LONG TERM COMPARISON OF AN ULTRASONIC METER AND A TURBINE METER WITH AN ORIFICE METER AT EMS TEST LOOP

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1 INTRODUCTION

Statoil and Ruhrgas decided in 1996 to conduct a test program in an especially built test loop at the Europipe Metering Station in Emden.

The aim of the project was to gain controlled operational experience with large ultrasonic gas flow meters (USM) and gas turbine meters (GTM).

The Scope of Work aimed at comparing the GTM and USM with the already installed orifice plate station, built in accordance with the existing regulations (PTB, NPD) and standards (ISO 5167) for fiscal gas measurement systems. The USM and the GTM were calibrated at the Pigsar calibration facility in Dorsten, Germany, at Westerbork calibration facility in Netherland and at K-Lab, Kårstø, Norway.

The complete test loop system was installed, commissioned and pre-tested from autumn 1997 to April 1998. The long term tests were performed from May 1998 to the end of October 1999 interrupted by a break in March and April 1999.

Later on, Gaz de France has joined and supported the project.

A second long term test will start autumn 2000 with other and additional trades of meters. Other parties are as well welcome to join this and potential other projects in the future. The facilities have been proven to be well suited for these kind of tests.

2 TEST SET UP AND OPERATION

The test loop is a special designed 16" pipe section was erected in the prolongation of one of the meter run. This special designed pipe section is shown in Fig. 1. The pipe section consists of two straight sections each 38 m long. The two sections are connected by a "U-bend" 3 m wide. In each of the sections spools are designed to allow for two flow meters, with 30 D straight pipe in front of each meter. In this test project only two of the slots were in use. A first presentation of the facility has already been given in [1].

For the purpose of this comparison project, an additional flow computer (FC) for the orifice measurement was installed and connected to the fiscal meter. The system comprising of this additional FC and the orifice plate measuring system is called OPM while the fiscal system with its fiscal FC is called L5. The main difference between the two is that OPM uses the SGERG method for density determination while the L5 uses Solartron densitometer for density determination.

The USM and the GTM is connected to separate FC together with their respective temperature and pressure transmitters.

Both the USM and the GTM were calibrated at several flow calibration laboratories prior to the start of the test.

Fig. 1 - The test loop

It was decided to apply a meter factor of 1 for the USM, i.e. using the dry calibration results.

It was decided to use a single calibration factor for the GTM found during the flow calibration. All results for the GTM(s) reported in this paper are obtained by using this calibration factor only.

During the test period the operation, maintenance and calibration method and procedures were like that for a fiscal metering system. In this case it means monthly calibration checks on pressure, temperature and differential pressure. Monthly operational reports are also worked out.

3 DATA COLLECTION

Data are transmitted via X-400 to Statoil's Transportation Control Center (TCC) at Bygnes, Norway. The following data are transmitted:

From OPM:

- Hourly and daily average of pressure, temperature, differential pressure and density.
- Hourly and daily totals of actual volume and mass.

From USM:

- Hourly and daily averages of pressure, temperature, density, flow velocity from each chord and average flow velocity, velocity of sound from each chord and average velocity of sound.
- Hourly and daily total of actual volume and mass.

From GTM:

- Hourly and daily average of pressure and temperature.
- hourly and daily total of actual volume

Flow velocity (m/s) - values:

Time					Path A	Path B	Path C	Path D	Avg.
98	/ 10	/	1	07	8,748	10,293	10,213	8,618	9,798
98	/ 10	/	1	08	8,587	10,091	10,011	8,456	9,611
98	/ 10	/	1	09	8,640	10,158	10,075	8,508	9,670
98	/ 10	/	1	10	8,671	10,188	10,121	8,538	9,706
98	/ 10	/	1	11	8,618	10,125	10,065	8,482	9,649
98	/ 10	/	1	12	8,462	9,942	9,859	8,321	9,465
98	/ 10	/	1	13	8,440	9,927	9,850	8,309	9,452
98	/ 10	/	1	14	8,405	9,880	9,809	8,289	9,411
98	/ 10	/	1	15	8,449	9,929	9,859	8,333	9,460
98	/ 10	/	1	16	8,448	9,924	9,855	8,315	9,454
98	/ 10	/	1	17	8,427	9,906	9,844	8,313	9,440
98	/ 10	/	1	18	8,448	9,920	9,845	8,311	9,447
98	/ 10	/	1	19	8,439	9,911	9,845	8,318	9,445
98	/ 10	/	1	20	8,417	9,894	9,823	8,293	9,424
98	/ 10	/	1	21	8,433	9,918	9,850	8,317	9,447
98	/ 10	/	1	22	8,425	9,908	9,839	8,300	9,436
98	/ 10	/	1	23	8,443	9,929	9,855	8,329	9,456
98	/ 10	/	2	00	8,429	9,919	9,846	8,314	9,445
98	/ 10	/	2	01	8,434	9,911	9,839	8,297	9,438
98	/ 10	/	2	02	8,323	9,787	9,711	8,200	9,320
98	/ 10	/	2	03	8,292	9,747	9,672	8,173	9,282
98	/ 10	/	2	04	8,280	9,725	9,647	8,151	9,260
98	/ 10	/	2	05	8,277	9,717	9,645	8,156	9,258
98	/ 10	/	2	06	8,287	9,733	9,657	8,163	9,271
Daily avg.					8,451	9,933	9,860	8,325	9,460

Fig. 2 - Example of reported flow velocities from USM

Velocity of sound (m/s) - values:					
Time	Path A	Path B	Path C	Path D	Avg.
98 / 10 / 1 07	396,8	396,5	396,7	396,9	396,7
98 / 10 / 1 08	397,0	396,7	396,9	397,1	396,9
98 / 10 / 1 09	397,2	396,9	397,1	397,3	397,1
98 / 10 / 1 10	397,2	396,9	397,2	397,3	397,1
98 / 10 / 1 11	397,2	397,0	397,2	397,4	397,2
98 / 10 / 1 12	397,2	396,9	397,2	397,3	397,2
98 / 10 / 1 13	397,1	396,9	397,1	397,3	397,1
98 / 10 / 1 14	397,2	396,9	397,2	397,3	397,1
98 / 10 / 1 15	397,1	396,9	397,1	397,2	397,1
98 / 10 / 1 16	397,2	396,9	397,1	397,3	397,1
98 / 10 / 1 17	397,1	396,8	397,1	397,2	397,1
98 / 10 / 1 18	397,2	396,8	397,1	397,3	397,1
98 / 10 / 1 19	397,1	396,9	397,1	397,2	397,1
98 / 10 / 1 20	397,1	396,8	397,0	397,2	397,0
98 / 10 / 1 21	397,0	396,8	397,0	397,1	397,0
98 / 10 / 1 22	397,0	396,8	397,0	397,1	397,0
98 / 10 / 1 23	397,0	396,8	397,0	397,2	397,0
98 / 10 / 2 00	397,0	396,7	397,0	397,1	396,9
98 / 10 / 2 01	396,9	396,7	396,9	397,1	396,9
98 / 10 / 2 02	397,1	396,7	397,0	397,2	397,0
98 / 10 / 2 03	397,0	396,8	397,0	397,2	397,0
98 / 10 / 2 04	397,0	396,8	397,0	397,1	397,0
98 / 10 / 2 05	397,1	396,8	397,0	397,2	397,0
98 / 10 / 2 06	397,1	396,9	397,1	397,3	397,1
Daily avg.	397,1	396,8	397,1	397,2	397,0

Fig. 3 - Example of VOS reported from USM

The chromatograph system consists of two chromatographs, A and B. A control system selects which of the two should be used. A typical daily information is shown in Fig. 4

1999 /10 / 12	06:05				
			GC A average	GC B average	Used average
Methane	C1	Mol%	89,78	89,73	89,74
Ethane	C2	Mol%	7,133	7,138	7,143
Propane	C3	Mol%	0,623	0,639	0,632
Iso-Butane	iC4	Mol%	0,255	0,251	0,253
Normal-Butane	nC4	Mol%	0,074	0,074	0,074
Iso-Pentane	iC5	Mol%	0,045	0,046	0,046
Normal-Pentane	nC5	Mol%	0,015	0,016	0,016
Hexane Plus	C6+	Mol%	0,087	0,095	0,091
Carbon Dioxide	CO2	Mol%	0,458	0,472	0,460
Nitrogen	N2	Mol%	1,529	1,546	1,536
Sum			100	100	100
Normal Density		kg/Nm³	0,7950	0,7956	0,7951
Gross Cal. Value		MJ/Nm³	42,07	42,09	42,07
Wobbe Index		MJ/Nm³	53,64	53,63	53,64
Mole Weight		kg/kmol	17,56	17,57	17,57

Fig. 4 - Example of reported gas analysis from the on-line gas chromatographs

4 TEST CONDITION

The operational conditions during the test period are presented by the graphs in Figs 5 and 6.

The pressure varied between 55 and 67 bar throughout the test period while the temperature varied between 2°C and 10°C; the density of the gas was between 50 kg/m³ and 62 kg/m³.

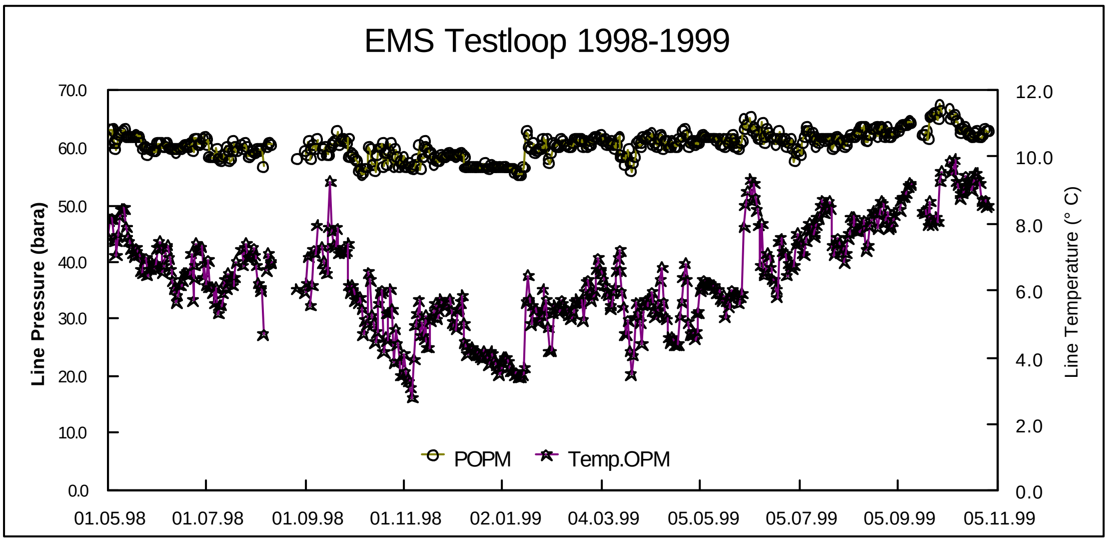

Fig. 5 - Daily average pressure and temperature during the test period

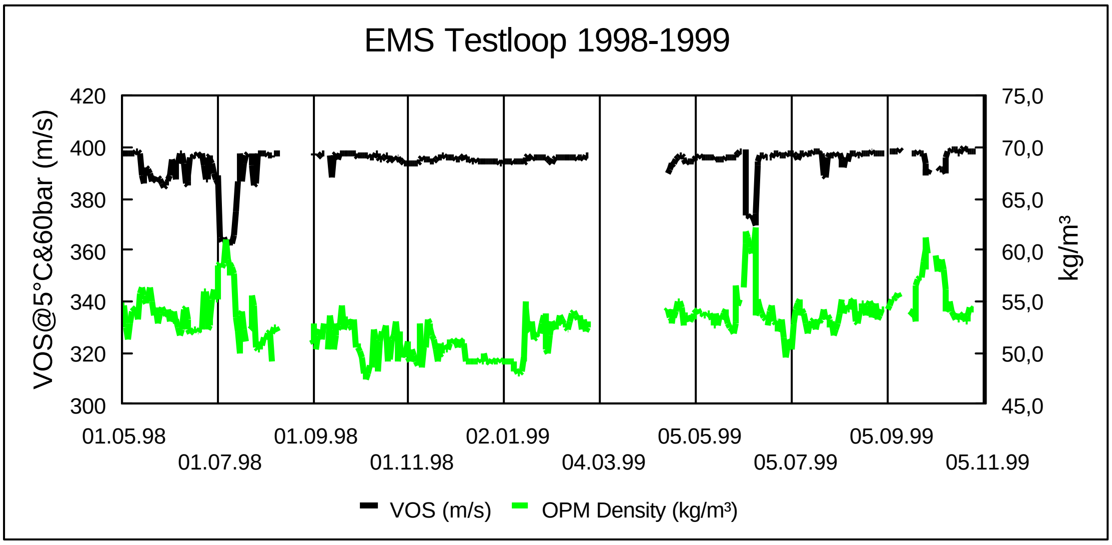

Fig. 6 - Daily average of density and velocity of sound (VOS) at operating conditions during the test period

The orifice discharge coefficient was determined according to ISO 5167-1/1991 up till October 20, 1998. Then it was changed to be in accordance with ISO 5167-1/ A-1.

5 CHECK BETWEEN MEASURED DENSITY AND CALCULATED DENSITY

5.1 Check Between Measured Density and OPM/USM Density

The daily average density for OPM and USM are compared with the measured density in L5. In fact, this is a comparison between SGERG density and measured density.

Any difference between the two can be attributed to error/uncertainty in the gas analysis (the SGERG input variables ND, GCV and CO_2 is based on the gas analysis), error/uncertainty in p_{OPM} and p_{USM} (which only affects ρ_{OPM} and ρ_{USM} respectively), error/uncertainty in the densitometer itself and error/uncertainty in the T_{DL5}. The measured density in L5 is in fact the measured density at the condition in the densitometer (i.e. p_{DL5}, T_{DL5}) transformed to the condition in the line (i.e. p_{OPM}, T_{OPM}).

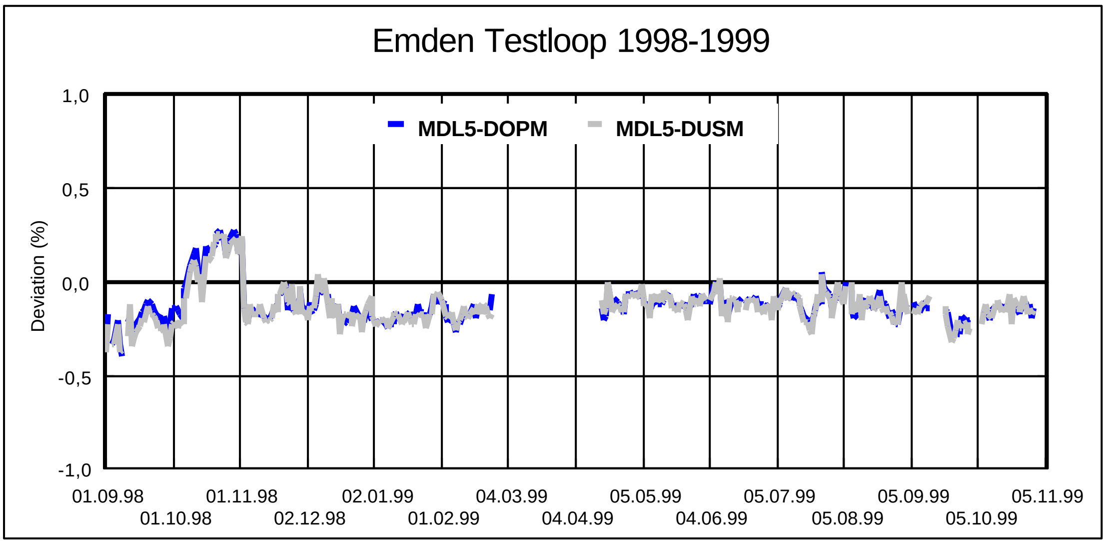

Fig. 7 - Comparison between measured density (MDL5) and the SGERG density calculated by OPM system (DOPM) and the USM system (DUSM)

During the period shown in Fig. 7, good consistency between ρ_{OPM} and ρ_{USM} is verified. The higher deviation in the period from 8th October 1998 to 3rd November 1998 is due to a low reading of C6+ from the OGC system. This was an error in the SGERG density. The OPM volume had to be corrected for this error.

5.2 Check Between Measured Density and Density Determined From Measured VOS

Like in many other applications, it has been observed a clear relationship between density and VOS. This relationship could to a certain degree also be seen in Fig. 6. The relationship is shown more clearly if both VOS and density are converted at 60 bar and 5°C and presented like in Fig. 8.

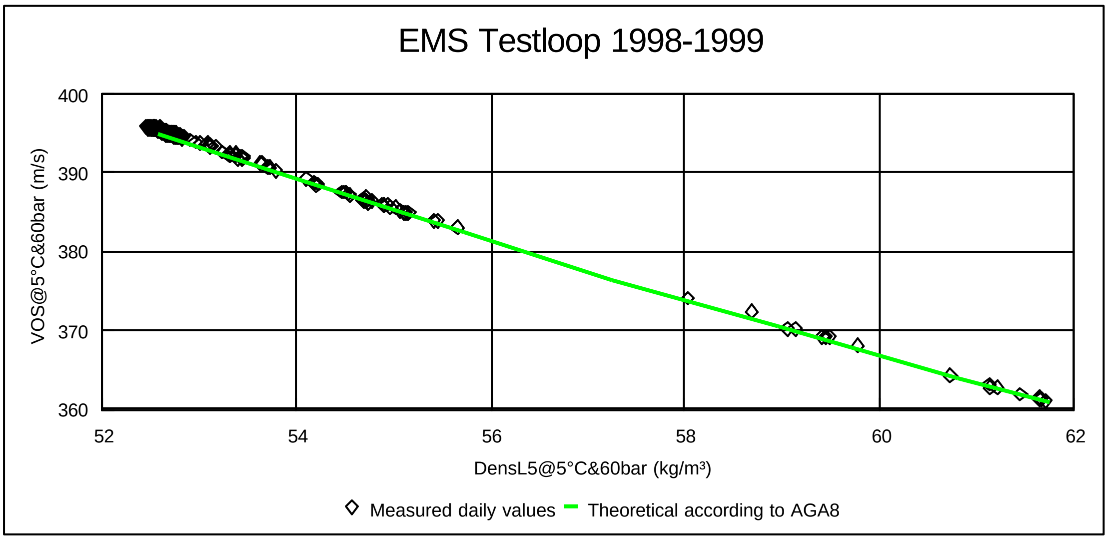

Fig. 8 - Relationship between VOS and density. Measured VOS and measured density (diamonds) compared with the theoretical relationship.

By applying a model which calculates density from VOS, pressure and temperature and compare it with measured density is a good way of checking the consistency between these variables. The result from such a comparison is shown in fig.9.

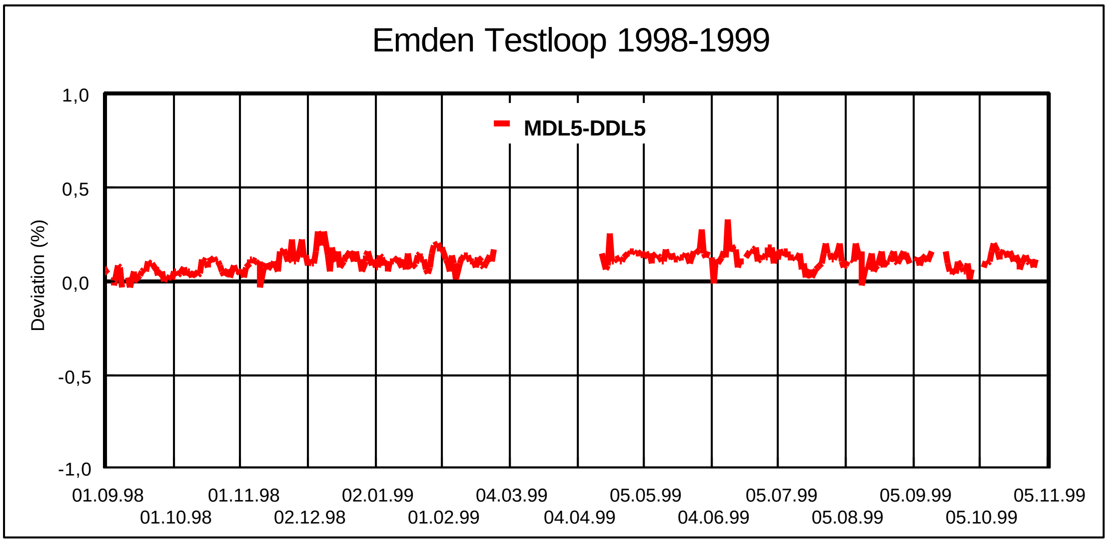

Fig. 9 - Difference between measured density (MDL5) and density calculated based on VOS, pressure and temperature (DDL5)

6 VOLUME COMPARISON

Comparison on volume has the advantage over comparison on mass that secondary parameters like density do not affect the results from USM and GTM. The disadvantage is that the all the metered volumes had to be corrected or converted to a common condition, i.e. correct for differences in pressure and temperature between the meters.
All actual volumes are converted to the conditions of the USM.

The results can be summarized as follows:

From May 98 until October 98 when the discharge coefficient for OPM was calculated according to ISO 5167 -1, the deviations between USM/GTM and OPM were mainly between about -0.1% to -0.4%.

After the OPM was modified to use discharge coefficient according to ISO 5167 – 1/A-1, the deviations were mainly between +0,1% and -0,2%.

7 DISCUSSION

7.1 USM Results

Several conclusions can be drawn based on these results:

- the OPM at the EMS can be regarded as a reference on equal level with the calibration facilities.
- the USM has been stable during the test period.
- the dry calibrated USM is within 0.3% whether it is compared with calibration references or with a well designed orifice plate metering system.

By comparing the distribution of VOS observed in the field with the distribution observed during calibration, it is possible to evaluate if the condition of the meter during operation is similar to the conditions of the meter when it was calibrated. The result of such a comparison is shown in Fig. 10. As can be seen, the scatter of the single path results around the calibration values (solid lines) is low. This means that the relation between the path-results remained fairly constant. In case of problems with single paths such as failures or deposits on the transducers this could have been detected in Fig. 10.

One conclusion that can be drawn based on this result:

- the USM submit information enabling the user to control the condition of the meter during operation relative to the condition of the meter during calibration. This is in line with previous reported experience. [2].

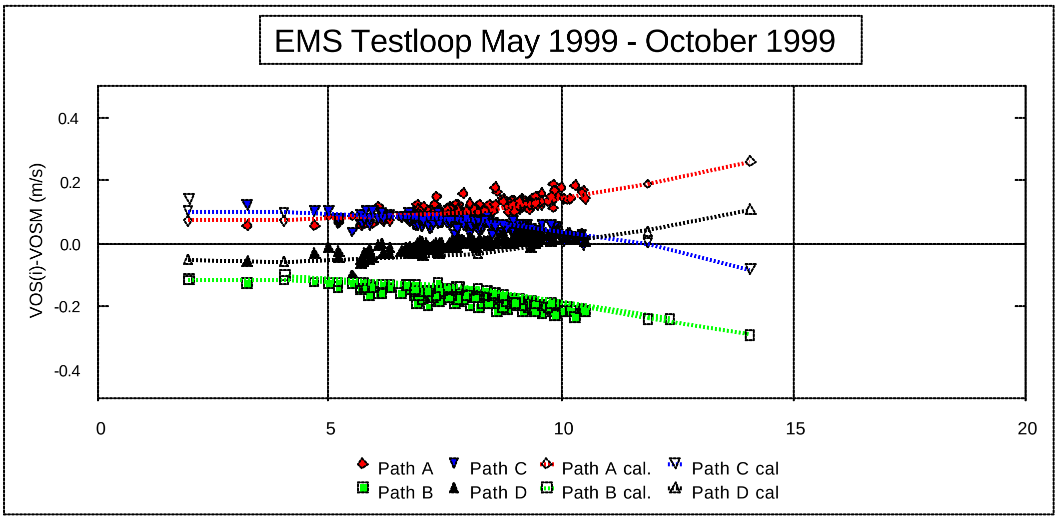

Fig.10 - Plot of VOS from the individual paths relative to average measured VOS, VOSM, during the test period, "Path (i)", and during calibration, "Path (i) cal", as a function of flow velocity.

7.2 GTM Results

The most remarkable that happened with the GTM was the breakdown of the meter on 25th February 99. However, ever since 20th of February there were clear signs in terms of increased deviation that something was wrong with the meter. This can be clearly seen from fig. 11, which enables one to study the trend in deviations. Throughout these last days of the GTM's life, the USM was performing very normal.

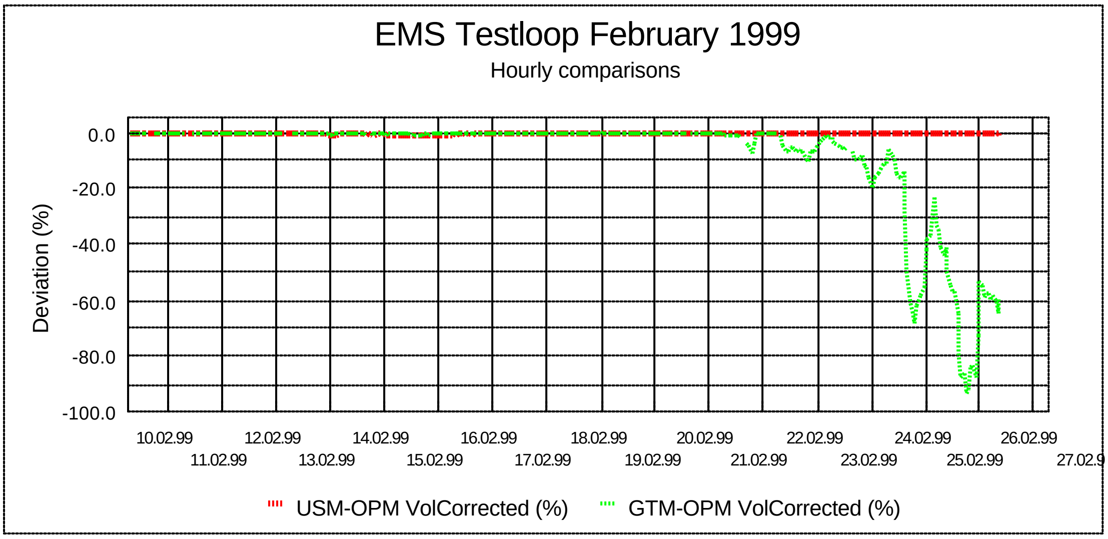

Fig.11 - Comparison of USM and GTM deviation relative to OPM in February 1999 showing what happened prior to 25th of February 1999 when the GTM broke down.

Whatever was causing the problems for the GTM, it did not cause any problems for the USM.

Due to the breakdown of the GTM in February 1999, the GTM was replaced by another GTM of the same make and the test was restarted May 1999 with a GTM that can be regarded as new.

Some conclusions can be drawn:

- the test loop system is capable of detecting in detail what happens prior to a meter breakdown
- the new GTM was stable in the actual flow range during the test loop period – based on the calibration results before and after the test period

8 MAIN CONCLUSIONS FROM THE TEST

The main conclusions from the test from May 1998 to the end of October 1999, after 16 months of operation are the following:

- the test loop facility offers well controlled real life conditions suitable for long term studies of large flow meters behavior
- a great number verification possibilities exist including cross checks and calibration checks using reference equipment
- data collection system can be established enabling relevant data evaluation
- after test start on 1st May 1998, the system comparing the OPM with the USM has worked properly.
- the GTM failed at the end of February 1999, leading to a replacement of GTM. This resulted in a test period from May'98 till February'99 with one GTM and a test period from May'99 till October'99 with another GTM.
- a thorough review of all secondary parameters is of crucial importance to be able to reveal the behavior of the flow meters themselves.
- the USM and the GTM deviates overall less than +/- 0.25 % from the OPM. This deviation is very low with respect to the uncertainties involved.
- the massive information from the USM enables the user to control the condition of the USM, i.e. to perform a health checking.

9 FUTURE PLANS

The co-operating companies expect that the test loop will be a very useful facility in the future for more comparative testing. Potential interested parties could be meter manufacturers as well as gas companies and perhaps authorities as well.

The next project will start in autumn this year. In this cooperation project between Statoil, Gaz de France and Ruhrgas a second long term test over 18 months will be performed similar to the tests described here. The GTM will be replaced by a GTM of a different manufacturer; the USM of the former project will be used again but calibrated and installed in the reverse flow position. Additionally a second USM will be installed which will be a meter of a different manufacturer.

Other companies are invited for participation in future projects. These projects might include parameter testing, test of long term effects, installation effects, etc. It is planned to give manufacturers the possibility to test their meters on this facility under real live conditions.

10 REFERENCES

[1] VIETH, D., and SDUN, W. "Use of Orifice, Turbine and Ultrasonic Meters for Comparative Purposes in the Gas Transmission Sector Eurogas 1999". The European Applied Research Conference on Natural Gas, Bochum, Germany, 25 – 27 May 1999

[2] SAKARIASSEN, R. "On-line verification of ultrasonic flow meter", North Sea Flow Measurement Workshop, 1997.