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FLOW

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PAPER 10 - 3.2

EXPERIENCE FROM OSBERG C WITH A PROTOTYPE 6" MULTI-PATH ULTRASONIC GAS FLOW METER IN WELL DEVELOPED FLOW, SWIRL FLOW AND FLOW STRAIGHTENED CONDITIONS, COMPARED TO AN ORIFICE GAS FLOW METER.

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16th NORTH SEA FLOW MEASUREMENT WORKSHOP 1998

EXPERIENCE FROM OSEBERG C WITH A PROTOTYPE 6" MULTI-PATH ULTRASONIC GAS FLOW METER IN WELL DEVELOPED FLOW, SWIRL FLOW AND FLOW STRAIGHTENED CONDITIONS, COMPARED TO AN ORIFICE GAS FLOW METER

Trond Folkestad, Norse Hydro ASA

1 INTRODUCTION

Norsk Hydro has an installation for measuring fuel gas on the Oseberg C platform comprising a 6" multi-path Ultrasonic gas flow meter in series with an Orifice gas flow meter downstream. The Ultrasonic gas flow meter is a Fluenta 6-path FMU 700 while the Orifice gas flow meter is a simplified installation consisting of an orifice plate between orifice flanges. The Orifice gas flow meter is used as a qualitative check meter to evaluate the long-term performance of the Ultrasonic gas flow meter.

The flow conditions inside the Ultrasonic gas flow meter can change from a fairly well developed flow to a severe asymmetric swirl flow, coming from two different sources with different piping arrangements. After one year in continuous operation a flow conditioner was installed 9.9 D upstream of the Ultrasonic gas flow meter to eliminate the swirl flow.

This paper will share the experience gained with the original flow regimes and with the flow conditioner installed and the paper will conclude with a recommendation for installation and use of this type of Ultrasonic gas flow meters.

2 BACKGROUND

The simplified Orifice gas flow meter was the originally installed fuel gas measurement system on the Oseberg C platform. Soon after the introduction in 1993 of the new regulation from the Norwegian Petroleum Directorate (NPD) relating to measurement of fuel and flare gas for calculation of CO_2 tax, Norsk Hydro was requested by NPD to improve the fuel gas measurement installation on the Oseberg C platform.

There is very limited space available for the fuel gas measurement system on the platform. After performing several studies in 1993 and 1994 evaluating possible measurement principals and installation solutions with space requirements, it was decided to install a prototype 6-path Ultrasonic gas flow meter. It was also decided to retain the original installation as a qualitative check meter.

The Ultrasonic gas flow meter was ordered from Fluenta 01.11.1994. With the installation of a prototype meter the mandatory delays were inevitable and the meter was finally installed at the Oseberg C platform in October 1995 after extensive testing at K-lab and considerable software development. After the commissioning phase and after several errors had been corrected in the software the Ultrasonic gas flow meter was finally put in operation 13.02.1996.

3 MEASUREMENT PRINCIPALS

3.1 The Ultrasonic Gas Flow Meter

The 6-path Ultrasonic gas flow meter has an acoustic path arrangement as seen in Figure 1. Acoustic paths A and B are in the top half of the meter, and paths C and D are in the bottom half. This acoustic path arrangement should enable the meter to measure and correct for a symmetric swirl flow, and also to measure the secondary transversal flow component.

Calculation of CO_2 tax is based on the amount of gas used measured as standard volume (Sm^3) of gas.

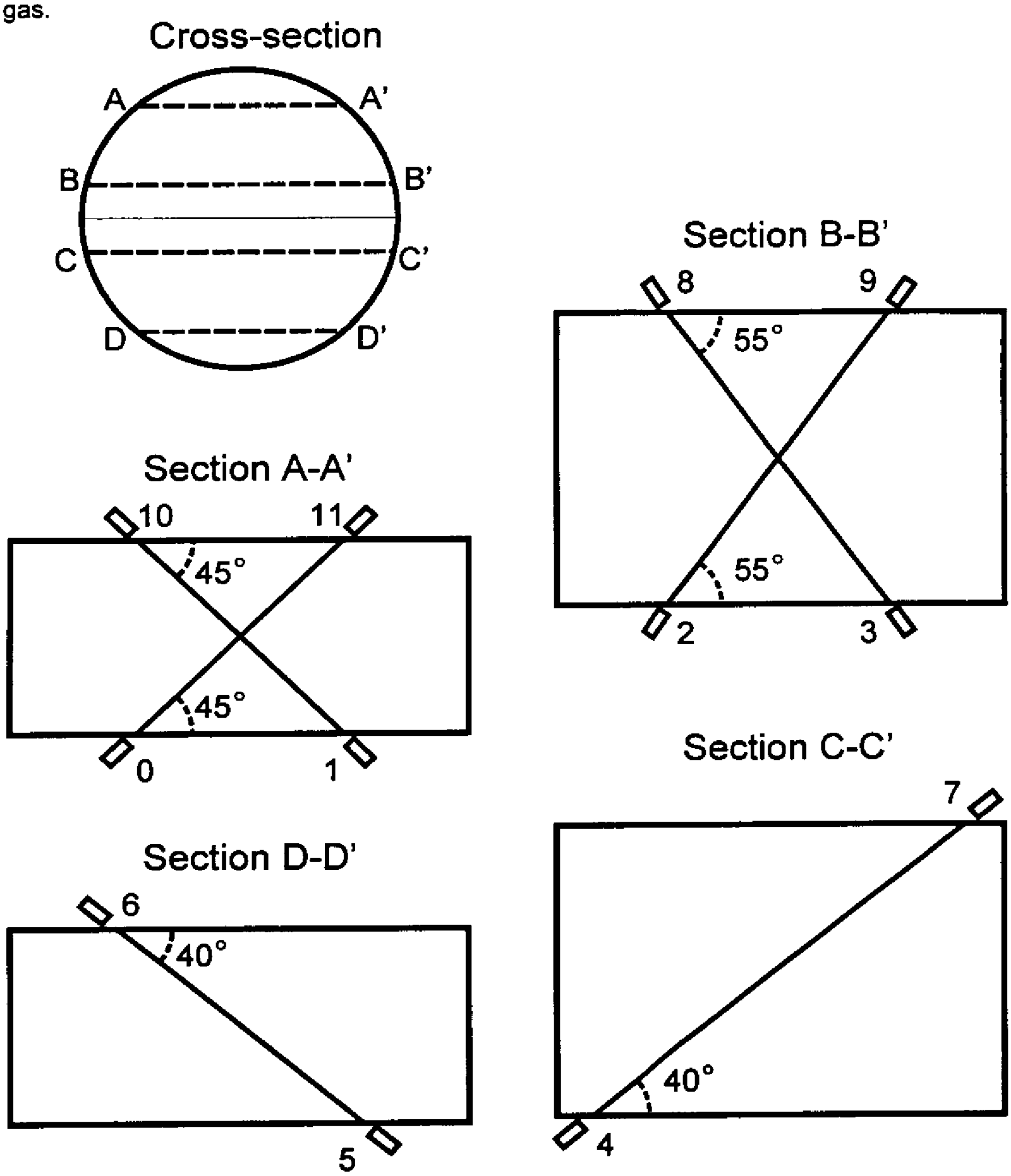

Figure 1 - Acoustic path arrangement in the 6-path Ultrasonic gas flow meter showing the position and numbering convention for transducers. Path A is the topmost acoustic path. Internal diameter is 146.25 mm.

The Ultrasonic gas flow meter measures actual volume flow and using PZT correction gives the standard volume flow, see Equation (1).

$$V_S = V_A \cdot \frac{P_A \cdot Z_S \cdot T_S}{P_S \cdot Z_A \cdot T_A} \qquad \left[Sm^3/h\right] \qquad (1)$$

Temperature and pressure are measured using transmitters with HART protocol.

3.2 The Orifice Gas Flow Meter

The Orifice gas flow meter is a 6" orifice plate between orifice flanges. The differential pressure, temperature and pressure are measured using 4 – 20 mA transmitters connected to the platform control system. This arrangement tends to give flow also at zero flow since no cut-off limit has been implemented and the zero accuracy of the 4 – 20 mA differential pressure signal is limited.

The flow calculations in the platform control system is simplified with no iterative compensation for flow, see Equation (2).

$$V_S = K \cdot \sqrt{\frac{\Delta p_A \cdot P_A}{MW \cdot T_A}} \qquad \left[Sm^3/h\right] \tag{2}$$

The constant K in Equation (2) has been calculated using typical gas composition, flow rate, temperature and pressure, and has not been changed since installing the Ultrasonic flow meter in series. The molecular weight (MW) is changed when adapting a new gas composition.

4 CALIBRATION

The multi-path Ultrasonic gas flow meter has been zero calibrated by Fluenta and then flow calibrated two times at K-lab. The calibrations were performed at 55°C and 37 bar a, while the conditions at Oseberg C are 58 – 62°C (regulated) and 39 bar a.

The first calibration of the 6-path Ultrasonic gas flow meter was performed at K-lab in May / June 1995. The calibration curve shoved unexpected large deviations from reference, which could not be explained, see Figure 2. The calibration was repeated several times but the same curve was obtained. The calibration curve was then implemented in the flow computer to eliminate the offset error.

A large effort was put in to try to find the cause of the peculiar calibration curve but so far no explanation has been found.

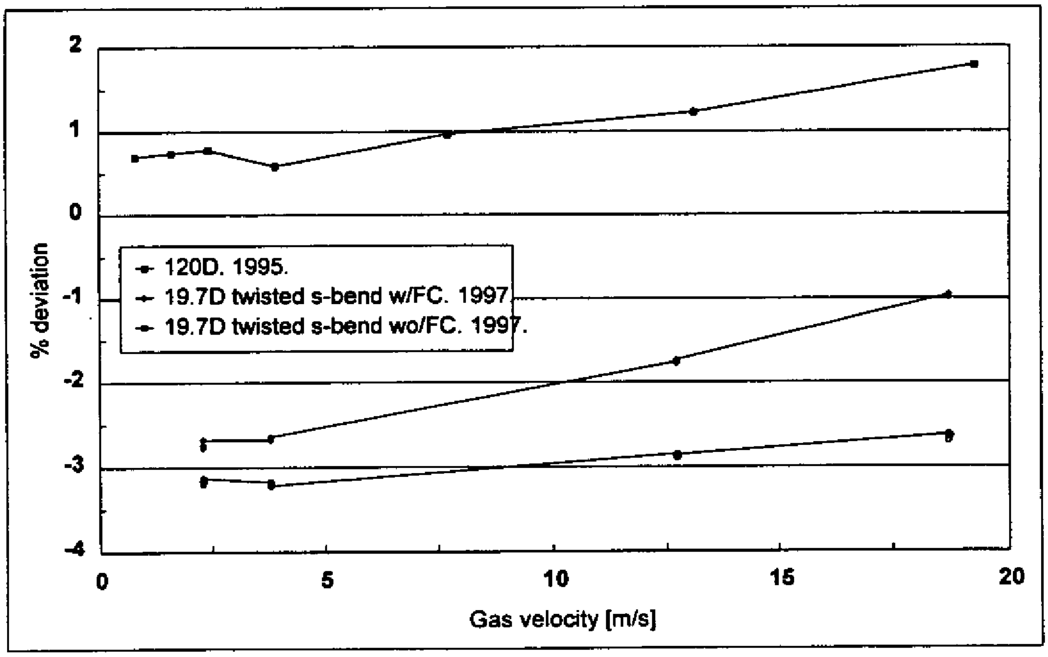

Figure 2 - Calibration curves from calibrations at K-lab in 1995 and 1997.

Errors in geometric dimensions were suspected and thoroughly checked but all angles, lateral positions and acoustic path lengths used in the flow computer were either measured values or were within acceptable design tolerances.

The second calibration was performed at K-lab in June 1997, after some modifications to the transducer face, reducing the length of each transducer. This modification was done to enable higher gas temperatures through the meter. The significant shift, exceeding 3%, between the calibration curves before and after modification demonstrates that a small bore Ultrasonic gas flow meter must be flow calibrated before installation.

The calibration curve was implemented in the flow computer to eliminate the offset error.

As can be seen from Figure 2 the Ultrasonic gas flow meter is in this case underestimating the flow with a swirl through the meter. This swirl is rotating in the opposite direction and is not so severe as the one at the Oseberg C platform. The swirl is generated by two 90° bends out of plane, with 5.5 D between the bends, 20 D upstream of the Ultrasonic gas flow meter. With flow conditioner installed there is a positive shift in the calibration curve as well as a change in the curve gradient towards the gradient seen during calibration in June 1995.

5 IN OPERATION

During final commissioning (05 – 06.02.1996) everything looked in order. We got a nice symmetrical "flow velocity profile" see Figure 3, and a fairly constant sound velocity profile. Refer to Figure 1 for transducer numbering and path positions convention.

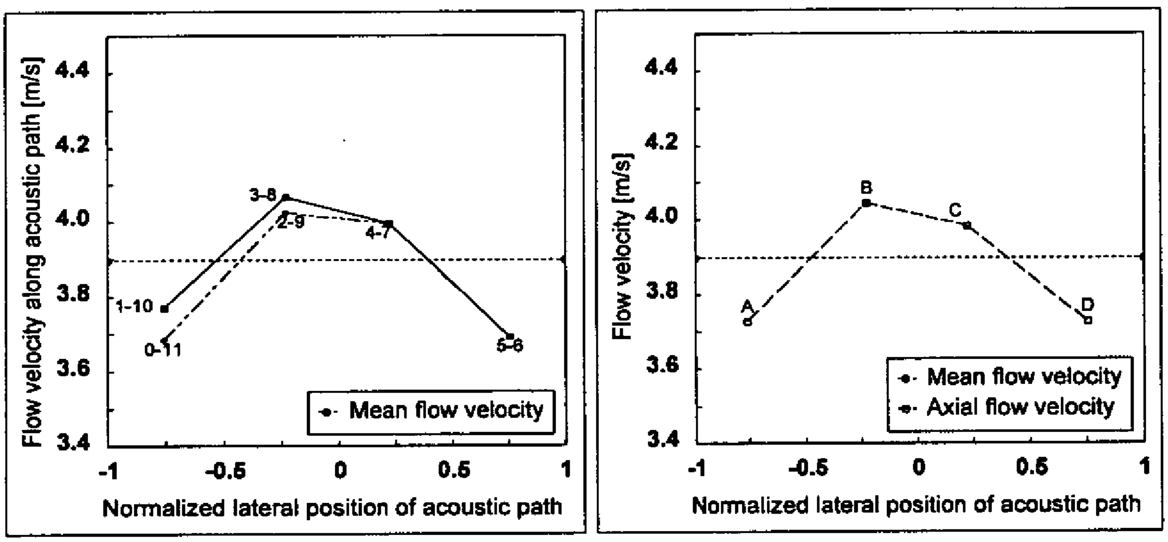

Figure 3 - Gas from Fuel gas heater A. The transducer numbering and the path positions refer to convention defined in Figure 1.

When we left the platform, the Ultrasonic gas flow meter seemed to function almost 100%, only two minor software errors remained. On our next visit 7 days later (13.02.1996) to implement the corrected software, nothing seemed in order. The "flow velocity profile" had suddenly as if by magic changed to a severe asymmetric swirl profile, see Figure 4.

"What is wrong with this meter!?" "First the calibration and now this!?" Nothing it turned out. Everything was re-checked and double-checked then finally some good detective work by Fluenta revealed that the fuel gas supply had been changed by the process operator during the night after we had left the platform (07.02.1996) from Fuel gas heater A to Fuel gas heater B.

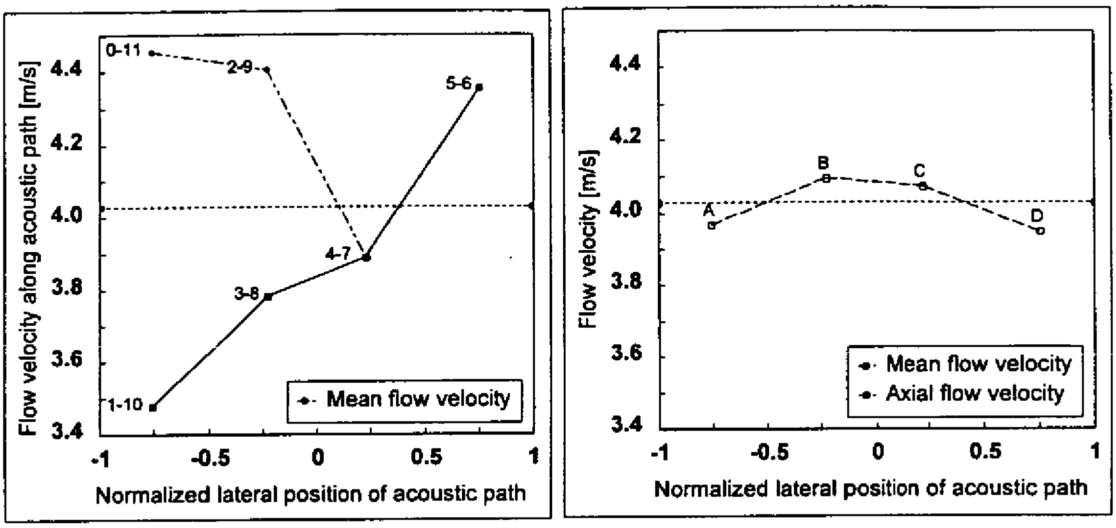

Figure 4 - Gas from Fuel gas heater B. Severe asymmetric swirl flow. The transducer numbering and the path positions refer to convention defined in Figure 1.

The "flow velocity profiles" in both Figure 3 and Figure 4 are interpreted as symmetric swirl flow by the algorithms used in the flow computer of the Ultrasonic gas flow meter.

The Swirl in Figure 3 is very small while the Swirl in Figure 4 is severe, asymmetric and rotates in the opposite direction from that in Figure 3. The calculated axial flow velocity profile in Figure 4 indicates a very flat swirl profile, while the one in Figure 3 is more parabolic but still flat.

Changing back to Fuel gas heater A (14.02.1996) returned everything back to "normal", see Figure 5.

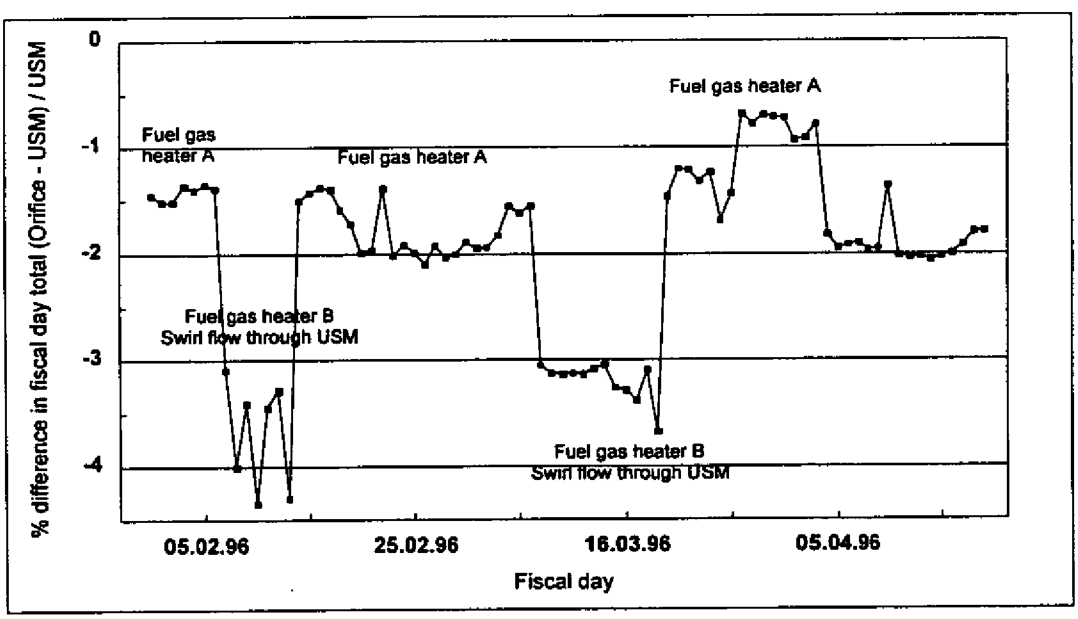

Figure 5 - Percentage difference between the Ultrasonic gas flow meter and the Orifice gas flow meter with and without swirl flow through the Ultrasonic gas flow meter.

The process operators were instructed to use only Fuel gas heater A until the problem could be resolved. The original layout drawings were not to scale and revealed no apparent reason for the observed change in flow regime.

A new test was performed (08 - 19.03.1996) with Fuel gas heater B to verify the observation, see Figure 5.

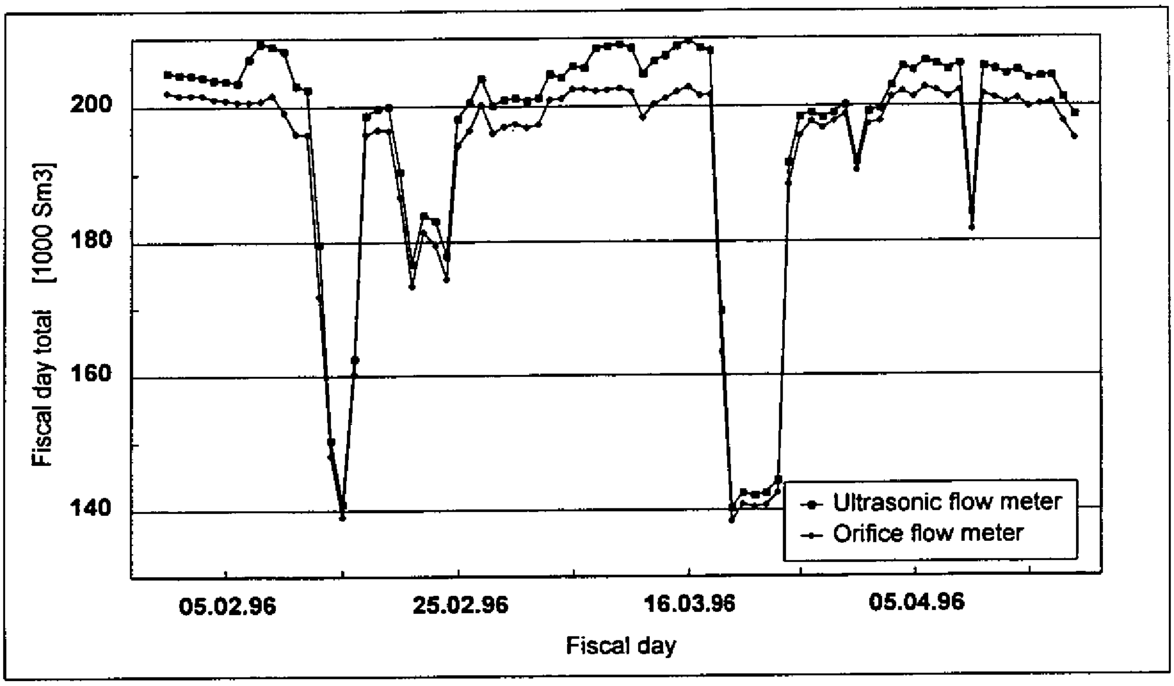

Figure 6 - Fiscal day total from the Ultrasonic gas flow meter and the Orifice gas flow meter with and without swirl flow through the Ultrasonic gas flow meter.

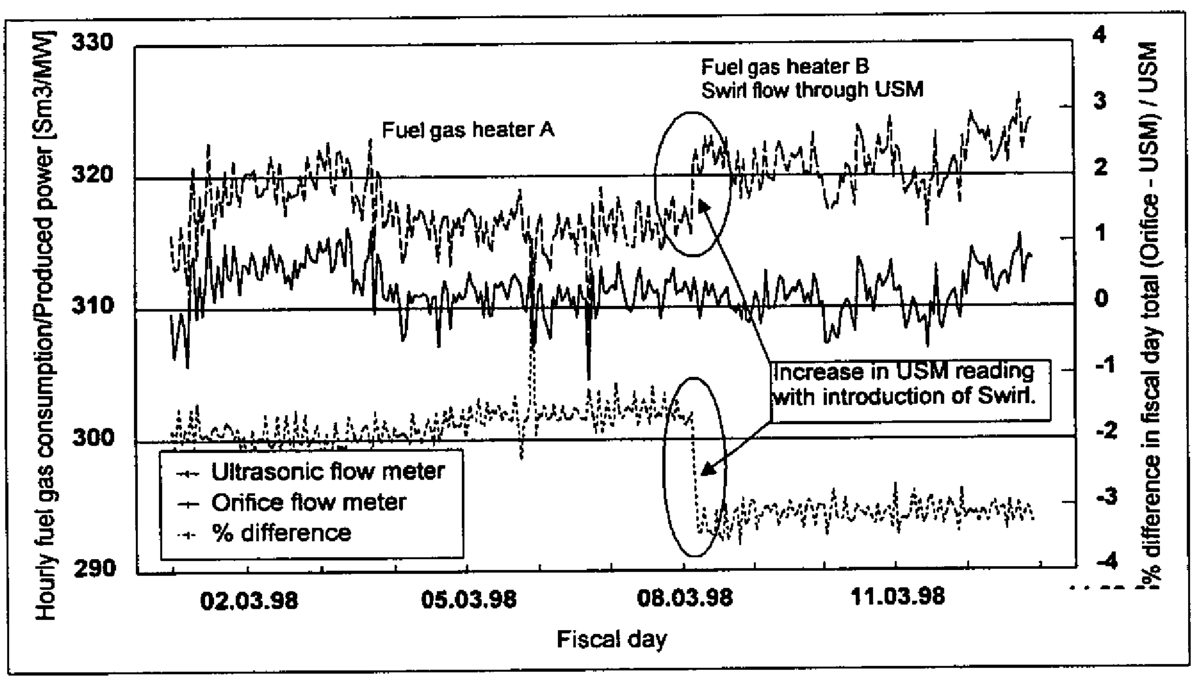

Figure 7 - Hourly fuel gas consumption per MW produced power for the Ultrasonic gas flow meter and the Orifice gas flow meter with and without swirl flow through the Ultrasonic gas flow meter. The Ultrasonic gas flow meter experiences a systematic increase in flow rate reading when the flow changes to severe asymmetric swirl flow. The flow rate from the Orifice gas flow

meter remains constant throughout this change. Not easily seen from the plot in Figure 6 of fiscal day totals but very clearly seen when the time series for hourly fuel gas consumption per MW produced power is plotted in Figure 7.

There appears to be well-defined bands for the percentage difference between the flow rates from the Ultrasonic gas flow meter and the Orifice gas flow meter. One band with fairly well developed flow when gas from Fuel gas heater A is used, and another band with severe asymmetric swirl flow when gas from Fuel gas heater B is used, see Figure 5 and 7.

The severe asymmetric swirl with gas from Fuel gas heater B, was found to be due to two 90° bends out of plane 39.2 D upstream of the Ultrasonic gas flow meter, easily detected when the layout is drawn to scale, see Figure 8.

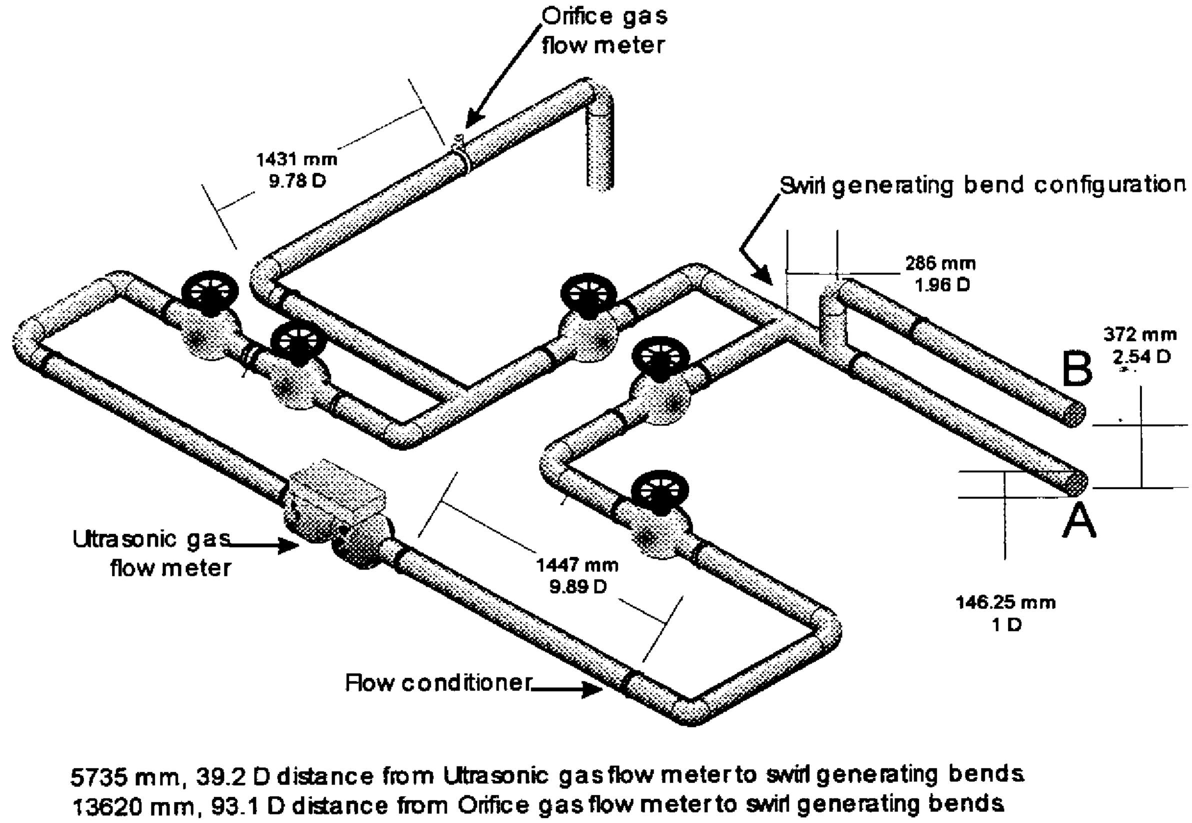

Figure 8 - Layout to scale reveals swirl generating bends.

The two 90° bends out of plane are very closely coupled with less than 2 D between the centre lines of each bend and they are also tee bends. In addition a third 90° bend is located only 2.5 D upstream of the two bends possibly adding some cross-flow to the swirl.

With gas from Fuel gas heater A, the flow is only passing through 90° bends in the same plane resulting in a reasonably well behaved flow, as could be expected.

5.1 Time Synchronisation Problems

The Orifice gas flow meter uses the platform control system as flow computer. Therefor the hourly and daily values from the Orifice gas flow meter are always time-synchronised.

For the Ultrasonic gas flow meter the flow computer is a PC with a real time clock. The real time clock has an uncertainty less than 0.001%. However, in the first 7 months after the Ultrasonic gas flow meter was put in operation the fiscal day total was calculated using a fiscal day that was reduced with approximately 40 sec. (-0.046%) every day. This was due to an error in the accumulation software and not the real time clock. This effect can be seen as the gradient in Figure 9.

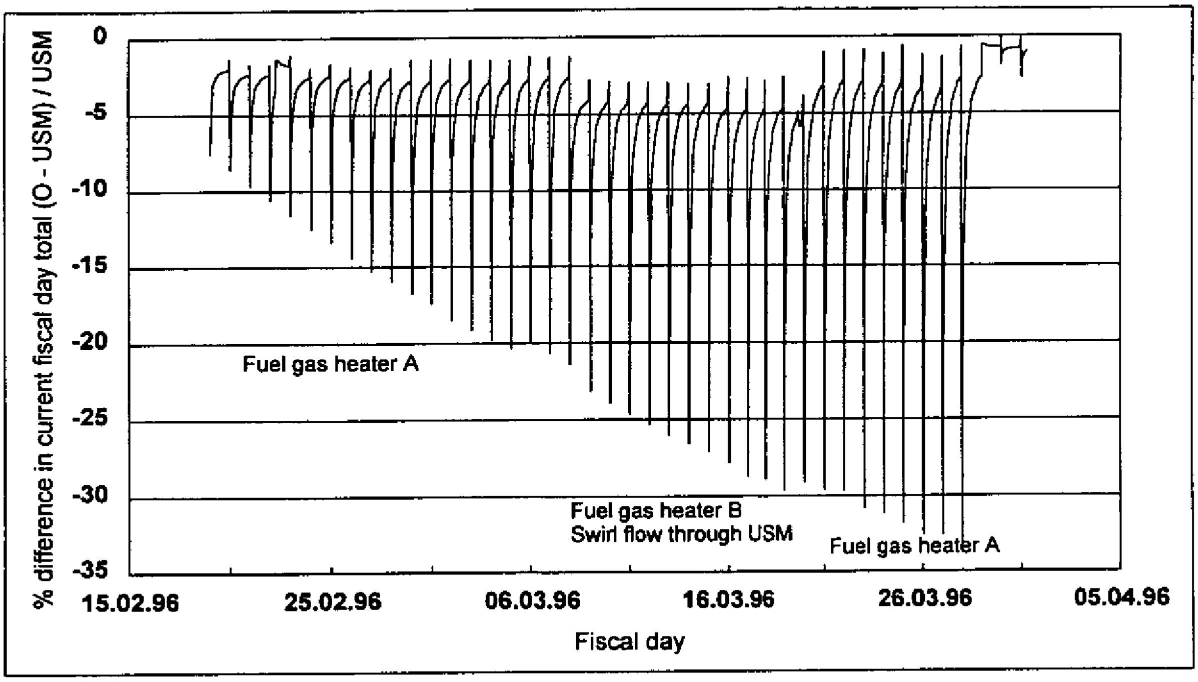

Figure 9 - Percentage difference in accumulation of current fiscal day totals every hour between the Ultrasonic gas flow meter and the Orifice gas flow meter. The positive going peaks are at 00:00 every day while the negative going peaks are at 01:00 every day.

Because of this the Fiscal day in the Ultrasonic gas flow meter starts earlier every day. The time offset from midnight (00:00) can be seen from the plot of percentage difference between the hourly values of current fiscal day totals in Figure 9, as a negative peak at 01:00. -10% difference (- 2% offset) indicates that the start of the Fiscal day is approximately 6 minutes before midnight. This of course made the comparison between the two meters difficult.

The platform control system log values every 10 minutes. The current Fiscal day totals for the Ultrasonic gas flow meter and the Orifice gas flow meter are calculated and logged every hour as the maximum value of the 6 last 10 minutes values. In addition the previous Fiscal day total for the Ultrasonic gas flow meter is logged every hour.

Knowing this, the data containing the timing problems illustrated in Figure 9 can be time-synchronised. To do this one has to derive the time synchronised hourly values. By accumulating the 24 hourly values thus found, the time synchronised Fiscal day total at midnight (00:00) for the Ultrasonic gas flow meter have be calculated for the data presented in this paper.

The daylight sawing time was implemented as an automatic time function from Microsoft in the flow computer for the Ultrasonic gas flow meter, but the time selected was the time on Hawaii and not Central European Time. This error has been corrected.

5.2 In Operation With Fuel Gas Heater A

The Ultrasonic gas flow meter was taken out of operation in March 1997 and sent for modification at Fluenta AS and re-calibration at K-lab. Figure 10 shows typical percentage difference between the two meters before this modification.

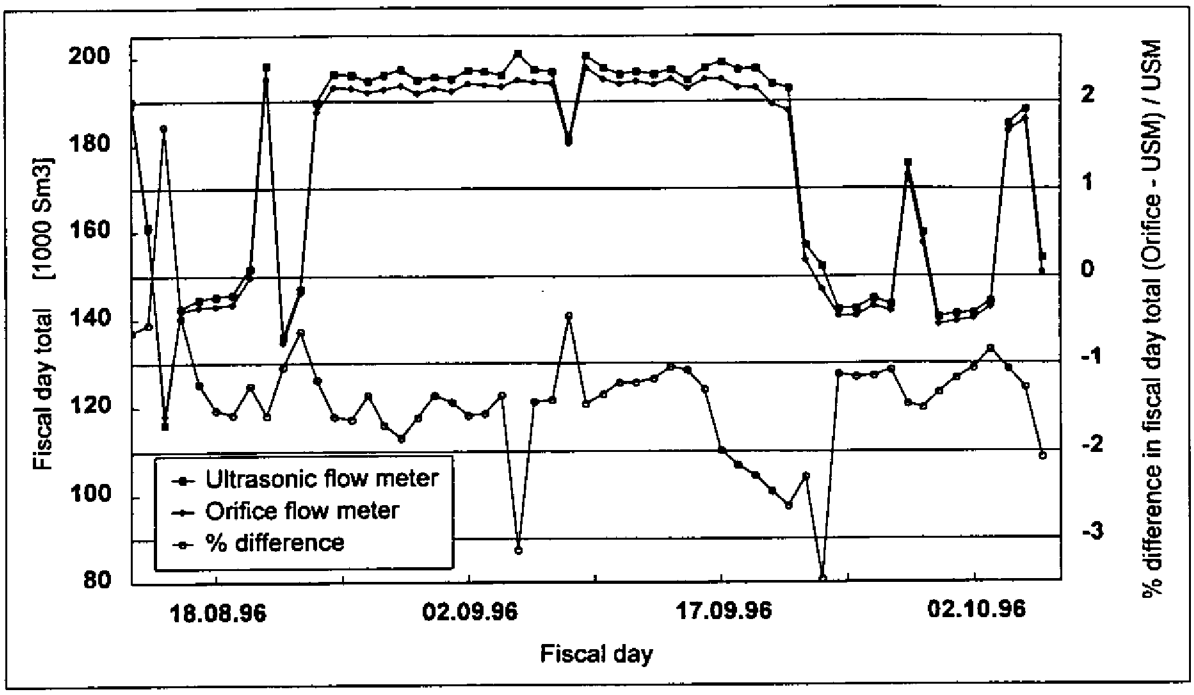

Figure 10 - Typical percentage difference for various fuel gas levels. Gas from Fuel gas heater A.

The percentage difference between the two meters is fairly constant between 1 – 2 % but some larger variations are also seen when the flow rate changes.

6 RECALIBRATION AND INSTALLATION OF FLOW CONDITIONER

The Ultrasonic gas flow meter was recalibrated at K-lab in June 1997, see Chapter 4 and Figure 1.

The Ultrasonic gas flow meter was reinstalled in August 1997 together with a K-lab Model Laws flow conditioner Type 1-6-12 (holes), with the new calibration curve implemented in the flow computer. The percentage difference between the measured flow from the Ultrasonic gas flow meter and the Orifice gas flow meter is back to the level seen before modification, with gas from Fuel gas heater A, see Figure 11.

The flow conditioner has eliminated the swirl and shaped the profile as can be seen in Figure 12 and Figure 13.

Figure 12 is comparable to Figure 3 while Figure 13 is comparable to Figure 4. The axial flow velocity profiles are now more parabolic in shape with gas from both Fuel gas heater A and B. The K-lab Model Laws flow conditioner both stops the swirl and shapes the flow profile.

The "flow velocity profiles" in both Figure 12 and Figure 13 are interpreted as symmetric swirl flow by the algorithms used in the flow computer of the Ultrasonic gas flow meter.

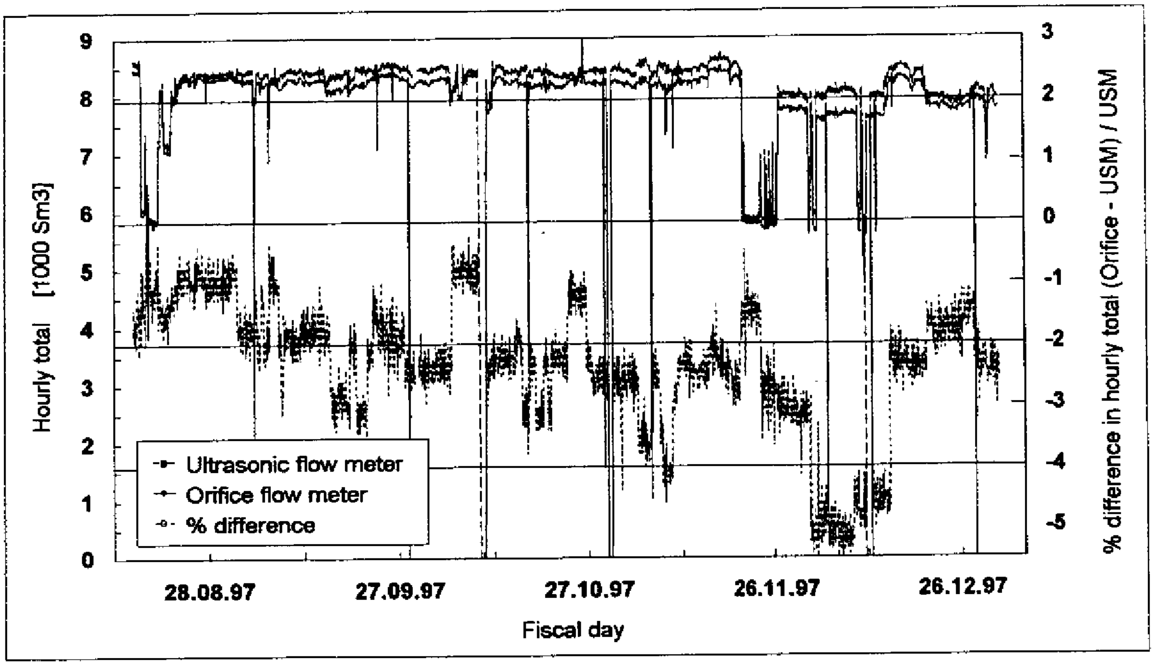

Figure 11 - Typical percentage difference for various fuel gas levels, with flow conditioner.

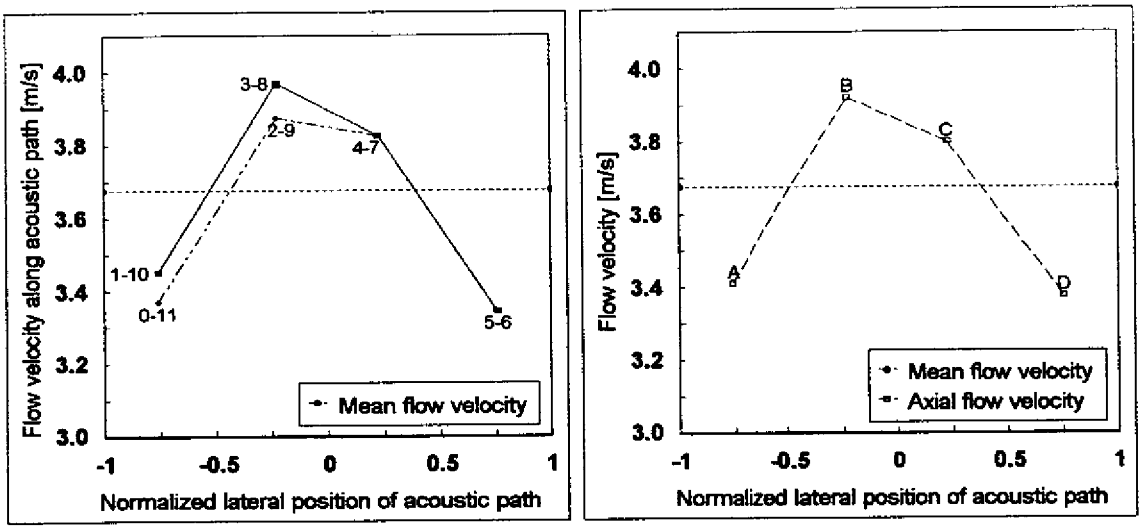

Figure 12 - Gas from Fuel gas heater A, with flow conditioner. The transducer numbering and the path positions refer to convention defined in Figure 1.

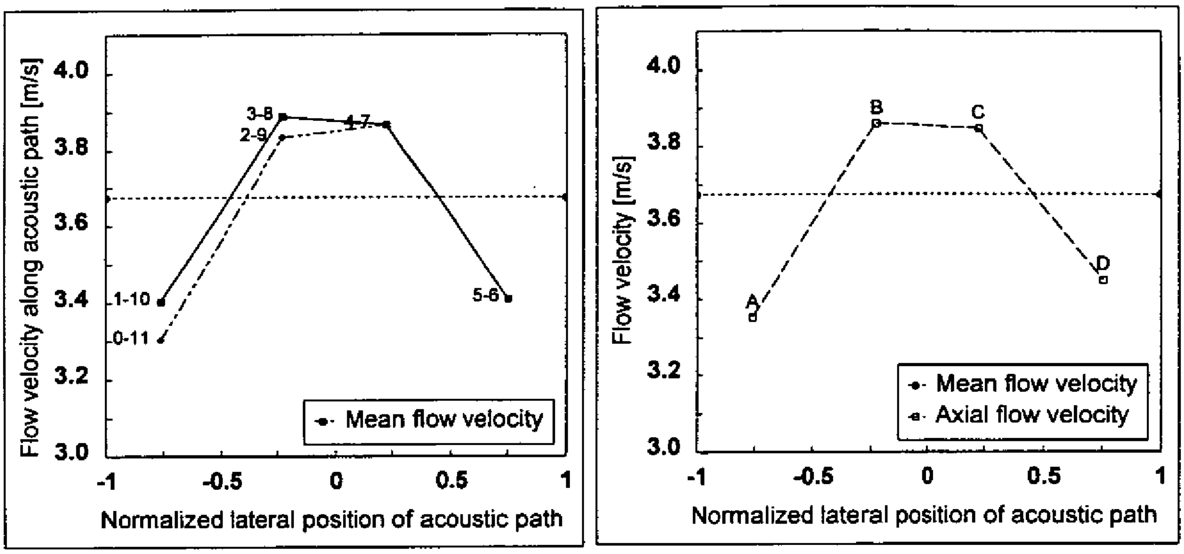

Figure 13 - Gas from Fuel gas heater B, with flow conditioner. The transducer numbering and the path positions refer to convention defined in Figure 1.

From calculations of the transversal flow velocity components in path position A and B the improvement with flow conditioner is clearly seen in Figures 14 and 15.

In Figure 14 an asymmetric swirl line is added to the measured values to indicate what the transversal flow velocity components might be in the lower half of the pipe, in path positions C and D. This indicates that the swirl is probably not symmetric i.e. the axis of rotation in the swirl does not coincide with the axis of the pipe.

In Figure 15 symmetric transversal flow velocity components are added in the lower half of the pipe, in path positions C and D, as assumed and used by the flow computer, see Figure 15.

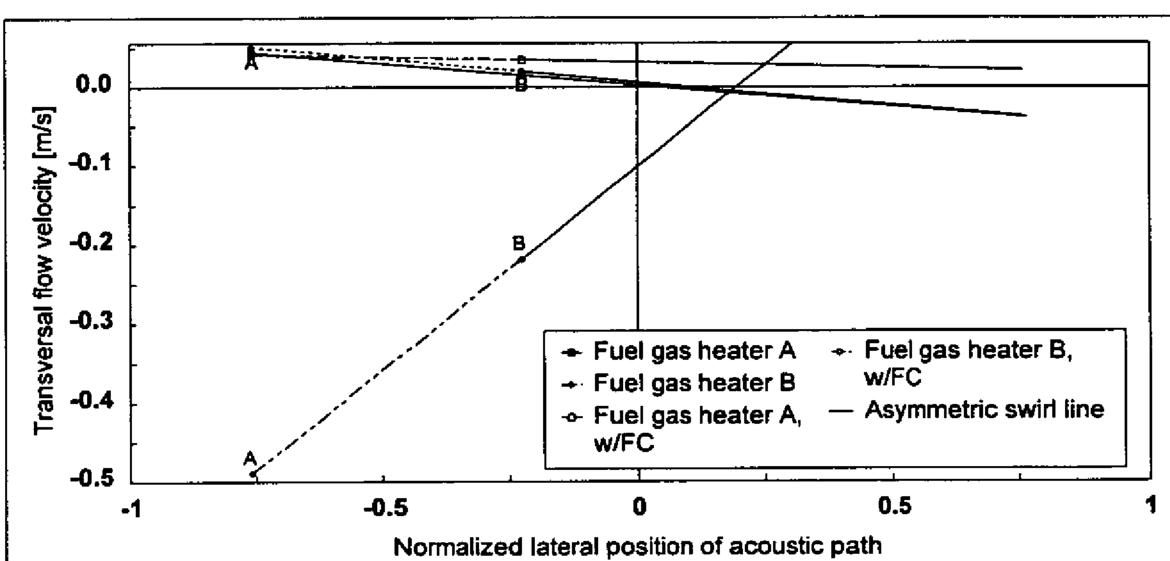

Figure 14 - Transversal flow velocity components indicating asymmetric swirl. The path positions refer to convention defined in Figure 1.

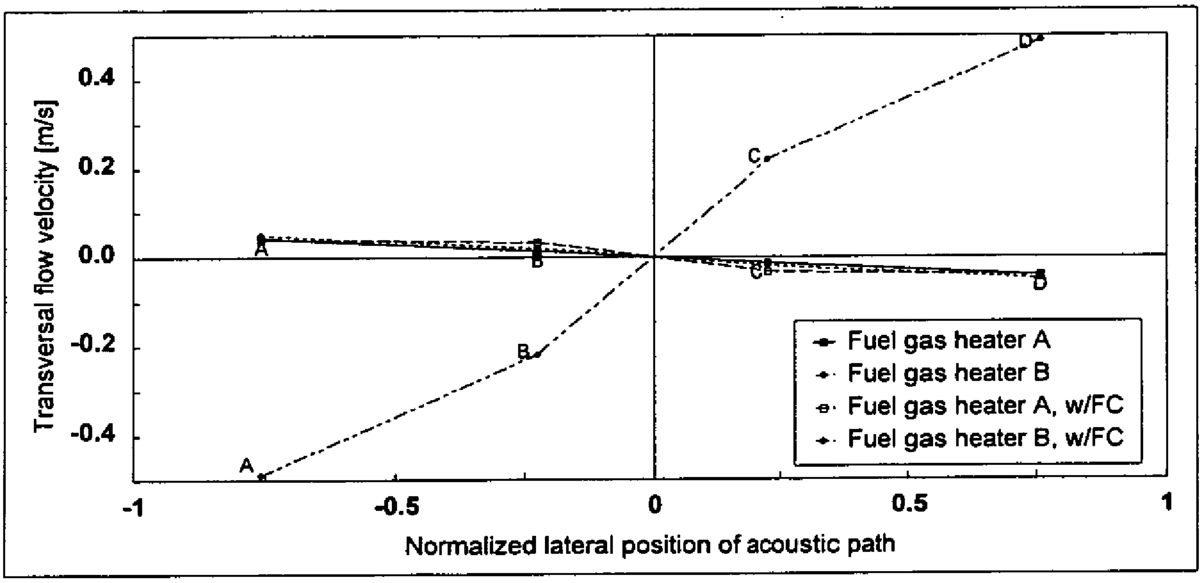

Figure 15 - Transversal flow velocity components used in the flow computer, assuming symmetric swirl. The path positions refer to convention defined in Figure 1.

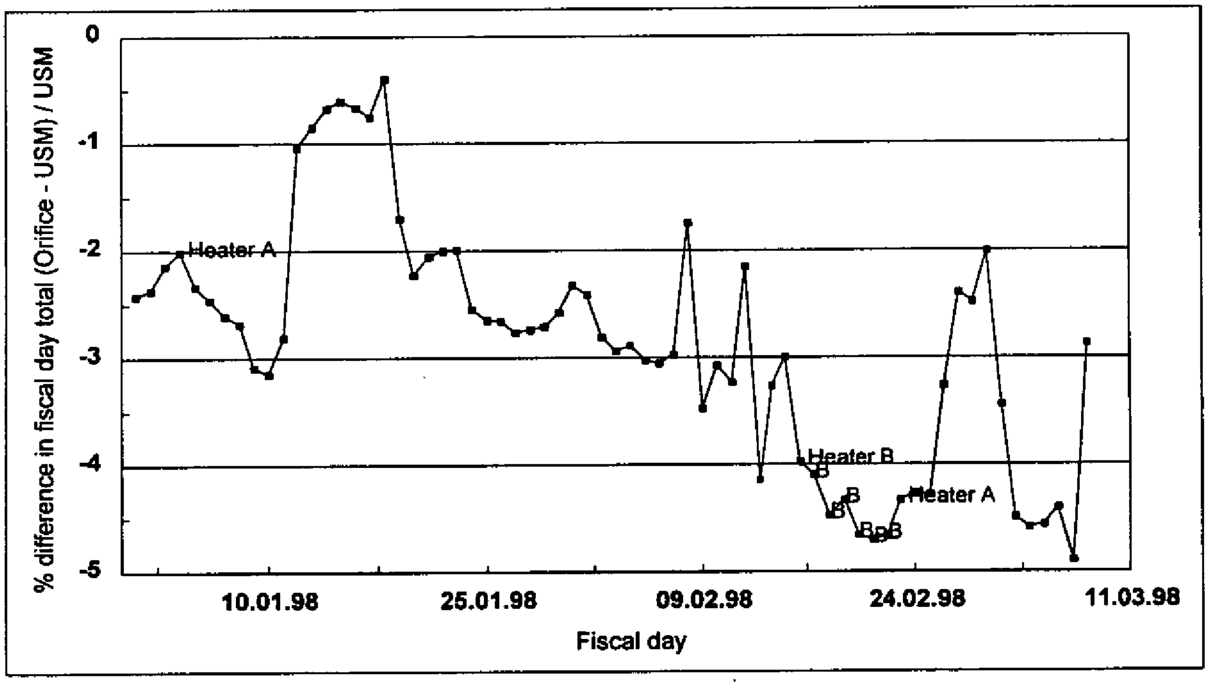

Figure 16 - Typical percentage difference with gas from Fuel gas heater A and B, with flow conditioner. Verifying the performance of the flow conditioner.

The severe asymmetric swirl flow, with gas from Fuel gas heater B has been effectively eliminated by the flow conditioner. A test was performed in February 1998 to verify the performance of the flow conditioner, see Figure 16. With flow conditioner, no significant shift can any longer be seen when changing from Fuel gas heater A to B and back to A.

We experienced some trouble with tuning in the pulse detection criteria after modification of the transducers, resulting in the use of the Orifice gas flow meter as master fuel gas meter for some time after reinstallation. Also a defective A/D converter giving odd pulses as a result was discovered. These problems have now been fixed.

6.1 Variations In Gas Composition

Another reason for the shifts in percentage difference was found to be due to the adaptation of new gas compositions in both the Ultrasonic gas flow meter and the Orifice gas flow meter. In the flow computer for the Ultrasonic gas flow meter the gas composition is used and a full calculation of compressibility is performed, see Chapter 3.1. For the Orifice gas flow meter only molecular weight (MW) is used and no iterative calculation is performed, only a simplified model with constant K is used, see Chapter 3.2.

Figure 17 illustrates the effects of changing gas composition. The Orifice gas flow meter is experiencing shifts in reading due to changing MW while the reading from the Ultrasonic gas flow meter remains unaffected. This also explains some of the shifts seen in other Figures in this paper, especially in Figure 11.

In December 1997 the major gas producing well was permanently closed down resulting in larger variations in gas composition.

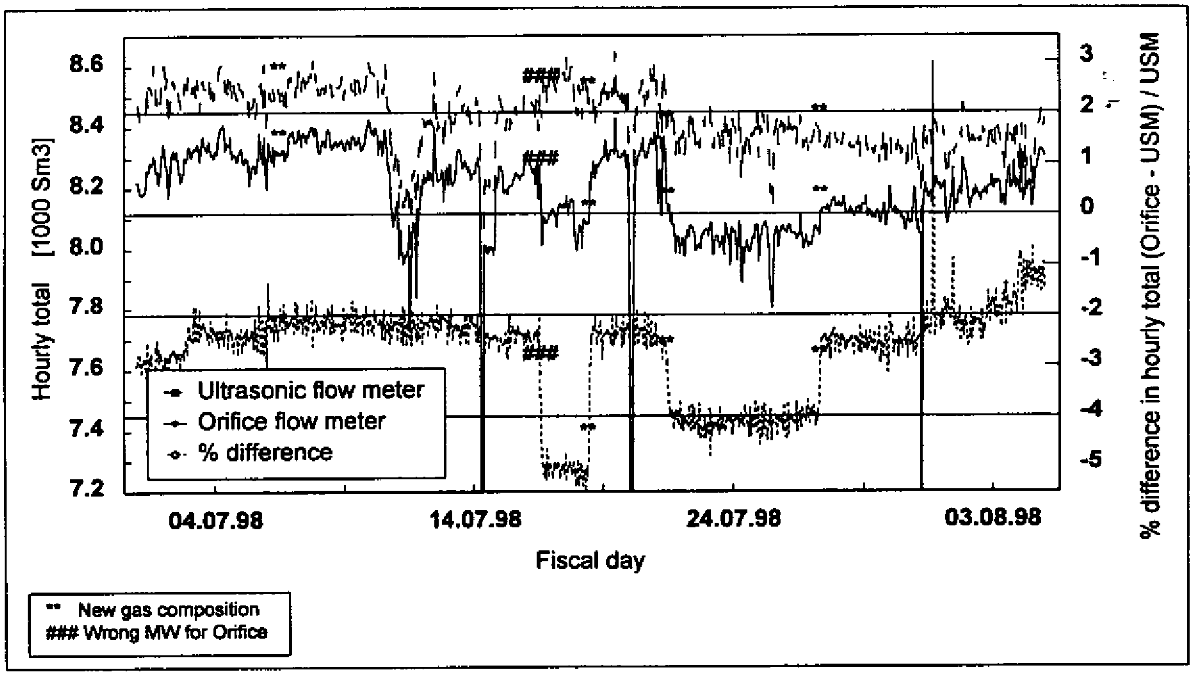

Figure 17 - Typical shifts in percentage difference and in the Orifice gas flow meter readings after adapting new gas compositions.

7 ENHANCEMENTS TO THE ULTRASONIC GAS FLOW METER

Several features were added to the flow computer of the Ultrasonic gas flow meter to make the meter as user friendly as possible. All configuration, currently measured values and software verification test data were made available via Modbus.

A PC in the central control room (CCR) on the platform collects this data. All these values can be printed as a 7 pages long Configuration report printing approximately 410 values. The Daily report seen in Figure 18 contains the same data as in the first part of this Configuration report.

```
Daily report for FMU 700
Date: 06.02.96 16:31:25

Program version.....................................: 6.2
Configure audit no...................................: 7
Start of fiscal day.................................: 0 hr
Line Volume Flowrate................................: 238.664108276367 m3/hr
Standard Volume Flowrate............................: 8477.021484375 Sm3/hr
Mass Flowrate.......................................: 7254.849609375 kg/hr
Mean Flow velocity..................................: 3.9936249256134 m/s
Line Temperature....................................: 57.7221145629883 Deg C
Line Pressure.......................................: 38.4959716796875 Bar A
Line Density Calculated AGA-8 (1985)................: 30.3977395944137 Kg/m3
Line Compressibility factor AGA-8 (1985)............: .928581542388127
Standard Compressibility factor ISO 6976 (1983).....: .996894349409422
Daily Total, Line Volume today, Forward.............: 520 m3
Daily Total, Line Volume yesterday, Forward.........: 0 m3
Daily Total, Std. Volume today, Forward.............: 19060 Sm3
Daily Total, Std. Volume yesterday, Forward.........: 0 Sm3
Daily Total, Mass today, Forward....................: 15543 kg
Daily Total, Mass yesterday, Forward................: 0 kg
Non-Resettable Total, Line Volume, Forward..........: 520 m3
Non-Resettable Total, Std. Volume, Forward..........: 19060 Sm3
Non-Resettable Total, Mass, Forward.................: 15543 kg
Gas Composition Methane.............................: 82.84 Mol%
Gas Composition Ethane..............................: 8.27 Mol%
Gas Composition Propane.............................: 4.02 Mol%
Gas Composition n-Butane............................: 1.13 Mol%
Gas Composition i-Butane............................: .42 Mol%
Gas Composition n-Pentane...........................: .3 Mol%
Gas Composition i-Pentane...........................: .21 Mol%
Gas Composition n-Hexane............................: 0 Mol%
Gas Composition n-Heptane...........................: .42 Mol%
Gas Composition n-Octane............................: 0 Mol%
Gas Composition Nitrogen............................: .74 Mol%
Gas Composition Carbon dioxide......................: 1.65 Mol%
Gas Composition H2O.................................: 0 Mol%
Gas Composition H2S.................................: 0 Mol%
Mean Flow velocity along transducer path #1.........: 3.78926753997803 m/s
Mean Flow velocity along transducer path #2.........: 3.84272813796997 m/s
Mean Flow velocity along transducer path #3.........: 4.13601016998291 m/s
Mean Flow velocity along transducer path #4.........: 4.16018295288086 m/s
Mean Flow velocity along transducer path #5.........: 4.08981275558472 m/s
Mean Flow velocity along transducer path #6.........: 3.79233145713806 m/s
Mean Sound velocity along transducer path #1........: 403.946685791016 m/s
Mean Sound velocity along transducer path #2........: 403.918304443359 m/s
Mean Sound velocity along transducer path #3........: 403.641632080078 m/s
Mean Sound velocity along transducer path #4........: 403.629608154297 m/s
Mean Sound velocity along transducer path #5........: 402.193145751953 m/s
Mean Sound velocity along transducer path #6........: 403.378021240234 m/s
Measurements % used #1..............................: 100
Measurements % used #2..............................: 100
Measurements % used #3..............................: 92.9577484130859
Measurements % used #4..............................: 100
Measurements % used #5..............................: 100
Measurements % used #6..............................: 100
Measurements % used #7..............................: 100
Measurements % used #8..............................: 100
Measurements % used #9..............................: 98.591552734375
Measurements % used #10.............................: 100
Measurements % used #11.............................: 100
Measurements % used #12.............................: 100
```

Figure 18 - Typical daily report.

The only real problem with the Ultrasonic flow meters is the vast number of configuration data, making it a tedious task to verify the correct set-up of such a meter. (In addition this data is not always readily available in all Ultrasonic flow meters.)

As a consequence the software verification task was completely automated. All data needed to carry out complete software verification test is entered on a separate page in the flow computer. As there is a problem guessing at a sensible set of transit times to start with, the flow computer suggests using the current values. So all one really has to do is set the duration of the test. The software verification test can be run while the meter is measuring so there is no need to take the meter out of operation in order to verify the software. When the test is finished all configuration values and test results are collected by the PC in the CCR and stored to file.

A verification program developed by Fluenta then reads this file and prints a software verification test report as documentation, see Figure 19. What used to be a very tedious task to perform requiring an expert on the measurement principal, can now be performed by any maintenance technician using a fraction of the time needed previously.

```
Filename: H:\GAI\SANDSLI\TROND\T_BRGASS\960213C3.TXT

Results from Fluenta FMU 700 Verification program. Ver1.3
Logged: 11:30:48  13/02/1996

--------------- TR.DELAY [us] ------ T.CORR. [us]  ----- CAVITY [mm] ------
Path 0-11       1.119400e+001      -1.300000e-003          18.360000
Path 1-10       1.110600e+001       3.100000e-003          17.830000
Path 2-9        1.122400e+001       2.100000e-003           8.160000
Path 3-8        1.113000e+001      -2.900000e-003           8.120000
Path 4-7        1.121500e+001      -7.000000e-003          13.280000
Path 5-6        1.126400e+001      -1.900000e-003          20.180000
Path 6-5                                                   20.190000
Path 7-4                                                   13.290000
Path 8-3                                                    8.120000
Path 9-2                                                    8.160000
Path 10-1                                                  17.820000
Path 11-0                                                  18.360000

Pipe diameter                       146.250000 [mm]
Flow calibration coefficient          0.060900
Flow calibration offset               0.552500


--------------- ACOUSTIC PATH [mm] -- TR.ANGLE [deg] ---------------------
Path 0-11          135.140000         45.000000
Path 1-10          135.140000         45.000000
Path 2-9           173.890000         55.000000
Path 3-8           173.890000         55.000000
Path 4-7           221.570000         40.000000
Path 5-6           148.660000         40.000000


---------------------- MOLFRACTIONS [%] -----------------------------------

Component     Entered fractions    Normalized fractions
 Methane         82.840000            82.840000
 Ethane           8.270000             8.270000
 Propane          4.020000             4.020000
 N-Butane         1.130000             1.130000
 I-Butane         0.420000             0.420000
 N-Pentane        0.300000             0.300000
 I-Pentane        0.210000             0.210000
 N-Hexane         0.000000             0.000000
 N-Heptane        0.420000             0.420000
 N-Octane         0.000000             0.000000
 Nitrogen         0.740000             0.740000
 CO2              1.650000             1.650000
 H2O              0.000000             0.000000

 Sum            100.000000           100.000000


------------- GAS COMPOSITION CALCULATIONS --------------------------------
Zmix ISO 6976                          0.996740
Zmix AGA-8 85                          0.930545
Sound velocity                       400.210832 [m/s]
Density                               29.829650 [kg/m3]
Temperature                           59.000000 [deg C]
Pressure                              38.000000 [BarA)


-------- TOTAL TIME-OF-FLIGHT [us] -- VELOCITY [m/s] ----------------------
Path 0-11     4.32000000e+002         5.163846
Path 1-10     4.40000000e+002         5.046137
Path 2-9      4.78000000e+002         5.739229
Path 3-8      4.85000000e+002         5.736217
Path 4-7      6.20000000e+002         5.762602
Path 5-6      4.85000000e+002         5.689737
Path 6-5      4.77000000e+002
Path 7-4      6.32000000e+002
Path 8-3      4.78000000e+002
Path 9-2      4.85000000e+002
Path 10-1     4.34000000e+002
Path 11-0     4.38000000e+002


-------------------- FLOW CALCULATION RESULTS -----------------------------

Duration                             5.030288217       [min]


                Calculated                 Measured                 Deviation [%]
Velocity 5.597587477e+000 [m/s]     5.597587480e+000 [m/s]       0.000000054
Act.Rate 3.354962178e+002 [m3/hr]   3.354962180e+002 [m3/hr]     0.000000045
Std.Rate 1.169185574e+004 [Sm3/hr]  1.169185570e+004 [Sm3/hr]   -0.000000320
Act.Vol. 2.812737786e+001 [m3]      2.812737790e+001 [m3]        0.000000155
Std.Vol. 9.802234025e+002 [Sm3]     9.802234030e+002 [Sm3]       0.000000056
Density  2.982965017e+001 [kg/m3]   2.982965020e+001 [kg/m3]     0.000000102


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Prepared by:                         Signature:        Date: 13/02/1996

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Approved by: Trond Folkestad         Signature:        Date: 13/02/1996

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Figure 19 - Typical software verification report.

8 CONCLUSION

The multi-path Ultrasonic gas flow meter operated continuously for the first year without any major difficulties and demonstrated good long-term stability.

The multi-path Ultrasonic gas flow meter can not handle a severe asymmetric swirl flow to fiscal accuracy. A flow conditioner / straightener can be used in front of the Ultrasonic gas flow meter to eliminate error in measurement due to swirl.

The 6" Ultrasonic gas flow meter must be flow calibrated before installation and the calibration curve must be implemented in the flow computer.

It is critical that all geometrical dimensions in the meter spool are certified and entered into the flow computer.

Upstream bends should be kept in the same plane for at least 50 D, then it should be sufficient with 10 D straight pipe upstream of the Ultrasonic gas flow meter. If this can not bee achieved a flow conditioner should be installed.

This type of Ultrasonic gas flow meter is now recommended for use in fiscal gas metering systems operated by Norsk Hydro.

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.