OPTIMISING THE ENERGY VALUE CHAIN

Gerard Bottino, Panametrics, a Baker Hughes business, France, maps out the challenges in metering and monitoring key medium throughout the LNG value chain.

Given the current geopolitical situation and in order to address the energy trilemma, ensuring that energy is available, affordable, and sustainable, gas in general – and LNG in particular – will continue to play a pivotal role. LNG is meant to be a critical component of the energy mix for the next couple of decades according to studies from the International Energy Agency,[1] among others. With the market being rebalanced with the war in Ukraine, more investments are required to sustain the demand.

The liquefaction processes need to be optimised for best possible energy usage combined with the lowest possible carbon footprint. The same applies to the regasification plants.

Obviously, the critical assets remain the compressors that are now available with improved efficiency, higher yield, and lower methane emissions. However, flow measurements are also contributing to the same objective.

Panametrics, a Baker Hughes business, began deploying its flow measurement technologies to LNG plants in the late 1990s – the company now has significant experience in the LNG sector. The company's long track record can be attributed to the quality of measurement technology used, ultrasonic transit time. The flow meter uses one or more pairs of transducers featuring encapsulated piezoelectric crystals. They are alternatively transmitting and receiving ultrasonic signals. The transmitting transducer crystal is 'excited' by a voltage from the meter electronics and sends an acoustic pulse which travels into the fluid to the opposite receiving transducer which captures the pulse and transforms it into a voltage for computation.

Imagine that this acoustic pulse goes upstream, or against, the flow (green arrow on Figure 1), and the travel time is identified as time up or tup. Alternatively, the receiving transducer now becomes the transmitting transducer and the other one the receiver. This acoustic pulse now goes downstream and is carried by the flow (orange arrow on Figure 1) and the travel time is identified as time down or tdn. The acoustic signal that goes with the flow is accelerated while the acoustic signal that goes against the flow is decelerated. This generates a time difference which is directly proportional to the velocity of the fluid being measured. This technique is accurate whether it is gas, steam, or liquid.

The flow velocity is calculated from the following equation:

$$V = \frac{P}{2 * \cos\theta} * \left(\frac{1}{tdn} - \frac{1}{tup}\right) = \frac{P}{2 * \cos\theta} * \left(\frac{\Delta t}{tdn * tup}\right)$$

Where P is the length of the acoustic path between the transducers coming with a Θ angle to the centre line. The primary measurement is therefore time which will determine the velocity of the fluid based on the distance between the transducers and the required angle to generate this time shift. The rest is pipe geometry related. Once the velocity is known, it is then multiplied by the cross-sectional area of the pipe to get to the volumetric flow Qv with a meter factor k, as per the equation:

$$Qv = k * V * CSA$$

It should be noted that pressure, temperature, viscosity, nor density are part of this simplified equation. The measurement needs to be taken from a fully developed flow profile, meaning that there is a requirement for straight runs of pipe before and after the measurement point to ensure the measurement taken is representative. The number of required straight runs varies depending on the type of medium (liquid or gas), the required accuracy, and the number of measurement paths.

Flow measurement technology

Where is this flow measurement technology used and why?

There are multiple flow measurement points where Panametrics technology is frequently deployed – feed gas, acid gas, fuel gas, lean gas, dry gas, boil off gas (BOG), nitrogen, flare gas, LNG, condensate, water, etc. – this article will focus on just a few.

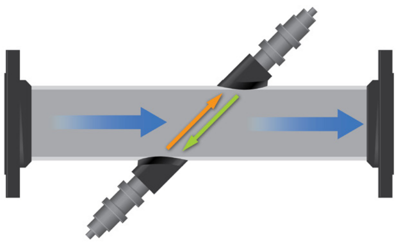

Figure 1. Ultrasonic transit time working principle.

Following the liquefaction process, raw gas is measured as the main feedstock entering the plant. It is handled at medium to high pressure and is dried before passing through the different refrigeration stages to become LNG. Using ultrasonic transit time, flow metering technology presents several benefits. The measurement is not prone to drift over time as it uses an accurate internal clock and has nothing to wear and tear over time, making it reliable and accountable. It is energy efficient since it does not generate additional pressure loss with no obstruction to the flow beside one of the equivalent straight pipes.

Once the gas is cooled down to approximately -160˚C to move to its liquid phase, it is often handled close to its vapour pressure point to limit the energy usage to just what is required to get there. When the liquefaction process is complete, the LNG is stored in dedicated tanks, and finally loaded into LNG vessels to ship to the customers. The absence of pressure drop helps in preventing any risk of local flashing of the LNG due to its liquid to vapour ratio of 1:600. This means that when even a droplet of LNG flashes, it may cause measurement challenges – a single liquid droplet turning into gas will occupy 600 times the volume that of LNG. Keeping it fully liquid is therefore key. The ultrasonic transit time flow meters have proven their reliability and robustness in many of these applications, for line sizes ranging from 4 in. up to 44 in. (the biggest LNG flow meters Baker Hughes has ever manufactured).

With the volume of LNG energy traded and the corresponding value at stake, it is also needed to understand how accurate these meters can be. During the last decade, there were extensive European Metrology Research Programs led by the Dutch VSL (one of the National Metrology Institutes). These three research projects, spanning over 10 years, resulted in the construction of a fully traceable and accredited mid scale LNG flow calibration facility in Rotterdam, the Netherlands, to verify and validate flow meter performances. The research programmes also led to a new ISO standard, the ISO 21903-2020.[2] Multiple tests were run at the facility to experiment and validate flow meters' metrological performances. For example, some tests were used to assess the water to LNG calibration transferability. This was done by calibrating the flow meter on water and thereafter inserting it into the LNG flow loop and checking the measurement error without changing the water calibration factors. This was an important outcome, especially when the volumes involved across the LNG sector are considered – the calibration facility can flow up to 400 m^3/h, an LNG tanker loading or offloading is more, flowing in the dozens of thousands of m^3/h.

There is a long-lasting measurement standard available for LNG, widely used and recognised globally in the industry, the International Group of Liquefied Natural Gas Importers (GIIGNL), now in its 6th edition from 2021.[3] It is very valuable and used in multi-year contractual agreements between sellers and buyers. However, it only deals with static measurement to calculate the LNG volume and ultimately the energy transferred with the gas gross calorific value and the gas density, with the subtraction of the energy being displaced, the BOG.

Boil-off gas in LNG facilities

BOG is a fundamental element in all LNG facilities, and it is required to get an accurate energy transfer determination –

every time there is LNG movement, there must be a gas phase flow going into the capacity from where the LNG is pumped out. This is part of a safety process to prevent the so-called roll-over. The BOG is sent in the opposite direction in a cryogenic gas phase. This BOG while at cryogenic temperature is handled at low pressure. Whether in the cryogenic liquid phase or in the cryogenic gas phase, these are sweet spot flow measurement applications for ultrasonic meters.

When going to the regasification terminals, while the overall process is simpler, the same applications are present. LNG is offloaded from the LNG carrier to be stored into large, dedicated storage tanks onshore or onboard FSRUs. It is common to cross check using ultrasonic flow meters what is being measured and calculated by the tank level gauges onboard the vessel (following the GIIGNL standard), by the ones from the receiving terminals, and what has been flowing through the lines feeding the storage tanks. These offloading lines can be quite large, as mentioned before. It makes sense to have such checks, since depending on the vessel trim, tank strapping, and other factors, just a few millimetres of height represent significant LNG volumes and could lead to measurement errors on these large tanks.

The LNG is then pumped from the storage tanks and put at a higher pressure before going to the vaporisers to feed the gas grid. These vaporisers use sea water that can also be measured with ultrasonic transit time meters. Commonly, the sea water lines are made of fibreglass pipes given all the technical and economic advantages they bring. There are ultrasonic liquid flow meters here as well, typically clamp on meters allowing measurements to be recorded from outside the pipe and that are easy to install and maintain.

And of course, at the end of the LNG value chain, there is the gas outlet to the gas grid, where there is also a key measurement point because of the change of ownership from the regasification terminal owner to the gas grid operator. This takes it back to the gas phase and close to ambient temperature like the typical natural gas supply conditions.

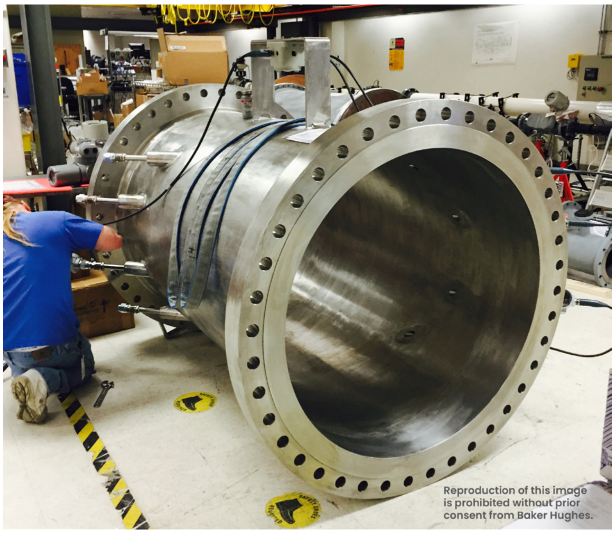

Figure 2. 44 in. four path LNG flow meter under assembly in Baker Hughes' workshop.

Flare measurement

Last and not least for ultrasonic transit time flow technology in LNG plants is flare measurement. While available for almost four decades now, it is increasingly important to not only properly record the flare flow rate, but also to monitor and control greenhouse gas emissions, instead of using a reporting method that is often empirical. Panametrics developed, some six years ago, a flare solution to meet this gap in the market, mainly driven by more stringent regulations and increased carbon taxation. This is particularly relevant when the combustion at the flare tip is not complete. An incomplete combustion leads to the release of methane not being fully burned and therefore escaping into the atmosphere. This is a serious concern because the global warming potential of methane is far worse than carbon dioxide. Looking at a 100-year time scale, this is 25 times more harmful vs carbon dioxide and 84 times on a 25-year time scale. This is the reason why carbon dioxide equivalent is heard about more and more rather than carbon dioxide to account for the methane slip and its environmental impact.

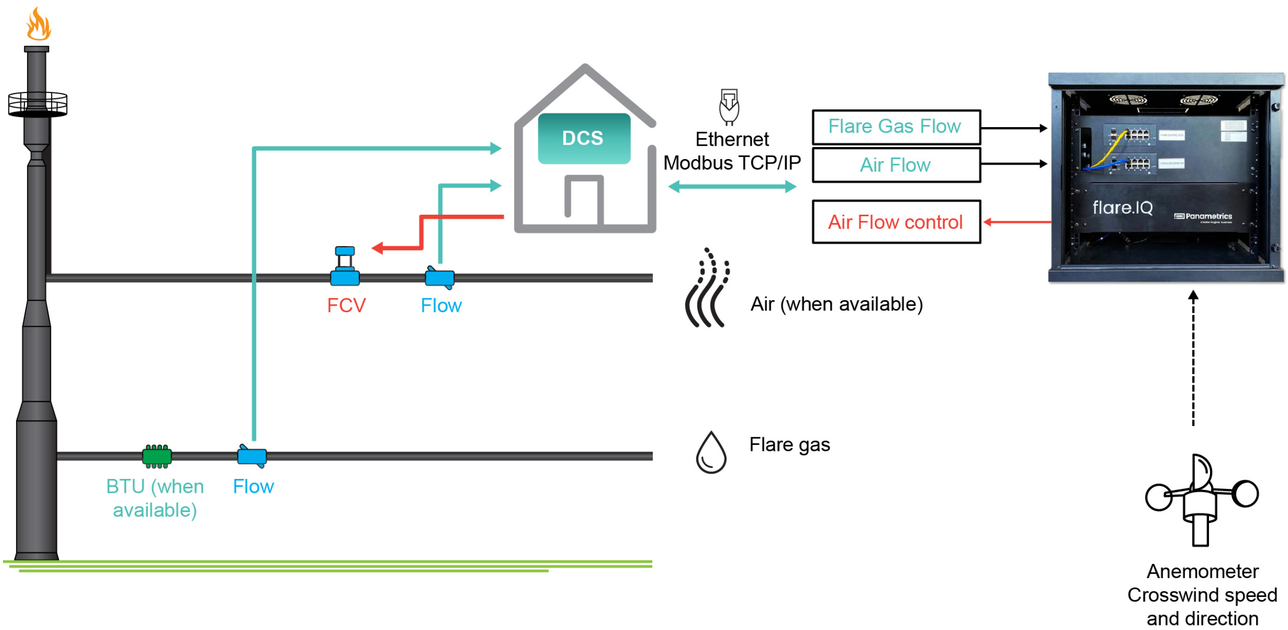

Figure 3. flare.IQ live monitoring and control typical layout on a LNG plant for carbon emission reduction.

This parametric solution needs to have a flare ultrasonic flowmeter installed on the flare line as a pre-requisite, as well as other available data coming from the existing infrastructure of the asset, such as cross-wind speed and direction, flare flow rate, flare gas speed of sound (always available from the flow meter), and if used at site, air or steam flow rate. The data is collected by the plant digital control system – no changes here. The data will then be communicated to the company's industrial computer that comes pre-programmed as per the asset's existing infrastructure via Modbus TCP/IP communication. The computation runs and refreshes every few seconds to feed the customer control system with all the required data for live monitoring and reporting: combustion efficiency; destruction and removal efficiency; carbon dioxide; carbon dioxide equivalent (coming from an incomplete combustion leading to methane slip into the air); carbon monoxide; and volatile organic compounds.

Fit-for-purpose solutions

Having a good combustion and destruction efficiency requires the flared gas to have a minimum net heating value in the combustion zone at the flare tip. On LNG facilities, either liquefaction, storage, or regasification, the net heating value is high since they deal with a high proportion of methane. However, sometimes, the flares are air assisted and the air flow rate sent at the tip may be too high, leading to reduced efficiency, hence much higher than expected, and potentially also reported carbon emissions. Panametrics' 'flare.IQ' is another fit-for-purpose solution that has started to be deployed in LNG plants.

Since the pipelines in LNG plants are often insulated (cryogenic plants are always insulated), there is a common requirement for flow measurements to have transducers online retraction capability in the unlikely event of a transducer failure. It is therefore required to be able to service the meters while in operation to prevent very costly unplanned production outages. Whether it is a gas flow meter at normal temperature range, a BOG meter at cryogenic temperature, or LNG, it is always possible to replace the transducers online safely without the need to interrupt the flow. Although a failure rarely occurs (the mean time between failure of these transducers is more than 100 years), however, for operators the introduction of the online solution de-risks the process completely.

As the world manages through the energy trilemma, flow meter technology is providing the LNG sector, and indeed virtually every industry on the planet, with accurate and reliable data. This is helping operators to maximise efficiencies, reduce energy consumption, and optimise their operations. As the energy transition gains momentum, so too does the demand for cutting-edge flow meter technology. **LNG**

References

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