Aspects of bi-directional fiscal metering by means of ultrasonic meters

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Introduction

N.V. Nederlandse Gasunie is the major gas transmission company in the Netherlands. In 1998 the company sold 79.8 billion m^3 natural gas. From this amount of gas 43.4 billion m^3 was sold in the domestic market and 36.4 billion m^3 was exported to other European co untries.
To deliver the gas to its customers Gasunie operates an extensive gas transmission grid, with 11389 kilometres of transmission lines, 8 compressor stations, 75 regulator stations, 15 export stations and 1114 city gate stations in the domestic market.
Starting in 2001, Russian gas will flow via Poland and Germany to the Netherlands. The gas will enter the Dutch transmission system at the existing Oude Statenzijl export station in the northern part of the country.
Importing gas via a station that has been designed as an export station is a new phenomenon for Gasunie and a redesign of the existing station is necessary. Gasunie Research was approached with the instruction to work out and test a proposal for a bi-directional flow measurement concept based on ultrasonic gas meters. In this paper an overview of the work executed so far will be presented, together with results of experimental work that has been done at Gasunie's high pressure, high flow Bernoulli laboratory at Westerbork, the Netherlands.

Flow measurement at export measurement stations

Due to the stringent requirements in terms of availability and uncertainty of the measurement, at Gasunie's major export stations, the gas flow measurement is implemented as a complete double system. Not only the flow meters, but also the temperature and pressure sensors and flow computers are doubled and in the number of meter runs always a spare run is included, which can take over from one of the regular meter runs in case of failure. Results of research work on the design of the export stations have been published in [1], [2] and [3].
At the Oude Statenzijl station the meter runs are equipped with a turbine meter, which is considered as primary meter, and an ultrasonic flow meter, which is used as backup meter. A typical layout of such a meter run is shown in Figure 1.

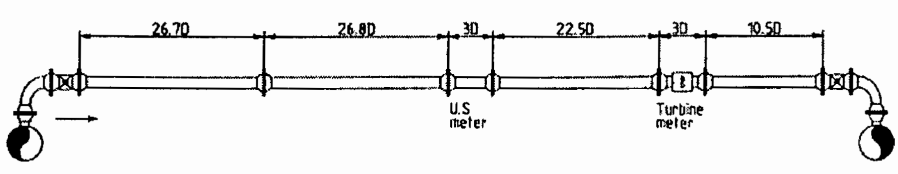


Figure 1 - Layout of a typical meter run

Upstream of the ultrasonic meter a Laws flow conditioner is installed to remove the flow disturbances coming from the underground header and riser, which in fact form a double bend out of plane. The results of the flow measurement by the turbine and ultrasonic meter are continuously compared by means of an on-line comparison technique, based on hourly averages. Results of this comparison have been reported before in [].

Approaches for a bi-directional flow measurement

As a first stage in the project alternative approaches for a bi-directional measurement were considered: duplication of the total measuring station, switching of meter runs so that the gas always flows in the same direction through the metering section and use of full bi-directional meter runs. From an economical point of view the third alternative is the most favourable one. No extra piping and valves are needed, no extra station space is required and when the direction of the flow changes no switching actions have to be executed.
Focus was given to the design of a meter run equipped with meters that can be used bi-directionally. Taking into account the required uncertainty and availability of the flow measurement only one candidate meter, the multi-path ultrasonic flow meter, could meet these requirements. Standard turbine meters, although certain manufacturers claim that they can be used in a reversed flow without damage, were not considered as an alternative of full value.

A bi-directional meter run with ultrasonic meters

Figure 2 - Schematic design of a bi-directional meter run

After the selection of the measurement principle the stringent availability requirement lead to the decision that two ultrasonic meters in one run were required. The requirement to use the bi-directional meter run in an existing export measuring station restricted the available length for the meter run. The bi-directional nature of the meter run lead almost automatically to a symmetric design as in Figure 2.The gas flows from the header via a riser pipe through a 90 degree elbow and a ball valve into the actual meter run. To eliminate flow disturbances caused by the header - elbow combinations, which form double bends out of plane, flow conditioners are required at both sides of the meter run.
Now the questions arises where to install the meters? A first intuitive approach is to situate the ultrasonic meters are far away as possible from each other to avoid acoustic influences from one meter to the other (Figure 3) ; an alternative, however, is to place the meters as

close as possible to each other (Figure 4). Now the meter manufacturer will be able to predict the paths of the ultrasonic beams and advise how the meters should be positioned to avoid that an ultrasonic beam from one meter interferes with the transducers of the other meter. The first approach brings the ultrasonic meter relatively close to the flow conditioner due to the restricted length of the meter run, imposed by the station layout. In both cases a temperature transmitter has to be situated upstream of one of the meters, depending on the direction of the flow.

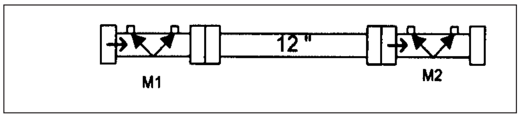


Figure 3 - Meters apart

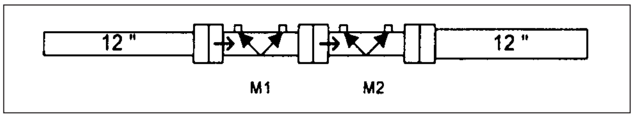


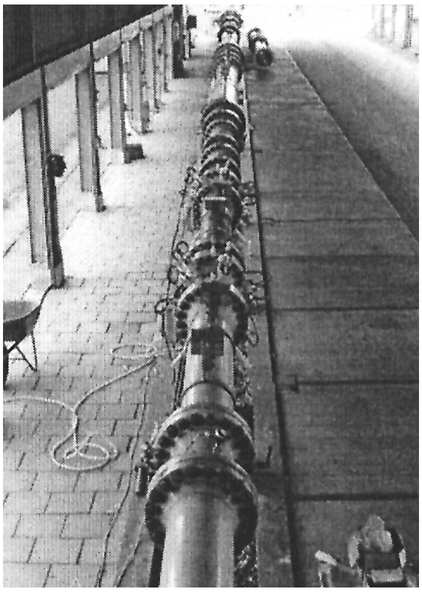
Figure 4 - Meters adjacent

Both possible alternatives resulted in a number of questions, for which the answers were not clear beforehand:

- What is the mutual acoustic influence of two ultrasonic meters in one meter run?
- What is the effect of a temperature transducer upstream, relatively close to an ultrasonic meter?
- What is the effect of a nearby flow conditioner on an ultrasonic meter?
- Are calibration curves for a bi-directional meter calibrated in both directions comparable?

In order to find answers to these questions a set of experiments at Gasunie's Bernoulli flow laboratory at Westerbork were conducted. In the next section a selection from the measurements, giving a representative overview, is presented.

Experimental results



Equipment

In the experiments two 12” Q.sonic 5 ultrasonic meters, made available by Instromet Ultrasonics, were used. The pulse outputs of the meters were connected to the data-acquisition system of the Bernoulli system to be able to compare the readings of the meters to the flow indicated by the reference meters of the laboratory.
Uniform, Instromets diagnostic software package for ultrasonic meters, was used to monitor the performance of the ultrasonic meters during the experiments. Standard, calibrated, pressure and temperature sensors from the laboratory were used in the experiments. Existing flanged piping was used to form the different straight pipe lengths that were required in the experiments.

Acoustic influence

Figure 6 shows one of the configurations that has been used to determine the effect of the upstream meter on the behaviour of the downstream meter. The results obtained with this configuration are shown in Figure 7.

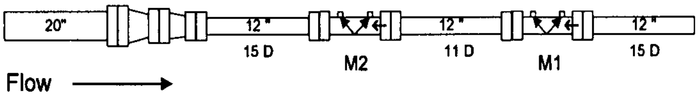


Figure 6

At a distance of 11 pipe diameters no influence from the upstream meter on the downstream meter can be seen. Also the performance of the individual paths of the downstream meter, read out by the Uniform software, was not affected. The spread of the results at the lower flow rates is a phenomena that is likely to be caused by a line pack effect in the installation. For these experiments, where a large pipe section had to be installed, the large meter run of the installation had to be used. This meter run is normally not used for 12 " meters.

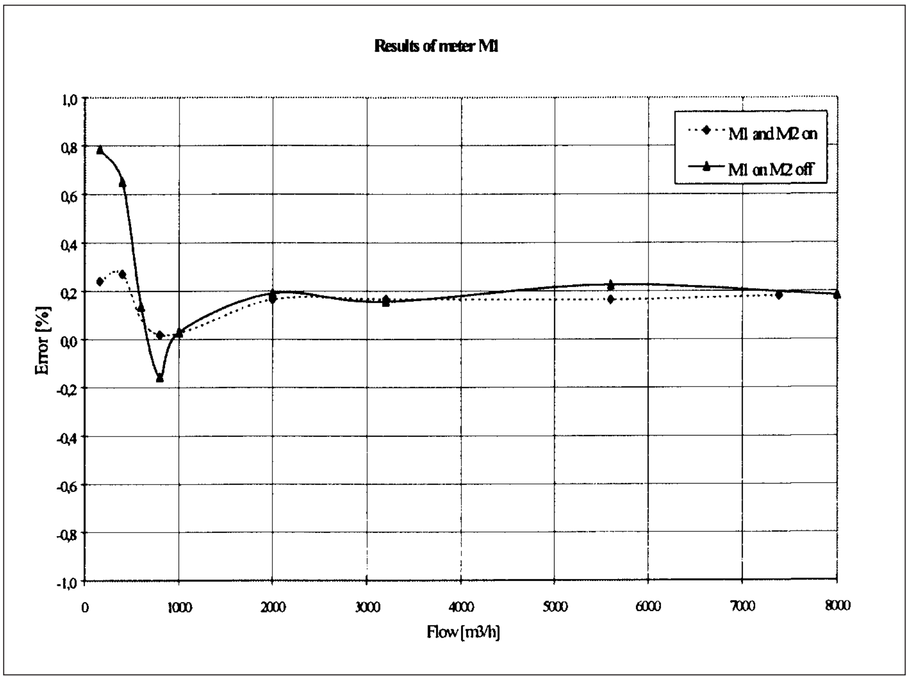


Figure 7 - *Results interference at distance*

With two meters adjacent to each other a similar experiment was carried out. The set up from Figure 8 was used for the measurements. After the measurement one of the meters was rotated one bolt position (12°) and the measurement was repeated. The results are shown in Figure 9.

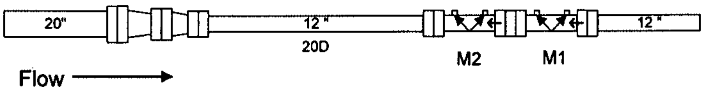


Figure 8

Due to flow limitations on the day of the second set of measurements no higher flow than 3200 m3/h was possible. There seems to be an influence of meter 2 on meter 1 when meter two is rotated. This means that the position of the meters is very critical when both meters are very close to each other. A slight rotation may influence the performance of the meters, indicating that the ultrasonic signal from the meter upstream is picked up by the downstream meter.

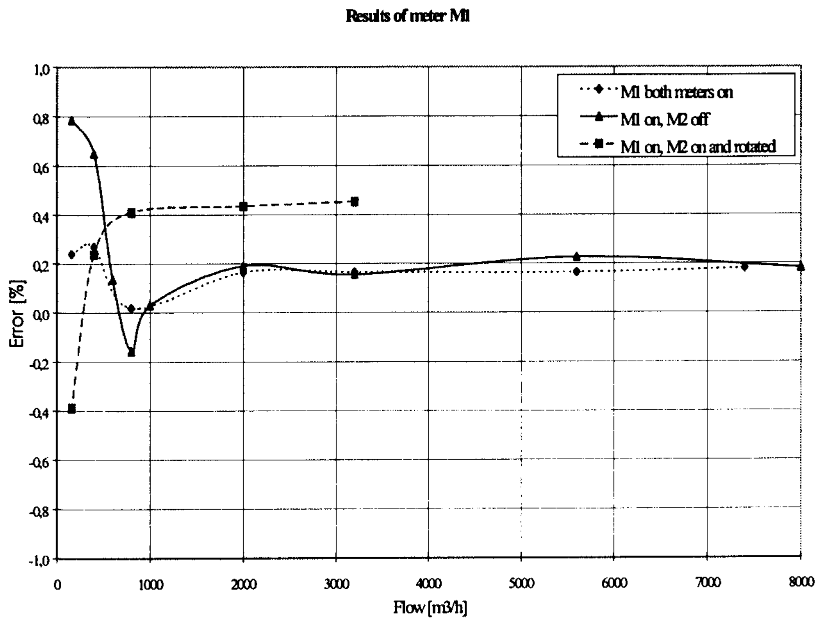


Figure 9 - Results adjacent meters

Temperature transducers upstream

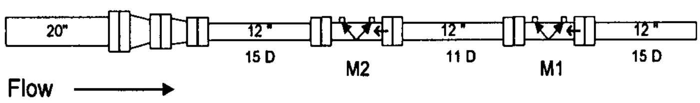
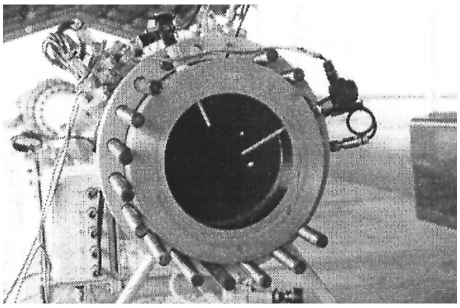


Figure 10

The configuration from Figure 10 was used to investigate the effect of Pt 100's mounted in front of one of the meters. In Figure 11 a photograph of the Pt 100's used can be found.



As can be seen in Figure 12 the Pt 100's mounted in front of the first meter change the curve of the first meter at higher flow rates. The curve of the second meter, which is further away from the disturbance, is not affected. In field practice the effect of Pt's will be more severe as Gasunie is using pocket mounted temperature transducers with a larger diameter than the Pt 100's used in these experiments.

Figure 11- Pt's in front of the meter

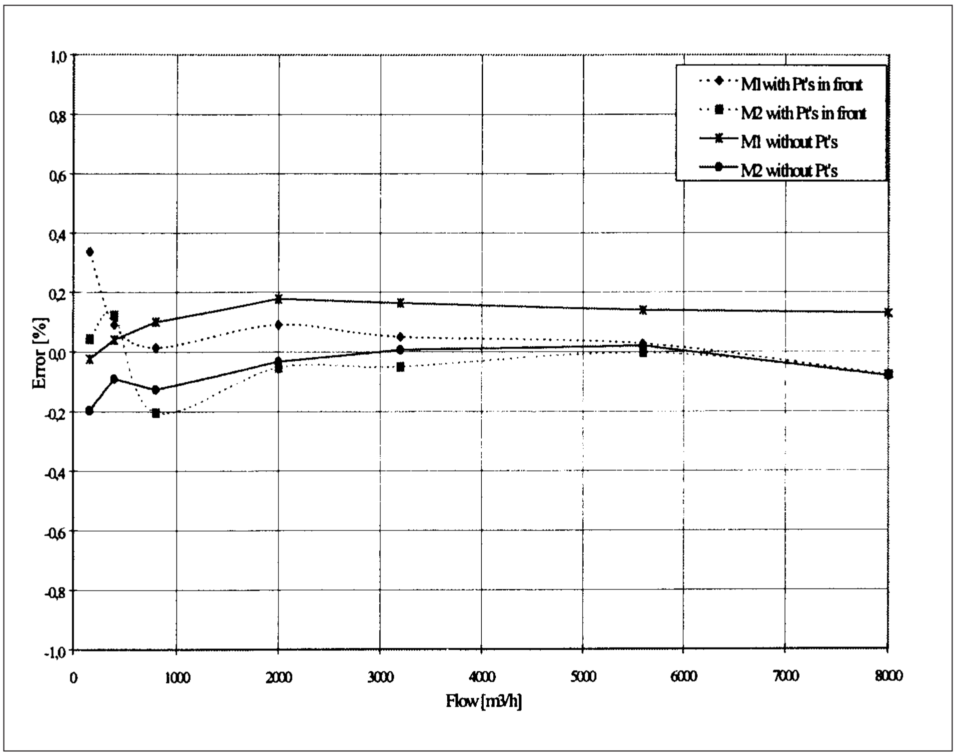


Figure 12 - Effect of Pt's upstream

Influence of nearby flow conditioners

In the meter runs of the Gasunie export stations currently Laws flow conditioners [], from the type shown in Figure 13, are used. This was the reason that for the experiments with flow conditioners this type of flow conditioner was selected.

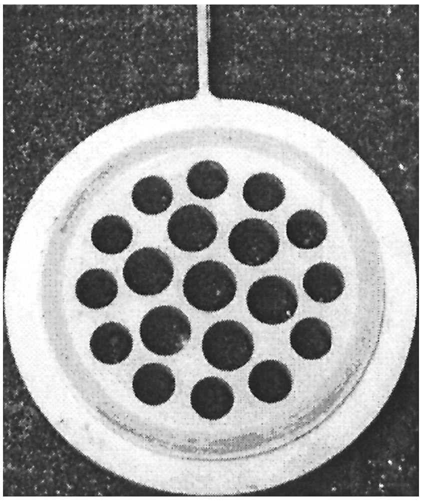


Figure 13 - Laws plate

To investigate what the effect of distance of a Laws flow conditioner to the ultrasonic meter a series of calibrations with the flow conditioner at different distances from the meter has been done. As flow disturbance a pipe diameter reduction from 20 " to 12" was used. From flow profile measurements it is known that reducers lead to a very flat profile, causing misreading of meters. In Figure 14 the results of these calibrations are shown.

Calibration results with the flow conditioner at 20D, 13.5D and 10D are lying close together and taking the repeatability of the test installation and line pack effects at low flow rates into account one may state that these results are comparable. The graph of the experiment with the flow conditioner at 5D, however, deviates. This leads to the conclusion that a Laws flow conditioner at 5D is too close to the meter and that it is advisable to have at least 10D between flow conditioner and ultrasonic meter.

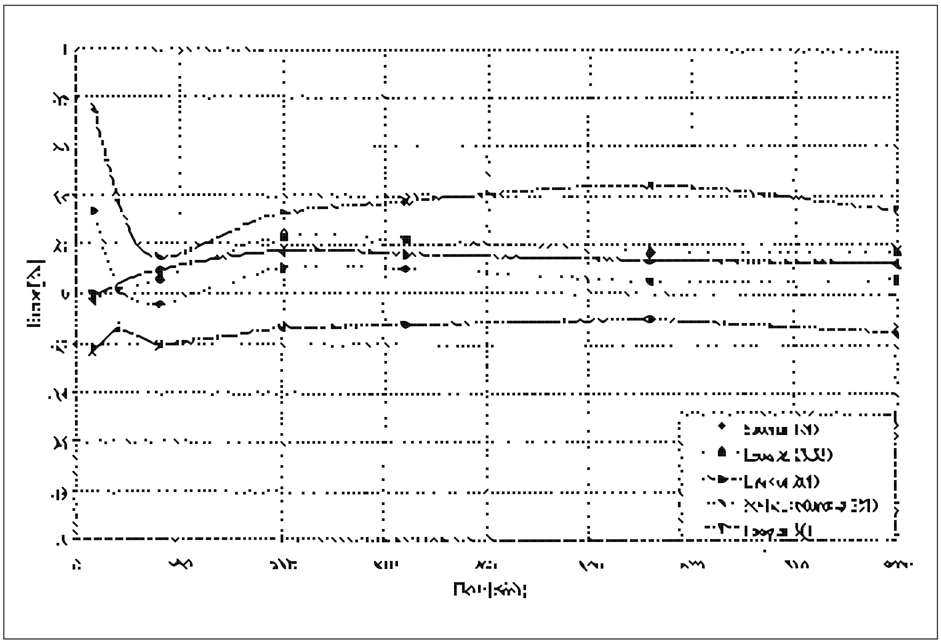


Figure 14 - Influence of flow conditioner

Calibrations in both directions

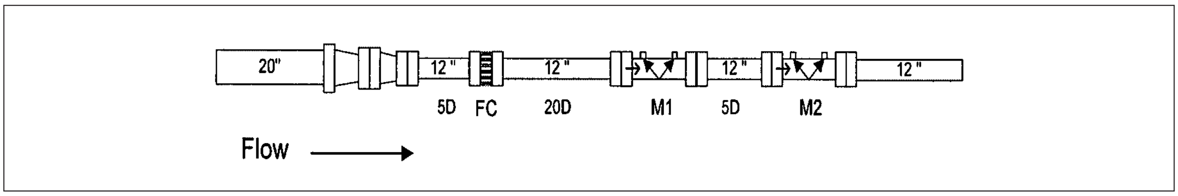


Figure 15

With a flow conditioner at 20 D in front of the meter as shown in Figure 15 two calibrations were performed.

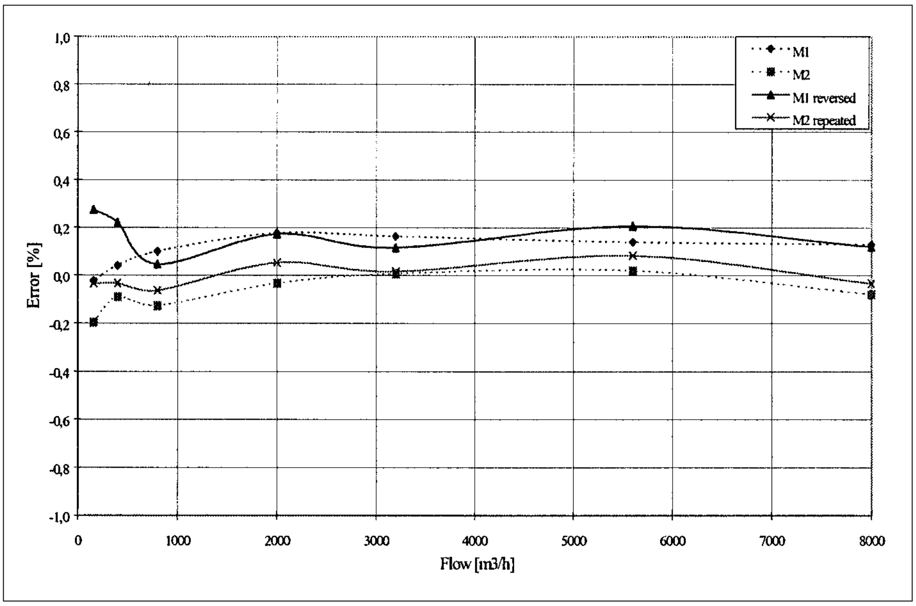


Figure 16 - Calibration in both flow directions

After the first calibration the first meter was taken out of the meter run and mounted facing the reverse direction. The results of this experiment are shown in Figure 16. As might be expected from the concept of the ultrasonic meter, no significant differences between the two calibration curves of meter 1, have been found. As explained earlier results at lower flow rates show more variance due to a line pack effect in the test installation.

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Overall test of the concept

With the set up from Figure 17 a calibration was done to test a complete meter run.
The results are given in Figure 18.

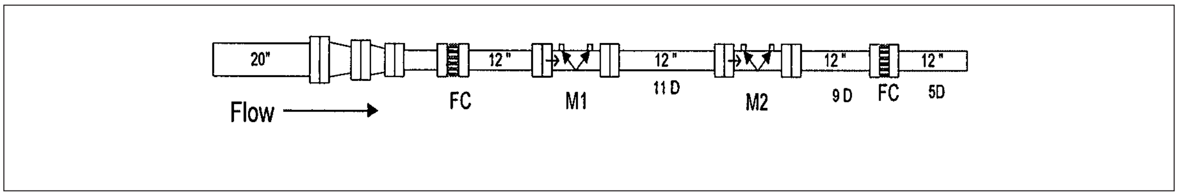

Figure 17

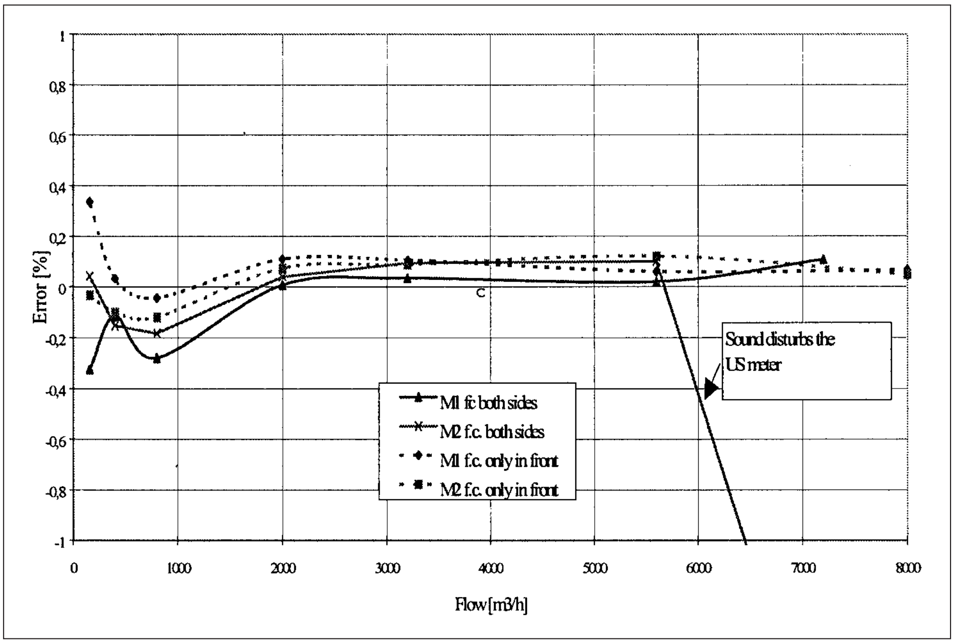

Figure 18 - Results overall test

Although in the experiments with one flow conditioner in the test line a slight whispering, coming from the flow conditioner, was heard it came as a complete surprise that with the above set up at high flow rate the whole meter run was producing a deafening sound. At a distance of one meter from the pipe wall a sound level of 105 dBa was measured. From the fact that one of the meters malfunctioned at higher flow rates it may be concluded that the sound produced is not limited to the audible range. The test was repeated with the flow conditioner reversed to investigate whether the chamfered rim of the holes, which where in the first experiment at the downstream side of the second plate, would influence the sound production. No significant difference with the first experiment was found

Another test that has been done with two different types of flow conditioners. Upstream the Laws plate was mounted. Downstream a Spearman [] flow conditioner, shown in Figure 19, was used to find out if different designs, using different sizes of holes would eliminate the sound. This attempt was unsuccessful. Only a minor difference in sound level was measured. Due to the limited time available for the experiments at the test installation is was to decided to spend more time on this phenomena at a later time.

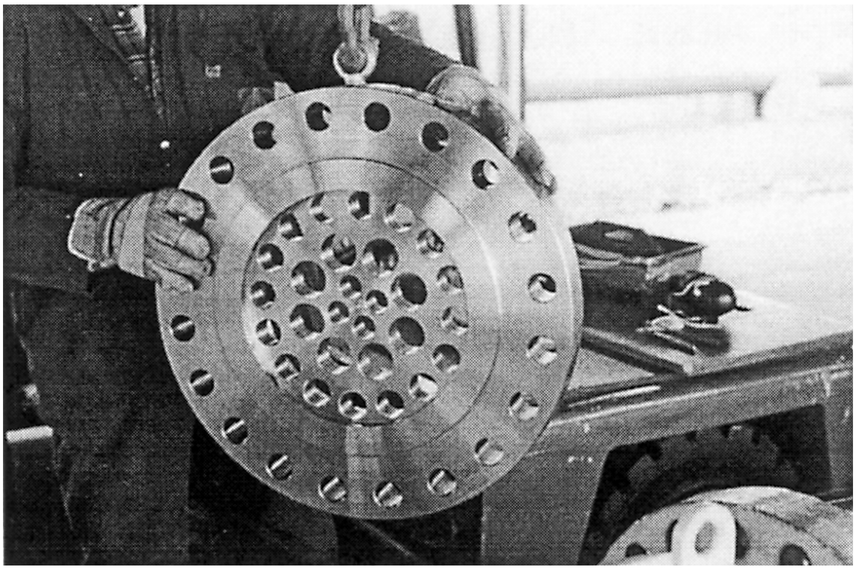

Figure 19 - Spearman flow conditioner

Conclusions

Ultrasonic gas flow meters are by design bi-directional meters, which is confirmed by the calibration curves recorded in both flow directions, which lay in a relative narrow band.
Flow disturbances relatively short in front of the meter, for example caused by temperature transducers or flow conditioners, may disturb the functioning of the meter, leading to misreading.
Two ultrasonic meters mounted at a distance of 10D do not mutually influence each other. A minimum distance has not been determined in this project. When two meters are mounted adjacent, influences may be found depending on the relative position of the meters.
A combination of two plate-type flow conditioners in one meter run, although mounted at a relatively large distance, may lead to a high level sound production in the meter run. The produced sound exceeds not only the acceptable level for audible sound, but may also lead to a malfunctioning of the meter at high flow rates. This means that the tested design, with two plate type flow conditioners, can not be used in the current form for export stations. Alternative designs for the meter runs will have to be considered.

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.