# Paper 14

# GE-Panametrics Clamp-on Flow Meter, Results in Industrial Gas Applications

*Shirley Ao, R&D and Jacob Freeke, GE-Panametrics, USA*
*Steven Milford, GE- Panametrics, UK*

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# Industrial Gas Applications of GE Panametrics Clamp-on Flowmeter Model GC868

**X. Shirley Ao**
**Jacob Freeke**
**GE Panametrics.**
**Waltham, MA , USA**



## Abstract

This paper describes the technical features of the GE Panametrics GC868 clamp-on ultrasonic flowmeter for gases. General application requirements related to pipe sizes; pipe geometry, gas composition and pressure are outlined. The meter creates no pressure drop, has a 100:1 turndown ratio and is useful for measurement of erosive, corrosive and toxic gas flow rates.

Applications and test results for the meter on flow measurements of natural gas for re-injection to sub-sea well reservoirs, flow measurements of natural gas at a separator outlet, accuracy verification of flow measurement of natural gas at a compressor station and import/export of natural gas at an underground salt-cavern storage facility are discussed.

## Introduction

Clamp-on type ultrasonic flowmeter were developed and used for liquid measurements since the 1960s. Panametrics introduced the first commercial clamp-on ultrasonic flowmeter for gases flowing in metal pipes in 2001. The model GC868 is a clamp-on gas flowmeter for monitoring, control and diagnostic applications.

In 2002, Chevron-Texaco and GE Panametrics presented a paper [1] in the 20th North Sea Flow Measurement Workshop covering an evaluation of two GE Panametrics commercial clamp-on GC868 meters under controlled conditions at the Colorado Engineering Experiment Station, Inc. (CEESI) Wet Gas Test Facility located in Nunn, Colorado, U.S.A. The objective of the evaluation was to determine the accuracy of clamp-on gas flowmeters in field operating conditions where the gas is dry or contains a small amount of entrained liquid. This paper will present data obtained in the field using the GC868, including some measurement data on wet natural gas from a wellhead.

**Development of the Clamp-On Gas Flowmeter**

The application of ultrasonic meters for natural gas flow measurement has been known since the 1970s and became widely accepted for large volume custody transfer measurement in the 1990s. The acceptance of ultrasonic flow metering comes from its advantage of zero pressure drop and wide turndown ratios. The ultrasonic custody transfer flowmeter is typically a multi-path wetted flowmeter, which is a system consisting of a pre-fabricated meter body with several pairs of transducers installed to contact the gas/liquid stream. The geometric factors such as pipe inner diameter are well controlled or even monitored in real time to eliminate any possible error caused by a variation in the pipe's cross section. The multi-path measurement eliminates error caused by flow profile disturbances and generally provides excellent absolute accuracy in flow measurement.

The clamp-on ultrasonic flowmeter has unique non-intrusive properties that meet additional application needs in flow measurement. It causes no pressure drop and does not require flow to be shut down for installation. There is no tapping or cutting of the pipe wall required. Since the transducers are clamped on the outside of the pipe wall, it is also useful for metering of erosive, corrosive or toxic gases, or in any application where penetrating the pipe wall is undesirable. Furthermore, permanent installation costs are significantly reduced.

Ultrasonic gas flowmeters utilize the transit time or the time of flight ultrasonic flow principle to measure the difference in travel time between pulses transmitted at an angle with and against the fluid flow in the pipe. The GE Panametrics ultrasonic clamp-on gas flowmeter uses a patented Correlation Transit-Time detection technique to measure the time of flight through the metal pipe wall. In a typical single-path configuration, the flowmeter measures flow velocity using two identical transducers at the up and the down stream locations. Each transducer transmits and receives signals up and down stream alternatively so that flow velocity can be calculated based on the transit-time difference between the two signals.

Until 2001, it was generally considered impossible to have the clamp-on method applied to gas flowing in metal pipe due to a very limited energy transmission through the pipe wall into the gas. At the time the GC868 was introduced, clamp-on gas flow measurements were generally limited to low pressure flow in plastic pipe, high-pressure flow in steel pipes, or to laboratory studies. The limitation in clamp-on metering of gas flowing inside a metal pipe was long thought to be due to practical difficulties in signal transmission through the gas/pipe interfaces. The GE Panametrics flowmeter model GC868 overcomes this difficulty and measures gas flow velocity in metal pipes

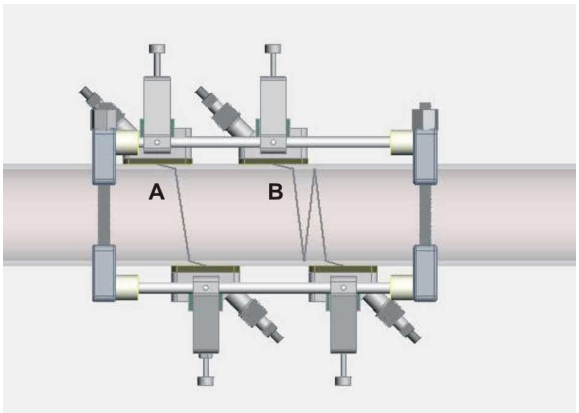



Figure 1. Transducers can be installed in either a one-traverse configuration (Pair A) or a three-traverse configuration (Pair B) using a single channel flowmeter depending on the application. The user may also use a two-channel meter on the same pipe to obtain a higher turndown ratio and precision.

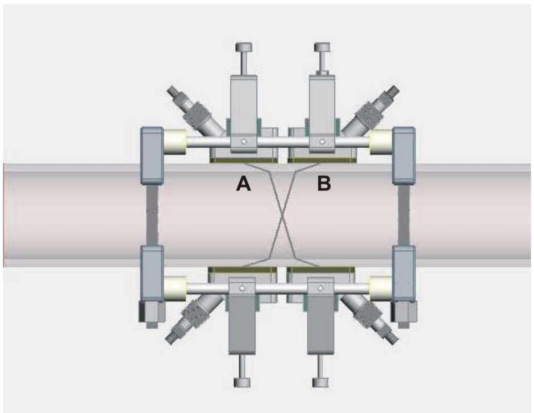



Figure 2. By averaging the results of a two-channel GC868 flowmeter with transducers clamped in the X configuration as shown, the influence due to cross flow can be effectively eliminated.

even when the gas is at low pressure. The GC868 is designed to improve the signal-to-noise ratio in clamp-on gas flow measurements internally and does not rely on pipe wall resonance to enhance the signal transmission. Therefore, it is less dependent on the properties of pipe wall to make a measurement. It has been shown that the GC868 can measure gas flow on copper or stainless steel tubing with wall thickness as small as 1 mm or on heavy pipes with wall thickness of more than 20 mm.

To measure low-pressure gas flow in metal pipe, an odd number of traverses is recommended (shown in Figure 1) to achieve a better signal-to-noise ratio for the measurement. A 20-diameter upstream straight run is the minimum requirement to have fully developed flow and a location with longer straight run is always a better choice. In the case that the straight run conditions are not met, one can apply an X pattern (shown in Figure 2) to eliminate the error caused by cross-flow or use one channel in the V-traverse configuration when gas pressure is high. Since the limit is imposed by the transmitted signal-to-noise ratio, the specification of the gas to be measured is mostly determined by the magnitude of $\rho C$, the product of the density $\rho$ and sound speed $C$ of the gas, which needs to be equivalent or higher than the value of air at 6 barg (87 psig) at room temperature. In typical pipe conditions, the GC868 flowmeter measures air/nitrogen gas at a minimum pressure of 6 barg (87 psig) or natural gas at a minimum pressure of 12 barg (174 psig). The measurable flow velocity is from 0 to 0.1 in Mach number (*e.g.* 0 to 40 m/s (132 f/s) in natural gas) depending on the pipe size and the accuracy requirement.

## Field Applications of GC868

The GC868 unit consists of an electronics console, clamp-on ultrasonic transducers, connecting cables, and a clamping fixture that mounts on the pipe. The meter has been used in a variety of applications since its market introduction.

The GC868 system has been widely used in the United States, Central Asia and Europe to measure natural gas flow at pressures greater than 69 bar (1000 psig) in thick wall pipes. The pipe sizes range from 80mm (3”) to 900 mm (36”). Tests were performed at various Flow Calibration facilities such as SWRI, CEESI, TCC, GDF, GSO, Advantica and others.

More recently the GC868 meter was successfully in what might be considered more challenging applications than natural gas transmission measurement. Several of these applications will be discussed in more detail in this paper.

1) Statoil – Flow Measurements of Natural Gas for re-injection to sub sea well reservoirs.
2) Statoil – Flow Measurements of Natural Gas on Separator Outlet
3) UralGaz – Accuracy verification on Flow measurement of Natural Gas
4) UK Mainland – Import/Export of Natural Gas at an underground salt-cavern storage facility

Additionally, other interesting applications were performed successfully in the field. Although not covered in this paper other successful applications include wet sour gas from a wellhead, natural gas distribution lines, hydrogen purity, hydrogen recycle flow, cryogenic ethane, instrument air, compressed air supply and ultra pure nitrogen used in semiconductor manufacturing.

**Field Application Note #1**
**Statoil ASA Test clamp-on gas flowmeter on Re-injection gas of Statfjord B**
**Measurements of Natural Gas for reinjection to sub sea well reservoirs.**

The Norwegian oil & gas reservoirs consist of a proportionally large amount of gas. Because natural gas is lower in monetary value than oil, the production of natural gas varies with its market price. The market price of natural gas, and thus its production, fluctuates with the seasons, while oil production is generally at a constant rate. Quite a number of wells are mature and loosing pressure. Processed natural gas is re-injected to wells, both as a driving force for oil production and as a natural storage for future deliveries. Water is also injected to mature wells.

Rather than exporting all natural gas produced on offshore platforms, some of the gas is used as a driving force for oil transport from mature oil/gas wells. Incoming multiphase flow and export flows are measured. The third measured flow parameter in the mass balance is the flow of re-injected gas.

Gas for re-injection is processed and is identical to the exported gas. The gas is fed to large compressors. Outlet pressure at measuring point may exceed 300 barg (4350 psig). Temperature of the gas after compressing is typical 70 to 120 ºC (158 to 248 ºF). The re-injected gas keeps well pressure up for enhanced oil production and acts as a carrier for residual oil when retransferred to the surface.

The traditional measuring principle is orifice plates, requiring flanged pipe connections. Some applications use ultrasonic flow meters with wetted transducers. The main interest for clamp-on technology is based on EHS, security and maintenance concerns. Today there is a high focus on these issues. Flanges and gaskets, as well as orifice plates, represent a potential security risk especially at high pressures and are therefore undesirable. Leakages and blowouts were reported in the past. Another advantage is cost reduction through avoiding costly retrofits and repairs. As this is a process control measurement, the accuracy specification is acceptable within +/- 3 to 5 % of the reading. The repeatability is therefore of a more interest. For injection gas and separator gas measurement the use of DP cell, Orifice and V-cone meter has traditionally been the most commonly selected instrument.

**Test location**

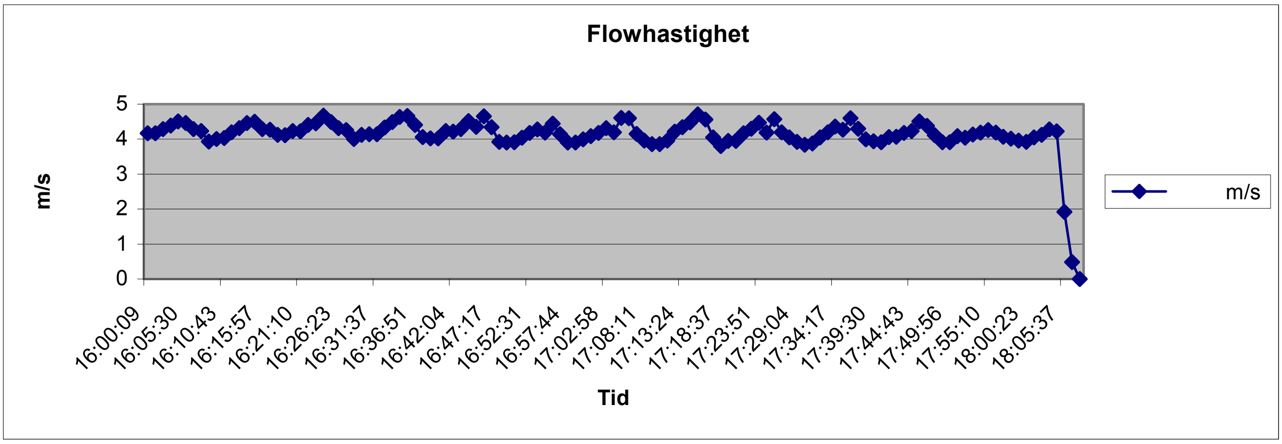
The test location consist of an 8 inch, XXS Carbon steel ASTM106 B SMLS pipe with an OD of 220.5 (8.625”) and a wall thickness of 37.40 mm (1.5”). The natural gas had a pressure of 352 bara (5104 psig) and a temperature of 106 ºC (228 ºF). Flow comparisons were made in terms of velocity [m/s] between the GC868 and the current PCDA. The test was performed on well B26, since this showed the highest flow rate, and presented the easiest access.

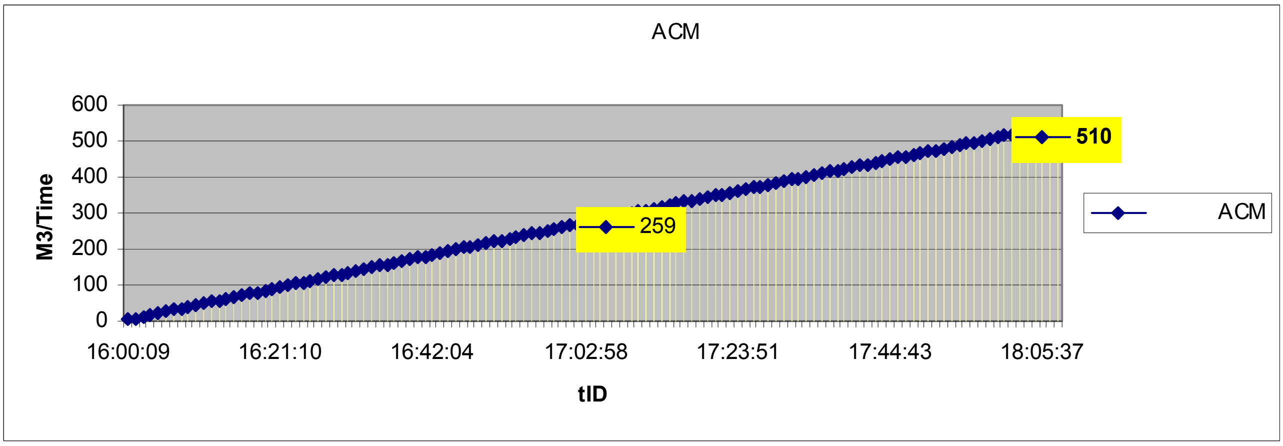
**Test 1.**

Average deviation was found to be 0.3% lower on the GC868 than on the PDCA.

## Test 2

In this test accumulated volume was recorded on both GC868 and PCDA over 2 hrs.




*First Hour. 16:00 to 17:00hr*

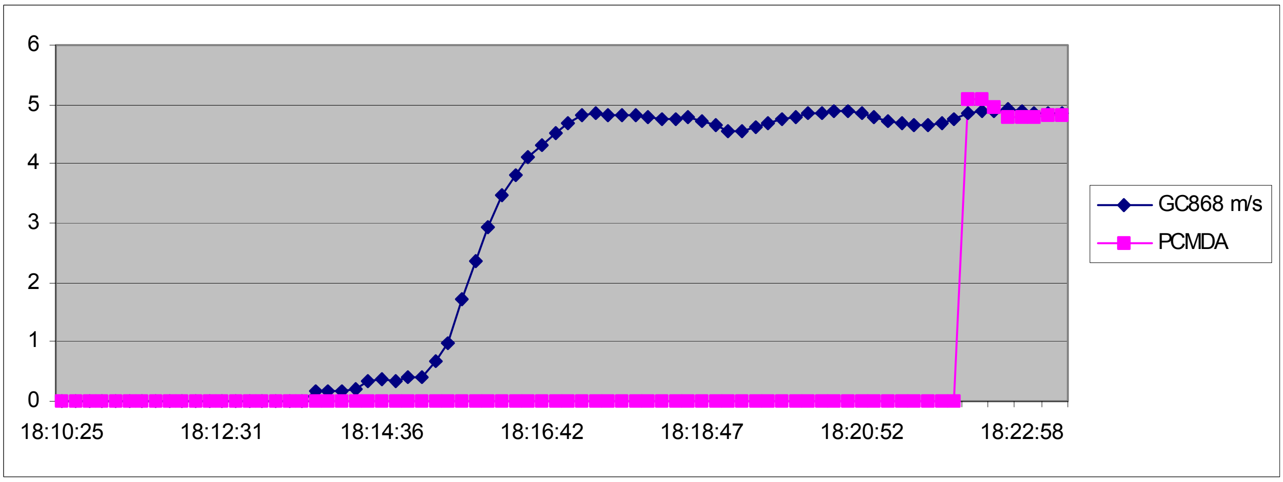
GC868 measures 259 $m^3$, which amounts to an average flow rate of 4.24 m/s. PCDA recorded to 71082 $SM^3$, average density 252 $kg/m^3$, which gives a calculated flow rate of 4.34 m/s. Thus the GC868 data is 2.3% lower than PCDA.

*Second Hour 17:00 to 18:00hr*

GC868 shows 251 $m^3$, which amounts to a flow rate of 4.16 m/s. PCDA records show 61169 $SM^3$, corresponding to 4.23 m/s at the same density as above. The deviation is 1.6% lower for the GC868 compared to PCDA.

*Average from 16:00 to 18:00 hr*

Measured over 2 hours the deviation is 2% lower for the GC868 compared to the PCDA-figures. If compensated for the known error in d/p-cell output, the deviation comes out as 1.3% higher flow for GC868 than shown by PCDA.




**Test 3**

Performance from zero flow was tested. This test is similar to test 1, but was performed at a slightly higher flow rate, approximately 80000 $m^3$/hr. The results are shown above. Average deviation is 0.2% higher flow from GS868 compared to PCDA.

**Note:** Until 18:21 the PCDA meter was off-line for calibration reason.

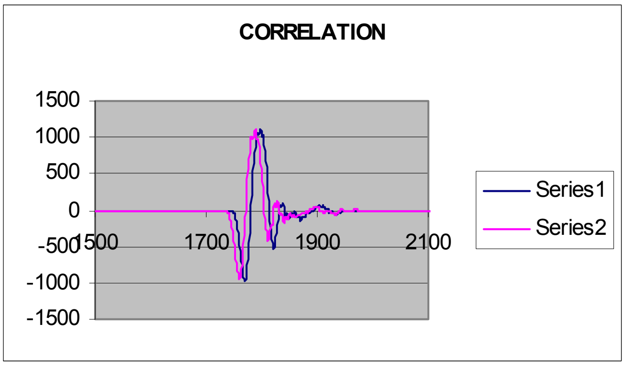
Results show excellent correlation. The installation and start-up proved efficient and good performance of this clamp-on technology flow meter was demonstrated. Summarizing, it can be said that Statoil's main arguments for using Clamp-on technology are safety, low cost of ownership, low installations cost, no modification or engineering required on pressure containing parts, little or no maintenance required, head count reduction and wide operational flow range.

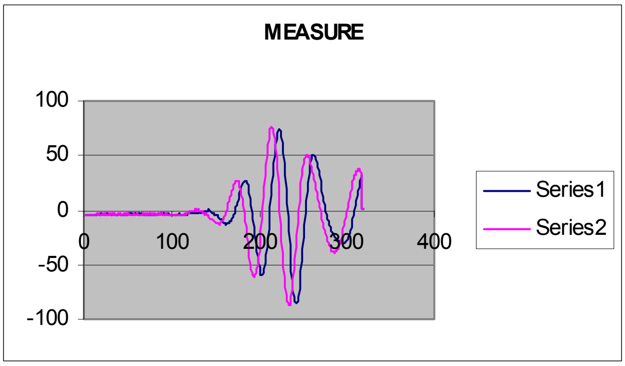
## Field Application Note #2
## Statoil – Flow Measurements of Natural Gas on Separator Outlet Statfjord A

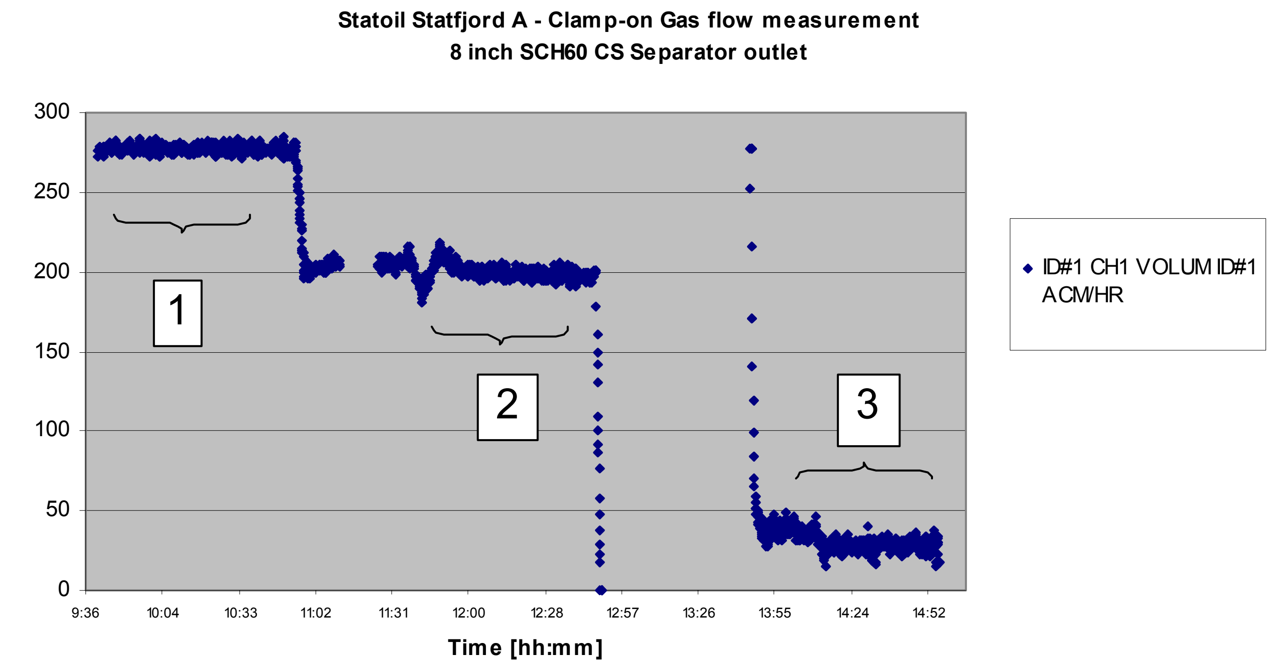
Another test was done with Statoil on Statfjord A platform. The objective was to test clamp-on gas flow metering on a gas separator application. Separator applications are typically challenging due to the risk for liquid carry-over. The gas here is not dried and contains higher amount of moisture then test #1 on Statfjord B. Secondly, we are here faced with lower pressure, and gas densities from 25-60 kg/m3. The pipe is an 8-inch SCH 60 CS pipe Pressure rating is ANSI 600#. OD is 219.1 mm (8.625") and wall thickness is 10.32 mm (0.406"). The pressure is 26 barg (377 psig) to 68 barg (986 psig) and the temperature is between 50 ºC (122 ºF) and 87 ºC (189 ºF).

The current meter on the well separator outlet well is an orifice plate, which was used for comparison. The GC868 US clamp-on meter was installed and tested eight diameters of straight run downstream of the orifice plate. There were approx. 25 diameters of straight run upstream of the measurement point. The plan to measure natural gas from different wells in sequences, testing at different pressures and gas densities. Temperature and pressure transmitters were located close to the orifice meter.

For illustration, the acoustic signals for the clamp-on meter are shown above.




As there are 3 logs from different operation conditions, the log should be read as follows:

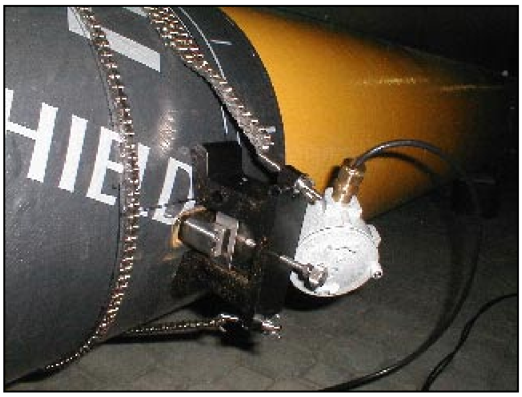
| | Part 1 | Part 2 | Part 3 | |
|---|---|---|---|---|
| *Well type* | High Pressure | High Pressure | Low Pressure | Low pressure |
| *Time window* | 0940 to 1040 | 1125 to 1225 | 1346 to 1406 | 1425 to 1445 |
| *Pressure* | 68 barg | 68 barg | 27 barg | 27 barg |
| *Temperature* | 75 deg C | 75 deg C | 62 deg C | 62 deg C |
| *Flow* | Full flow | 70% of full flow | Full flow | Reduced flow |

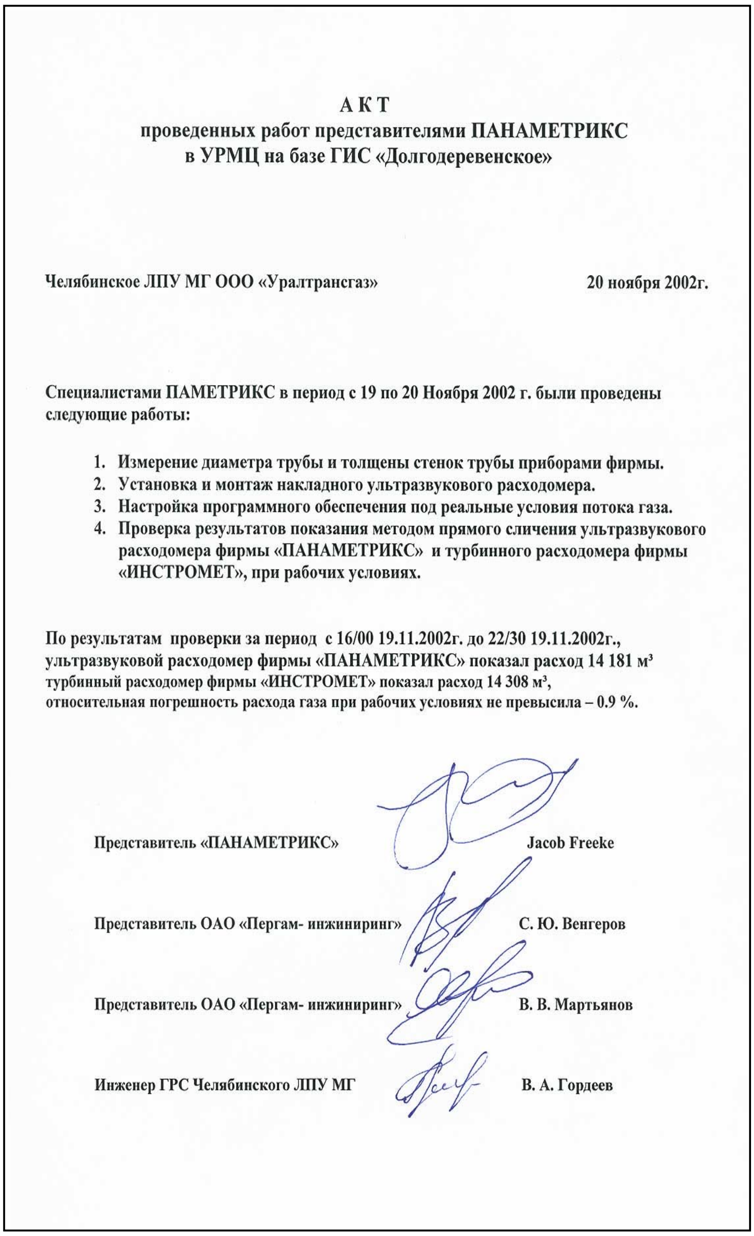
Measurement was found to be possible and stable flow readings at different pressures were obtained succesfully on this moist gas.

## Field Application Note #3
## TEST AT URALTRANSGAZ, Chelyabinsk, Russia

The performance of the GC868 was verified at UralTransgaz (subsidiary of Gazprom) compression station in Chelyabinsk, Russia. This station is outfitted with two ultrasonic multi-path meters and a single turbine meter as custody transfer reference meters. Here the GC868 clamp-on meter was demonstrated and its accuracy verified on a 427.3 mm (16 inch SCH 40 CS) pipe with a wall thickness of 12.48 mm (0.5"). Single traverse set-up was selected and installed at a location with more than 30D of upstream straight run, downstream of two 90-degree elbows in the same plane.

The test was performed at a flow rate of 3.5 MMSCM/day and the accuracy was found to be –0.9% of reading. See certificate below. As the GC868 utilizes a single ultrasonic path, a Reynold's correction factor must be applied to relate the flow velocity determined along the diameter to the velocity of the entire area of the pipe cross-section. It was further noted that a slightly incorrect application of the Reynold's correction algorithm was applied during the test. With proper input parameters the error would have been just +0.4%.

**А К Т**
**проведенных работ представителями ПАНАМЕТРИКС**
**в УРМЦ на базе ГИС «Долгодеревенское»**

Челябинское ЛПУ МГ ООО «Уралтрансгаз» 20 ноября 2002г.

Специалистами ПАМЕТРИКС в период с 19 по 20 Ноября 2002 г. были проведены следующие работы:

1. Измерение диаметра трубы и толщены стенок трубы приборами фирмы.
2. Установка и монтаж накладного ультразвукового расходомера.
3. Настройка программного обеспечения под реальные условия потока газа.
4. Проверка результатов показания методом прямого сличения ультразвукового расходомера фирмы «ПАНАМЕТРИКС» и турбинного расходомера фирмы «ИНСТРОМЕТ», при рабочих условиях.

По результатам проверки за период с 16/00 19.11.2002г. до 22/30 19.11.2002г., ультразвуковой расходомер фирмы «ПАНАМЕТРИКС» показал расход 14 181 м³ турбинный расходомер фирмы «ИНСТРОМЕТ» показал расход 14 308 м³, относительная погрешность расхода газа при рабочих условиях не превысила – 0.9 %.

Представитель «ПАНАМЕТРИКС» Jacob Freeke

Представитель ОАО «Пергам- инжиниринг» С. Ю. Венгеров

Представитель ОАО «Пергам- инжиниринг» В. В. Мартьянов

Инженер ГРС Челябинского ЛПУ МГ В. А. Гордеев

**DOCUMENT (ACT) ISSUED BY URALTRANSGAZ STATING FOUND ACCURACY**

**Field Application Note #4**
**UK Mainland – Import/Export of Natural Gas at an underground salt-cavern storage facility**

A UK mainland natural gas storage facility accepts raw natural gas from offshore into underground salt-caverns. As the raw gas is wet and contains sulfur the application poses maintenance challenges for in-line meters. Furthermore when the gas is required for export to the distribution system, methanol is injected for drying as it is further processed for export. The GC868 Gas Clamp-on Ultrasonic Flowmeter was installed on a section of 6-inch schedule 160 carbon steel pipe (Fig. 11) with a line pressure of 150 barg (2175 psig). Pressure in this line can vary between 70 and 200 barg (1015 and 2900 psig) during the year and the flow can be bi-directional according to demand. There are a number of identical bi-directional lines of this type within the facility, all monitored by non-operational multi-path ultrasonic meters that have experienced transducer failure over the years. The transducer failures are believed to be due to contamination and pressure cycling stress. A fiscal-standard, multi-path ultrasonic meter monitors the total flow of the facility.

The facility operators were interested in determining how well this new technology could perform and whether it offered a practical replacement for the in-line ultrasonic meters. The clamp-on installation would not require any form of shutdown and there would be no anticipated maintenance or reliability issues. A known and well accepted practice associated with ultrasonic flowmeters for validating the measurement in the field is to verify the measured soundspeed of the natural gas with the theoretical calculated soundspeed of the known gas composition. The composition data is typically available by means of an on-line gas chromatograph. The soundspeed can be calculated by means of commercially available software packages. Once these two soundspeeds are better then 1% in agreement, confidence that the meter will perform to its specifications is reinforced. A comparison with the GC868 diagnostic for measured sound-speed gave exact agreement, which served to validate the GC868 installation.

**TEST DATA FROM CAVERN 30/04/02**

| TIME | DCS | GC868 | PRESSURE | TEMPERATURE | % DEVIATION FROM DCS |
|---|---|---|---|---|---|
| | SCMH | SCMH | BARG | DEG C | |
| | | | | | |
| IMPORT | | | | | |
| 10:20 | 24,000 | 23,868 | 147 | 17 | -0.55 |
| 10:40 | 46,000 | 46,469 | 147 | 15 | 1.02 |
| 10:55 | 68,000 | 69,188 | 149 | 17 | 1.75 |
| 11:30 | 86,000 | 86,626 | 150.5 | 21.5 | 0.73 |
| 11:34 | 88,000 | 87,045 | 150.5 | 22.5 | -1.09 |
| | | | | | |
| EXPORT | | | | | |
| 12:03 | 14,000 | 14,337 | 146 | 20.5 | 2.41 |
| 12:08 | 25,000 | 25,040 | 146 | 20.5 | 0.16 |
| 12:23 | 80,000 | 81,693 | 143 | 21 | 2.12 |
| 12:32 | 110,000 | 110,281 | 137 | 22.5 | 0.26 |
| 12:37 | 115,000 | 116,235 | 135 | 24 | 1.07 |
| | | | | | |

There seemed to be sufficient straight pipe run, both the up and downstream to ensure good results for bi-directional measurement. Flow data from the GC868 was compared to the customer DCS readings and process conditions at marked times. The comparison data can be seen above. There were no live pressure and temperature inputs available to the GC868 for standard volume correction, and thus these parameters were entered manually based upon control room updates. As a certain amount of error can be expected using this off-line methodology, a permanent installation with live pressure and temperature inputs would certainly yield improvements to the data recorded.

## Summary and Conclusion

Gas clamp-on ultrasonic flowmeter technology has proven itself capable, in both field and calibration laboratory, of delivering better than +/- 2% of reading performance in the majority of cases. The technology provides the advantages of clamp-on ultrasonic flow measurement for gas applications. The flowmeter causes no pressure drop, has a very wide range, and is non-intrusive. There is no tapping or cutting of the pipe wall required. Since the transducers are clamped on the outside of the pipe wall, it is also useful for metering of erosive, corrosive or toxic gases, or in any application where penetrating the pipe wall is undesirable. Seen from environmental, health and safety (EHS) perspective this is an attractive fact. Furthermore, permanent installation costs are significantly reduced.

The meter has been used in a variety of applications since its market introduction, including wet, sour natural gas, compressed air, hydrogen and petrochemical process gases in thick walled lined pipes, copper tubing and stainless steel pipes. The GE Panametrics GC868 is a proven solution for clamp-on flow measurement of gases in metal pipes at minimum pressures of 6 barg in air/nitrogen or 12 barg in natural gas. Work continues to extend the scope of the meter to smaller pipes, thin-wall metal tubing, lower pressures and higher temperatures. A full-featured portable flowmeter package will also be available in 2004.


## Acknowledgements

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