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NEW DESIGN CONCEPTS IN ULTRASONIC GAS FLOW METERS

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1 INTRODUCTION

Today ultrasonic gas flow meters are widely accepted for custody transfer measurement.

Particularly for applications with larger pipe diameters (10 inch and larger) ultrasonic gas flow meters are an attractive alternative and have proven to offer excellent and reliable performance. The key to this is the fact that the ratio between transducer diameter and nominal pipe diameter is most favourable within this diameter range.

When applying current transducer technology to smaller sized meters (nominal diameter range 4 to 8 inch), the ratio between transducer dimensions and pipe diameter becomes substantially less favourable. This results in more severe effects regarding the flow profile inside the meter and hence on the accuracy.

In order to offer better performance in the smaller diameter range, new design concepts had to be developed to reduce transducer dimensions.

2 DEVELOPMENT TARGETS

In order to offer a meter with better performance in smaller size pipe diameters, the development target was to design and construct smaller sized transducers.

In addition to this, a new meter concept requiring less overall space and if possible less weight, would be welcome.

A further issue was to allow product standardisation. As in practical applications various pipe schedules may be found, it is desirable to develop a meter using a “standard core” that can be adapted to various pipe schedules.

3 ALTERNATIVE TECHNOLOGIES

For today’s generation of meters the most common technology is of axially radiating transducers where the ultrasound beam is in line with the transducer and its housing. The transducer and its housing must, therefore, point in the direction of the desired acoustic path. Figure 1 shows a typical example of such a transducer. As a consequence, for accommodating the transducers, the meter should have nozzles welded at particular angles onto and extending out from the meter body. Given the size of the most commonly used transducers, relative to a meter of 4 inch nominal diameter, the transducers themselves are large and the supporting nozzles add even more to the required space and volume of such a meter. Figure 2 shows a typical example of such a meter body.

The alternative technology is to have transducers that are designed in such a way that the beam is offset at an angle with respect to the axis of the transducer and its housing. Figure 3 shows an example of such a transducer. This allows for an assembly that is installed perpendicular to the meter body while the beam points in the appropriate direction. Instromet has been using similar transducers in a hot tap system designed to be installed on existing pipelines. Using this technique, ball valves and their attachments are welded (perpendicular) onto the pipe. A transducer insertion mechanism and transducer assembly is then installed on top of each ball valve. Figure 4 shows a diagram of such a system. These systems are usually implemented as single path configurations, having a reflected acoustic path through the centre of the pipe.

4 HOT TAP MULTIPATH ULTRASONIC GAS FLOW METERS

In an actual case (pipeline monitoring in North America) a customer required a hot tap system with higher accuracy than could be guaranteed with a single path system. It turned out that Instromet's proprietary three path configuration could be implemented using multiple transducer pairs with an offset beam angle, hot tap installed, perpendicular to the pipe. To accomplish the desired path configuration, it was necessary that the beam angle be offset to an appropriate value, the centre to centre distance between the transducer assemblies chosen accordingly, and that the transducer be installed with an offset angle (rotated) relative to the pipe axis.

It was decided to build and test a meter body (spoolpiece) equipped with these hot tapped assemblies before applying this concept in a field installation to ensure the concept's feasibility. This enabled us to test this configuration at the Bernoulli flow test lab of Gasunie in the Netherlands. (As an additional design feature it was decided to build all the hot tap assemblies on the upper portion of the pipe to provide for easy maintenance and accessibility.) The test results with this meter were better than expected, see Figure 7.

5 NEW TRANSDUCER DEVELOPMENTS

In parallel with other developments Instromet designed a new type of ultrasonic transducers. This new transducer was developed for two main reasons, one being its smaller dimensions and the other being its higher operating frequency. The higher operating frequency is desirable with respect to applications where high levels of ultrasonic noise are present, since the noise level typically decreases with increasing frequency.

This new transducer was initially built into a standard transducer housing. Figure 8 shows a picture of both transducer tips, the standard as well as the new design in the same kind of housing. The difference of the internal parts in size can clearly be seen.

However this new transducer concept enabled the design a much smaller housing, one much more appropriate to meters with a nominal diameter of 4 to 8 inch. Figure 9 shows a picture of this new transducer and housing.

6 NEW METER BODY DESIGN

In order to benefit from the new transducer design, a new meter body was also designed. This meter body is manufactured form thick wall steel pipe, and in order to accommodate the transducers, the tube is machined with three flat faces. Each face has two large holes to insert the transducers and a number of smaller threaded holes to secure the transducers. This concept allows for a design that avoids large extending parts an requires significantly less space overall. Figure 10 shows a picture of the new meter body.

6.1 Diameter Reduction

It was found to be advantageous to design a meter body with the measuring section having a reduced bore. Benefits of this concept are:

- It allows to use the thick wall pipe required for machining the flat faces and the threaded holes for transducer installation.
- It allows a more compact design.
- It increases the gas velocity in the measuring section, thus allowing the entire 30 m/sec capability of Instromet's ultrasonic meter technology to be fully utilised, whilst maintaining the integrity of measuring installations where the gas velocity typically will not exceed 20 m/s.
- A diameter reduction (tapering) is beneficial since it reduces distortion in the flow profile.
- It allows standardisation of the meter "core" or body with respect to various pipe schedules. As Figure 11 shows the diameter reduction is accomplished using an insert as an adapter that can be varied in degree to match different pipe schedules.

This adapter has a tapering on the inside, making a smooth transition between the (reduced) meter bore and the diameter of connecting pipe work according to the pipe schedule as used.

The table as shown in Figure 12 lists the nominal dimensions for the meter sizes and adapters for various pipe schedules.

7 TEST RESULTS

The new design concepts have been implemented in a number of test meters, with nominal sizes of 4 inch, 6 inch and 8 inch diameter. All are ANSI class 600. The test program of these meters is ongoing, with several tests having been completed and some other still to be performed. Results are currently available of tests at Instromet's own facilities at Silvolde (atmospheric pressure) and Utrecht (8 bar Natural gas) in the Netherlands. Both test facilities are operated under NMi supervision. Other tests have abeen performed at the Pigsar test facility of Ruhrgas in Germany and in the laboratory of Gasunie in Groningen in the Netherlands.

As the basic path configuration and integration algorithms are identical to the existing Instromet multi-path ultrasonic meters, it is to be expected that the performance with respect to installation effects due to flow profile distortion is at least of the same order or better. The possible improvement being due to the profile improvement that may be expected from the diameter reduction. For this reason the tests until today have concentrated on straight line pipe configurations to establish base line performance.

Figure 13 presents test results for the 4 inch meter at atmospheric pressure (Silvolde) and at three different pressures at Pigsar

Figure 14 presents results of the same meter tested in Utrecht at 8 bar Natural gas with both forward and reverse flow.

Figure 15 shows test results of an 8 inch meter tested at Pigsar at three different pressures.

Figure 16 shows test results of a 6 inch meter, again at Pigsar at three different pressures, at Silvolde at atmospheric pressure and also some data points from the Gasunie laboratory in Groningen.

The differences in performance are mostly due to limitations regarding reproducibility and test facility uncertainty. There are no indications of a significant systematic pressure dependency and linearity and repeatability were found to be quite satisfactory. In fact it is rather unique that the new ultrasonic meter displays this performance starting from atmospheric pressure (the standard maximum design pressure is 150 bar).

The tests above were performed with inlet and outlet adapters providing the smoothest transition from the inner diameter of the adjacent piping to the reduced meter bore, later identified as the "standard" adapter. We were interested to know whether the shape and dimensions of the adapter would be critical or not. Therefore tests were designed in order to compare the following configurations:

1. The standard configuration (smooth transition over the length of the adapter).
2. An adapter ring having the tapering only over 50% of its length. The angle of the tapering in the "standard" case being approximately 6 degrees is now increased to approximately 13 degrees.
3. A "standard" adapter ring (6 degrees) but with the addition of a mismatch with the upstream pipe diameter resulting in a diameter step of approximately 2%.
4. A cylindrical adapter ring (no tapering at all) resulting in a diameter step of approximately 11%.

Figure 17 shows the shapes of the three variations, gas flow is from left to right, Left of the adapter is the inlet pipe; Right of the adapter is the reduced bore of the metering section.

Figure 18 presents the results obtained with the 4 inch meter with configurations 1. and 4.

Figure 19 presents the results obtained for the 6 inch meter tested at Pigsar with configurations 1. and 4.

Figure 20 shows the results of the 6 inch meter tested at Utrecht with all 4 of the configurations.

For all these tests it is remarkable that only the 11% diameter step has a significant impact, in the order of 0.4 to 0.5% With respect to the large diameter step of 11% this may be considered to be a quite an acceptable result.

The difference between the other configurations is acceptable small and therefore the shape of the tapering is not considered to be critical.

8 CONCLUSIONS

The test results of the new design concepts as implemented in the test meters can be considered to be very satisfactory.

The effects of a diameter step changes are considerably smaller than expected.

The test results show that the shape of the diameter reduction (tapered inside of the adapter ring) is not critical.

The new concepts have proven to be useful in order to design smaller sized transducers, particularly suitable for the construction of smaller ultrasonic flow meters size meters with enhanced performance.

The new transducers have made it possible to design a more compact meter requiring less space overall.

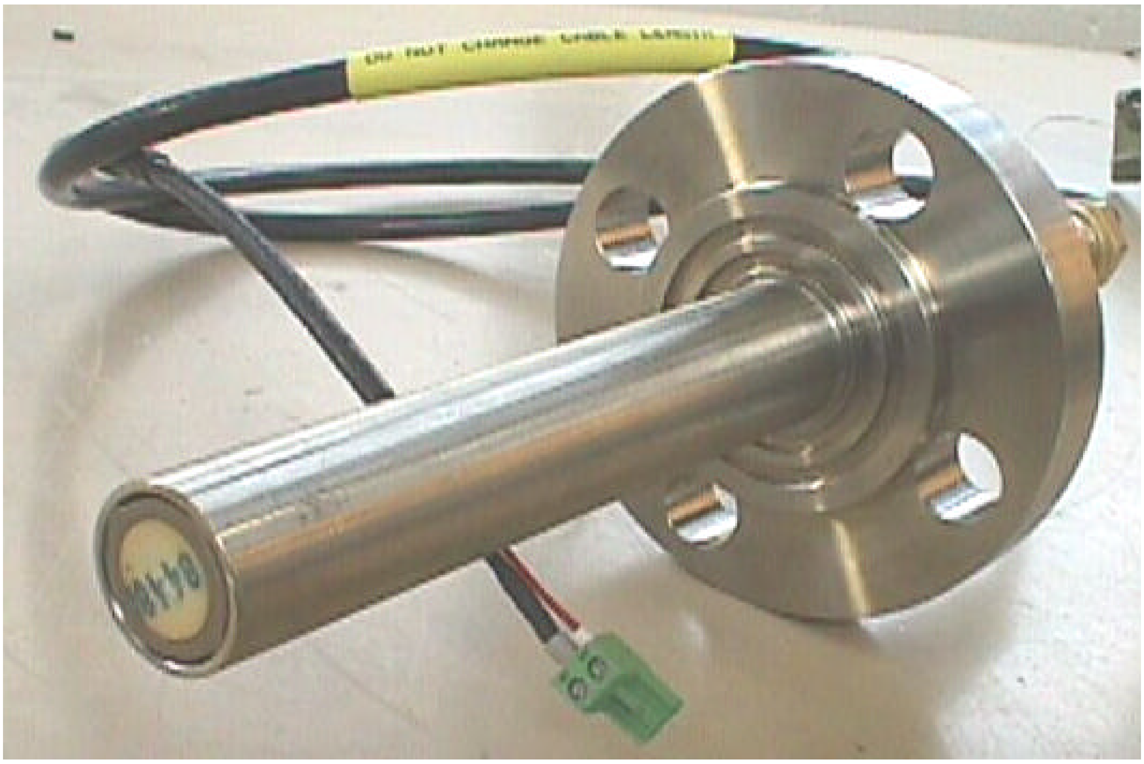

Figure 1 - Typical example of an axially radiating transducer

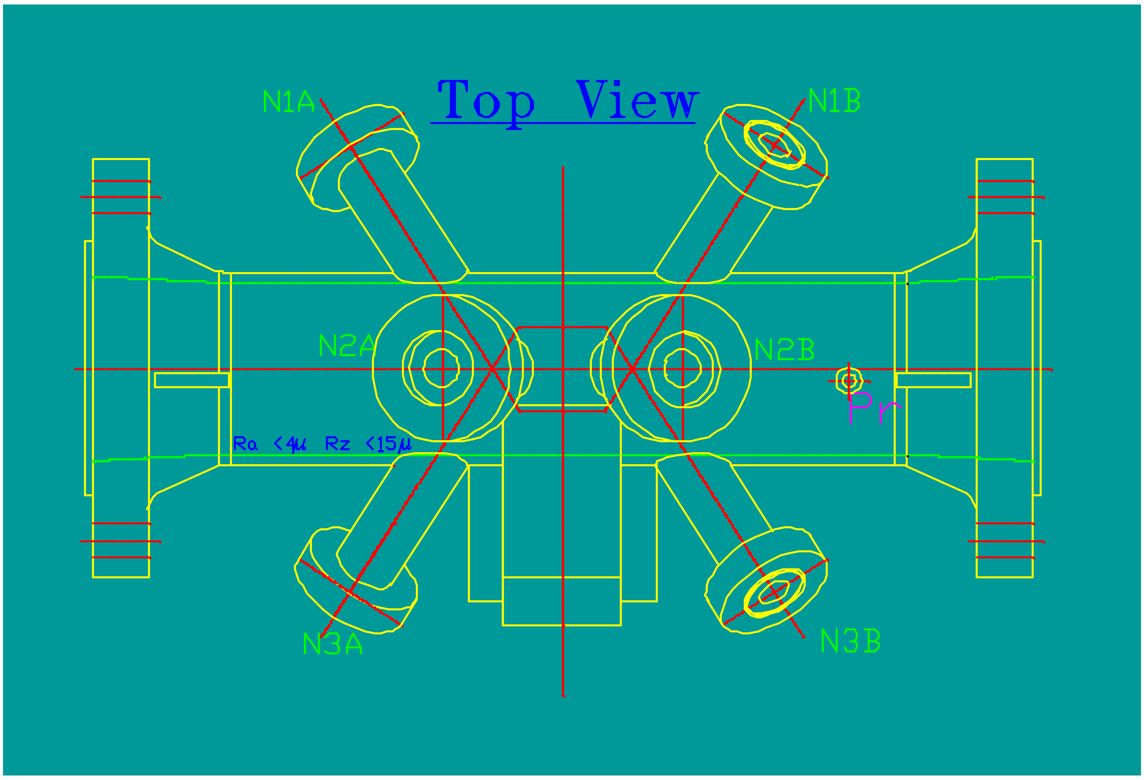

Figure 2 - Typical example of meter body with angled nozzles for the transducers

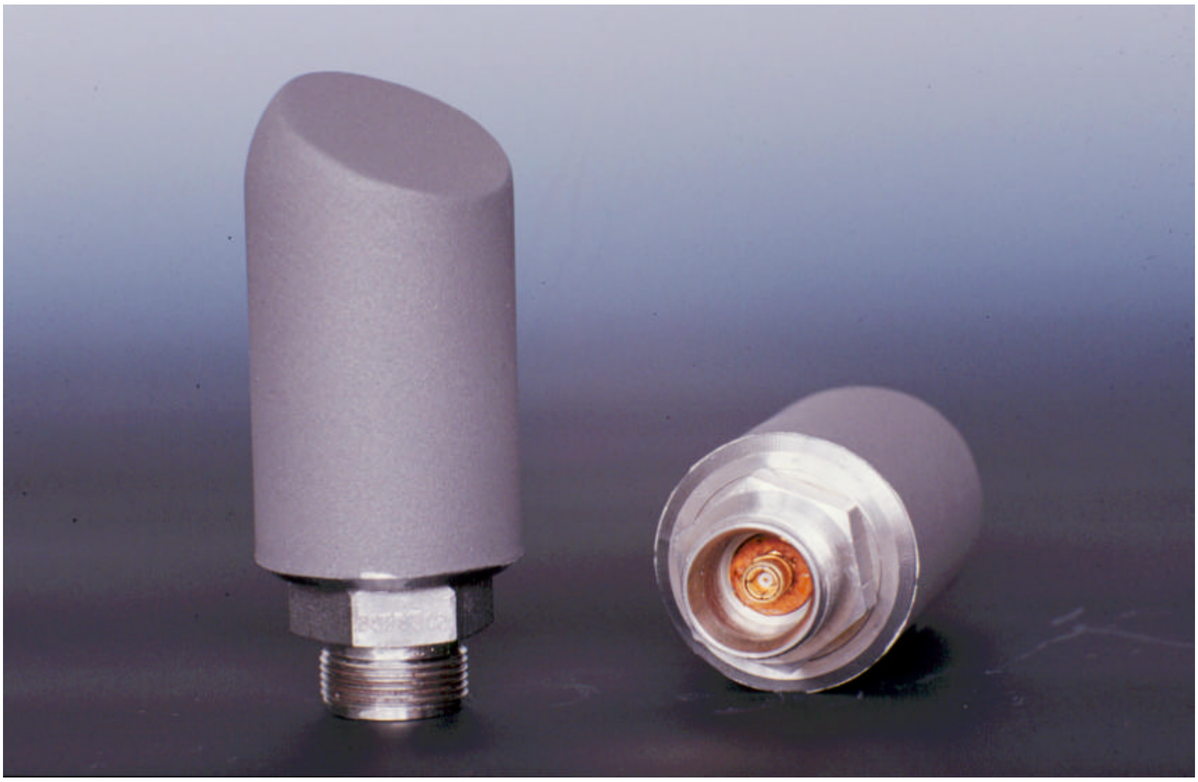

Figure 3 - Example of transducer with offset beam angle

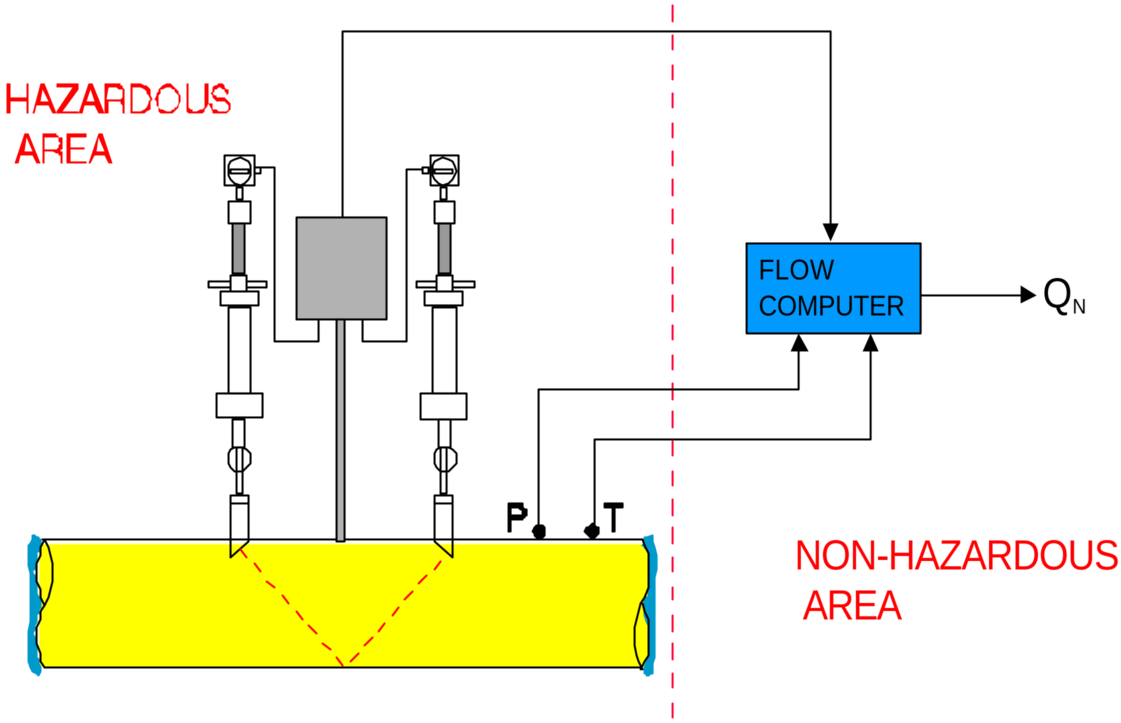

Figure 4 - Example of system using transducers with offset beam angle

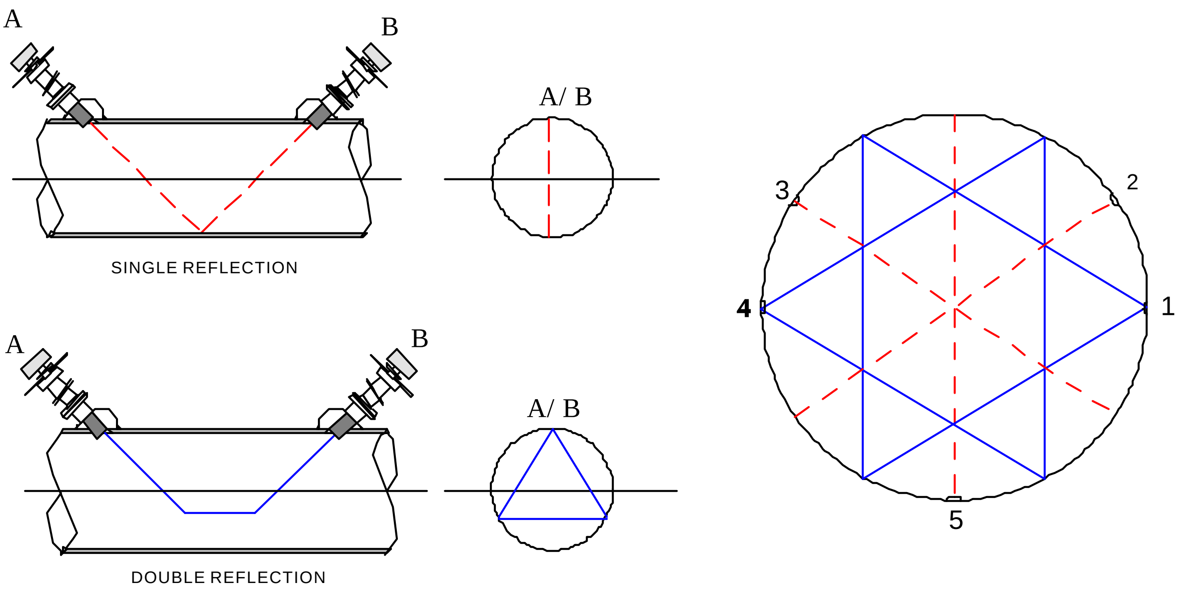

Figure 5 - Basic path configuration of Instromet's 3- and 5- path multi-path ultrasonic gas flow meters

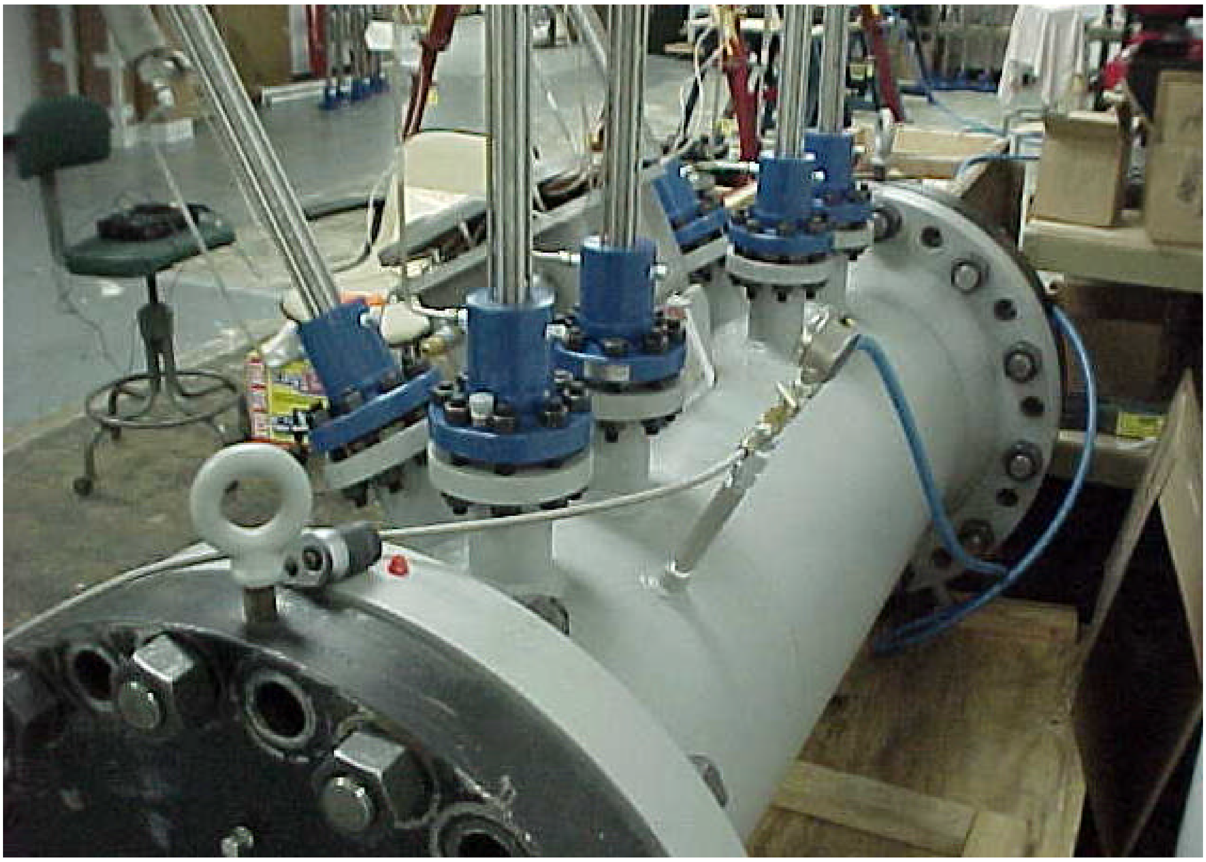

Figure 6 - Meter body for testing 3- path hot tap ultrasonic gas flow meter

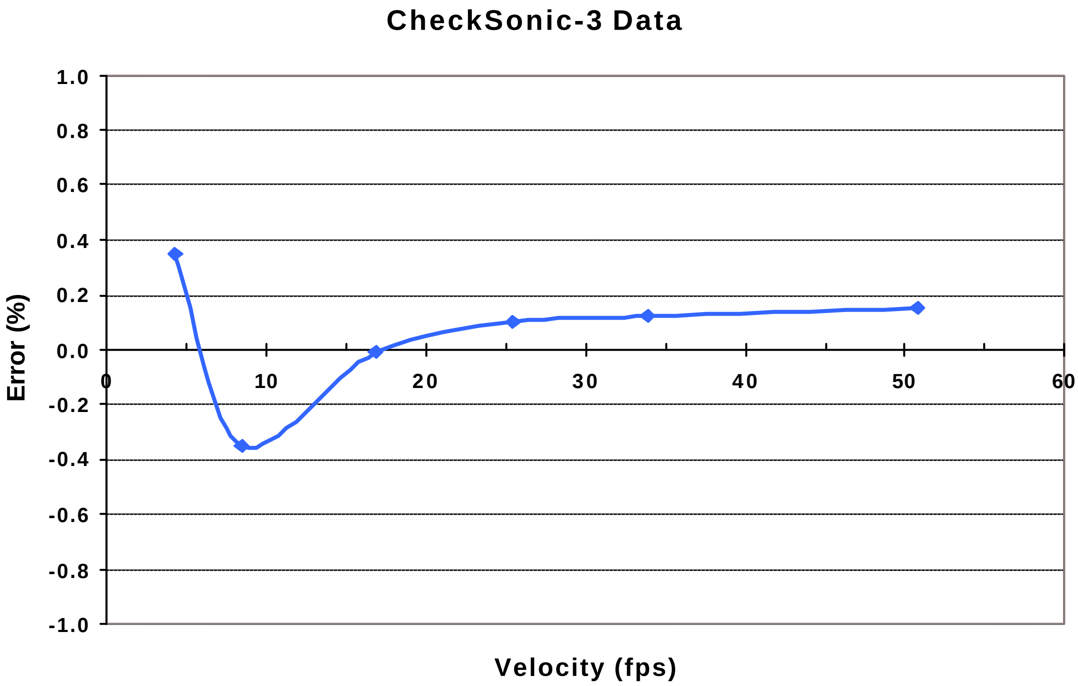

Figure 7 - Test results of 20 inch 3-path hot tap multipath test meter

Figure 8 - Transducer tips of standard and higher frequency transducer compared

Figure 9 - New small transducer housing

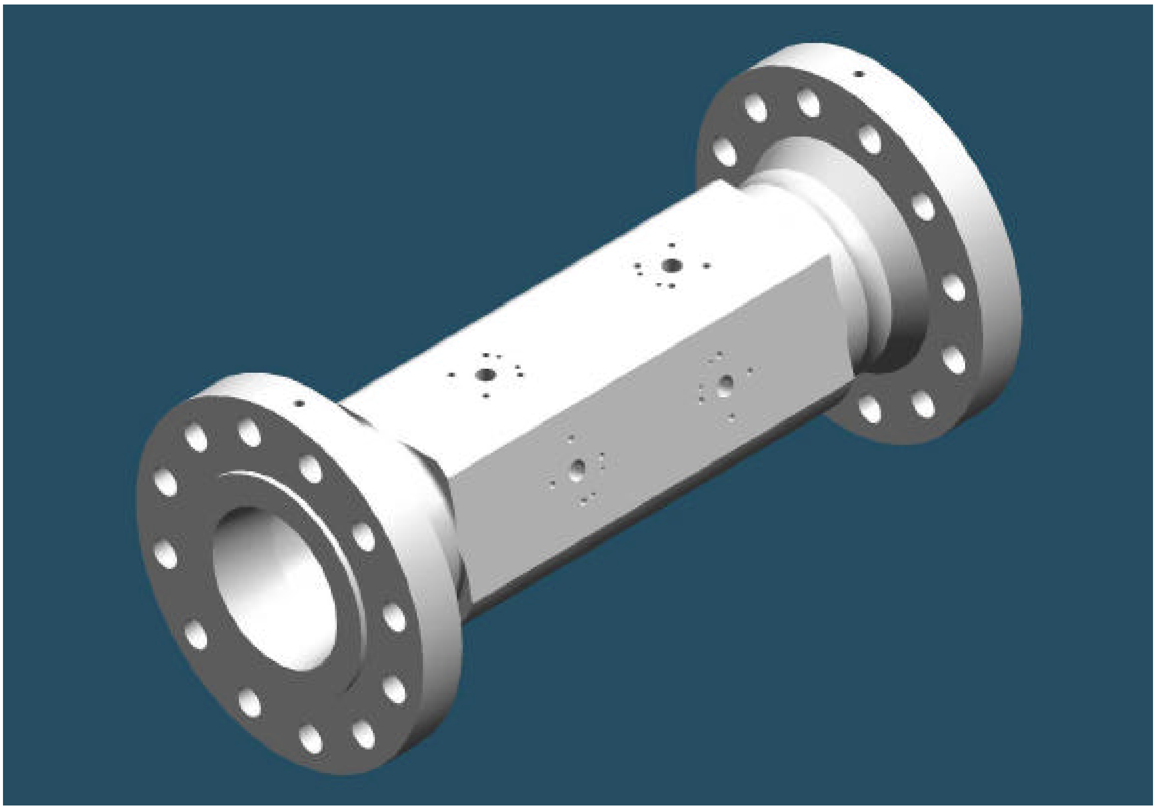

Figure 10 - New design meter body for new model transducer

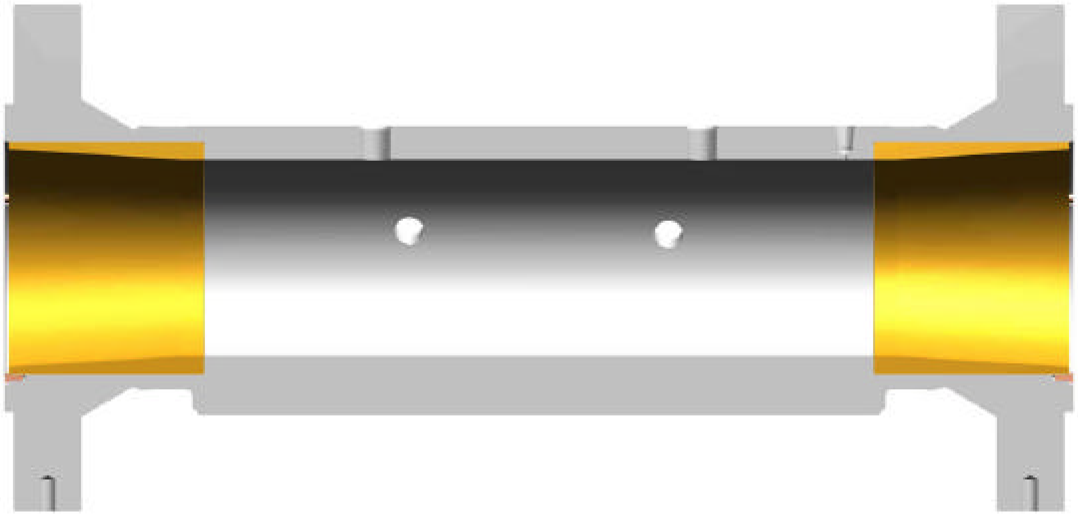

Figure 11 - New meter body cross section

nom dia	ID	adpt L	Sch	ID	D-ratio	Dia reduction	Qmin	Qmax	angle
inch	mm	mm		mm		%	1	30	degrees
4	91.5	50	40	102.3	0.89	10.56	30	904	6.2
4	91.5	50	60	99.6	0.92	8.13	30	904	4.6
4	91.5	50	80	97.2	0.94	5.86	30	904	3.3
6	137.8	75	40	154.1	0.89	10.58	68	2051	6.2
6	137.8	75	60	150.6	0.92	8.50	68	2051	4.9
6	137.8	75	80	146.3	0.94	5.81	68	2051	3.2
8	181.3	100	40	202.7	0.89	10.56	118	3550	6.1
8	181.3	100	60	198.5	0.91	8.66	118	3550	4.9
8	181.3	100	80	193.7	0.94	6.40	118	3550	3.5

Figure 12 - Table with nominal dimensions for new meter models

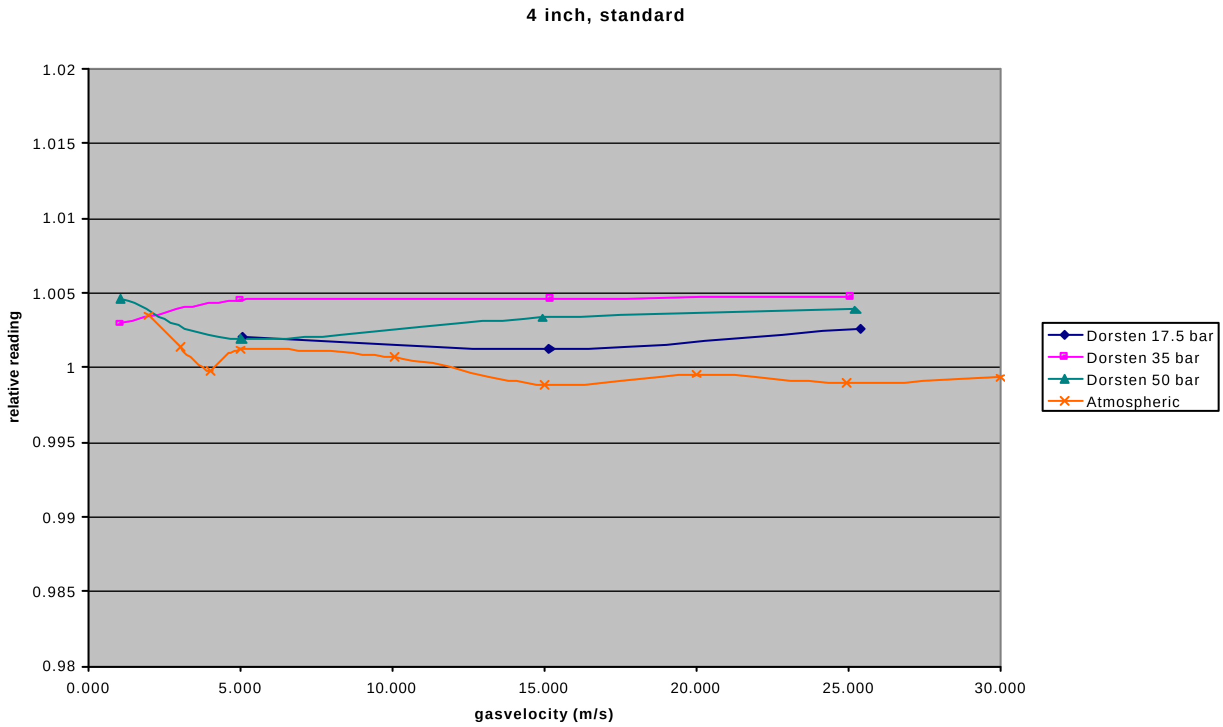

Figure 13 - Test results of new 4 inch meter with smooth transition (standard tapering)

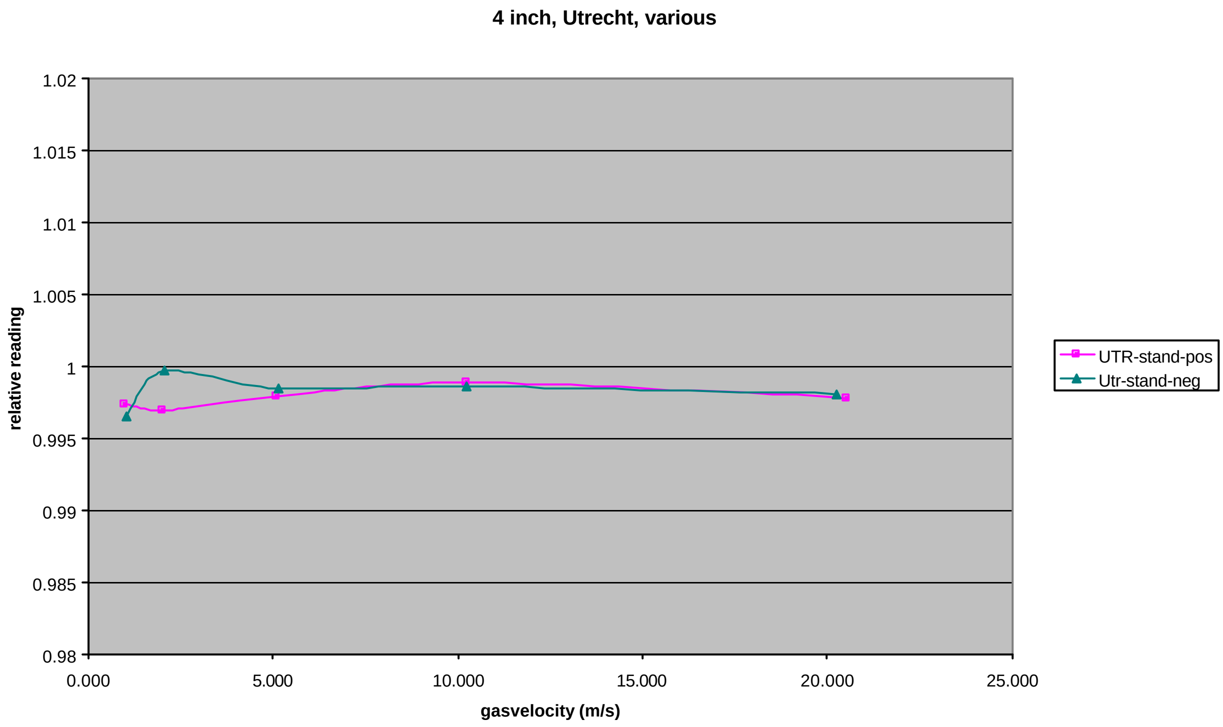

Figure 14 - Test results of 4 inch meter with forward and reverse flow

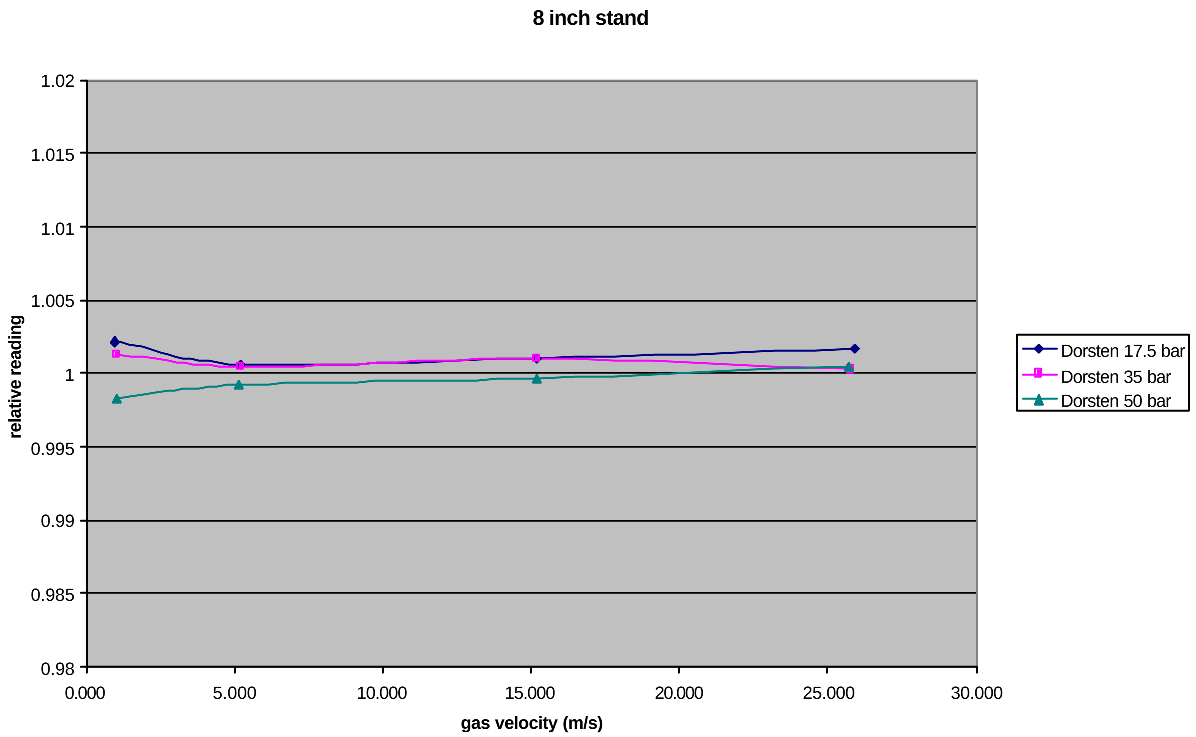

Figure 15 - Test results of 8 inch meter with standard adapter (smooth transition)

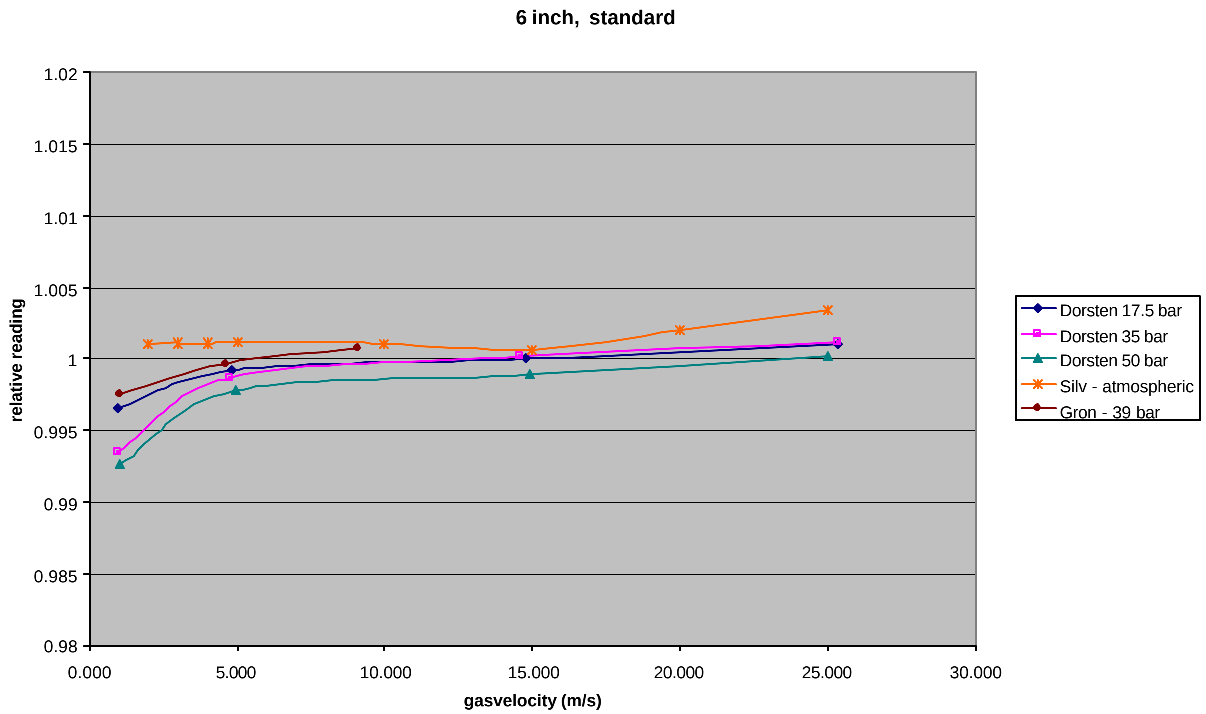

Figure 16 - Test results of 6 inch meter with standard adapter (smooth transition)

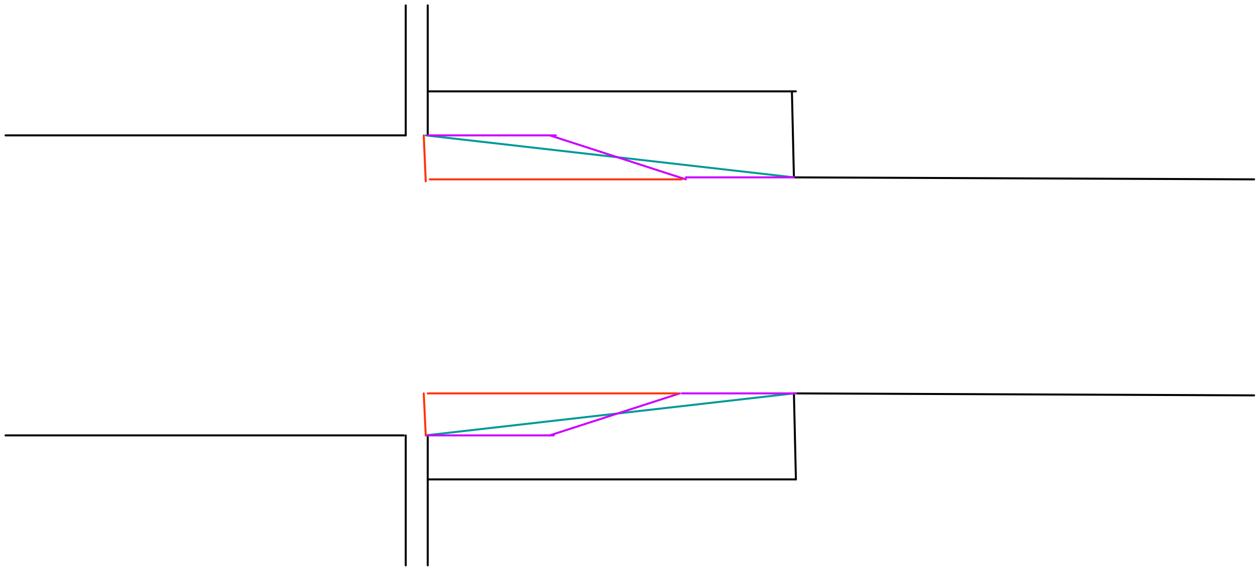

Figure 17 - Various shapes of adapters for diameter reduction

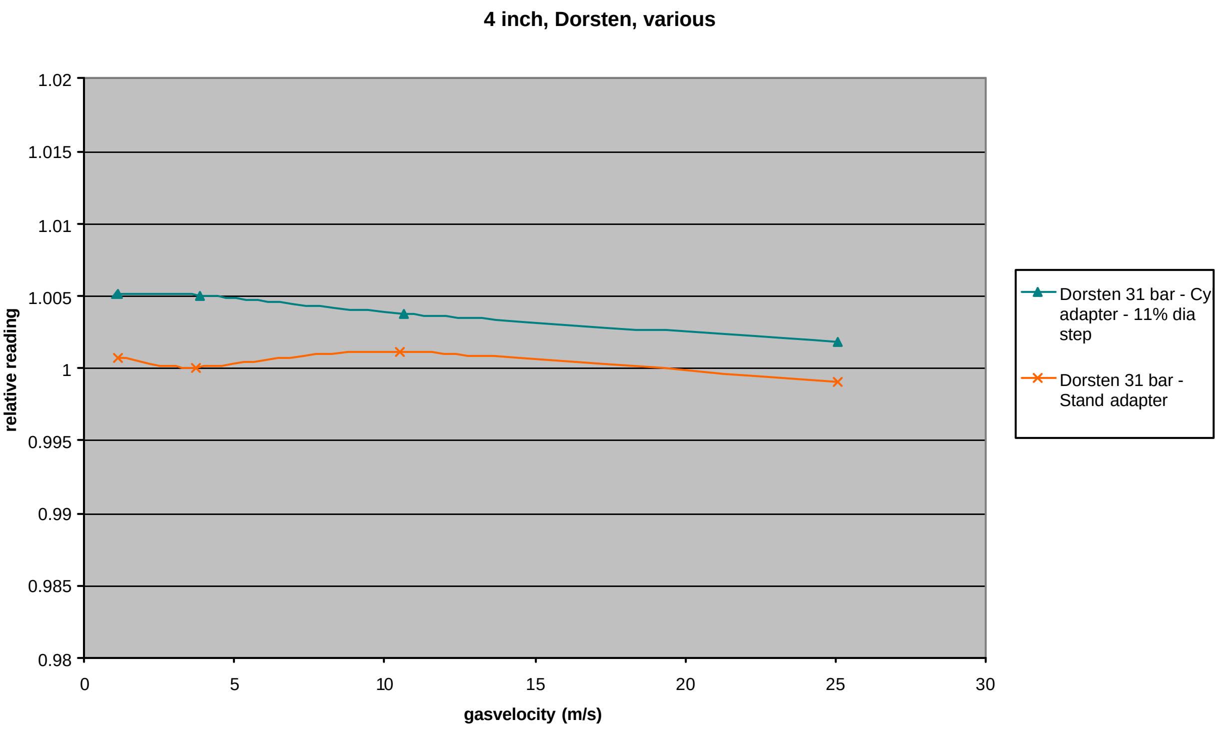

Figure 18 - Test results of 4 inch meter with different adapters

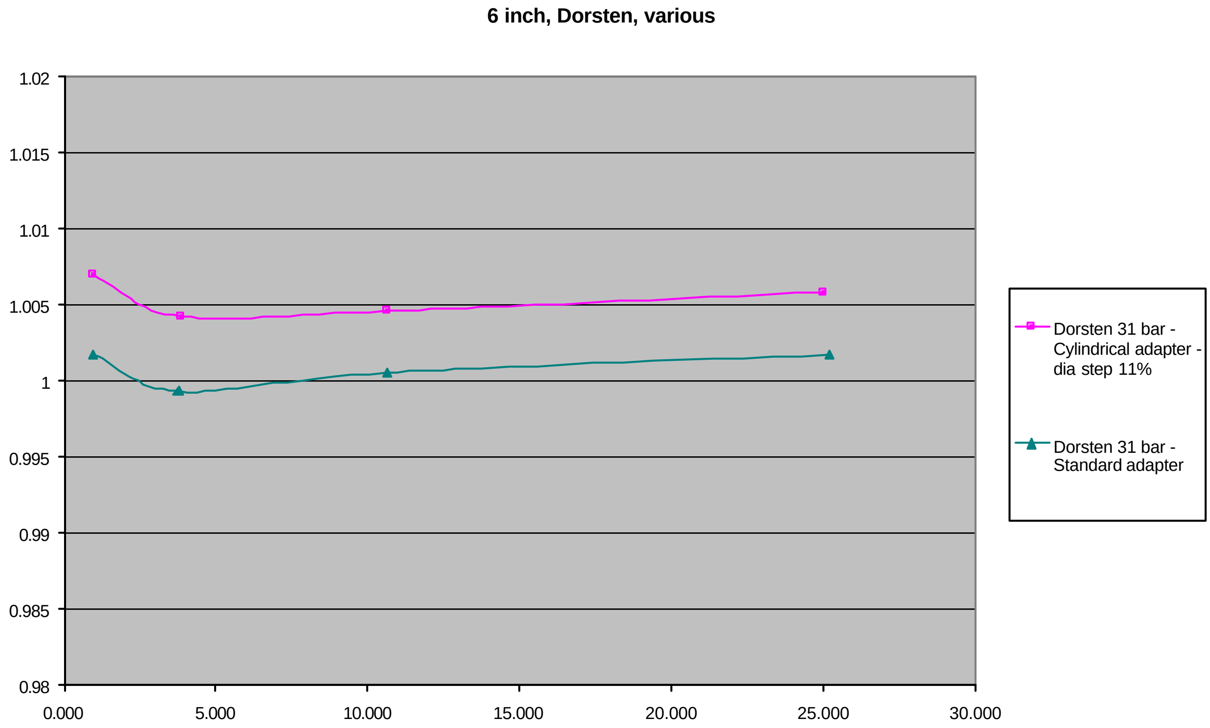

Figure 19 - Test results (Pigsar) of 6 inch meter with various adapters

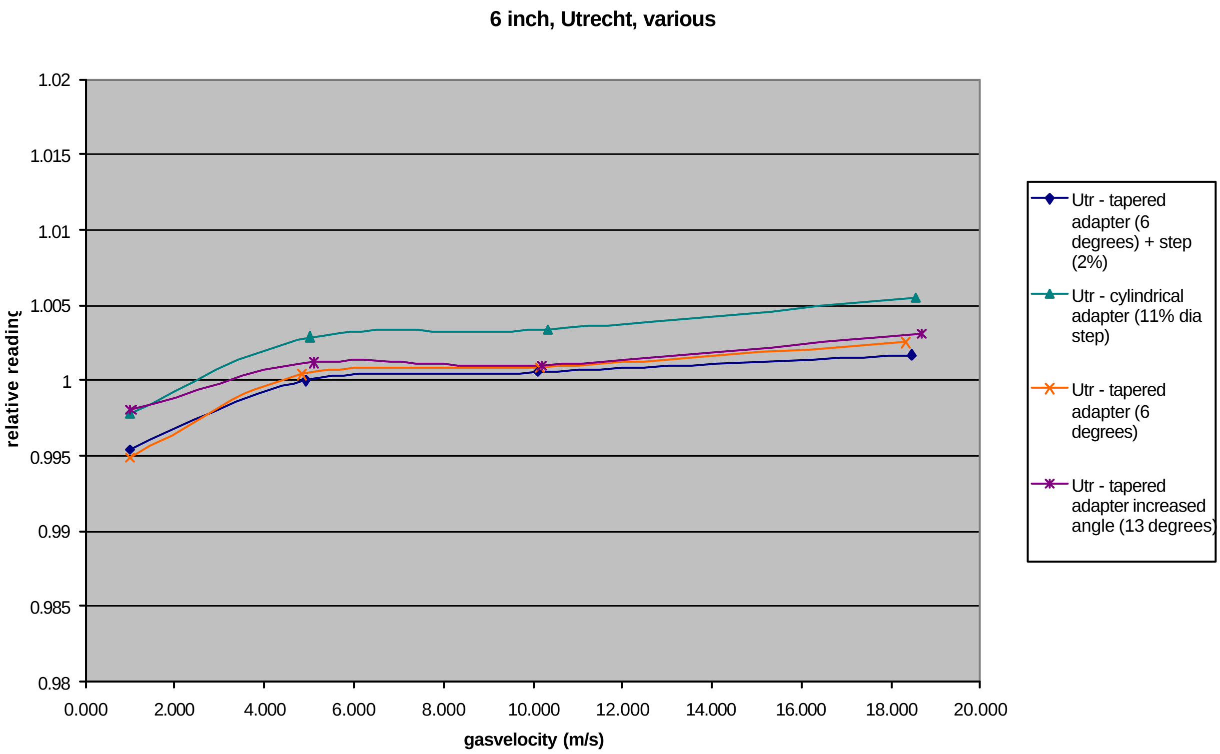

Figure 20 - Test results of 6 inch (Utrecht) with various adapters

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.