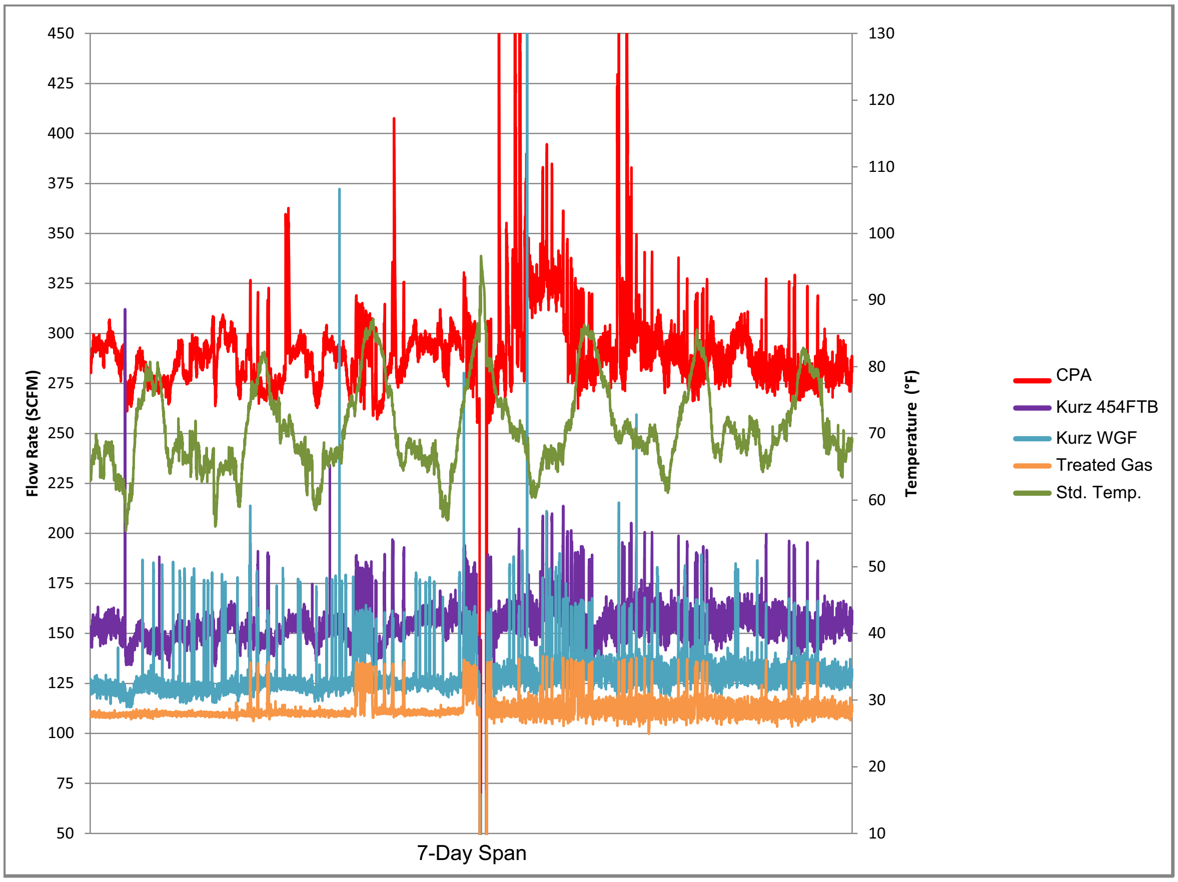
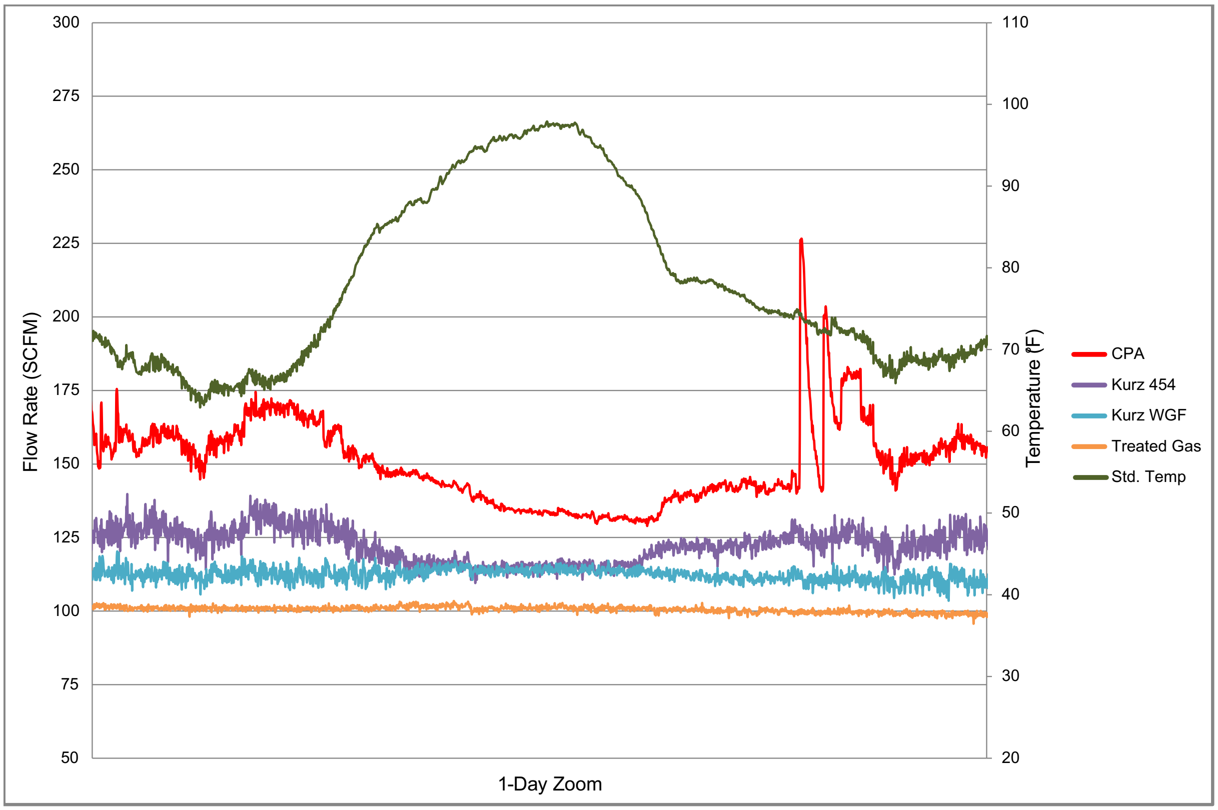
In a third test, all flow meters experienced fluctuations due to 70°F temperatures creating a denser fog in the digester flow stream. The Kurz WGF in the worst position remained highly consistent with the treated gas readings, while the CPA device provided erratic information in the best position.



As shown in this magnified data sample, only during the heat of the day when condensation in the pipe is lower are the Kurz 454 and Kurz WGF flow meters finally matching the treated gas levels. At all other times, the Kurz 454 and particularly the CPA device are unable to cope with the higher levels of fogging that occur due to changing temperatures.




As demonstrated in all graphs, the Kurz WGF outperformed the other thermal flow meters in its realtime monitoring capability of the wet gas flow from the digester. In all positions and at all points throughout the day, the Kurz WGF consistently remained steady with the dry total of the treated gas, and the flow meter maintained a totally accurate reading compared to the dry reading after the cleanup skid.

# Conclusion

Wastewater facilities have had few choices for obtaining accurate flow measurements in the wet gas environment. The economics and limitations of available technologies have lead many sites to accept substandard information in monitoring the effectiveness of digester operation. By ignoring the long-accepted deficiency, these sites are missing the ability to increase efficiency. The patent-pending design of the Kurz WGF flow meter creates a new level in realtime monitoring capability for the wet gas environment that has never been available.

Thermal flow meters produce high readings and spiking from liquid water condensing out of the process gas stream and from water droplets migrating onto the sensing element. As the temperature decreases, more water condenses out of the gas causing a standard thermal meter to read high, then spike and eventually rail given enough water.

The tests confirm that the Kurz WGF flow meter provides highly responsive measurements in a biogas environment. The Kurz WGF consistently and accurately tracks the dry gas in a wet gas flow with water migrating onto the sensing element causing only infrequently brief spikes. The tests also revealed the importance of sensor placement in a wet gas flow to reduce the impact of liquid on the signal.

By improving digester management, wastewater facilities have the opportunity to improve their efficiency and decrease operation costs.

- Accurate and realtime digester measurements can show indications of digester imbalances, enabling early corrective action and leading to increased gas production.
- Optimizing the digester process allows a facility to recover maximum digester gas.
- Monitoring the true gas flow can facilitate less gas being diverted to the flare and more directed toward energy production.

Additionally, when greenhouse gas laws are enforced, site operators will be positioned to report emissions with lower and more accurate numbers. For sites implementing electrical generators, a wastewater facility can become self-sustaining in power usage and potentially become profitable by selling excess electricity back to power companies.

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