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OIML R 137-1, the first ultrasonic meter to be tested to accuracy class 0.5?

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1. INTRODUCTION

Over the past 20, 10 and 5 years gas production world wide has been on an ever increasing rise. At the same time measurement of gas has been changing from the traditional turbine and orifice meters to the ultrasonic meters. Multi-path gas ultrasonic meters have by now become the preferred device for custody transfer measurement. The first step in an international acceptance of these state of the art technology based devices was probably the first edition of the AGA Report number 9 which was released in June 1998. This report was updated and the second edition was released in April 2007.

The AGA Report No. 9 has since been used all over the world as the reference "standard" when ultrasonic meters have been specified for most allocation and custody transfer projects. In Europe there has been a working group in session for several years working on a corresponding ISO standard for Ultrasonic meters, and the ISO 17089 will hopefully be officially released in 2009.

But, there is another standardization organ in Europe which released a gas meter recommendation in 2006 which is also applicable to ultrasonic meters – the OIML R 137-1. This creates a third "standard" which manufactures of gas ultrasonic meters may be asked to follow.

Already a number of meters have been tested to the defined accuracy class 1 in OIML R 137-1, but FMC has now fully tested what we have been informed is the first multi-path gas ultrasonic meter to the accuracy class 0.5 together with the PTB of Germany.

This paper will describe the key items of OIML R 137-1, point to the differences and similarities between OIML R 137-1 and AGA-9 and highlight certain limitations/shortcomings in OIML R 137-1. The second part of the paper will describe the detailed tests required for accuracy class 0.5, show the results from multiple size meters tested and comment on how the industry and standardization committees can work even closer together to get even more applicable and relevant standards and test methods. The latter to achieve more repeatable, comparable and usable results across the industry, and across the different geographical areas of our "shrinking" planet.

2. OIML R 137-1, AGA 9 and ISO 17089

The AGA Report No. 9, Measurement of gas by Multipath Ultrasonic Meters, Second Edition was released in April 2007. It has now been in use around the world for more than 10 years since the initial release in June 1998, and it has probably been the most influential document for ultrasonic meters. It has been adopted by most countries around the world and many national regulations and oil and gas company specifications have adopted the requirements described in AGA 9.

The yet to be released ISO 17089 also has the AGA 9 as its base even though it will differ in certain areas and be more comprehensive when it eventually is released. The intent was to also discuss ISO 17089 in this paper, expecting it to be released at this time, but since it has not been released, and the final version is not ready, it will not be further discussed here.

The OIML R 137-1 Edition 2006, International Recommendation Gas Meters, is a more general recommendation which does not target ultrasonic meters directly but sets forth the same requirements to be met by all devices designed to measure "quantities of gaseous fuels or other gases, except gases in the liquefied state and steam" [2]. This recommendation supersedes the previous versions of R 31 (1995) and R 32 (1989) and partially supersedes OIML R 6 (1989).

Both these "standards" put forth a number of requirements that gas/ultrasonic meters must meet and many of them are fairly similar but the main difference between the two is that AGA 9 has a section to be followed for each produced and delivered meter, placing requirements on the performance of the meter before, during and after a flow calibration. In addition it has a number of type approval tests taken from OIML R 6 and OIML D 11, specifically for the electronics.

The OIML R 137-1 on the other hand is designed to be used for type approval testing and not as a reference for testing every meter produced. It uses the same OIML D 11 for Environmental tests for electronics or devices but has in addition a range of other tests, including flow tests to be performed on a selection of sizes or worst case - most difficult scenarios.

2.1 AGA Report No. 9

The primary performance requirements in AGA 9 are described in chapter 5. It says that "When a meter is flow calibrated, it shall meet the minimum measurement performance requirements detailed below before the application of any calibration-factor adjustment" [1].

Small meters (below 12"):

- Maximum error is ± 1.0% for $q_t \leq q_i \leq q_{max}$
- ± 1.4% for $q_{min} \leq q_i < q_t$
- Maximum Peak-to-Peak Error is 1.0% for $q_t \leq q_i \leq q_{max}$
- 1.4% for $q_{min} \leq q_i < q_t$

Large meters (12" and above):

- Maximum error is ± 0.7% for $q_t \leq q_i \leq q_{max}$
- ± 1.4% for $q_{min} \leq q_i < q_t$
- Maximum Peak-to-Peak Error is 0.7% for $q_t \leq q_i \leq q_{max}$
- 1.4% for $q_{min} \leq q_i < q_t$

In addition to the specific flow calibration criteria they have a few general requirements for repeatability, resolution, velocity sampling interval, zero-flow reading, speed of sound deviation and maximum SOS path spread. In Appendix B AGA 9 lists all the OIML R 6 and D 11 electronics design testing which is to be performed on one meter. They are:

B.1	Static Temperature, Dry Heat
B.2	Static Temperature, Cold
B.3	Damp Heat, Steady State
B.4	Damp Heat, Cyclic
B.5	Random Vibration
B.6	Sinusoidal Vibration
B.7	Mechanical Shock
B.8	Power Voltage Variation
B.9	Short Time Power Reduction
B.10	Bursts (Transients)
B.11	Electrostatic Discharge
B.12	Electromagnetic Susceptibility

2.2 OIML R 137-1

The R 137 specifies a number of different accuracy classes for different applications. It states that "Gas meters shall be classified into the Accuracy Classes given in Table 2. The errors shall be within the applicable values given in Table 2" [2]. Table 2 is the table given below and the requirements are applicable to all meters produced.

Table 2 Maximum permissible errors of gas meters

Flow rate Q	On type approval and initial verification Accuracy Class			In-service * Accuracy Class		
	0.5	1	1.5	0.5	1	1.5
$Q_{min} \leq Q < Q_t$	± 1%	± 2%	± 3%	± 2%	± 4%	± 6%
$Q_t \leq Q \leq Q_{max}$	± 0.5%	± 1%	± 1.5%	± 1%	± 2%	± 3%

* Note: National Authorities may decide whether they will implement in-service maximum permissible errors or not.

Annex A lists their OIML R 6 and D11 tests to be performed on one type approval sample:

A.4.1.1	Static Temperature, Dry Heat (non condensing)
A.4.1.2	Static Temperature, Cold
A.4.2.1	Damp Heat, Steady State (non condensing)
A.4.2.2	Damp Heat, Cyclic (condensing)

A.5.1	Vibration (random)
A.5.2	Mechanical Shock
A.6.1.1	Radiated, radio frequency, electromagnetic fields
A.6.1.2	Conducted radio-frequency fields
A.6.2	Electrostatic Discharge
A.6.3	Bursts (transients) on signal, data and control lines
A.6.4	Surges on signal, data and control lines
A.7.1	DC mains voltage variation
A.7.2	AC mains voltage variation
A.7.3	AC mains voltage dips, short interruptions and voltage variations
A.7.4	Bursts (transients) on AC and DC mains
A.7.5	Surges on AC and DC mains lines
A.8	Low voltage of internal battery (not connected to the mains power)

As can be seen these are essentially the same as specified in AGA 9.

In addition to the above tests the type approval verification process listed the below tests to be performed from chapter 7.4:

7.4 TYPE EXAMINATION TESTS

In Table 4 the test program and appertaining requirements are summarized.

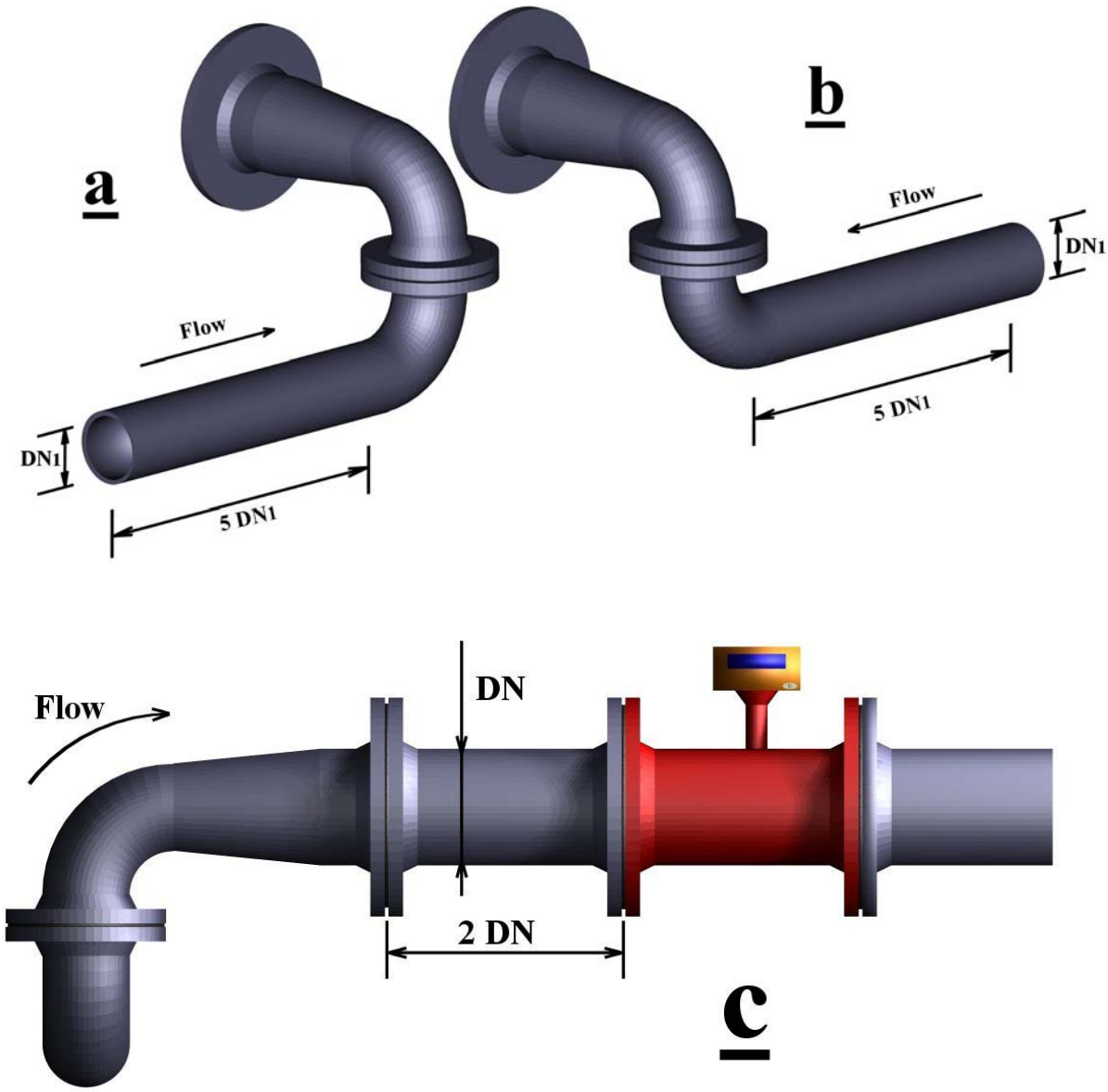
Table 4 Test program and requirements

Test	Clause	Minimum number of samples	Requirement
Design inspection	7.4.1	all	
Checks and alarms	7.4.2	1	
Error	7.4.3	all	5.3 and 5.4
Reproducibility	7.4.4	1	experimental standard deviation ≤ 0.15 MPE
Orientation and flow direction	7.4.5	1	5.3 and 5.4
Working pressure	7.4.6	1	5.3 and $\Delta e \leq 0.5$ MPE
Temperature	7.4.7	1	5.3 ($t_{gas} = t_{ambient}$) double MPEs ($t_{gas} \neq t_{ambient}$)
Flow disturbance	7.4.8	1	$\Delta e \leq 0.33$ MPE during
Durability	7.4.9	Table 5	Double MPEs of 5.3 and • $\Delta e \leq$ MPE for class 1.5 • $\Delta e \leq 0.5$ MPE for other classes
Drive shaft test (torque)	7.4.10	1	$\Delta e \leq 0.33$ MPE at Q_{min}
Overload flow test	7.4.11	1	5.3 and $\Delta e \leq 0.33$ MPE after
Different gases	7.4.12	1	$\Delta e \leq 0.5$ MPE
Vibrations and shocks	7.4.13	1	$\Delta e \leq 0.5$ MPE after
Interchangeable components	7.4.14	1	5.3 and $\Delta e \leq 0.33$ MPE
Electronics	7.4.15 + Annex A	1	Table 6
Software	7.4.16	1	5.3 and no detectable Δe

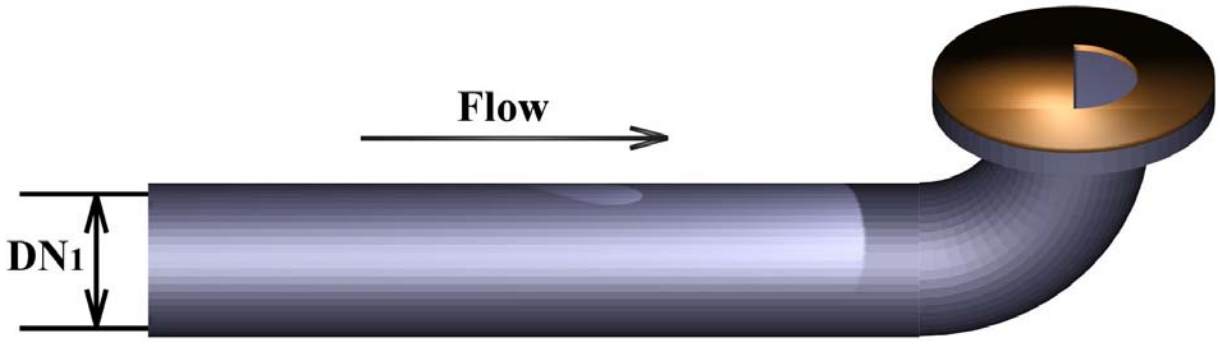
Note: Δe is defined in 2.2.10.

Clauses 7.4.9, 7.4.10 and 7.4.11 are not applicable to ultrasonic meters, ref Annex C.

Clause 7.4.8, refers to Annex B: Flow Disturbance Tests and consist of testing for mild flow disturbances in accordance with the figures below in B.2 [2]:



And severe flow disturbances using a half pipe, or half moon, plate installed between the two elbows with the opening toward the outside radius of the first bend as described in B.3 [2] and shown in the figure below.



For temperature there are 3 different options:

7.4.7 Temperature

The temperature dependency of the gas meter shall be evaluated in the temperature range specified by the manufacturer, by one of the methods stated below, ranked in the following preferred order:

1. Flow tests at different temperatures (for mechanical and electronic meters)

The flow tests are performed with a gas temperature equal to the ambient temperature as specified in 7.4.7.1 and with a gas temperature different from the ambient temperature as specified in 7.4.7.2.

2. Monitoring the unsuppressed flowrate output of the meter at no-flow conditions at different temperatures (for electronic meters)

At no-flow conditions the unsuppressed flowrate output of the meter is used in order to determine the temperature influence on the meter accuracy. At each temperature the error shall be within the maximum permissible error limits as stated in 5.3, while taking into account the influence of the flowrate shift on the meter curve.

Example: The unsuppressed flowrate output of an Accuracy Class 1 gas meter is changed with +1 l/h due to temperature variations. The initial error at reference conditions of this meter was + 0.3 % at a Q_{min} of 200 l/h. The influence due to temperature variations at Q_{min} is 1/200 × 100 % = + 0.5 %. The final value of + 0.8 % remains within the limits of the applicable maximum permissible error.

3. Evaluation of the construction of the meter

In cases when the meter cannot be tested to determine the effect of temperature, the uncertainty resulting from the expected influence of temperature on the meter construction shall be evaluated.

We did the testing according to the 2nd method; "monitoring the unsuppressed flow rate output of the meter at no-flow conditions at different temperatures (for electronic meters.)" [2]

This results in the following type approval test matrix with responding performance criteria:

Test	Clause	0.5 Accuracy class	1.0 Accuracy class
Error (WME=Weighted mean error)	7.4.2	Err < 0.5% for Q>=Q_t Err < 1.0% for Q<Q_t WME <= 0.2%	1.0% for Q>=Q_t 2.0% for Q<Q_t WME <= 0.4%

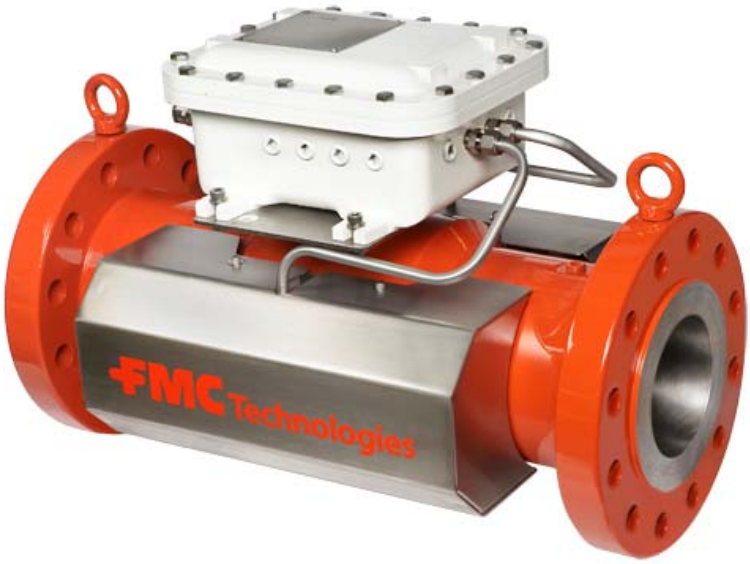
Reproducibility	7.4.4	Standard deviation: < 0.075	Standard deviation: < 0.15%
Orientation and flow direction	7.4.5	Same as error test	Same as error test
Working pressure	7.4.6	Shift less than 0.25% and Err < 0.5% for $Q>=Q_t$ Err < 1.0% for $Q<Q_t$	Shift less than 0.5% and Err < 1.0% for $Q>=Q_t$ Err < 2.0% for $Q<Q_t$
Temperature	7.4.7	See above	See above
Flow disturbance	7.4.8	Shift less than 0.165%	Shift less than 0.33%
Interchangeable components	7.4.14	Shift less than 0.165% and Err < 0.5% for $Q>=Q_t$ Err < 1.0% for $Q<Q_t$	Shift less than 0.33% and Err < 1.0% for $Q>=Q_t$ Err < 2.0% for $Q<Q_t$

It should be noted here the very stringent requirements in 7.4.8 of less than 0.165% for all the disturbance tests for the 0.5 Accuracy Class.

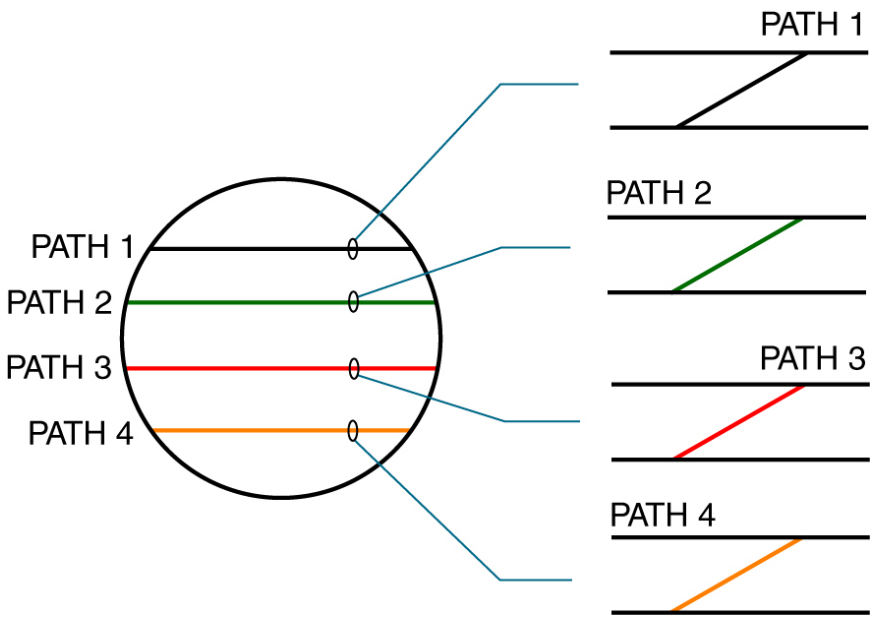
As opposed to the AGA 9 then one can use the OIML R 137-1 to present an “approval” in the form of a third party certified OIML test report, in the same mould as has been normal practice with for example OIML R 117-1 for liquid meters.

3. The MPU 800

The MPU 800 is a four path gas ultrasonic meter intended for use in custody transfer applications. It is the little brother of the well known MPU 1200 six path master meter and has been designed as the most cost effective custody transfer solution for applications with less complex upstream piping configurations.



The meter uses the well known four path configuration with four paths in four parallel planes as shown in the figure below.



It uses the same transducers, electronics, software and signal processing as the rest of the meters in the FMC gas and liquid ultrasonic meter family, the single path MPU 200, the three path MPU 600 and the six path MPU 1200 for gas, and the four path Ultra^4 and six path Ultra^6 for liquids.

The meter is available in a large range of materials, with different flange types and from 4" to 56" in size.

4. OIML R 137-1 testing of the MPU 800

To ensure a valid test report with results that are representative for the whole range of meter sizes available, three different meters were testes, a 4", an 8" and a 12".

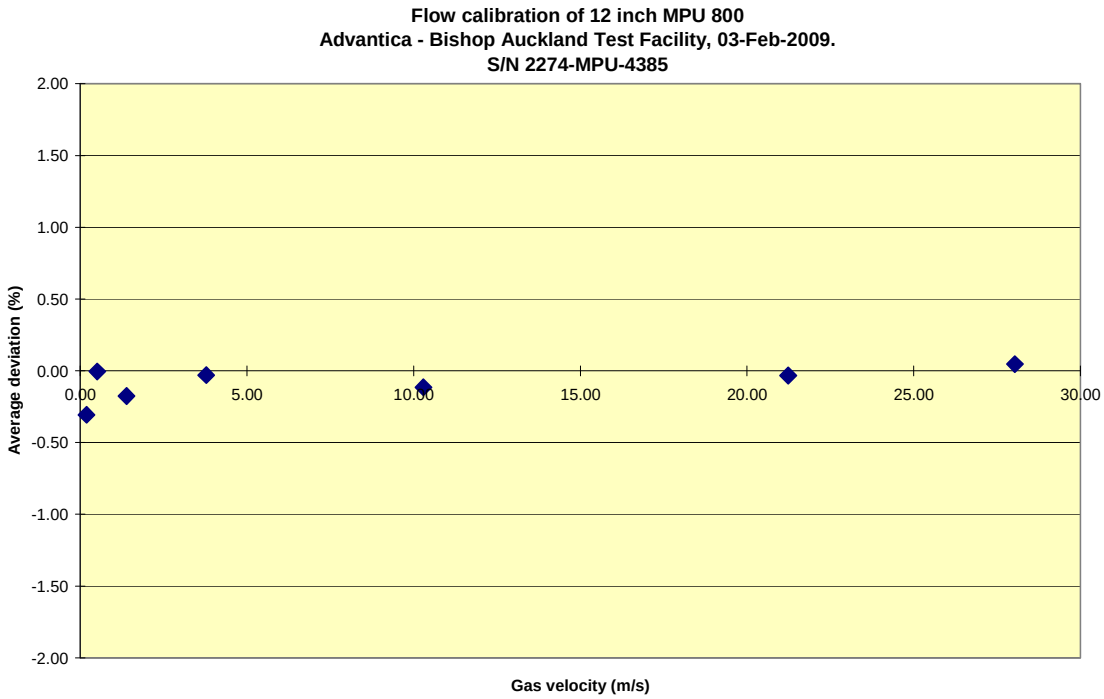
The 12" was tested at the Advantica facility, now GL Industrial Services, in the UK. The 8" was tested at both the Lintorf and the Pigsar facilities operated by Ruhrgas is Germany. And the 4" was tested at Pigsar.

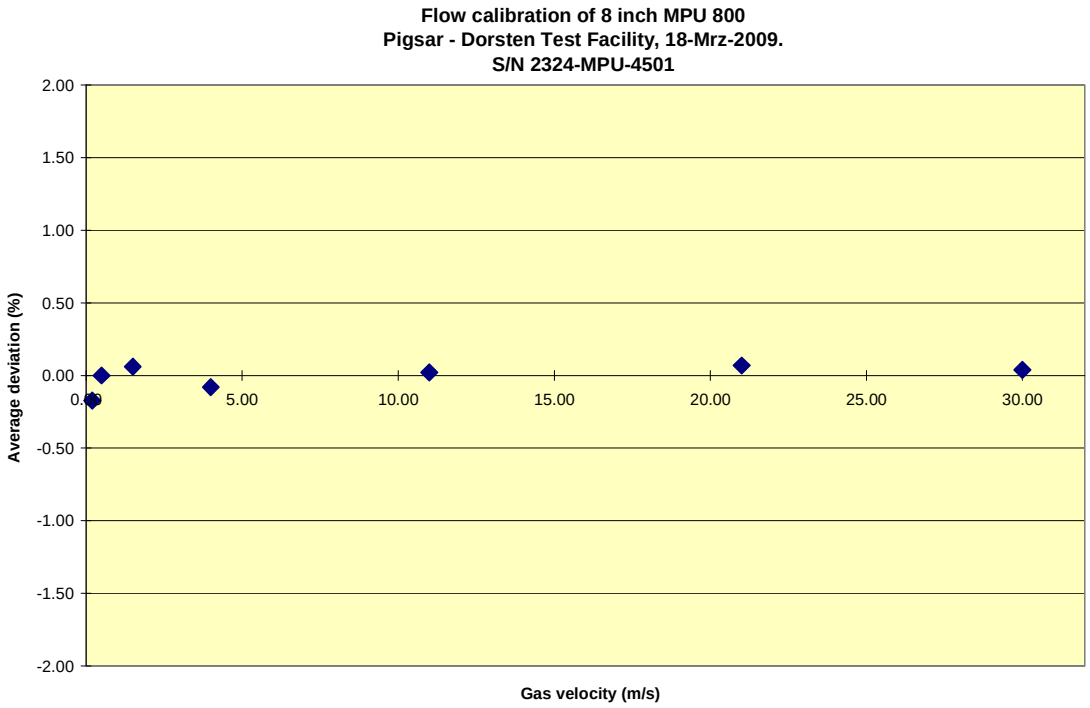
Multiple tests were completed to satisfy both the requirements in OIML R 137-1 and to verify meter performance under other frequently encountered and requested conditions:

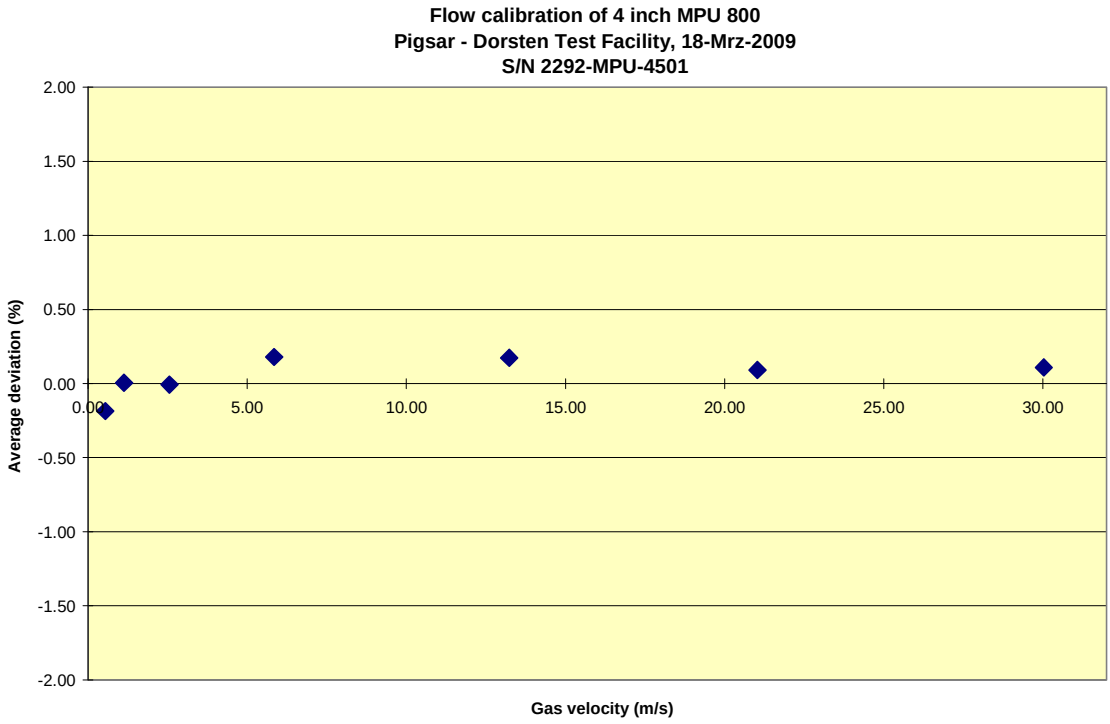
- Traditional flow test of all 3 meters
- Without Flow Conditioner (FC)
- With FC at 3D and at 5D
- Mild (low) flow disturbance and severe (high) flow disturbance testing as defined in Annex B of OIML R 137-1

4.1. Traditional flow test of all 3 meters

Below are the results from the traditional flow tests of all the three 12", 8" and 4" meter at the respective calibration facilities. As can be seen they all fall well within the requirements in OIML R 137-1.

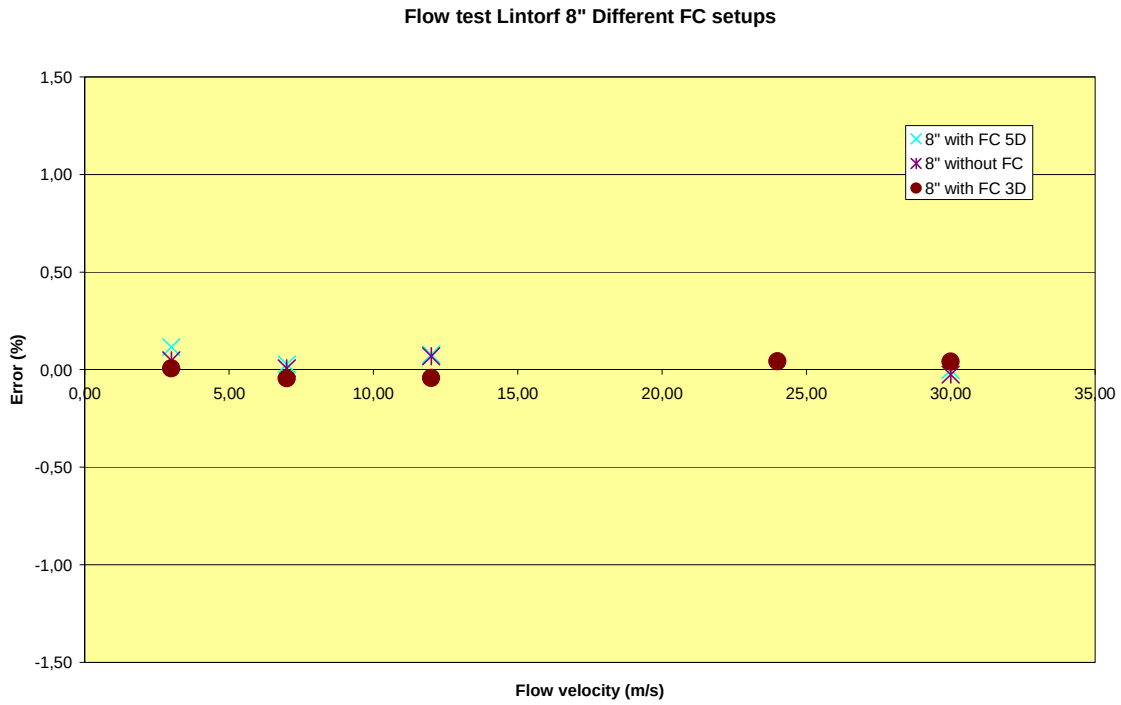

Flow calibration of 12 inch MPU 800
Advantica - Bishop Auckland Test Facility, 03-Feb-2009.
S/N 2274-MPU-4385
Average deviation (%)
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Gas velocity (m/s)


Flow calibration of 8 inch MPU 800
Pigsar - Dorsten Test Facility, 18-Mrz-2009.
S/N 2324-MPU-4501
Average deviation (%)
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
5.00
10.00
15.00
20.00
25.00
30.00
Gas velocity (m/s)


Flow calibration of 4 inch MPU 800
Pigsar - Dorsten Test Facility, 18-Mrz-2009
S/N 2292-MPU-4501
Average deviation (%)
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
0.00
5.00
10.00
15.00
20.00
25.00
30.00
Gas velocity (m/s)

4.2 Different flow conditioner setups

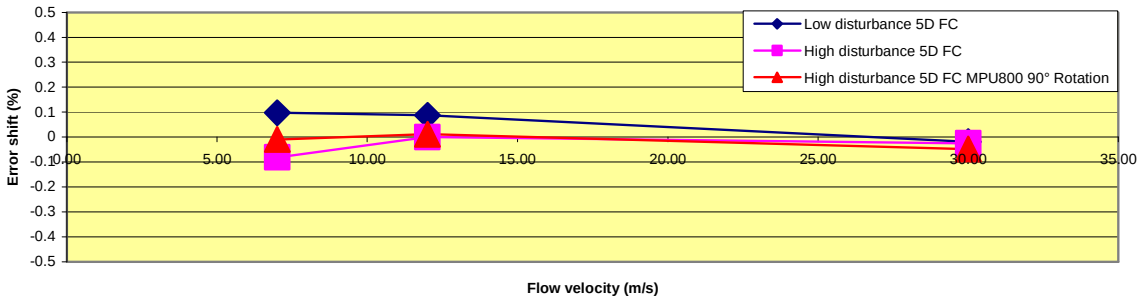
The three different flow conditioner tests were all performed at Lintorf using the 8” meter. The figure below shows the results from the 3 tests; without FC, with the FC at 5D and with the FC at 3D. As can be seen all the results were well within the OIML R 137-1 requirements.



4.3 Flow disturbance tests

The flow disturbance tests were also performed using the 8” meter at the Lintorf facility. As can be seen in the two graphs below a total of 6 tests were done. First we did the tests as described in the OIML R 137-1 in Annex B with the meter installed 5D after the flow conditioner. In addition to the low and high disturbance tests we also tested the high disturbance case with the MPU 800 rotated 90° to verify the performance with the bends originating in any plane.

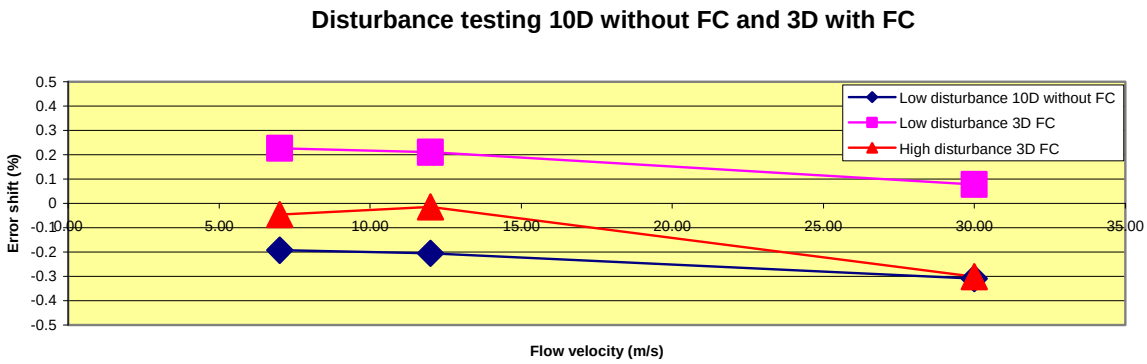
Disturbance testing 5D



The MPU 800 performed flawlessly at 5D and the results were all within the 0.165% requirement for Accuracy Class 0.5.

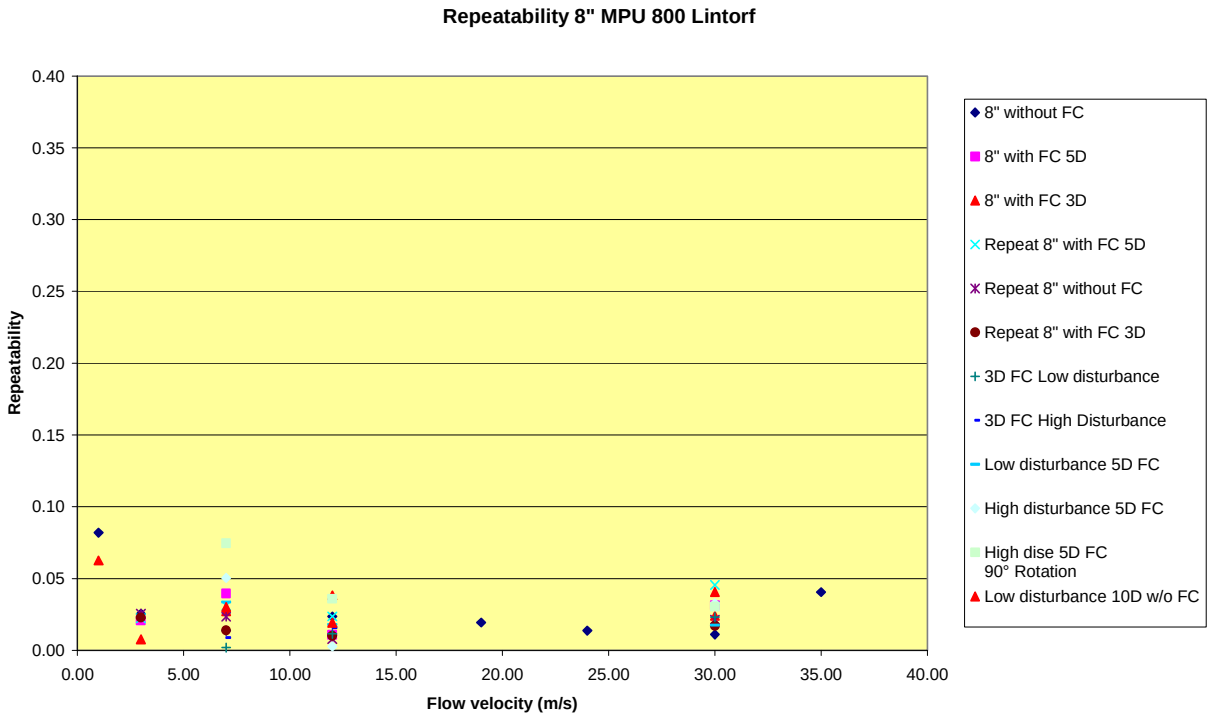
As the results were so good with the disturbances placed 5D upstream of the meter we decided to push the meter and to see where the boundaries of the performance was with respect to the low and high disturbances were. As showed in the figure below we found that the MPU 800 still complies with the OIML R 137-1 requirements for Accuracy Class 1.0, within 0.33%, if used:

- in a low disturbance application at 10D without a flow conditioner
- in a low disturbance application with a flow conditioner at 3D
- in a high disturbance application with a flow conditioner at 3D



4.4 Repeatability

The below figure show the repeatability numbers for all the flow tests to verify the performance numbers listed in the MPU 800 specifications.



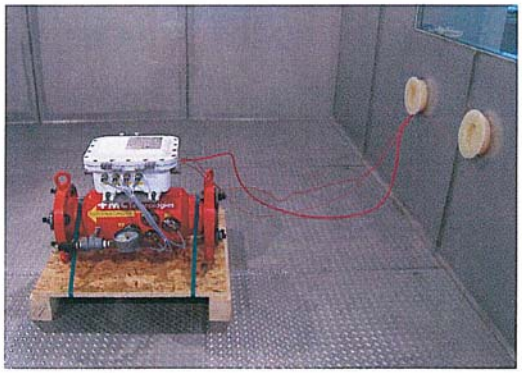
4.5 Interchangeable components

To show that the key components of the MPU 800, the electronics and the transducers, can be changed without significant effect on the meter performance the following results were obtained:

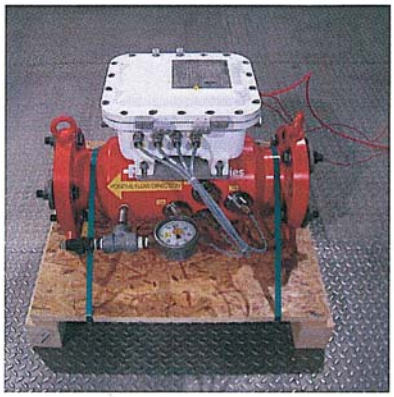
- Transducer exchange:
  - 1 transducer pair changed (Path 4) - Error shift: 0.09%
  - 2 transducer pairs changed (Path 3 and 4) - Error shift: 0.00%
  - Back to original transducers – Error shift: 0.06%
- Electronics change UDSP (Computer) and UAFE (analog front end):
  - Both boards changed - Error shift: 0.00%
  - Both boards changed back to original - Error shift: 0.00%

4.6 Environmental tests

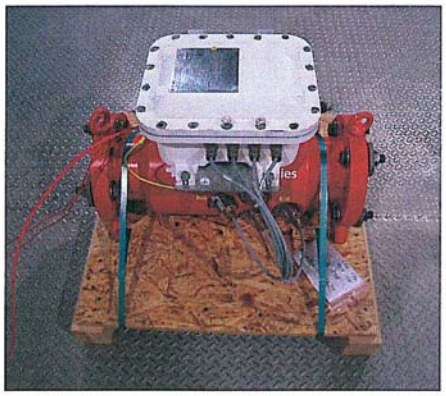
All the electronics tests as specified in AGA 9 were performed on the MPU 1200 several years ago and did not need to be repeated. The additional requirement in OIML R 137-1 was to test the full meter and monitor zero drift for the cold and dry heat conditions.



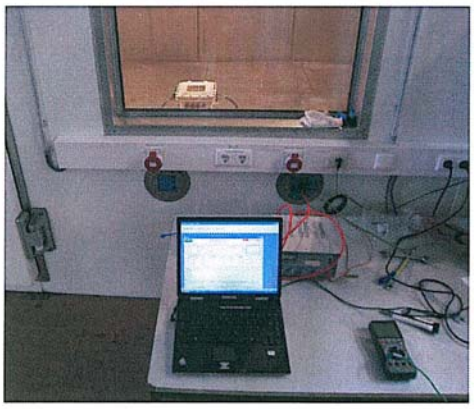
Picture 1:
EUT inside the climatic chamber



Picture 2:
EUT inside the climatic chamber



Picture 3:
EUT inside the climatic chamber



Picture 4:
Test set up for data logging

Low temperature (-25C):

	Flow rate at zero flow	Theoretical error at Qmin	Theoretical error including error at flow test	Requirement
	m3/h	*%*	*%*	*%*
Before (+20C)	0.017	0.11	0.31	1.0
After 2 hours at -25C	0.012	0.08	0.28	1.0
1 hour recovery to +20C	0.016	0.11	0.31	1.0

High temperature (+70C):

	Flow rate at zero flow	Theoretical error at Qmin	Theoretical error including error at flow test	Requirement
	m3/h	*%*	*%*	*%*
Before (+20C)	0.016	0.11	0.31	1.0
After 2 hours at +70C	0.022	0.15	0.35	1.0
1 hour recovery to +20C	0.009	0.06	0.26	1.0

To make this test relevant for the full size range of MPU 800 meters the most difficult size was chosen, the smallest - a 4" MPU 800. The tests were performed by the PTB at the Institute fur BSFV test facility in Hamburg Germany and as showed in the table above the meter were well within the requirements. Considering that this is the shift in output under essentially zero flow conditions, where any minute change will have a very large percentage influence, the above results support our claim that the FMC MPU ultrasonic meters are fully independent of any temperature influence. This is achieved thru the unique reciprocal design of the electronics and transducers, and the advanced temperature compensation implemented in all the MPU series ultrasonic gas flow meters.

5. CONCLUSIONS

The current international ultrasonic gas meter "standards" all try to achieve the same result – help users ensure they get high quality measurement from high quality meters. Unfortunately they all try to achieve this with similar but yet different specifications. As has been showed above a four path meter has been tested in various sizes and successfully passed all the test requirements for an OIML R 137-1 accuracy class 0.5 meter.
This was achieved using some test results from previous testing based on AGA 9 but a full compliance required further tests to be completed.

The world needs standards, this industry needs standards, and manufacturers and users all applaud the existence of standards. However, we encourage further cooperation between the standardization committees, industry stake holders and national organizations because standards in gas ultrasonic today can seem to be on its way to creating conflicting interests and recommendations. We have applications today where we as a manufacturer is being asked to be in accordance with two international recommendations, one national standard and one set of company guidelines – and quite frequently these 4 ask for quite a number of different results – although they all ultimately want the same thing – accuracy!

REFERENCES

[1] **AGA-9**, "Measurement of gas by ultrasonic meters", A.G.A. Report no. 9, American Gas Association, Transmission Measurement Committee (June 1998 and April 2007).
[2] **OIML R 137-1**, "International Recommendation Gas Meters, Part 1: Requirements", Organisation Internationale De Mètrologie Lègale (Edition 2006)