MEETING DEMANDS AND MOVING FORWARD





Dr Neil Bird, Fluenta, UK, explains how advanced digital technologies can provide an algorithmic solution to ultrasonic flare meter specification and be game-changing for predictive flare gas measurement.

The environmental spotlight on the oil and gas industry is intensifying with gas flaring facing increased scrutiny for its significant contribution to greenhouse gas emissions, requiring accurate and reliable measurement to comply with environmental regulations to limit its impact.

Flare gas is one of the most challenging mediums to measure due to its highly variable composition, often containing high levels of carbon dioxide (CO_2), methane (CH_4), and hydrogen (H_2), extreme temperatures, fluctuating atmospheric conditions, and wide-ranging flow rates which pose limitations for traditional measurement methods such as pressure, thermal mass, optical, or Coriolis mass flow meters.

In face of these unique measurement challenges, ultrasonic flow measurement has emerged as a preferred technology for flare gas measurement thanks to its accuracy and agnostic nature to the varying process conditions.

However, ultrasonic measurement is not without limitations and the need to accurately predict the performance of an ultrasonic flow meter for a set of process conditions remains an area of development.

Challenges in predicting ultrasonic meter performance

In an ultrasonic flow meter, a pair of transducers, positioned either side of the pipe, send and receive ultrasonic signals across the gas flow and use the time-of-flight principle to determine the flow velocity.

This method of measurement copes best with the variable characteristics of the flare gas. However, when it comes to gas composition, certain gases within the flare gas mix have unique ultrasound absorption characteristics. Much of the published foundational research on this topic dates to post World War II and new studies are nearly non-existent.

For example, the presence of CO_2 or H_2, which are commonly referred to as difficult gases in large concentrations, could affect the measurement. CO_2, for instance, absorbs ultrasonic energy, leading to signal attenuation or complete loss, while the high speed of sound in H_2 complicates signal reception due to signal reflection.

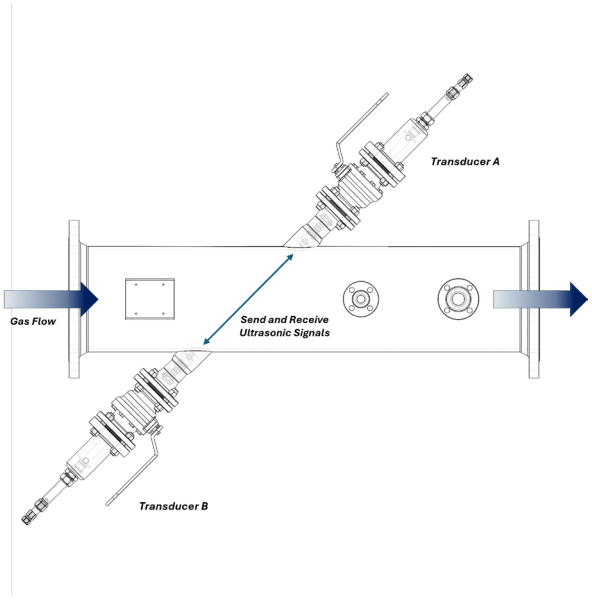


Figure 1. The principle of time-of-flight in ultrasonic measurement.

The increasing momentum to limit the impact of greenhouse gas emissions is driving a rise in carbon capture, utilisation, and storage (CCUS) projects, and a shift to using hydrogen as an energy storge and transport mechanism in many countries, including the UK. Such initiatives are some of the contributing factors leading to larger volumes of CO_2 or H_2 becoming more prevalent in flare gas applications.

In 2022 alone, over 140 new CCUS projects were announced, boosting storage capacity by 80% and capture capacity by 30%. These projects are now seen in over 45 countries globally.[1] In the UK, the government has rolled out a hydrogen strategy with one of its aims to generate 5 GW of low-carbon hydrogen production by 2030.[2] Similar initiatives are present in other European countries.

Laboratory measurements to evaluate ultrasonic flow measurement performance can only cover a limited range of gas compositions, making it difficult to predict the performance of a transducer in real-world scenarios. Fluenta's facilities allow testing in air or CO_2 and air mixtures, but not in gases such as H_2, CH_4, or hydrogen sulfide (H_2S), etc., due to their unsafe, explosive or corrosive nature. This limited ability to perform tests in the range of gas compositions found in flaring is common across all testing houses, and limits technology development and performance verification.

To understand the ultrasound absorption characteristics of difficult gases, technology manufacturers typically rely on data from existing installations and limited external testing to predict the capability of their systems for specific flare gas scenarios. However, this data cannot cover every possible combination of conditions, leading to less-than-optimal confidence in predicting the accuracy in higher concentrations of gases like CO_2 or H_2.

To address this challenge, Fluenta has developed a predictive model that helps its engineers determine the measurement accuracy of its transducer range across any combination of gases and other parameters.

A leap forward

After five years of development, FlareSpec is Fluenta's solution to determining the flow meter's performance against a set scenario, such as handling difficult gases or extreme temperatures, in advance of commissioning. This physics-based model predicts the performance of Fluenta's own transducers without extensive physical testing, helping operators meet their operational, safety, and environmental goals.

The solution leverages advanced algorithms and machine learning processes to assess the exact dispersion and transmission characteristics of any combination, in any concentration, of up to 20 different constituent gases commonly found in flare gas.

The model also takes into account various parameters such as pipe size, temperature, pressure, and the transducers' characteristics to match the operating

mode of an installation. As new data points are entered into the system, the model uses these to further refine the algorithm.

Using the input data, FlareSpec calculates absorption of the ultrasound by the process gas, factoring in the characteristics of the transducers and the ultrasonic signal processing implemented in the Fluenta flare meter. The resulting figure-of-merit confirms whether the system can reliably measure the gas flow.

Using this ability to incorporate data from real-world measurements helps to bridge the gap created by the lack of testing data.

The solution allows the user to accurately predict the in-situ performance of the proposed flare meter solution for any range of likely process scenarios, from very low flows during normal operation, to extremely high flows during abnormal conditions and everything in between. This essentially de-risks the choice of solution and provides the certainty that operators are increasingly seeking in this highly regulated industry.

Testing predictability with CO_2

CO_2 presents a unique challenge in ultrasonic applications due to its high attenuation of ultrasonic signals. Attenuation refers to the reduction in the amplitude and intensity of the ultrasound waves as they pass through a medium. This attenuation is particularly pronounced in CO_2 because of its specific molecular properties and behaviour at ultrasonic frequencies.

One primary factor contributing to this high attenuation is the molecular structure of CO_2. As an asymmetric molecule composed of one carbon atom and two oxygen atoms, CO_2 has distinct vibrational modes that readily absorbs ultrasonic energy. When ultrasonic waves propagate through CO_2, the energy from the ultrasonic signals is absorbed by the resonances of the CO_2 molecules. This resonance causes the molecules to absorb more energy, converting it into internal molecular vibrations, rather than allowing the waves to pass through effectively. This process is similar to pushing a child on a swing at the right frequency, which increases the swing's amplitude.

Practically, this means that CO_2 is a superb analogue with which to test a predictability model such as FlareSpec. The safety of the gas, combined with the presence of both Sigma and Pi bonds within the covalent structure, along with other unique characteristics that hinder the effectiveness of ultrasonic measurement, mean that testing the model against real-world data gives a great insight into the model's accuracy and effectiveness.

The significance of reference measurements

A crucial aspect of testing is obtaining reference measurements. These measurements establish the maximum percentage of CO_2 that a system can handle for a given pipe size before it becomes ineffective. This data point is essential to assess and calibrate the physics model to make accurate predictions for any combination of 20 gases typically found in flare gas, without needing to measure each individually.

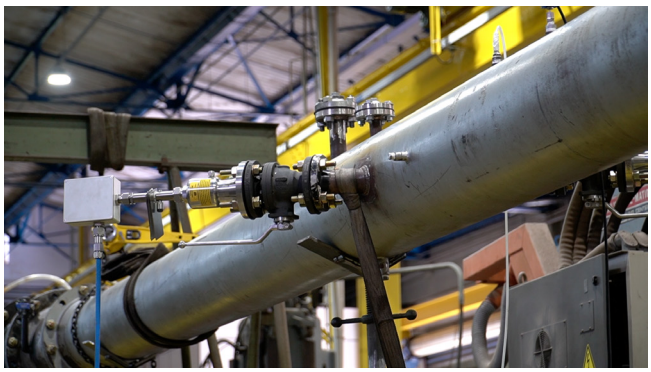


Figure 2. Fluenta's FlarePhase transducers tested in a gas mixture of up to 100% CO_2 at IPT Brazil.

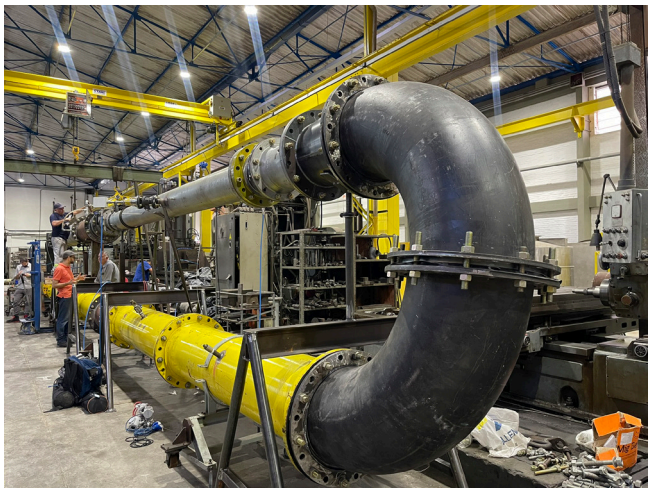


Figure 3. A 20 in. flow loop constructed to test Fluenta's CO_2 measurement capabilities.

Extensive reference measurements were conducted in Fluenta's lab in the UK, where the system was tested with mixtures of up to 94% CO_2 in combination with air, providing a host of data points for comparison with the predictive model.

To go beyond 94% CO_2, more industrial facilities were required. These were conducted in a series of tests at IPT labs in Brazil, where the system was able to produce stable and accurate flow measurements with a mixture of 99% CO_2 and 1% air in a 10.5 in. pipe.

To achieve this, IPT constructed a 20 in. flow loop facility to validate Fluenta's internal measurements. This CO_2 loop featured a 20 in. dia. pipe with spool diameters ranging from 12 to 20 in. The maximum flow reached 16 000 m³/h, with linear flows of 68 m/s for the 12 in. pipe, 42 m/s for the 16 in. pipe, and 27 m/s for the 20 in. pipe. The loop included a heat exchanger to stabilise gas temperature and a real-time analyser and gas chronometer verified CO_2/air mixtures up to 100% CO_2.

Impact on the industry

Confidence in technology choice and investment

FlareSpec's model enhances decision-making by de-risking the technology selection process for operators.

By accurately predicting the performance of proposed solutions, the technology enables operators to specify the optimal ultrasonic measurement solution modelled for their specific site conditions.

This level of assurance is invaluable in an industry where accuracy and reliability are paramount. As the oil and gas sector embraces digital transformation and moves towards a digital future, developments like this can exemplify the benefits of digitisation. They enable accurate and reliable measurements, fostering greater operational efficiency and better-informed decision-making.

Facilitating regulatory compliance

As stated earlier, the regulatory landscape for methane and flare gas emissions is tightening globally.

For example, in the US, regulations such as API 14.10 and 22.3 set specific requirements for flare gas measurement and are gradually being adopted in other territories. The EU is banning routine venting and flaring, restricting non-routine activities, and requiring detailed chemical breakdowns of emissions. And in Nigeria, operators must log daily all gas produced, consumed, delivered, flared, vented, or lost. These examples illustrate the increasing regulatory pressures.

FlareSpec helps operators meet these evolving requirements by ensuring the optimal solution is chosen for measurement, supporting the provision of reliable data for regulatory reporting and compliance.

Conclusion

It is crucial for new solutions to leverage advanced predictive modelling and machine learning in order to address the complex and variable nature of flare gas systems in ways traditional methods cannot.

In an industry where accuracy and reliability are critical, advanced technologies will be a game-changing tool.[5]

As regulatory pressures increase and the demand for environmental responsibility grows, digital tools will be essential in helping the industry meet these demands and move toward a more sustainable future.

References

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2. UK Government, UK hydrogen strategy. [Online]. GOV.UK. Last Updated: 14 December. https://www.gov.uk/government/publications/uk-hydrogen-strategy/uk-hydrogen-strategy-accessible-html, (2021).