Paper 17

Operating Experience with two Ultrasonic Gas Meters in Series

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OPERATING EXPERIENCE WITH TWO ULTRASONIC GAS METERS IN SERIES

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1 INTRODUCTION

Norsk Hydro has several gas metering stations in operation that contain two ultrasonic gas flow meters in series. This paper will share the experience gained since September 2000 with the use of this measurement configuration.

How Norsk Hydro operates a metering station with two meters in series using the "Reference meter method" will be explained. The wet gas performance of such a metering station will also be described.

2 BACKGROUND

The Oseberg D platform in the North Sea sends gas to Heimdal via a 109 km 36 inch pipeline at maximum flow rates of 10 000 m^3/h. The Heimdal platform sends gas to Statpipe and Vesterled, see Figure 1.

Figure 1. The Heimdal and Oseberg D platforms.

Norsk Hydro has 4 gas metering stations in operation that contain two ultrasonic gas flow meters in series, one at Oseberg D and three at Heimdal.

At Oseberg D (OSD) a metering station with two ultrasonic meters in series was put in operation in September 2000, measuring the gas entering the Oseberg Gas Transport (OGT) pipeline to Heimdal.

At Heimdal this gas can be sent through two metering stations, “OGT – Statpipe”, put in operation in September 2000, measuring the gas to the Draupner platform and “OGT – Vesterled”, put in operation in October 2001, measuring the gas to the St. Fergus gas terminal in Scotland.

Processed gas at Heimdal can be sent through the metering station “HEA - Vesterled”, put in operation in October 2001, measuring the gas to the St. Fergus gas terminal in Scotland.

Experience from these 4 metering stations will be discussed in this paper.

3 SYSTEM DESCRIPTION

A typical gas metering station with two ultrasonic gas meters in series is shown in Figure 2.

The metering station consists of duplicated equipment:

- Ultrasonic flow meters
- Temperature transmitters
- Pressure transmitters
- Density transmitters (not installed on OSD)
- Gas Chromatographs
- Flow computers
- Supervisory computer (Not duplicated)
- Flow conditioner (Not duplicated)

The metering station is functionally identical to a metering station with two parallel meter runs, only put in series. In this way the duplicated measurements provide 100% on-line redundancy.

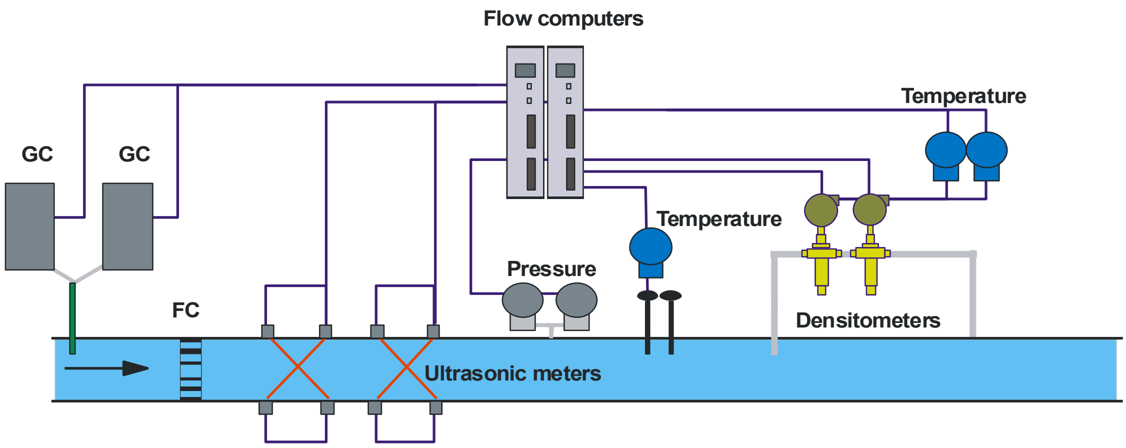

Figure 2. A typical gas metering station with two ultrasonic gas meters in series.

3.1 Automated Quality Control

The fiscal gas metering stations are designed for automated condition based maintenance. This includes the ability to automatically check the current condition of every primary measurement, like pressure, temperature, density, flow rate, composition etc. Current condition is checked by comparing measured values from duplicated equipment. All condition checks are done without intervention in online equipment.

The condition checks are against given deviation limits for each parameter, with alarm function. The alarm function is continuously active (condition checks every 10 seconds), and will raise alarms to the operator.

Calibration of measuring equipment is based on determined condition. Measuring equipment is calibrated, as soon as it is determined that the equipment no longer measures within valid uncertainty limits. However, scheduled calibration of measuring equipment is performed as required by the NPD regulation.

4 FLOW CALIBRATION

Ultrasonic gas meters are zero calibrated by the supplier and flow calibration in an accredited calibration laboratory before installation.

The ultrasonic gas flow meters presented in this paper, were all calibrated at Advantica Flow Centre, England, prior to installation, see Figures 3 to 6.

The uncertainty of the reference measurements at Advantica is stated in the accreditation certificate, to be ± 0.35% of measured volume up to 13 000 m^3/h, see Figure 26.

All meters were calibrated together with the complete metering run including flow conditioner, upstream spool, intermediate spool and downstream spool. This was done in order to eliminate any possible uncertainty related to the influence of pipe-work on the flow profile through the meters.

Furthermore, both meters in the metering station were calibrated simultaneously. This was done in order to eliminate the common influence of the uncertainty and reproducibility of the reference on the difference between the meters. As a consequence the difference between the meters in operation should now be related to the performance of the meters only.

The two meters in the “OGT-Statpipe” metering station were calibrated a total of three times over a period of six months in various configurations. Due to installation effects determined during the third calibration, the installed configuration of the two meters differed from any used during calibrations. The calibration curves implemented for the two meters were taken from the calibration runs best representing the final installation configuration of each meter.

4.1 Calibration requirements

The Norwegian Petroleum Directorate (NPD) regulation “Measurement of petroleum” §8 sets the following requirements to uncertainty for gas metering:

- Total uncertainty for the gas metering station:
  ± 1.0% of mass (Uncertainty at 95% confidence level, expanded uncertainty with coverage factor k=2)

- The following requirements are stated for ultrasonic gas flow meters:
  - Linearity limits (band):
    1.0% in working range (20:1).
    Deviation from reference in calibration shall be less than ± 1.50% in working range (20:1) before use of calibration factor.
  - Uncertainty limits component:
    ± 0.70% in working range (20:1) after zero point control.
  - Repeatability limits (band):
    0.50% in working range (20:1) after zero point control.

4.2 Calibration results

As can be seen in Figures 3 to 6 all meters fulfil the linearity requirement. The linearity is typically 0.4 – 0.5% and better than 0.8% for all meters.

The deviation from the reference is also less than ± 1.50% in working range (20:1) before use of calibration factor. The deviation from the reference is typically in the range –0.1 to –0.5%.

Instromet specifies that the linearity of their Q-sonic 5 shall be better than ± 0.20% over turn down ratio 10:1. As can be seen from the calibration curves, the meters perform within this specification as well.

Every calibration point is obtained based on at least 5 test runs at each flow rate. As both meters are simultaneously calibrated against the reference at each flow rate it is of interest to quantify the uncertainty of each calibration point relative to the reference. Based on the data from the calibration, the uncertainty (k=2) of each calibration point is given in Table 1 along with the repeatability band.

Table 1. Uncertainty of single calibration point for the "OGT - Vesterled" meters.

	Meter 1		Meter 2	
Relative flow rate [%]	Calibration point uncertainty [%]	Calibration point repeatability band [%]	Calibration point uncertainty [%]	Calibration point repeatability band [%]
5	0.12	0.236	0.10	0.226
10	0.09	0.182	0.06	0.111
25	0.08	0.156	0.04	0.092
40	0.04	0.091	0.03	0.065
70	0.03	0.058	0.03	0.057
100	0.09	0.19	0.07	0.137

If an offset is identified in the "footprint" for a metering station during later operation the uncertainty of single calibration points should be taken into consideration.

As can be seen from the table, the repeatability of the meters is well within the NPD repeatability limit (band) of 0.50%.

4.3 OSD

The calibration results of two 20-inch FMU 700 are shown in Figure 3. The metering station contains a flow conditioner 10D upstream meter 1 with 5D between the meters.

The calibration curves were implemented in the flow computers as a first order polynomial (a·X + b) curve:
- Volume flow OSD Meter 1 = (1.003573·Mesured volume flow + 1.278735) m^3/h
- Volume flow OSD Meter 2 = (1.005565·Mesured volume flow + 2.662486) m^3/h

Gas velocity at 10000 m^3/h is 17.7 m/s.

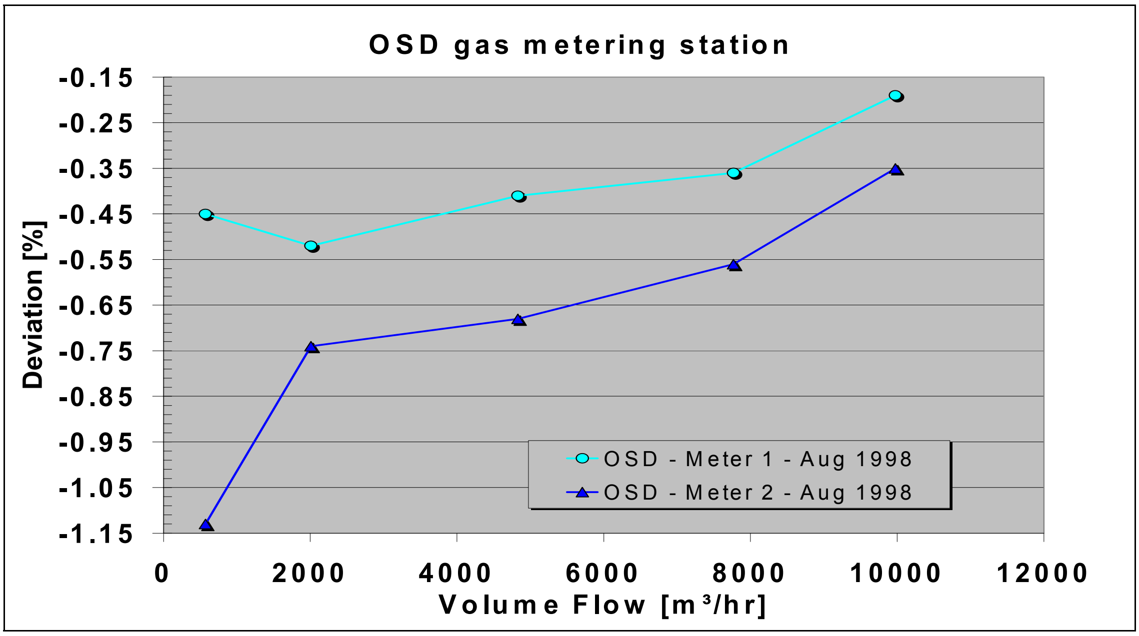

Figure 3. Calibration results of OSD ultrasonic meters, with natural gas.

4.4 OGT – Statpipe

The calibration results of two 20-inch Q-sonic 5 are shown in Figure 4. The metering station contains a flow conditioner 13D upstream meter 1 with 3D between the meters.

The calibration curves were implemented in the flow computers as single K-factors:
- K-factor 2801 Meter 1 = 1.003958
- K-factor 2801 Meter 2 = 1.001281

Gas velocity at 10000 m^3/h is 20.1 m/s.

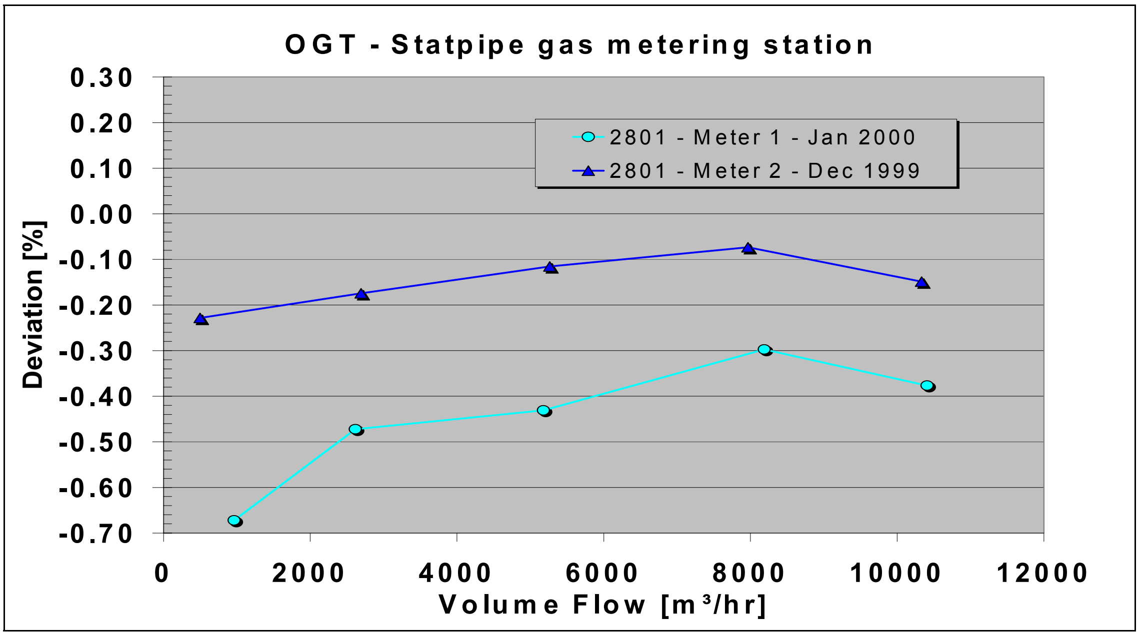

Figure 4. Calibration results of "OGT - Statpipe" ultrasonic meters, with natural gas.

4.5 OGT – Vesterled

The calibration results of two 18-inch Q-sonic 5 are shown in Figure 5. The metering station contains a flow conditioner 13D upstream meter 1 with 3D between meters.

The calibration curves were implemented in the flow computers using linear interpolation.

Gas velocity at 10000 m^3/h is 23.6 m/s.

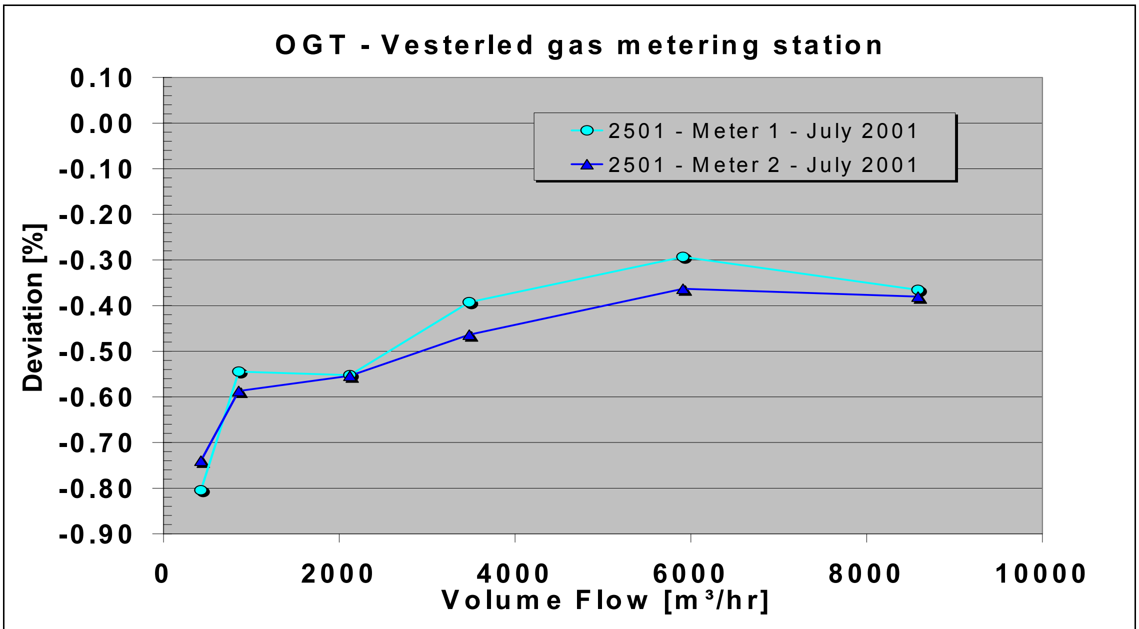

Figure 5. Calibration results of "OGT - Vesterled" ultrasonic meters, with natural gas.

4.6 HEA – Vesterled

The calibration results of two 18-inch Q-sonic 5 are shown in Figure 6. The metering station contains a flow conditioner 13D upstream meter 1 with 3D between meters.

The calibration curves were implemented in the flow computers using linear interpolation.

Gas velocity at 10000 m^3/h is 23.6 m/s.

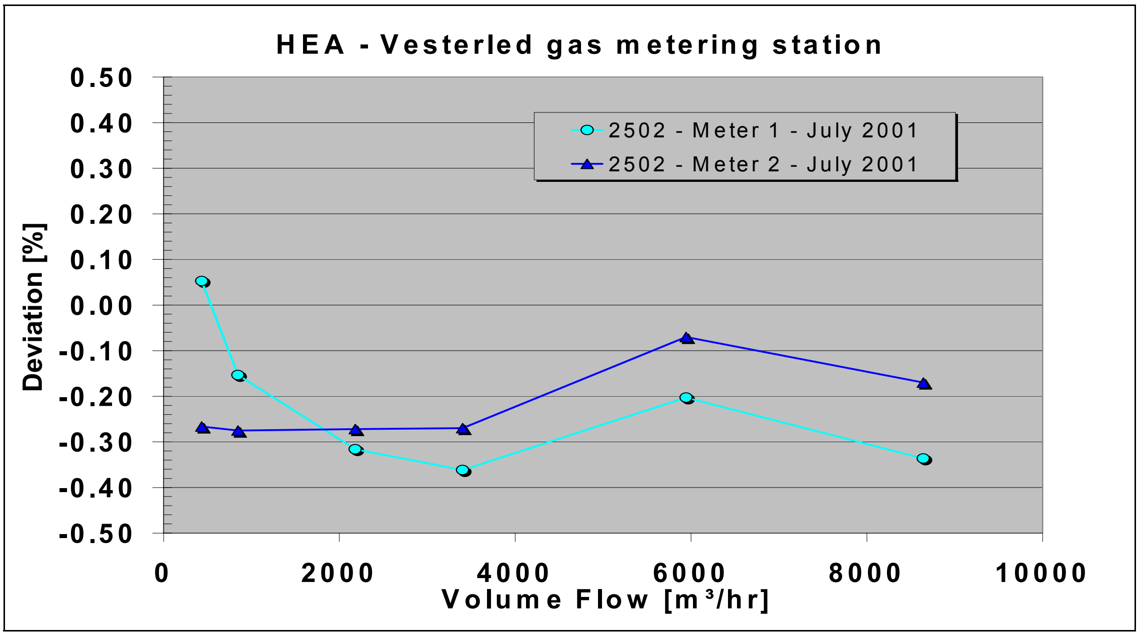

Figure 6. Calibration results of "HEA – Vesterled" ultrasonic meters, with natural gas.

5 OPERATING EXPERIENCE

The difference between ultrasonic gas meters in series is checked from first start-up and regularly during operation, using the difference between hourly volume totals at line conditions. The difference is evaluated according to the control limits given for the "Reference meter method", see Chapter 7.

Norsk Hydro generally maintains equipment to perform within its specification. The NPD requirement for ultrasonic gas meter uncertainty is ± 0.70% in working range (20:1). Regarded statistically, this allows a difference between the meters within ± 1% (K=2). As the stability of the ultrasonic meters is extremely good Norsk Hydro have adopted an action limit at a difference of ± 0.35% (K=2) which is 3 times better than the NPD requirement.

Daily quality assurance offshore includes check of the difference between the daily volume totals from the two meters. Onshore technical support performs a monthly quality assurance to check the difference between the hourly volume totals from the two meters at line conditions to establish the monthly difference "footprint" and compare it with the "footprint" from the previous month. Each metering station has its own characteristic difference "footprint". The "footprint" is used to check the stability of the meters and that there is no need for recalibration.

If a technical problem with a meter is discovered, the control limits of the "Reference meter method" will be used to determine the proper action. Before any actions are taken, troubleshooting is performed to determine which meter is faulty and whether external effects like condensation of gas may have affected the meters.

The ultrasonic gas meter may be flow calibrated during operation if the meter is considered to have a poor maintenance history. With two ultrasonic gas meters in series the "Reference meter method" is used to determine if there is need for recalibration in an accredited calibration laboratory.

5.1 Results

The results for the difference between the Duty and Check meters in the 4 metering stations are presented in Figures 7 to 18.

Positive difference means that the Duty meter measures a higher volume flow than the Check meter.

The control limits of the "Reference meter method" are used in the plots of the differences (K=1,2,3,4) and are established from the measurement uncertainty of the calibration laboratory. K=2 in the plots represents ± 0.35%.

Hourly volume totals below 400 m^3 (approximately 1 m/s at stable flow) are disregarded since these rates are outside the working range (20:1) of the meters. Hourly volume totals from hours with start-up or shutdown of flow through the meters are in most cases also disregarded.

The experience from comparing the difference between hourly volume totals from the two meters in series is that most differences exceeding ± 0.175% (K=1) can be either related to wet gas, start-ups or shutdowns.

For each metering station three different plots are presented:

- The first plot shows the historic difference "footprint", the difference between hourly volume totals from the Duty and Check meters as a function of volume flow rate, from first start-up. This is a collection of in some cases as much as 17000 data points. Periods with known wet gas conditions have been omitted.
- The second plot shows the normalized histogram of the difference data from the first plot. The data are divided into evenly distributed bins of 0.01%. There are few data points outside the range ± 0.50%.
- The third plot shows comparison of selected monthly difference "footprints" from the monthly quality assurance, since first start-up.

5.2 OSD

The difference between hourly volume totals from Duty and Check meters at the OSD gas metering station is shown in Figure 7.

The OSD meters have a rather broad difference distribution but still well within ± 0.35% (K=2), with a slightly positive skewness for the range 1000-5000 m^3/h. At higher rates the difference distribution becomes narrower. Below 1000 m^3/h the differences increases, apparently with a negative skewness however, the mean difference in this range is 0.17%.

The difference distribution seen in Figure 7 is influenced by the process conditions at Oseberg D with large gas flow rate variations and elements of wet gas, as well as variations in temperature and pressure. It has been necessary to impose restriction on permissible variation in temperature of the gas to achieve satisfactory results from the flow meters. Norsk Hydro has already considered an upgrade of the meters for OSD gas if in the future it proves difficult to operate with these restrictions on process conditions. However, the meters operate well within the requirement of NPD.

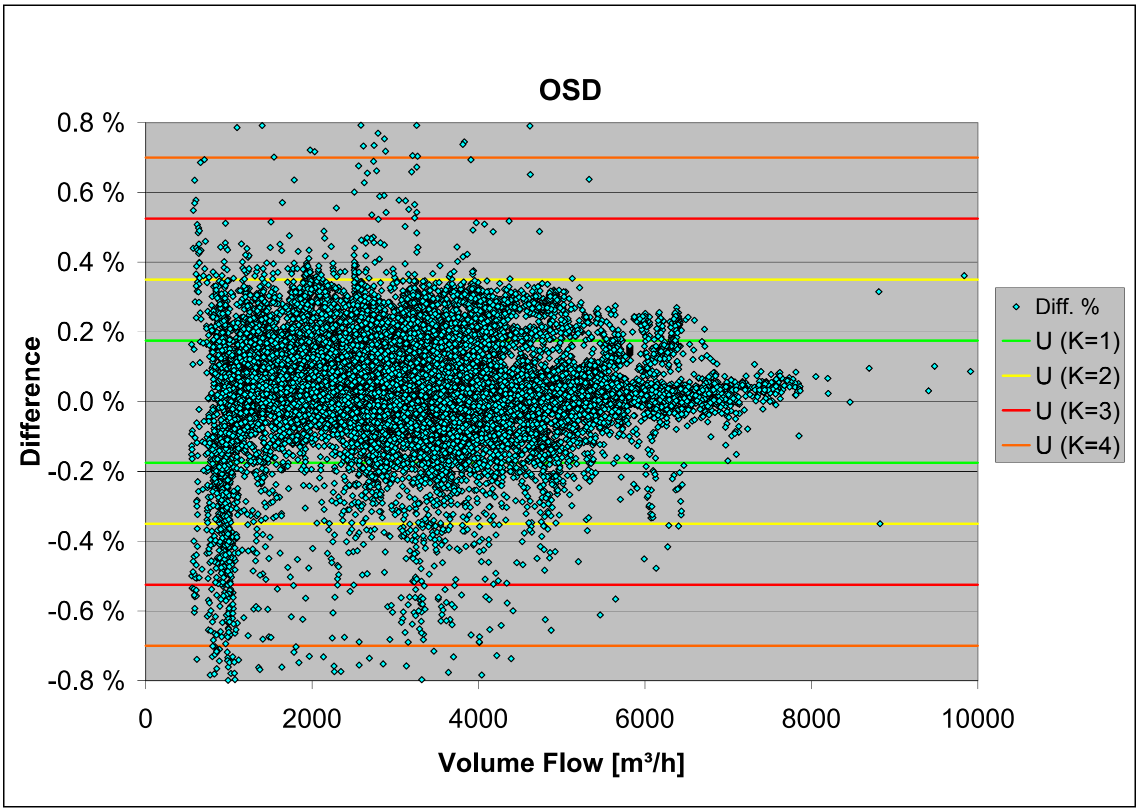

Figure 7. Difference between hourly volume totals since September 2000.

The normalized histogram of the difference data of the OSD gas metering station is shown in Figure 8.

OSD gas metering station "footprints" from four different months over a 32 months period, October 2000, November 2001, October 2002 and May 2003, are shown in Figure 9.

There are only small deviations between the "footprints" and there are no indications of significant drift or change in the operating performance of the meters.

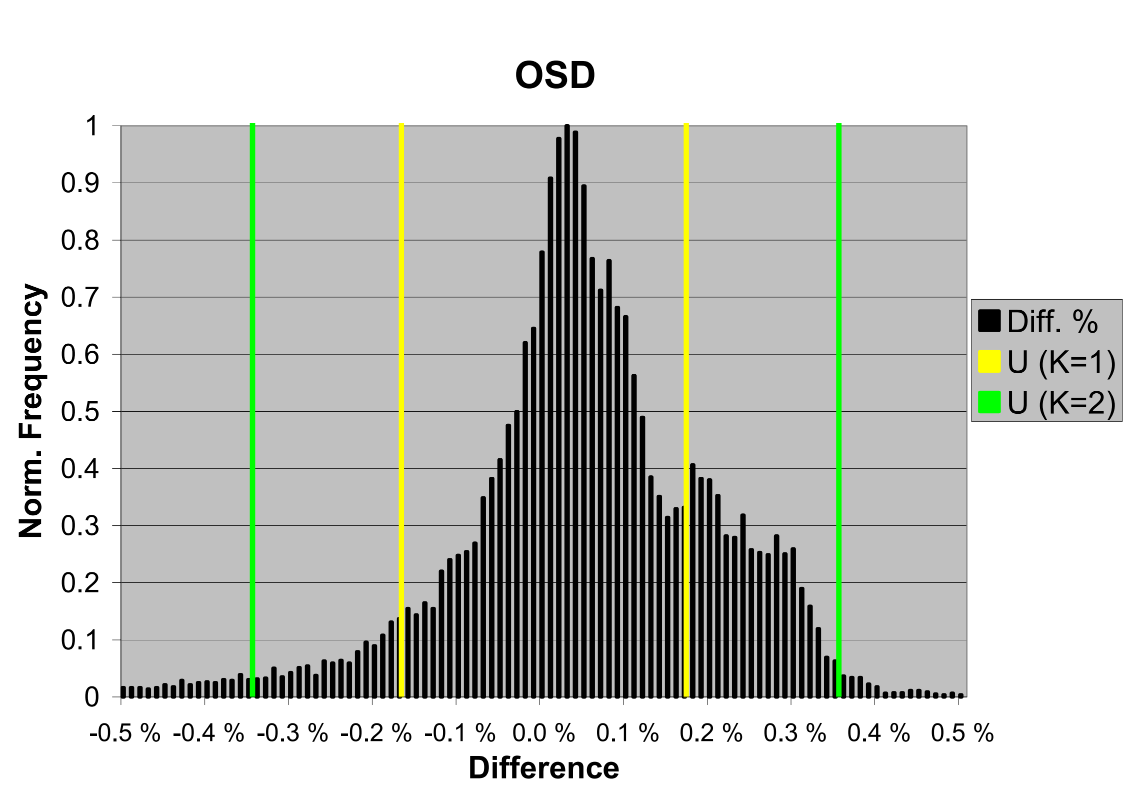

Figure 8. Histogram. Difference between hourly volume totals since September 2000.

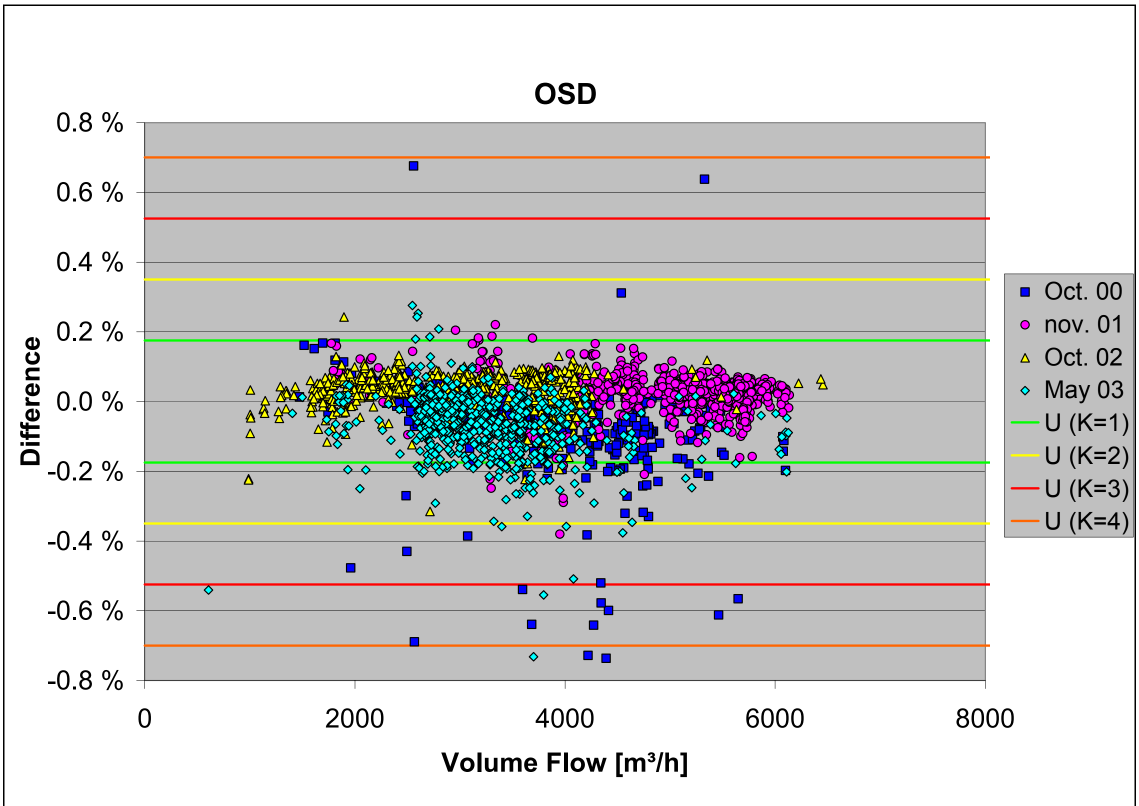

Figure 9. Four "footprints" of OSD gas metering station from October 2000 to May 2003.

5.3 OGT - Statpipe

The difference between hourly volume totals from Duty and Check meters at the "OGT – Statpipe" gas metering station over the last two years is shown in Figure 10.

The data are scattered around zero difference and similarly to OSD, the distribution becomes narrower at higher flow rates. This is consistent with the calibration results that show that the gas meters have better repeatability at higher flow rates than at lower flow rates.

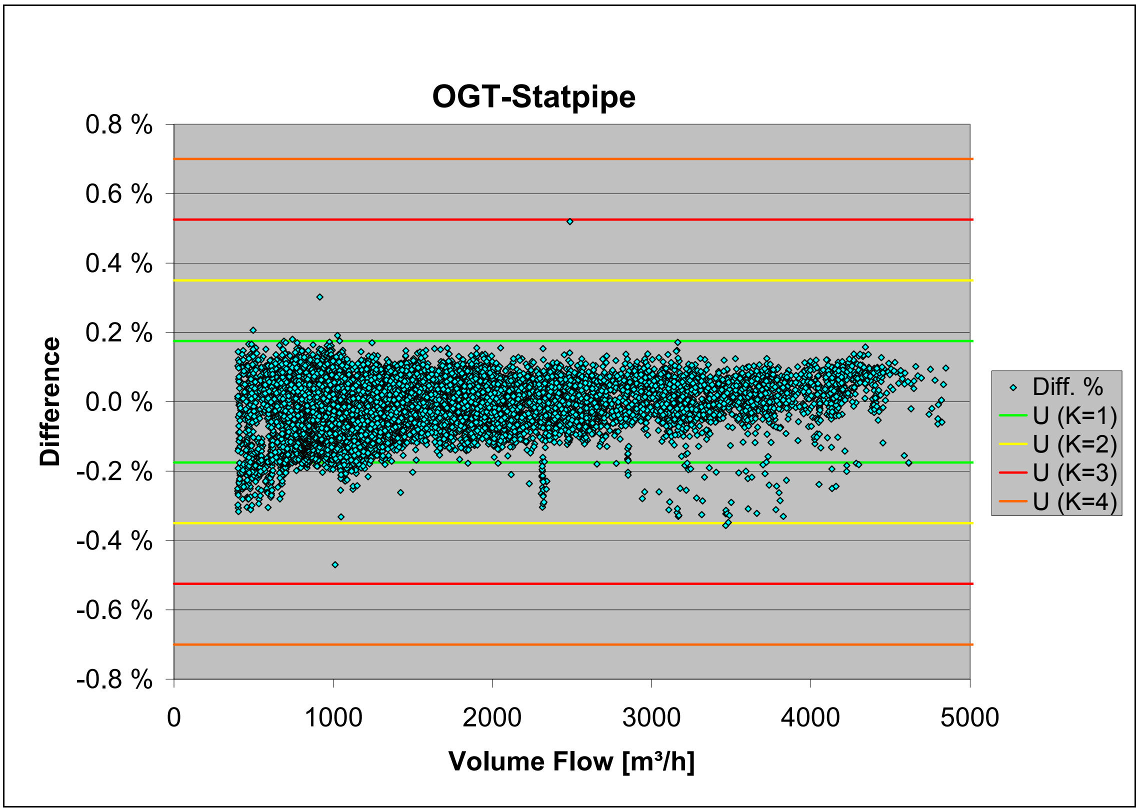

Figure 10. Difference between hourly volume totals since September 2001.

The normalized histogram of the difference data of the "OGT – Statpipe" gas metering station is shown in Figure 11.

The major differences between the meters are well within the limit of ± 0.175% (K=1). The distribution is considered to be very narrow.

A case with wet gas at "OGT - Statpipe" is discussed in Chapter 6.1.

"OGT – Statpipe" gas metering station "footprints" from three different months over a 20 months period, November 2001, October 2002 and May 2003, are shown in Figure 12.

There are no deviations between the "footprints". This indicates that there are no changes in the operating performance of the two meters.

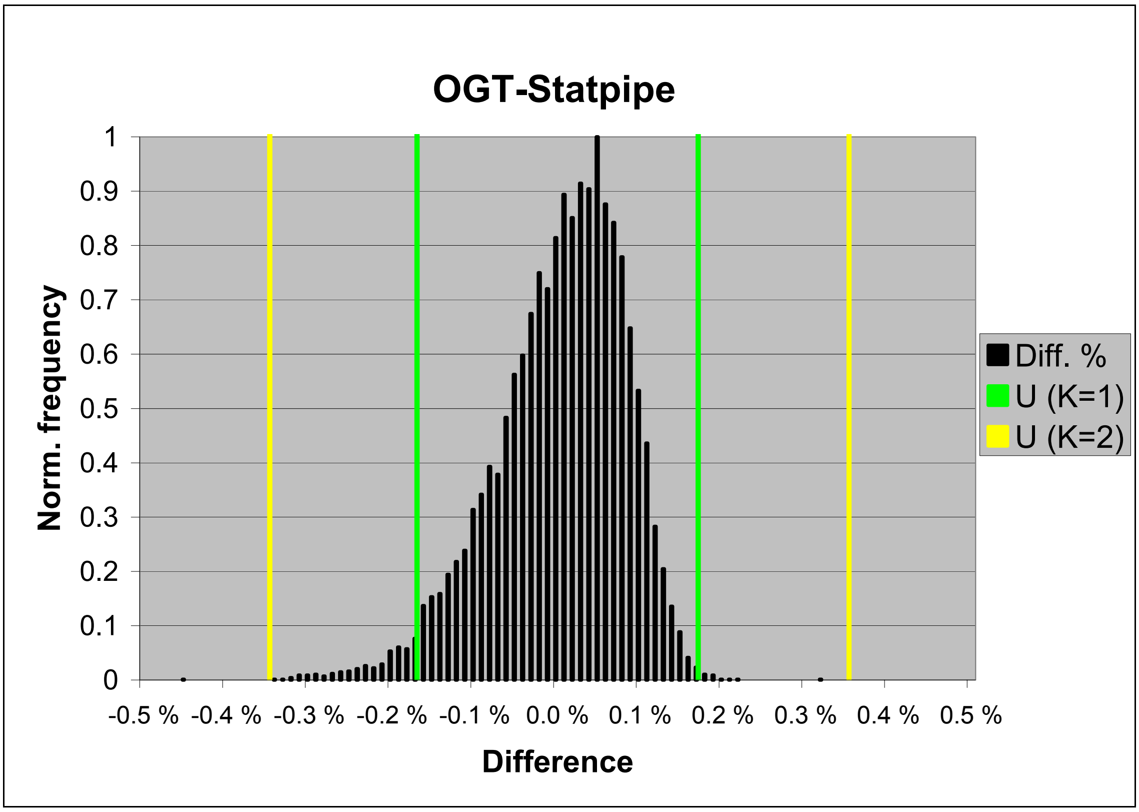

Figure 11. Histogram. Difference between hourly volume totals since September 2001.

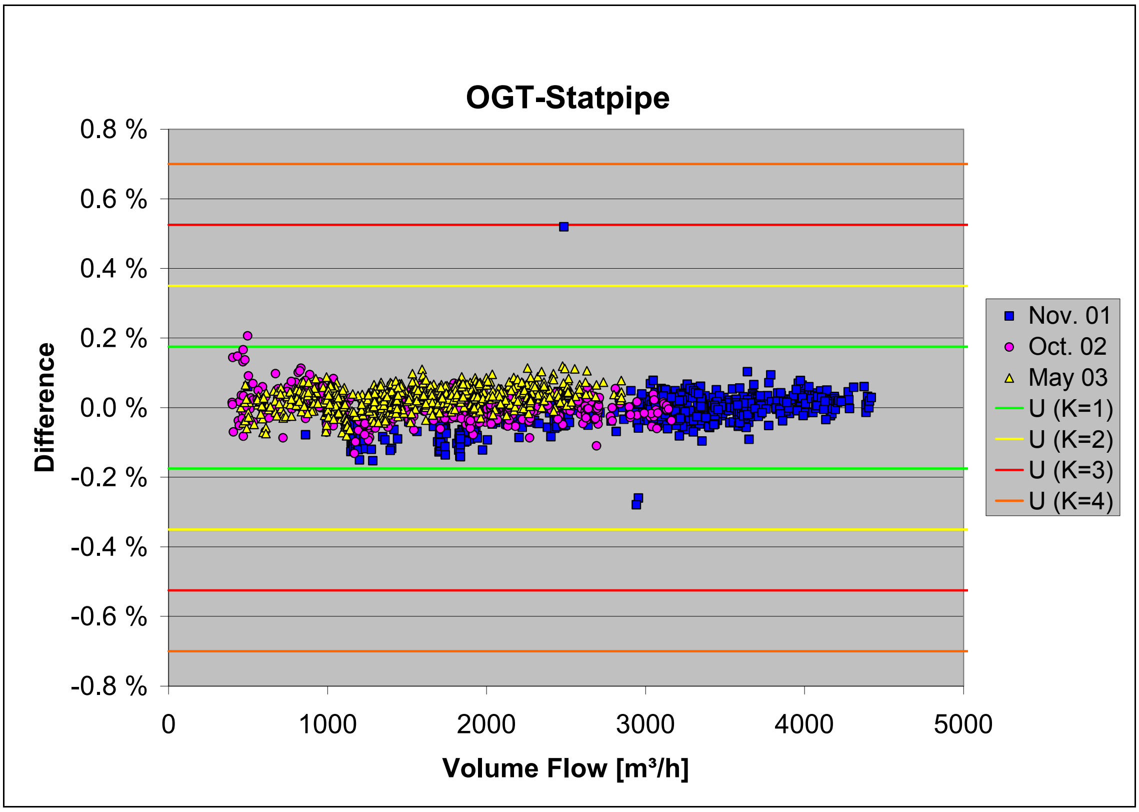

Figure 12. “Footprints” from three different months since September 2001.

5.4 OGT – Vesterled

The difference between hourly volume totals from Duty and Check meters at the "OGT – Vesterled" gas metering station over the last two years is shown in Figure 13.

The data are scattered around zero difference and the distribution becomes narrower at higher flow rates.

It can be noted that the mean value of the difference between the meters reach 0.2% at the lowest flow rate. However the difference at lower flow rates is not alarming as the uncertainty of the calibration points for each meter at lower flow rates are approximately 0.1%, see Chapter 4.2.

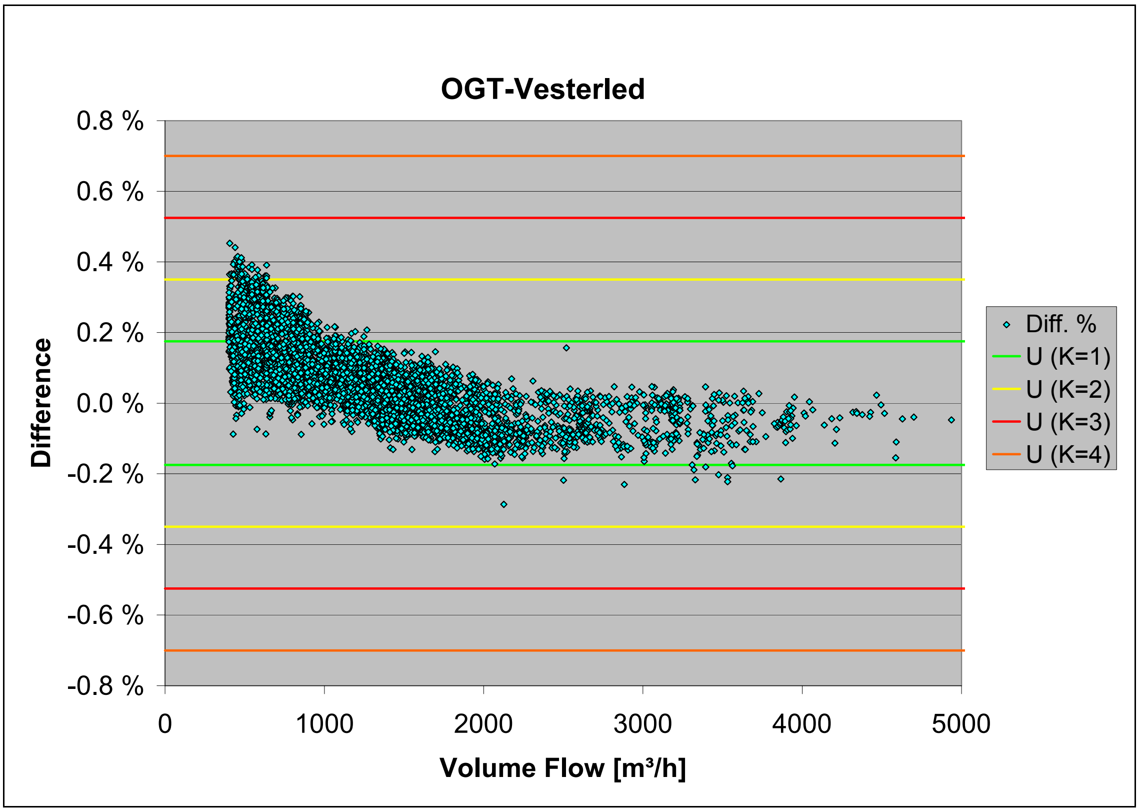

Figure 13. Difference between hourly volume totals since October 2001.

The normalized histogram of the difference data of the "OGT – Vesterled" gas metering station is shown in Figure 14.

The major differences between the meters are within the limit of ± 0.175% (K=1). The distribution is considered to be narrow and centred around a difference of 0.05%.

"OGT – Vesterled" gas metering station "footprints" from three different months over a 20 months period, November 2001, October 2002 and March 2003, are shown in Figure 15.

The "footprints" shown in Figure 15 may indicate that the "footprint" from March 2003 has shifted relative to the "footprints" from November 2001 and October 2002. The shift is not exceeding the warning limit of ± 0.175% (K=1).

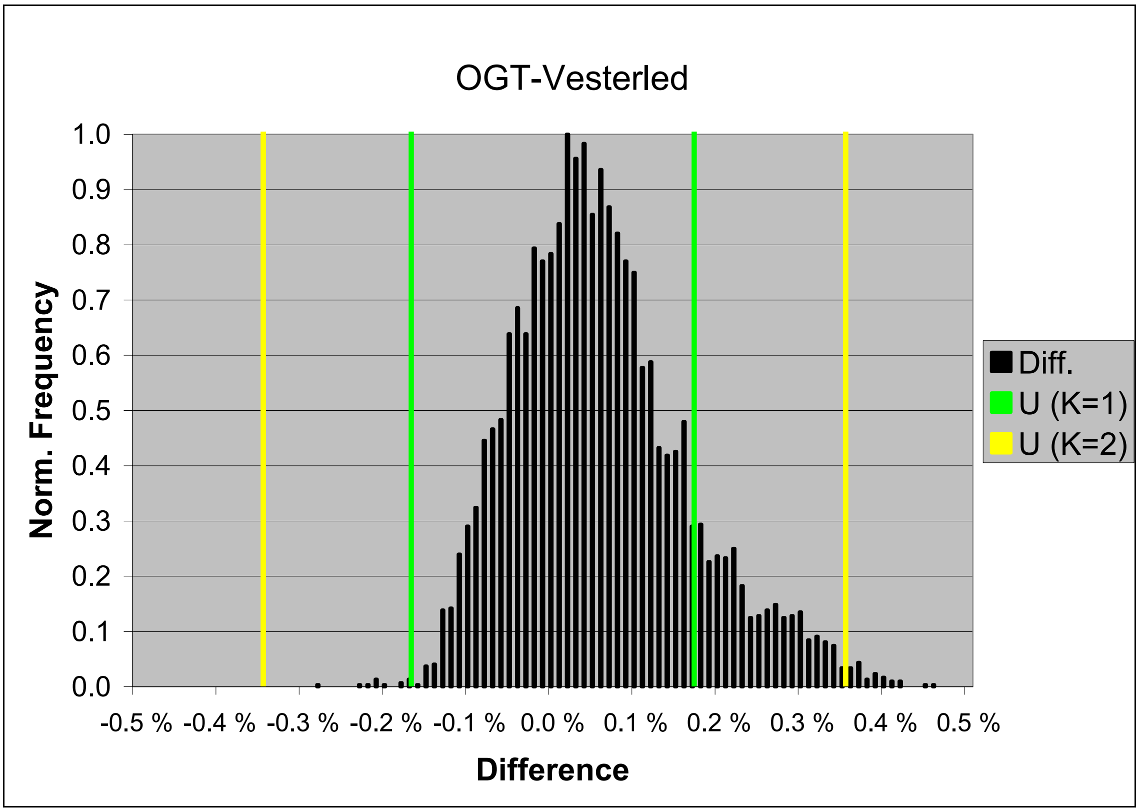

Figure 14. Histogram. Difference between hourly volume totals since October 2001.

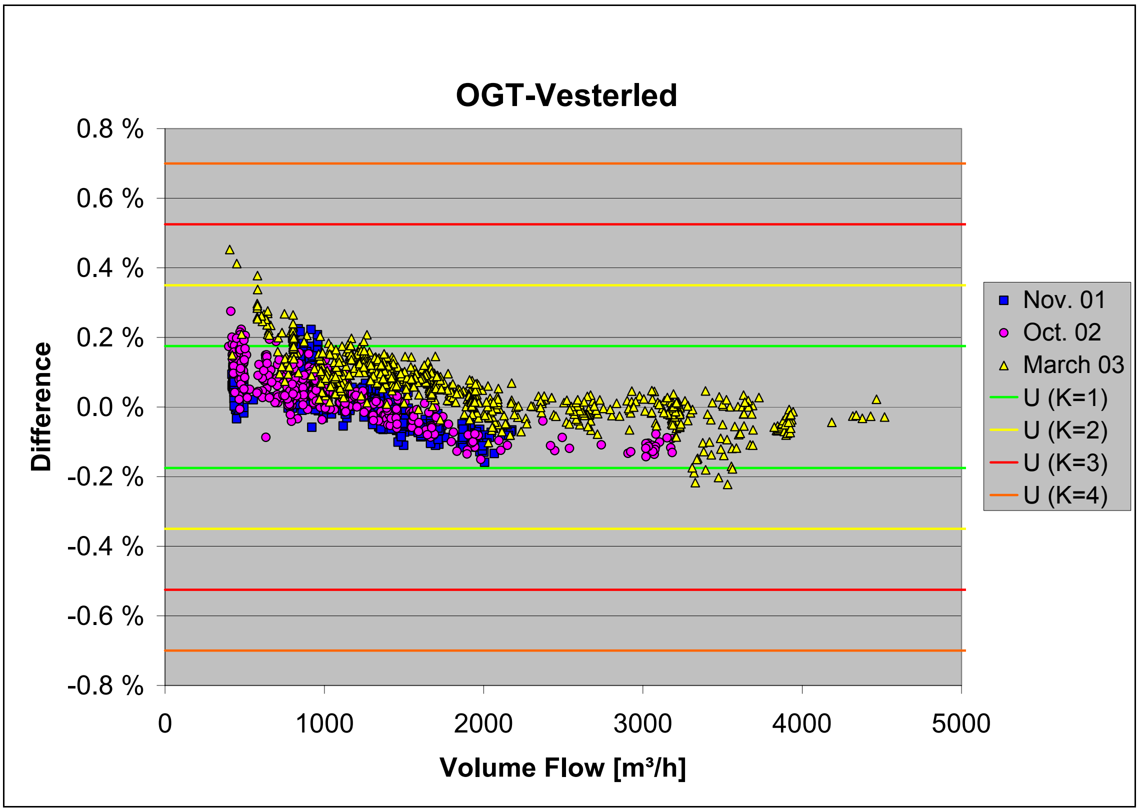

Figure 15. “Footprints” from three different months since October 2001.

5.5 HEA - Vesterled

The difference between hourly volume totals from Duty and Check meters at the "HEA – Vesterled" gas metering station over the last two years is shown in Figure 16.

The data are scattered around zero difference and the distribution becomes narrower at higher flow rates.

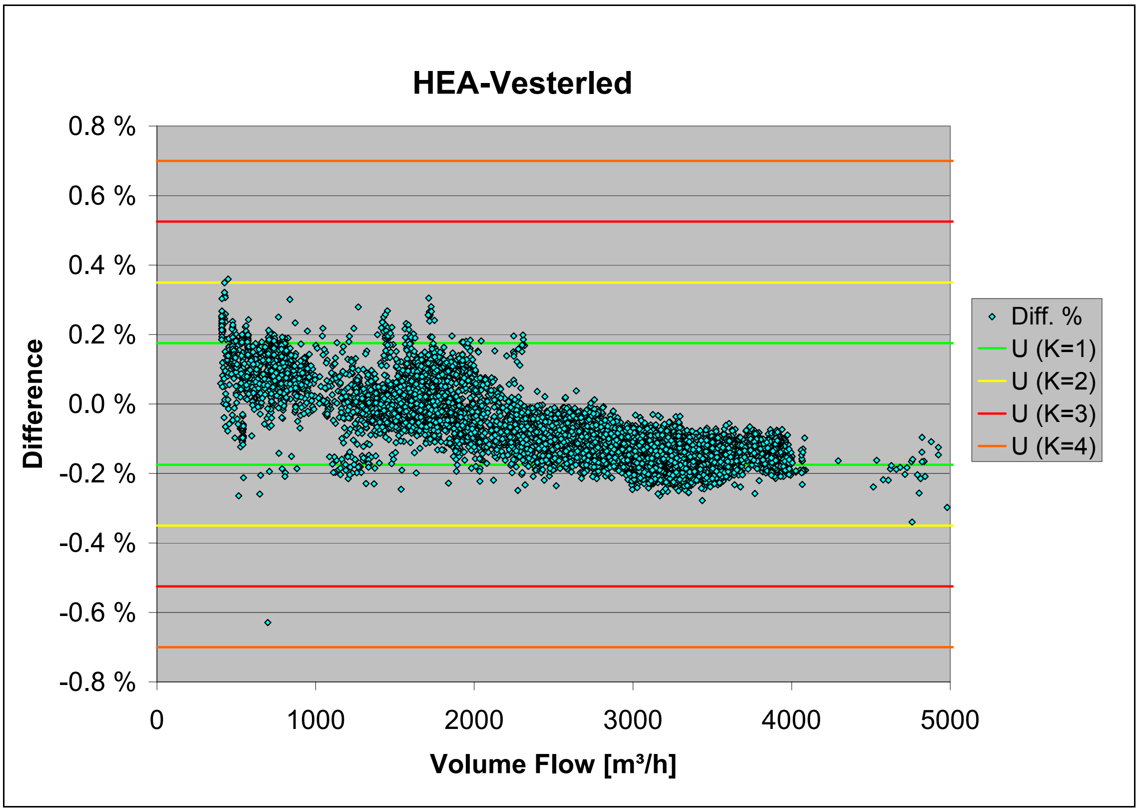

Figure 16. Difference between hourly volume totals since October 2001.

The normalized histogram of the difference data of the "HEA – Vesterled" gas metering station is shown in Figure 17.

The major differences between the meters are within the limit of ± 0.175% (K=1). The distribution is considered to be narrow but skewed and centred around –0.05%.

"HEA – Vesterled" gas metering station "footprints" from three different months over a 17 months period, February 2002, November 2002 and June 2003, are shown in Figure 18.

The "footprints" shown in Figure 18 may indicate that the "footprint" from November 2002 is shifted relative to the "footprints" from February 2002 and June 2003. The shift is not exceeding the warning limit of ± 0.175% (K=1).

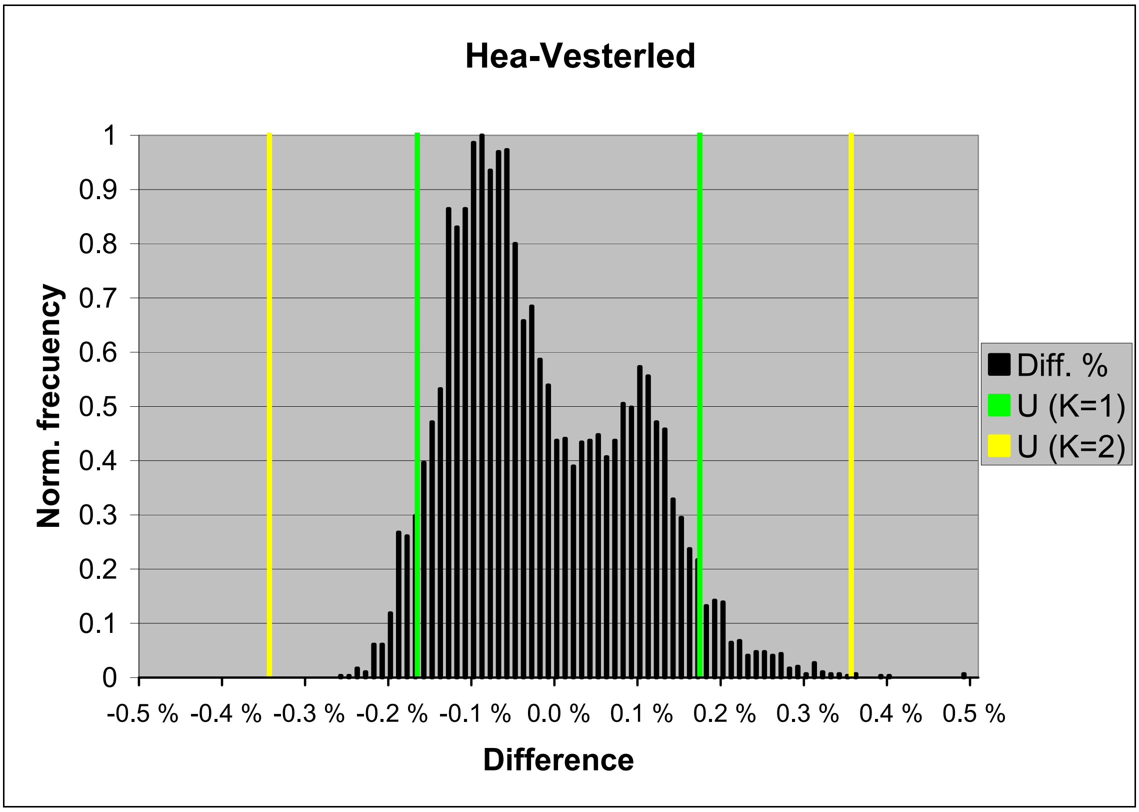

Figure 17. Histogram. Difference between hourly volume totals since October 2001.

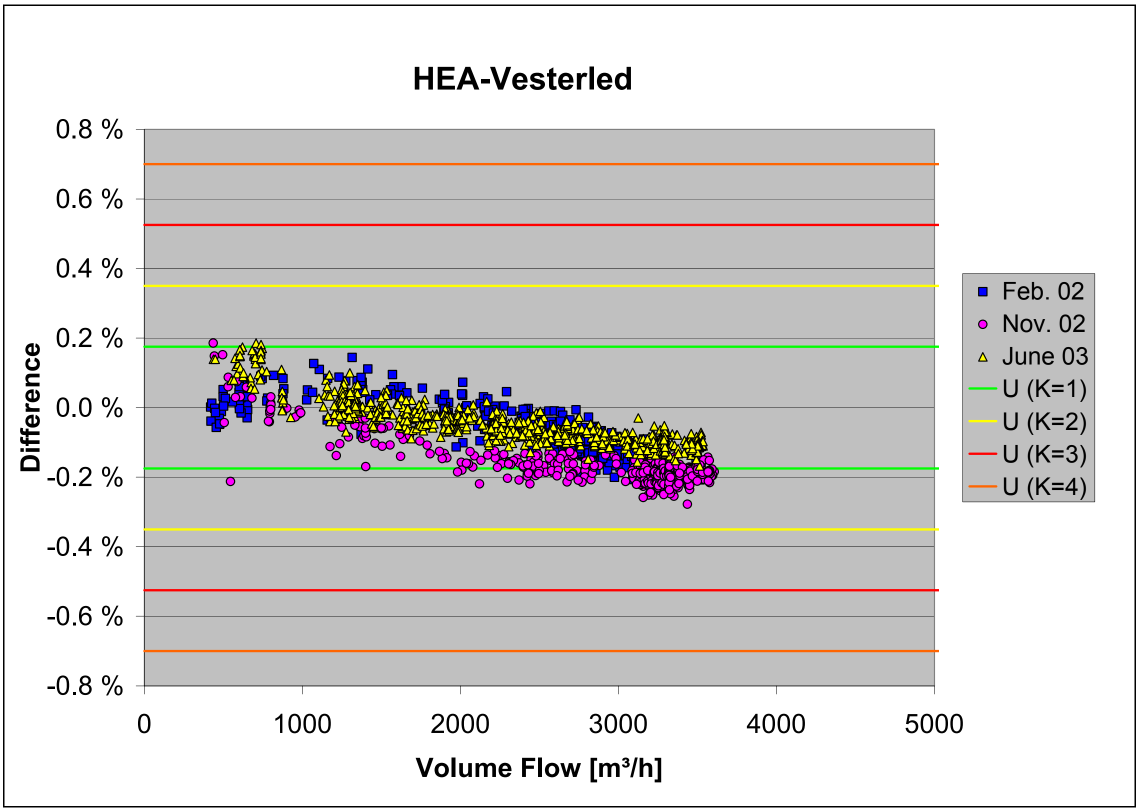

Figure 18. “Footprints” from three different months since October 2001.

5.6 Other aspects

The extreme stability of the meters makes it possible to see if the meters are affected by adverse process conditions like wet gas. The effect of wet gas has been observed and is described in Chapter 6. When such conditions have been identified this information has initiated an improvement of process control in order to avoid off-spec gas through the metering stations.

The difference between daily volume totals varies much less than the difference from hourly totals. Plotting daily difference as a function of average volume flow as in Figure 19 gives much less information about the difference "footprint" because of the 24 hours average effect, see Figure 10 for comparison with hourly data. Any flow variation during the 24 hours will be masked. This is why the "Reference meter method" is based on the difference between hourly volume totals. This point is more clearly illustrated in Figure 20.

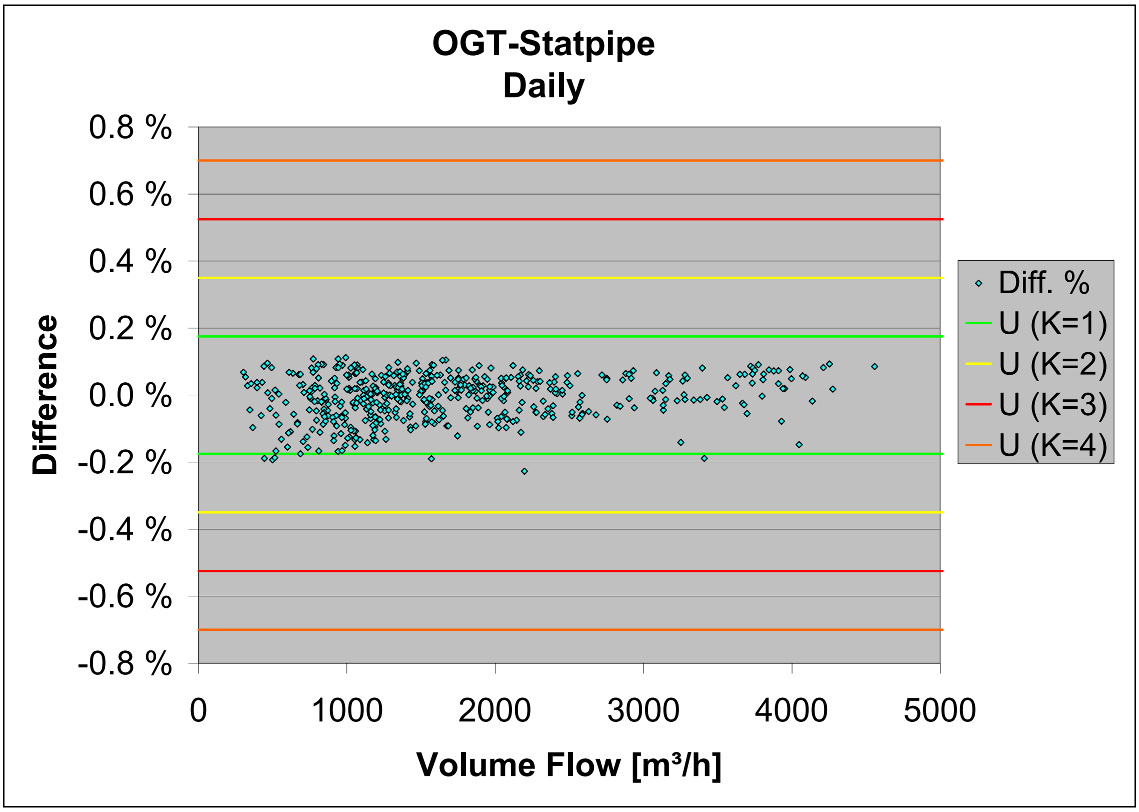

Figure 19. Difference between daily volume totals since September 2001.

The additional uncertainty caused by asynchronous metering systems is ± 1 second per time period. When totalising a steady flow for one hour this gives a "jitter" band of 0.56% in difference as opposed to 0.002% when totalising a steady flow for 24 hours. This effect is illustrated in the left part of Figure 20 when comparing the curves for "Hourly Difference" and "Daily Difference".

Another phenomenon may be seen when there are large changes in the flow rate, start-ups or shutdowns. Then the difference normally increases significantly as can be seen in the right part of Figure 20 from the curves for "Hourly Difference" and

"Volume flow". This illustrates the difference in transient response of the two measurement systems in series.

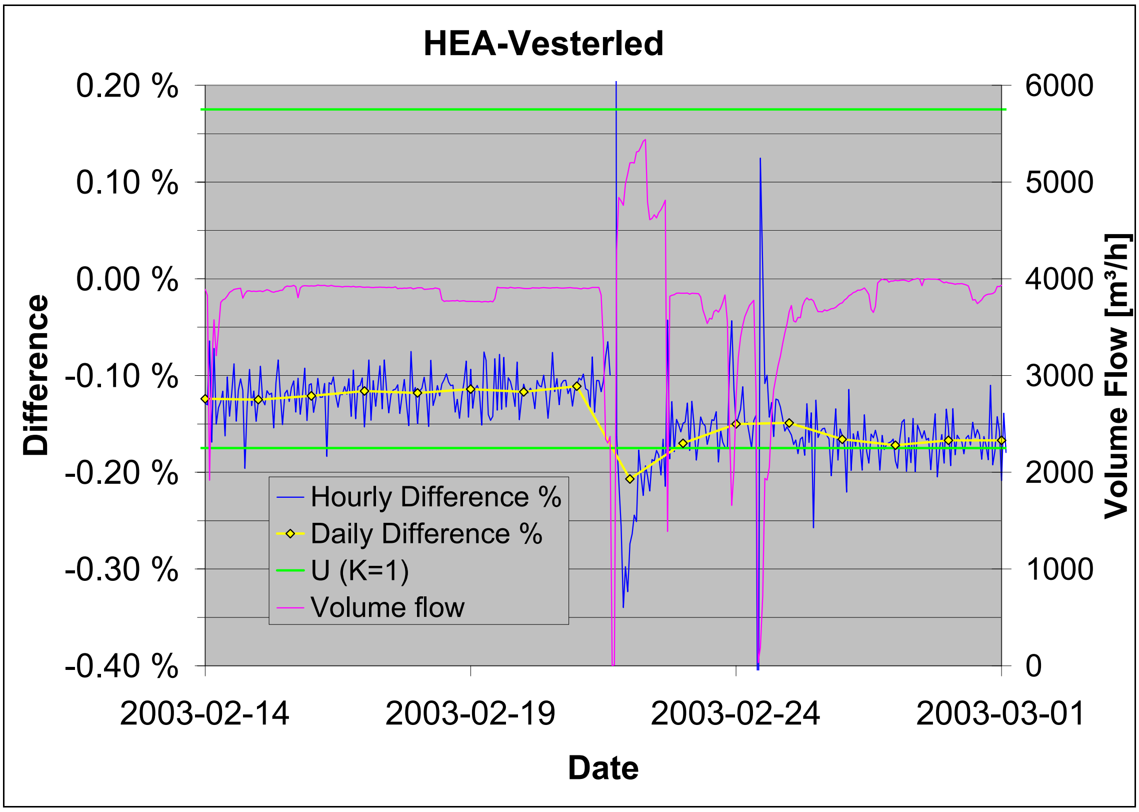

Figure 20. Examples of stable flow and flow rate fluctuations.

To summarize, the similarity of the "footprints" since start up demonstrates the excellent stability of the meters. The experience from the monthly quality assurance of two ultrasonic gas meters in series is that all differences exceeding ± 0.175% can be related to wet gas, start-ups or shutdowns. The difference between the meters when disregarding adverse process conditions has been within the warning limit of ± 0.175% (K=1) since first start-up for all four metering stations.

6 WET GAS PERFORMANCE

The pipeline from Oseberg D to Heimdal is 109 km long. Occasionally, heavier gas than specified has entered the pipeline for short periods of time. This wet gas has affected the performance of the metering stations both at the inlet and outlet of the pipeline. It has probably also lead to condensation in the pipeline.

6.1 Case study

One such occurrence happened between 19 and 26 September 2001 when the difference between the two ultrasonic gas meters became exceptionally large in the "OGT – Statpipe" metering station at Heimdal, reaching 21%, see Figures 21 and 22.

It is also evident from the plots that the good performance with stable small difference between the meters, returned after the period with wet gas.

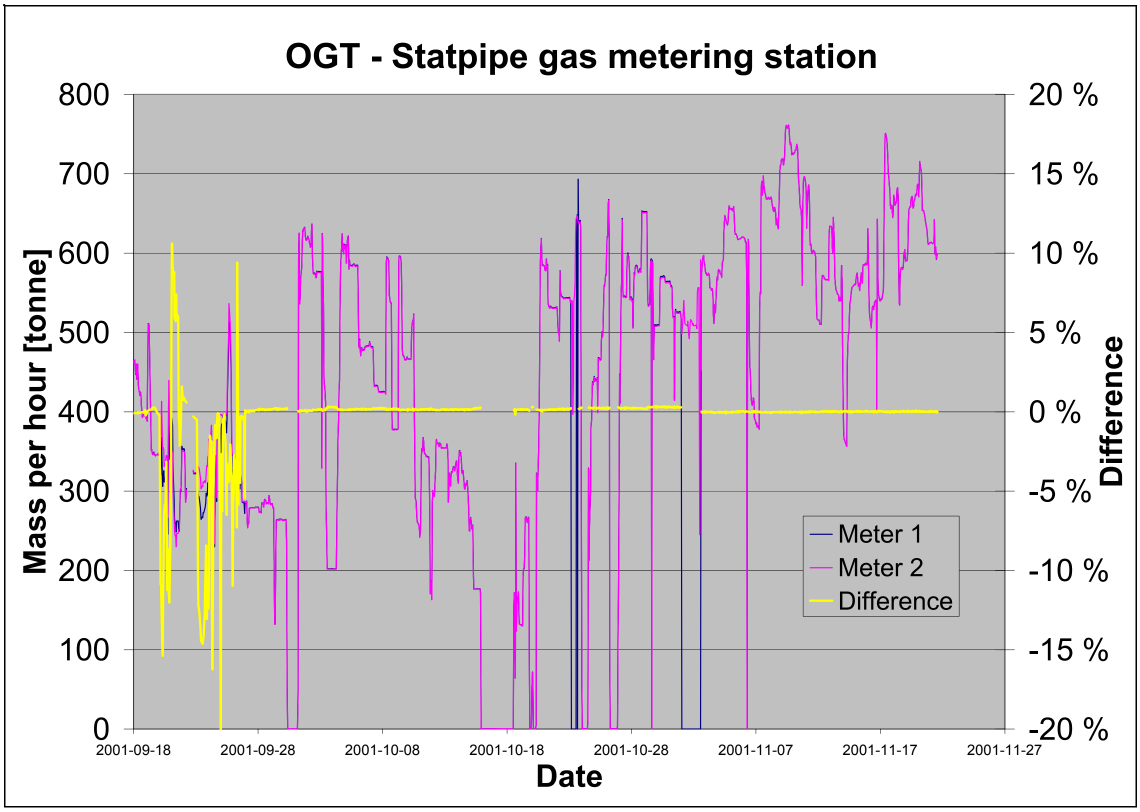

Figure 21. Differences between two ultrasonic gas meters in series.

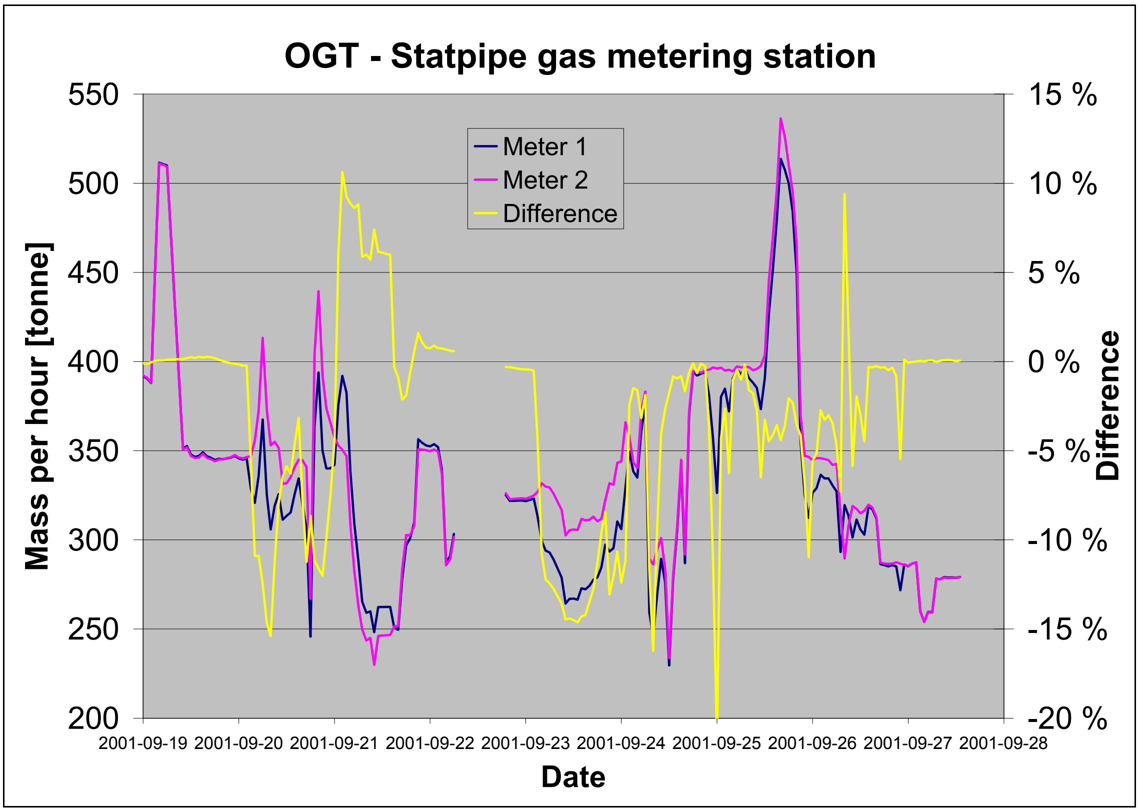

Figure 22. Differences between two ultrasonic gas meters in series. Expanded view.

This large difference clearly indicates an error condition and of course resulted in alarms to the operator. But none of the meters failed during this time period; therefore the large difference between the meters must be caused by an external influence.

The next question of course is which meter to "trust". Close examination of the curves in Figure 22 might give a clue. But to more clearly emphasise the difference in performance of the two meters, we have calculated a new curve showing the absolute difference between the first derivatives of the mass flow through each meter, multiplied by the absolute difference between the meters. In Figure 23 this "derivative-curve" is shown together with the mass flow through each meter, for the last part of the wet gas period. This "derivative-curve" will be zero when the two meters measure the same change in mass flow. If one of the meters changes more than the other, this "derivative-curve" will differ from zero.

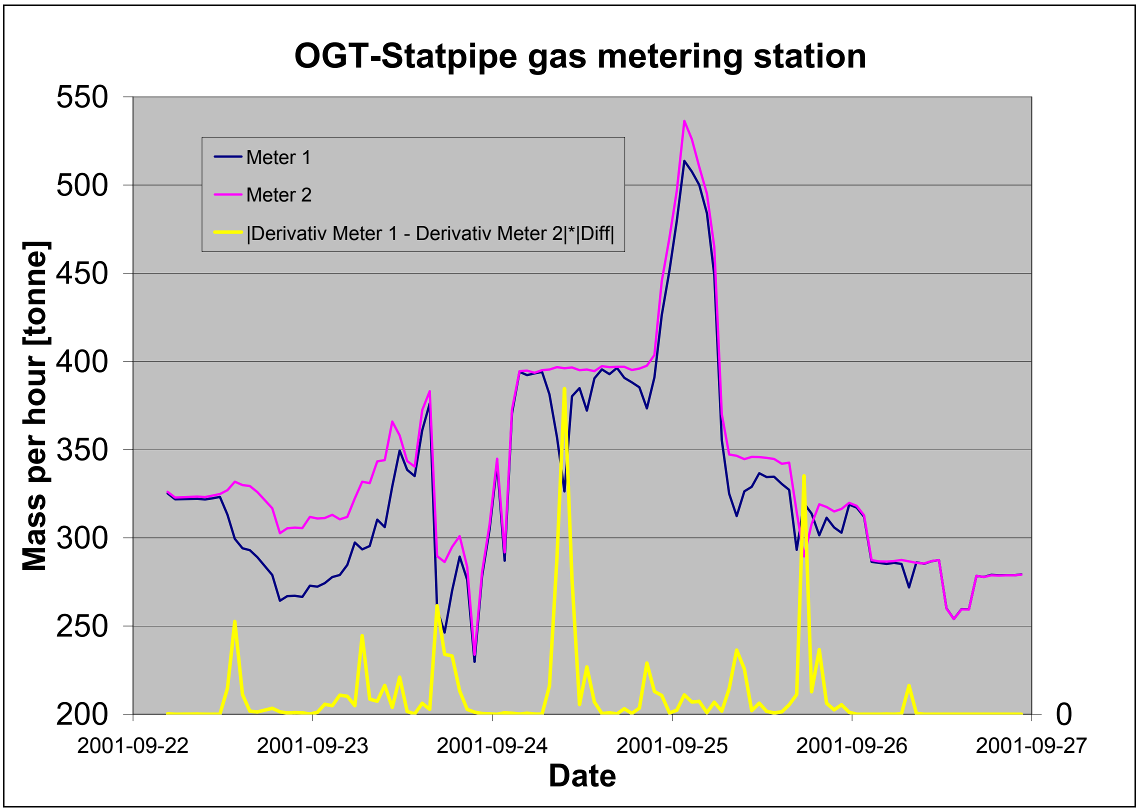

Figure 23. The difference between the first derivatives of the curves of mass flow.

From Figure 23 we now see that every time the meters start to deviate it is meter 1 that is (most) affected and consistently drops away from meter 2. A condition that is likely to affect meter 1 more than meter 2 should be searched for.

Closer investigation revealed that it probably had been condensation of gas in the pipeline. Both the metering stations at Oseberg D and at Heimdal have on-line gas chromatographs. Figure 24 shows a dramatic increase in the C5+ content at Oseberg D in the period starting at 09:00 hours on 17.09.2001 and ending at 09:00 hours on 18.09.2001.

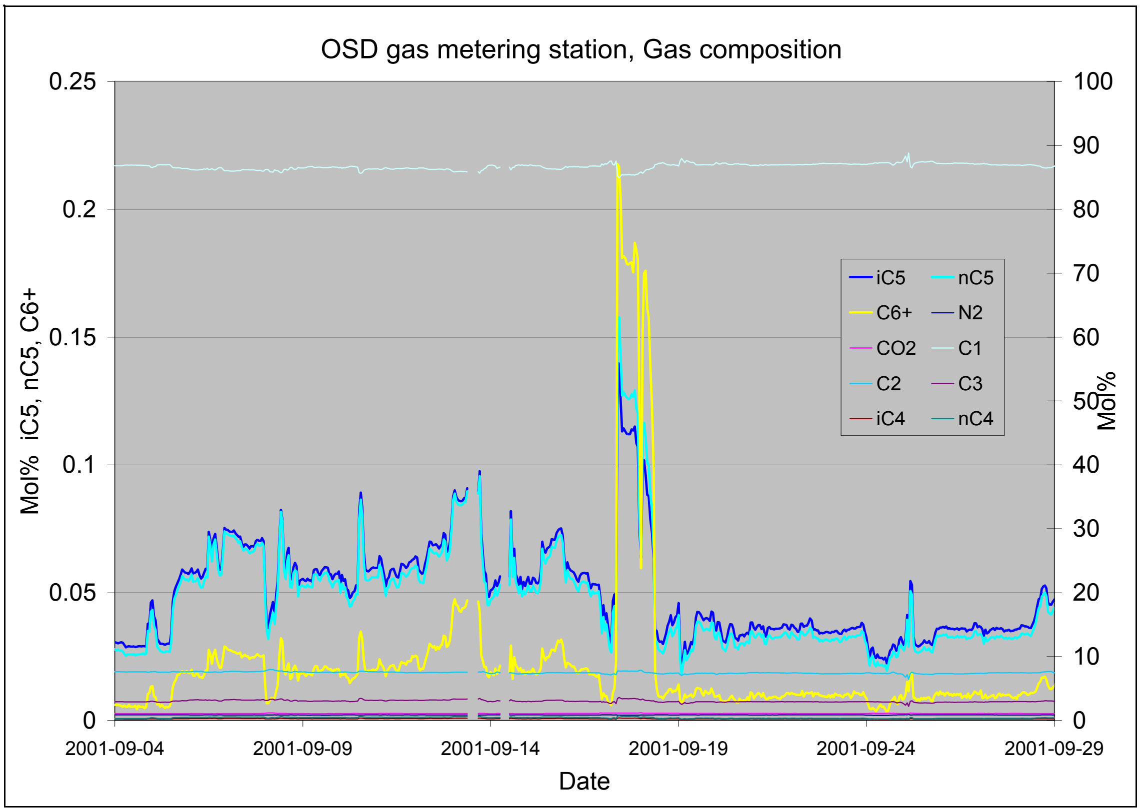

Figure 24. Gas composition at Oseberg D.

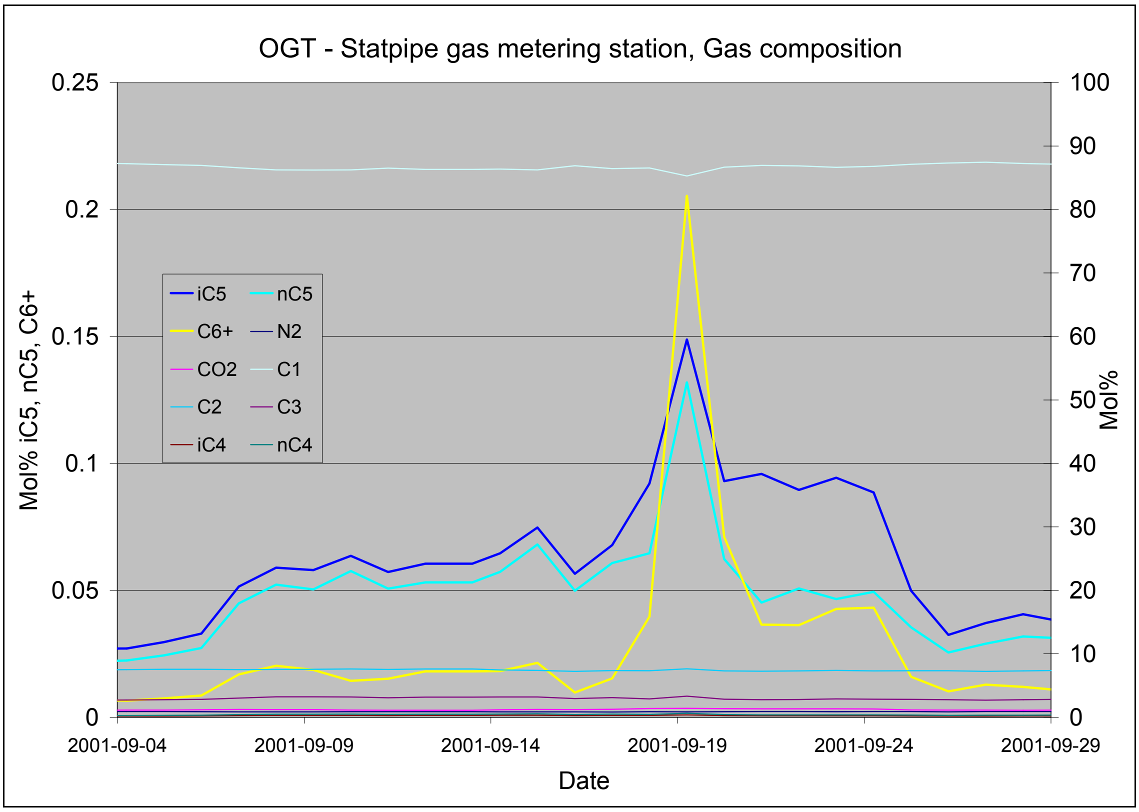

Figure 25. Gas composition at Heimdal.

Due to the gas transportation time between Oseberg D and Heimdal an increase in C5+ is first seen at Heimdal about 24 hours later, see Figure 25. However, the increased level of C5+ lasted for 6 days on Heimdal. A likely explanation is that it took 6 days before the gas had carried all the liquid in the pipeline through the metering station on Heimdal.

A K-lab / Laws flow conditioner (plate with 19 holes) is mounted 13D upstream the first ultrasonic meter.

A likely explanation for the deviating performance of meter 1 and 2 is that liquid build-up in the bottom of the pipe upstream the flow conditioner caused a disturbance of the flow profile when the liquid passed through the flow conditioner. Meter 2 is installed 8D further downstream from the flow conditioner than meter 1. It is therefore assumed that the flow profile is less disturbed in meter 2 than in meter 1.

The wet gas performance of meter 1 seems to be severely affected by the close proximity to the flow conditioner. The wet gas performance of meter 2 seems acceptable.

Based on this experience, meter 2 is selected as the Duty meter and meter 1 is used as Check meter. This philosophy is implemented in all metering stations containing two ultrasonic gas meters in series, operated by Norsk Hydro.

7 REFERENCE METER METHOD

The purpose of the “Reference meter method” is to provide means to re-establish traceability after having repaired one of two meters in series.

The method also provides control limits for evaluation of meter performance of two meters in series in normal operation.

7.1 The Reference meter method for ultrasonic gas meters in series

The “Reference meter method” consists of several steps.

1. Establish track record on the difference between hourly totals for volume flow at line conditions for various flow rates within working range, from first start-up and regularly during operation (every month for the last month).

2. Establish control limits for the “footprint”, the difference / change from historical track record (diff). We recommend using the measurement uncertainty (± 2 Std., relative expanded uncertainty with coverage factor k=2) of the calibration laboratory / original calibration certificate for the ultrasonic gas meter (or exercise your discretion when using two meters in series in a simplified measurement application).

   The actions that are valid when re-establishing traceability and for evaluation of meter performance are listed in Table 2 for each control limit. The control limits are valid in the working range (20:1) (The method uses similar control limits as in API MPMS 13.2 Table 14).

Table 2. Control limits with corresponding actions.

CONTROL LIMITS	ACTIONS (when re-establish traceability)	EVALUATION (of meter performance)
-1 Std. < diff ≤ +1 Std. (k=1)	Original calibration certificate is considered still valid.	**OK**
- 2 Std. < diff ≤ - 1 Std. or + 1 Std. < diff ≤ + 2 Std. (k=2)	Adjust calibration curve to match reference meter values. Traceability through reference meter calibration certificate.	**Warning:** Look for systematic shifts in footprint
- 3 Std. < diff ≤ - 2 Std. or + 2 Std. < diff ≤ + 3 Std. (k=3)	Adjust calibration curve to match reference meter values. Traceability through reference meter calibration certificate. Evaluate the need for re-calibration in an accredited calibration laboratory based on maintenance history for both ultrasonic gas meters, i.e. number of transducer replacements and number of and size of previous adjustments of calibration curves.	**Action:** Look for signs of wet gas, unusual process conditions, evaluate sound velocity profile etc.
- 4 Std. < diff ≤ - 3 Std. or + 3 Std. < diff ≤ + 4 Std. (k=4)	Re-calibrate in an accredited calibration laboratory.	**Tolerance:** Consider re-calibration.
Diff < - 4 Std. or + 4 Std. < diff	Service/ check to be performed by supplier. Re-calibrate in an accredited calibration laboratory.	**Fault:** Consider service and re-calibration.

3. When error occurs, service the faulty meter and put it back in operation as Check meter. The other ultrasonic gas meter is Duty meter and will be used as reference meter.

4. The two ultrasonic meters are compared using the difference between hourly totals for volume flow at line conditions for various flow rates within working range. Sufficient basis should be established before conclusions are drawn and comparing the two meters for at least one month should be considered.

5. Historical track record / "footprint" for the difference between volume flow at line conditions for the two ultrasonic gas meters shall be compared with track record / "footprint" established since the error was corrected. Changes in curve shape, shift in curve and size of difference shall be considered. Determine action based on control limit criteria.

7.2 Example using the Reference meter method for ultrasonic gas meters in series

Ultrasonic gas meter no.1 operated as a 4-path meter, with one failed single reflecting path since first start-up 01.10.2001. This meter was repaired 25.11.2001 replacing the faulty transducer.

Ultrasonic gas meter no. 2 had a short period with a failed single reflecting path due to a faulty connection. This was corrected 21.11.2001 and had no influence on the validity of the calibration certificate.

Ultrasonic gas meter no. 1 was checked using the "Reference meter method" with ultrasonic meter no. 2 as reference meter from 26.11.2001 to 31.12.2001.

The measurement uncertainty of the calibration laboratory Advantica Flow Centre, England, is ± 0.35% (k=2) for the range 200 to 8500 m^3/hour. See the schedule of accreditation issued by UKAS 05.03.2001 in Figure 26.

UKAS 0555 Calibration performed on permanent laboratory premises	**Schedule of Accreditation** issued by **United Kingdom Accreditation Service** 21 - 47 High Street, Feltham, Middlesex, TW13 4UN, UK **Advantica Technologies Ltd** Issue No: 06 Issue date: 05 March 2001

DETAIL OF ACCREDITATION

Measured Quantity Instrument or Gauge	Range	Best Measurement Capability Expressed as an Expanded Uncertainty (k=2)	Remarks
Volume Flow (Natural Gas)	20 m^3/hr to 480 m^3/hr	0.23%	
	480 m^3/hr to 1000 m^3/hr	0.25%	
	1000 m^3/hr to 2500 m^3/hr	0.28%	
	2500 m^3/hr to 6500 m^3/hr	0.34%	
	6500 m^3/hr to 13000 m^3/hr	0.35%	
	13000 m^3/hr to 19500 m^3/hr	0.36%	

Figure 26. Schedule of accreditation for Advantica Flow Centre, England, issued by UKAS 05.03.2001.

Using the "Reference meter method" with the control limits in Table 2, the following control limits apply:

- ± 1 Std. = ± 0.175% (k=1)
- ± 2 Std. = ± 0.35% (k=2)
- ± 3 Std. = ± 0.525% (k=3)
- ± 4 Std. = ± 0.70% (k=4)

The difference between hourly totals for volume flow at line conditions before and after repairing the faulty transducer (25.11.2001) is shown in Figure 27 over a period of 2 months. There is no visible change in the difference due to the repair.

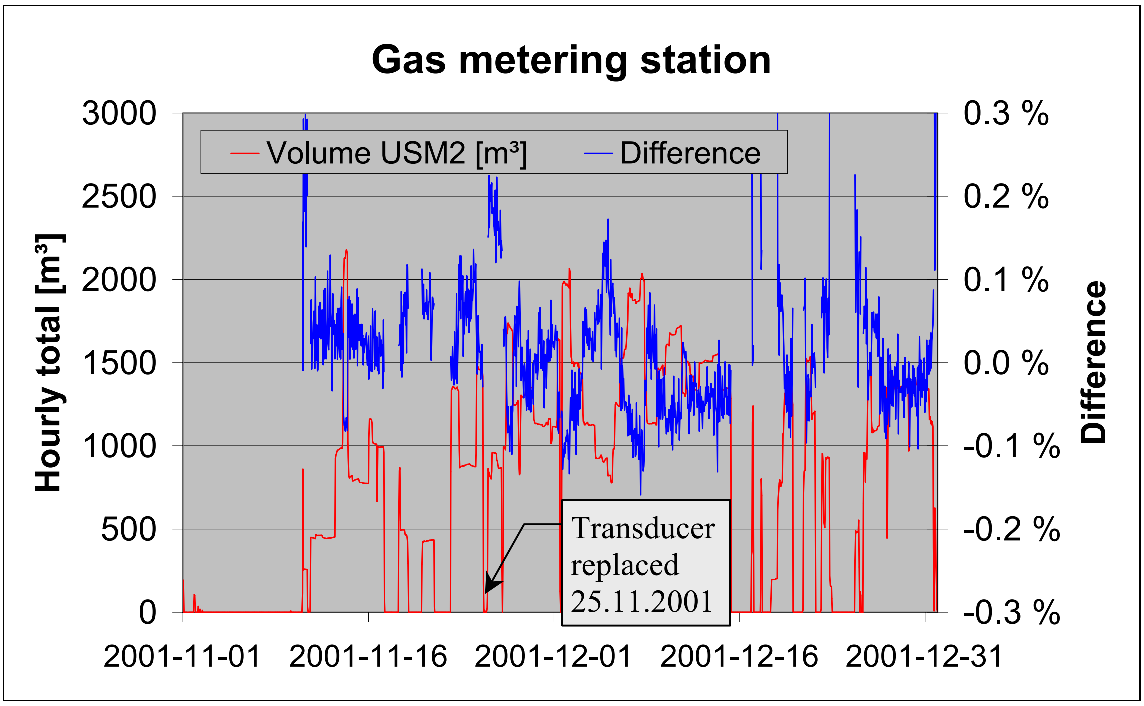

Figure 27. The difference between hourly totals for volume flow at line conditions before and after repairing the faulty transducer (25.11.2001) over a period of 2 months.

The "footprint" (difference between hourly totals for volume flow at line conditions as a function of volume flow rate) before and after repairing faults is shown in Figure 28 over a period of 2 months

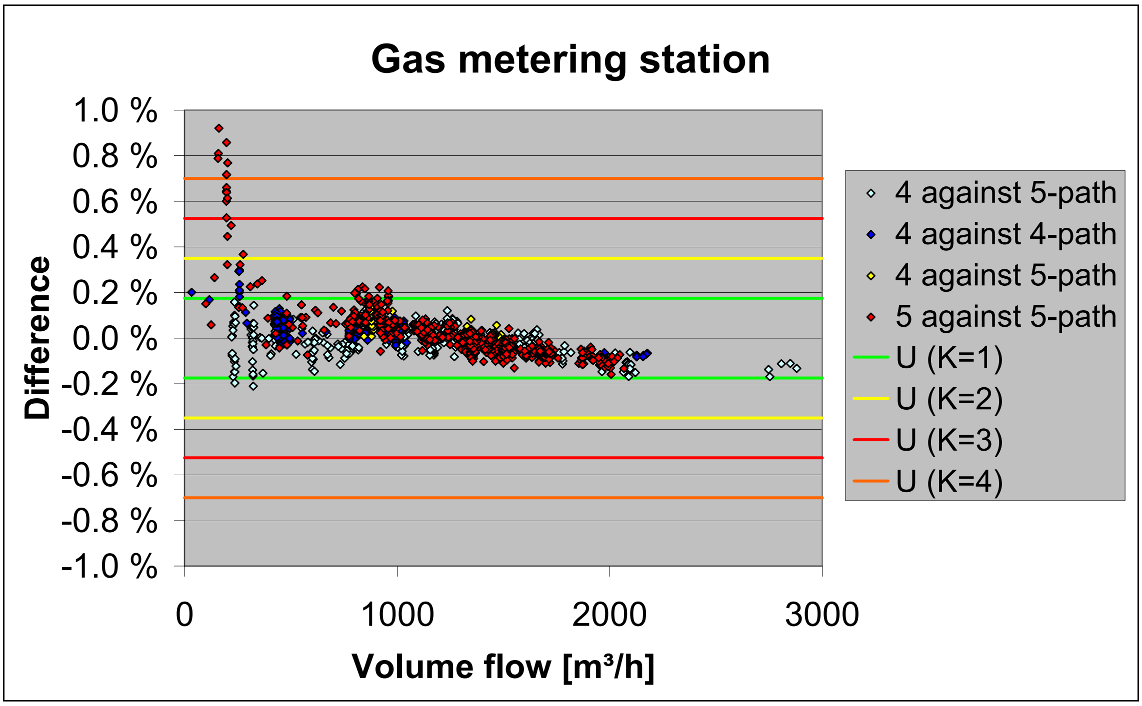

Figure 28. The "footprint" for various numbers of paths in operation in the two meters in series.

The difference between "footprints" before and after repairing the faulty transducer shows that the spread in data is maintained within approximately ± 0.175% (k=1) for relevant flow rates. The curve shape / "footprint" is not changed after repairing the faulty transducer.

The "footprint" is neither changed by the various numbers of paths in operation in the two meters in series. We can conclude that these meters are not significantly affected by a failing single reflecting path.

The difference between the two ultrasonic gas meters is within the control limit where the original calibration certificate is considered still valid. The original calibration certificate from Advantica Flow Centre, England, from 09.07.2001, can therefore still be used for Ultrasonic meter no. 1 after replacing one transducer.

8 CONCLUSIONS

Norsk Hydro recommends calibrating the meters together with the complete metering run. Further it is recommended to calibrate both meters simultaneously against the reference.

The use of two ultrasonic gas meters in series provides an extremely efficient means of demonstrating that the performance of the meters are within the requirements of NPD and Norsk Hydro as an operator. It also provides means to identify unfortunate process conditions like wet gas.

Norsk Hydro has been operating the meters within ± 0.175% difference between the meters since first start-up, when disregarding adverse process conditions. The experience from the monthly quality assurance is that all differences exceeding ± 0.175% can be related to wet gas, start-ups or shutdowns.

The eight meters in the four metering stations have a total of 20 years operation time. It has not been identified any significant drift of any meter since first start-up.

Norsk Hydro has so fare replaced one transducer in one meter since first start-up, with no shift in meter performance. The traceability for this meter was re-established using the "Reference meter method".

Based on wet gas experience, meter 2 is always selected as the Duty meter and meter 1 is used as Check meter in gas metering stations with two meters in series.

Based on the extremely good results with using two ultrasonic gas meters in series Norsk Hydro does not require scheduled recalibration of these meters. Recalibration is performed according to the control limits of the "Reference meter method".

The results presented in this paper demonstrates the benefit of Norsk Hydro's design requirement to always use two ultrasonic gas meters in series.

References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.