BS7965 2013 – "An overview of updates to the previous (2009) edition"

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Introduction

In November 2013, the current revision of BS7965 was published, "Guide to the selection, installation, operation and calibration of diagonal path transit time ultrasonic flowmeters for industrial gas applications". This paper seeks to look at some of the changes made since the previous edition (2009) was issued and the reasons for making the changes.

The BS7965 working group sits as part of the British Standards Institute CPI/030/05 committee covering measurement based on velocity and mass methods (primarily Ultrasonic and Coriolis meters). The guidelines contained within BS7965 were initially published in 2000 and then revised in 2009.

Since the publication of BS7965:2009, ISO 17089-1:2009 (Measurement of fluid flow in closed conduits — Ultrasonic meters for gas — Part 1: Meters for custody transfer and allocation measurement) and ISO 17089-2:2012 (Measurement of fluid flow in closed conduits - Ultrasonic meters for gas - Part 2: Meters for industrial applications) have been published. Part 1 of ISO170989 covers class 1 and 2 meters, part 2 covers class 3 and class 4 meters.

The revision of BS7965 covered changes needed to provide

- Consistency with ISO17089 where these improved the document;
- To capture new meter sizes;
- To reflect performance offered by modern meters; and,
- To integrate the latest operator experience.

One of the main drivers in revising the document was the more frequent use of smaller meters, e.g. 2" & 3" meters, as these sizes had not been considered in the previous versions. As previously BSI wanted to keep all of the guidance in a single document.

At this point we would like to acknowledge members of the working group, the wider CPI/030/05 committee and all those who commented on draft versions of the documents. The working group covered a cross section of manufacturers, auditors and end users. The aim of the group was to produce a document that was practical, pragmatic & performance based.

Members of BS7965:2013 Working Group

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Scope of BS7965

BS7965 covers all industrial gas applications from class 1 to class 4. It covers full bore, reduced bore and insertion type meters. It does not cover clamp-on/externally mounted, domestic or stack/chimney (combustion exhaust) meters.

"This British Standard provides recommendations and guidance on the selection, installation, operation and calibration of transit time ultrasonic flowmeters (USMs) for industrial gas applications (including flare gas).

It is applicable only to those devices in which the entire gas stream flows through the body of the USM and the transducers (wetted or invasive type), or a wetted interface, are in contact with the fluid. This includes full-bore/reduced-bore and insertion type meters employing direct or reflective paths. It is also applicable to "dirty gases", i.e. those contaminated with solids and/or liquids in sufficiently small quantities, depending upon the application.

It is not applicable to clamp-on/externally mounted, domestic or stack/chimney (combustion exhaust) meters.

As an aid to selection, this standard incorporates an uncertainty classification for USMs. This takes into account the components of uncertainty relating to the meter plus those additional uncertainties associated with installation and operation effects. There are four classifications offered. These range from high accuracy applications (Class 1) to process flow indication and control applications (Class 4)."

Cartridge Type Meters

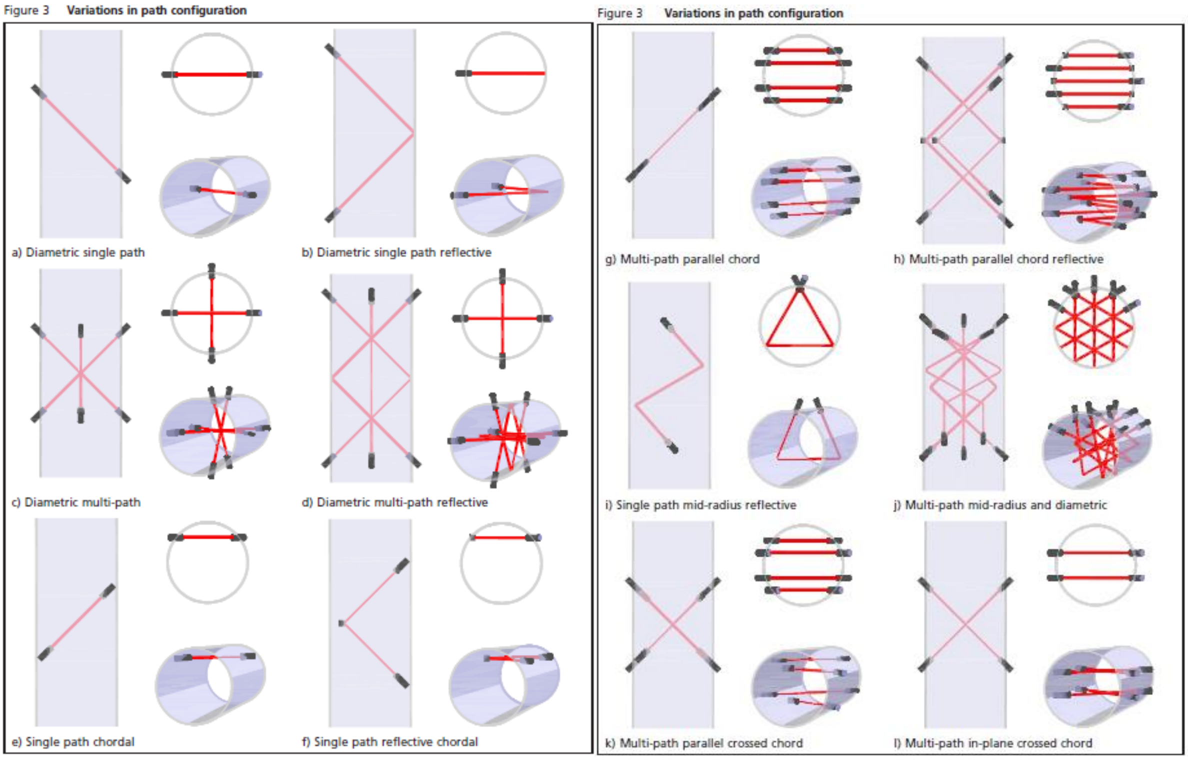
This is a new design of meter introduced to the market since the previous 2009 revision. They consist of an adaptor (the mechanical body) which holds the measurement section (the meter). The meters are designed with sizes of 2" - 6" and maximum pressures of 20 Bar, predominantly for onshore use. There are design differences to traditional multipath meters which have led to the inclusion of specific clauses relating to the upstream installation requirement, typically no straight lengths being required and the inclusion of a thermowell being part of the adaptor rather than being installed in the downstream pipework.

Figure 1 : Typical Cartridge Meter

Variations in Path Configuration

There are many different designs of path configurations in existing meters. These are usually based on a direct path (chordal), reflective path configuration or a combination of both. BS7965:2013 aims to show the configurations that were being implemented by meter manufacturers at the time of publication. Selection of any design can be influenced by process conditions (i.e. low pressure or high levels of attenuating gas components such as CO2) or by the installation conditions (i.e. perturbations caused by upstream pipework). The drawings show typical configurations however as BS7965:2013 is focused on performance, although a meter does not follow one of configurations shown, it may still conform with the requirements laid down within the document and therefore be compliant.

Figure 2 : Typical Path Layouts



Meter Size Specification

The major change, which was one of the primary drivers for updating the document, was the reclassification of meter sizes. During previous versions of the documents the meters available on the market ranged in size from 4” – 48”. Due to falling offshore gas production rates there has been an increase in use of the smaller meters, the 4” meter that has always been available and with the introduction of 3” and 2” meters. It was felt that performance figures for the previous small meters were not applicable for 3” & 2” meters. With this in mind the sizes were reclassified as follows;

BS7965:2009

Large meters are defined as those meters with nominal bores equal to or greater than 254 mm (10 inches), whilst small meters are defined as those meters with a nominal bore below 254 mm (10 inches).

BS7965:2013

Large meters are defined as meters with nominal bores equal to or greater than 300 mm (12 inches). Medium meters are defined as meters with a nominal bore below 300 mm (12 inches) but greater than 100 mm (4 inches). Small meters are defined to have a nominal bore equal to or less than 100 mm (4 inches).

The performance requirements for each size meter are defined within Table 2 of BS7965:2013

Table 2 Class performance criteria – Meter requirements

Class	Total USM uncertainty (actual volume flow)	Repeatability	Reproducibility	Resolution	Error limit (plus or minus) (q_t to q_{max})		
					Large meters	Medium meters	Small meters
	%	%	%	mm/s	%	%	%
1	<±0.7	<±0.20	<±0.30	<1	0.7	1.0	2.0
2	<±1.5	<±0.25	<±0.60	<2	1.0	1.5	3.0
3	<±3.0	<±0.35	<±0.90	<4	1.5	2.0	4.5
					Error limit (plus or minus) (q_{min} to q_{max})		
4	<±7.5	<±1.0	<±1.20	<10	5.0	5.0	7.0

NOTE 1 Large meters are defined as meters with nominal bores equal to or greater than 300 mm (12 inches). Medium meters are defined as meters with a nominal bore below 300 mm (12 inches) but greater than 100 mm (4 inches). Small meters are defined to have a nominal bore equal to or less than 100 mm (4 inches).

NOTE 2 Repeatability is defined as the closeness of agreement between successive flow rate measurements with the same flow meter when obtained under the same conditions (same fluid, same flow meter, same operator, same test facility and a short interval of time) and without disconnecting or dismounting the flow meter.

NOTE 3 Reproducibility is defined as the closeness of agreement between successive flow rate measurements with the same flow meter when obtained under any differing conditions (different fluid, different operator, different test facility) or disconnecting or dismounting and subsequent reinstalling of the flow meter.

Figure 3 : BS7965:2013 Class performance criteria

Performance figures should be treated as a minimum requirement i.e. if a meter complies with the criteria then it is in compliance with the requirements of BS7965:2013. There may be contractual requirements where the operator may choose to define more stringent requirements. i.e. to have a small meter operating under the criteria defined for a medium meter.

Repeatability

When looking at repeatability it should be noted that the way that this is defined within standards, by manufacturers and calculated by test sites is not consistent. BS7965:2013 defines repeatability as;

"Repeatability is defined as the closeness of agreement between successive flow rate measurements with the same flow meter when obtained under the same conditions (same fluid, same flow meter, same operator, same test facility and a short interval of time) and without disconnecting or dismounting the flow meter."

Within the Performance Specification charts in BS7965:2013, and also ISO17089, the repeatability is shown as a tolerance band with positive and negative limits. For example for a class 1 meter where flow is greater than qt, then the requirement is +/-0.2%. This requires that when a meter is subject to calibration, to comply with the standards, any individual calibration point should fall within this band. However manufacturers quote a statistical value and calibration facilities also calculate a repeatability based on statistical values. Depending upon the number of calibration points and spread of points it may be possible that the manufacturers stated repeatability is met with a point falling outside of the acceptance band. When calibrating a meter the acceptance criteria should be agreed in advance and agreed by all parties. If the acceptance is based on a statistical number then the method of calculation should also be agreed.

Performance Specification Summaries

Performance specifications were modified for all four classes of meters. For Class 1,2 and 3 meters this involved revising the small meter error limits to medium meter error limits and adding a third set of error limits to cover the new small meter category. Zero flow reading values were also modified. For class 1,2, and 3 meters the existing Qmin and Qt values apply. For class 4 meters the performance limits are only shown as Qmin and Qmax (of Qt can also be assumed to equal Qmin). Class 4 meters tend to be associated with flare gas applications and on review of manufacturers' literature the conclusion drawn was that these devices are usually only quoted with a minimum velocity (Qmin) and not with a Qt parameter.

Figures 4 to 7 on the following pages illustrate the revised performance specifications.

Figure 4: BS 7965 Figure 5 performance specification for Class 1 meters

Figure 5 **Performance specification summary for Class 1 meters**

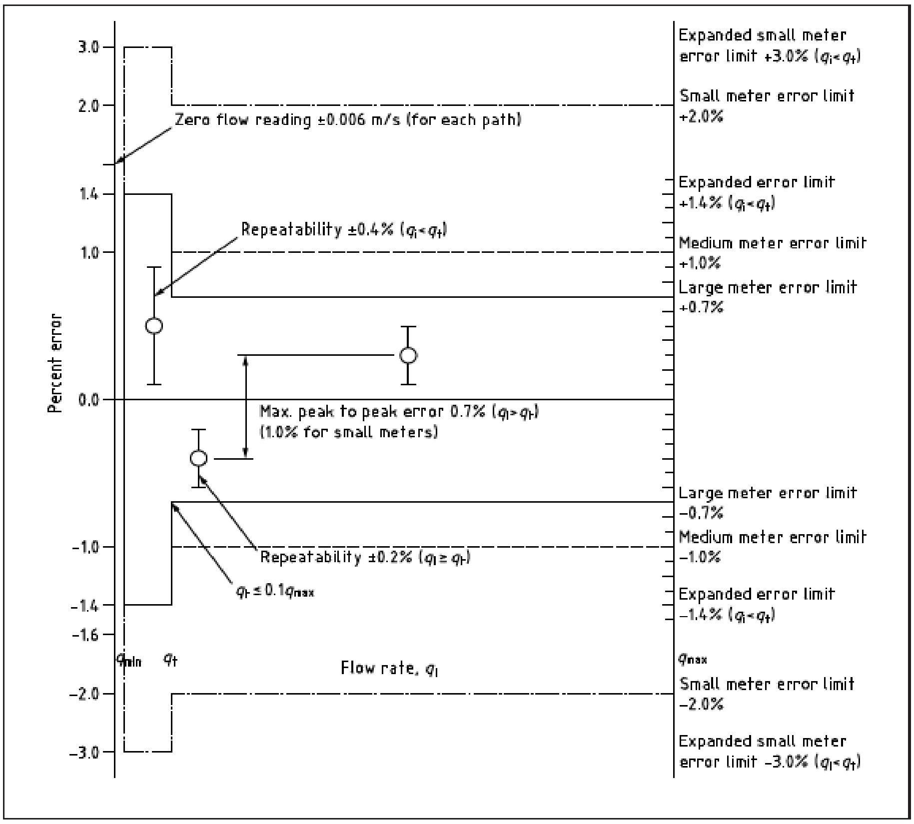


Figure 5: BS 7965 Figure 6 performance specification for Class 2 meters

Figure 6 **Performance specification summary for Class 2 meters**

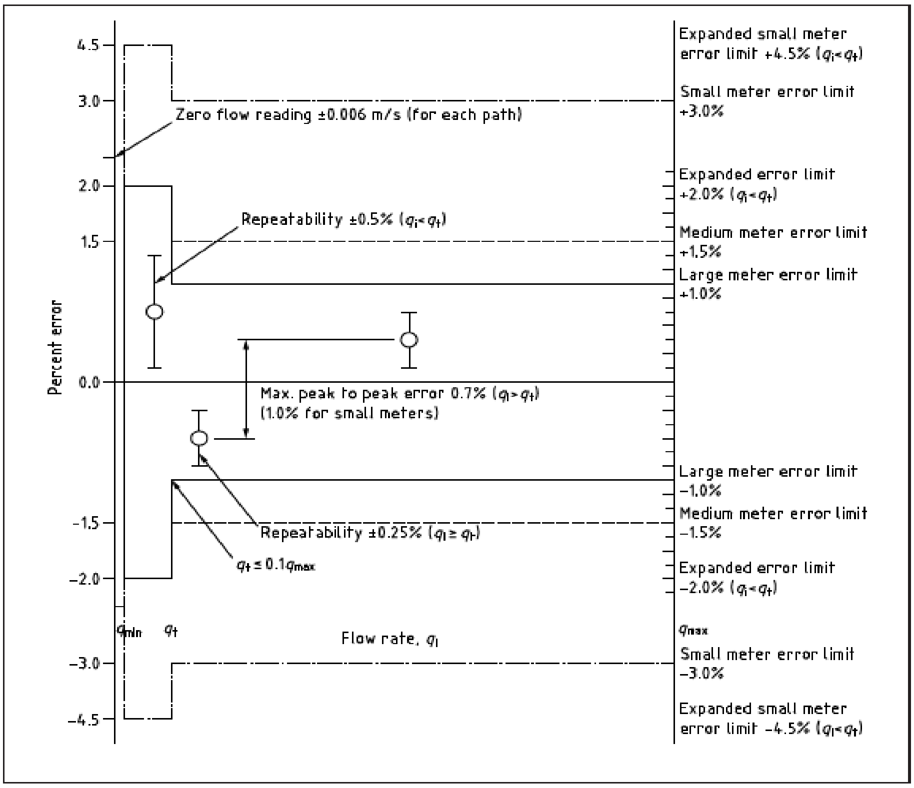


Figure 6: BS 7965 Figure 7 performance specification for Class 3 meters

Figure 7 **Performance specification summary for Class 3 meters**

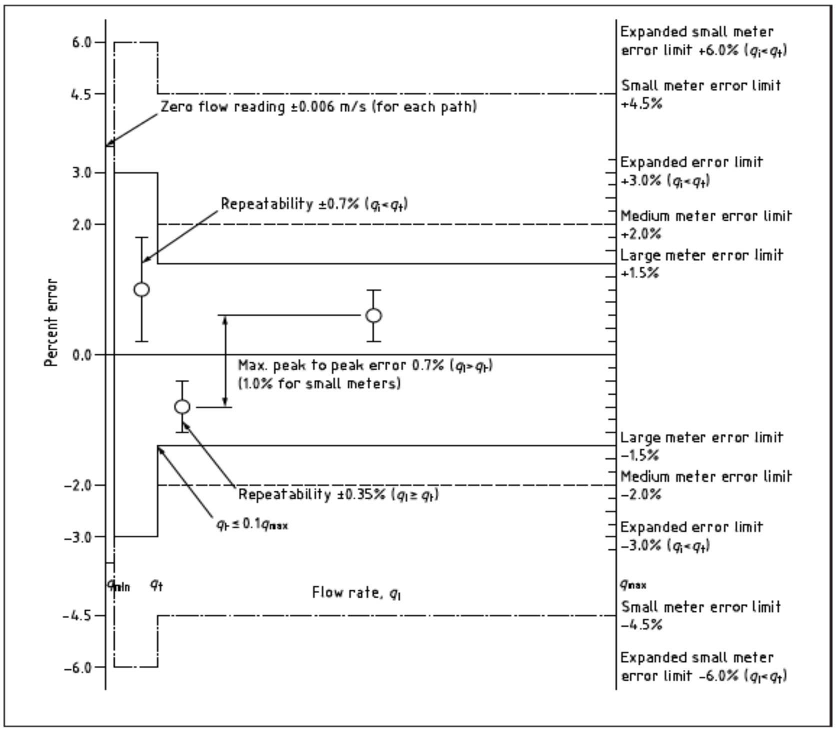
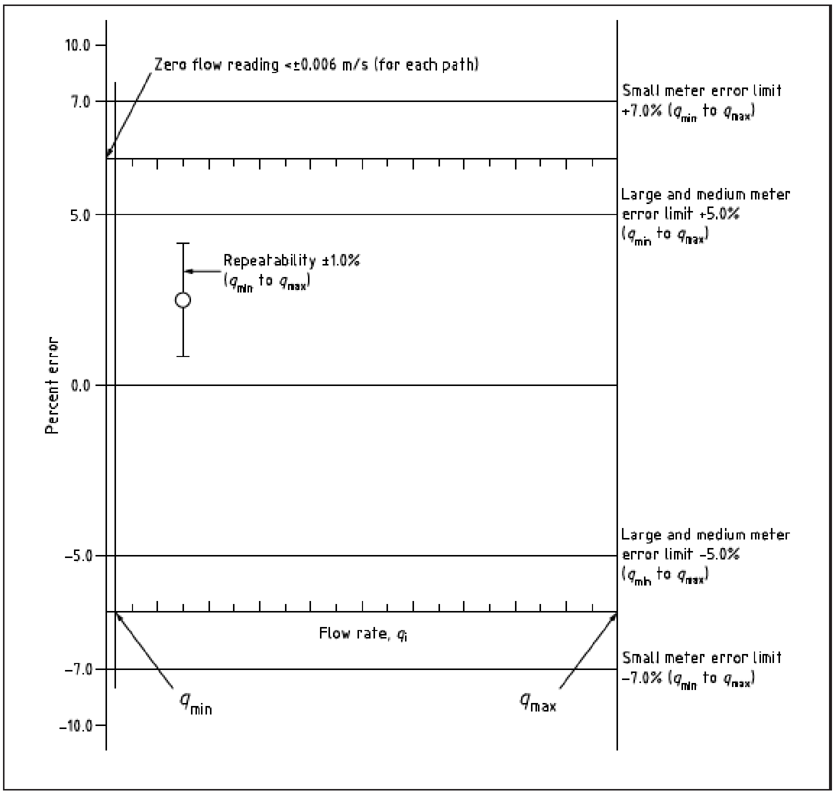


Figure 7: BS 7965 Figure 8 performance specification for Class 4 meters

Figure 8 **Performance specification summary for Class 4 meters**



Temperature Measurement , Thermowell Position

BS7965:2009 stated, *"For unidirectional flow, the thermowell should be installed downstream of the USM and the distance from the downstream flange face to the thermowell should be at least 5D"*.

This contradicted manufacturers' instructions, contradicted other standards and also allowed for the thermowell to be installed at an infinite distance downstream of the meter !

The BS7965:2013 revision addresses these issues, *"For uni-directional flow, the thermowell should be installed downstream of the USM and the distance from the downstream flange face to the thermowell should be a minimum of 2D and a maximum of 5D. If the meter has a feature to have inbuilt thermowell(s) these may also be used. For bi-directional flow installations, requiring optimum accuracy, the thermowell should be located either: at least 10D from either USM flange face; or between 5D and 10D from either USM flange face, in which case, the meter should be flow-calibrated in both directions with the thermowells installed and two correction factors derived."*

The reference to in built thermowell(s) is applicable to cartridge type meters which are commonly installed with either 1 or 2 measurement points.

Temperature Measurement, Thermowell Insertion Depth

In the previous document the insertion depth was not referenced but it has been customary practice to install temperature measurement within the middle third of the pipe. Research carried out and presented at previous North Sea Flow Measurement Workshops [1] has shown that measurement can be closer to the pipe wall or as an alternative surface mount technology may be used. Surface mount technology may be preferential to the use of thermowells on the smallest pipes e.g. 2" or 3" where the use of a thermowell may cause a major obstruction within the pipe or expanded pipe sections to be used

BS7965:2013

"The recommended insertion depth for the thermowell and the pockets is between D/10 and D/6.67. Where the insertion depth >D/3.33 then the meter run might not need to be insulated. Where insertion depth <D/3.33 (or where surface mount technology is used) then the meter run should be insulated from the meter inlet until at least 1D downstream of the temperature measurement point".

Previous papers [1] concluded,

"Gas temperatures measured on profile probes were <0.2ºC of mean gas temperature

- *For gas velocities > 1m/s*
- *Demonstrating centre third thermowell measurement not necessary"*

Zero Flow Test

BS7965:2013 contains updated acceptance criteria for zero flow tests on meters primarily associated with Class 1 and Class 2 meters.

"This subclause describes the zero flow test that can be carried out as part of the field verification of the meter performance. The system would have to be taken off line for about 30 min but this could prove to be beneficial, particularly for Class 1 and Class 2 meters. The zero flow test is carried out on a product, at operating pressure and zero flow conditions and isolated at the closest valves to the meter; once flow is confirmed to be zero the individual path velocities are measured. During the Factory Acceptance Test under controlled conditions, a limit of <±0.006 m/s for each acoustic path should be achievable when averaged over a period of not less than 100 s. In the field under true, verified zero flow conditions, a limit of <±0.012 m/s for each acoustic path should be achievable when averaged over a period of not less than 100 s. If in any doubt, the manufacturer should be consulted."

A zero flow test will be carried out in one of three situations,

1. Factory acceptance tests;
2. Flow Calibrations;
3. In service tests.

The factory zero flow test is carried out in a controlled situation, it is primarily a verification of the geometry of the meter body and the parameters entered into the meter signal processing unit. The factory test is carried out on gas with a known composition, which it typically pure Nitrogen or Air with a stable pressure and temperature. A typical factory test arrangement is shown in figure 8.With this high level of stability it will be possible to meet a limit of <±0.006 m/s for each acoustic path. Typical factory zero test values are shown below in figures 9a and 9b.

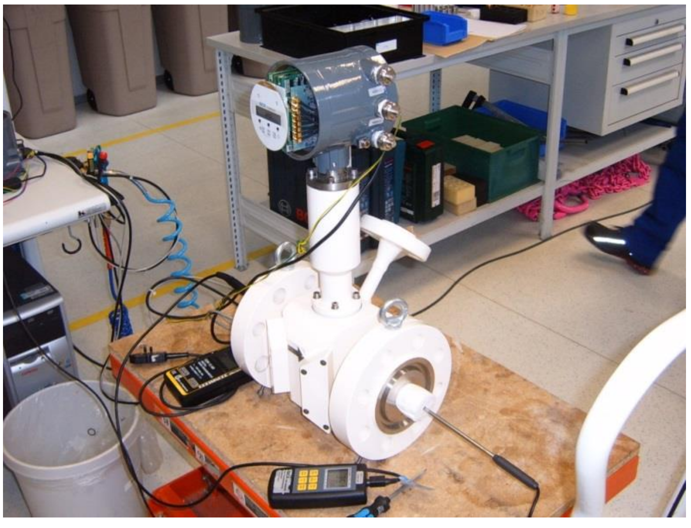
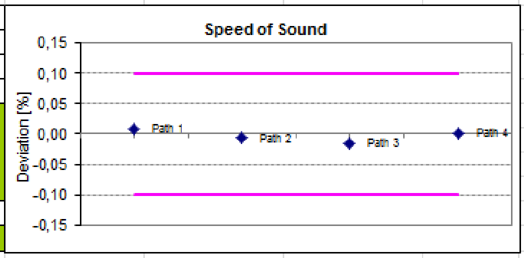


Figure 8 : Factory Zero verification

Speed of Sound Check

Max. allowed SOS Path Deviation [%]		Max. allowed SOS Path Deviation [m/s]	
P1, P4: ±0.1% / P2, P3: ±0.1%		P1, P4: ±0.3m/s / P2, P3: ±0.3m/s	
Measuring values			
	SOS [m/s]	Diff. to theor. [%]	Result
Path 1	346,531	0,008	ok
Path 2	346,479	-0,007	ok
Path 3	346,450	-0,015	ok
Path 4	346,509	0,002	ok
Max. allowed SOS Path Difference: 0.5 m/s			
Difference	0,082		ok



Zero Flow Test

Max. Error VOG [m/s]	0,006	
Measuring values		
	VOG [m/s]	Result
Path 1	0,001	ok
Path 2	0,000	ok
Path 3	0,000	ok
Path 4	0,001	ok
Avg. Pipe Velocity	0,000	

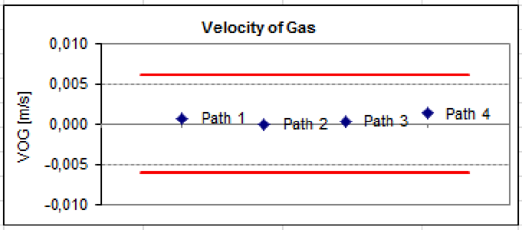
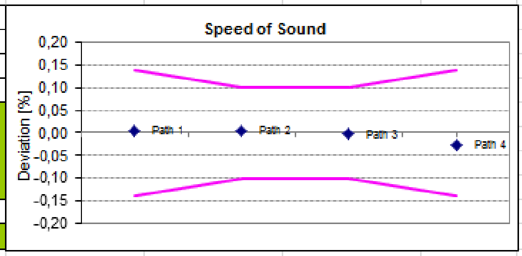


Figure 9a : Typical Factory Zero Flow Results _ 10" Meter

Speed of Sound Check

Max. allowed SOS Path Deviation [%]		Max. allowed SOS Path Deviation [m/s]	
P1, P4: ±0.14% / P2, P3: ±0.1%		P1, P4: ±0.5m/s / P2, P3: ±0.3m/s	
Measuring values			
	SOS [m/s]	Diff. to theor. [%]	Result
Path 1	345,820	0,006	ok
Path 2	345,814	0,004	ok
Path 3	345,790	-0,003	ok
Path 4	345,711	-0,026	ok
Max. allowed SOS Path Difference: 0.5 m/s			
Difference	0,109		ok



Zero Flow Test

Max. Error VOG [m/s]	0,006	
Measuring values		
	VOG [m/s]	Result
Path 1	0,002	ok
Path 2	0,003	ok
Path 3	-0,001	ok
Path 4	-0,003	ok
Avg. Pipe Velocity	0,000	

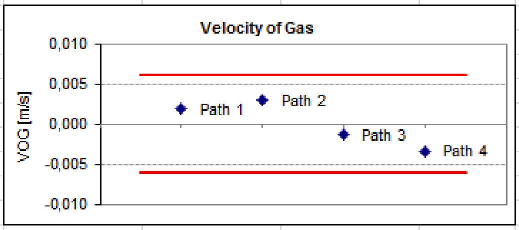


Figure 9b : Typical Factory Zero Flow Results _ 6" Meter

For class 1 and 2 meters it is also usual practice to carry out a zero flow test as part of a high pressure calibration. In this case data is taken either before the calibration commences or as flow is stopped at the end of the calibration. There will, however, be an optimum time to take the data. As flow ceases there will be a period before stabilisation occurs, once the gas is stable data can be taken. An example is shown in Figure 10. After a period of time stability will be lost mainly due to temperature effects and it will not possible to take useful data. Experience shows that at a calibration facility it will be possible to meet a limit of <±0.012 m/s for each acoustic path. Under some circumstances it is possible to meet the lower limit of <±0.006 m/s for each acoustic path but this is not a requirement.

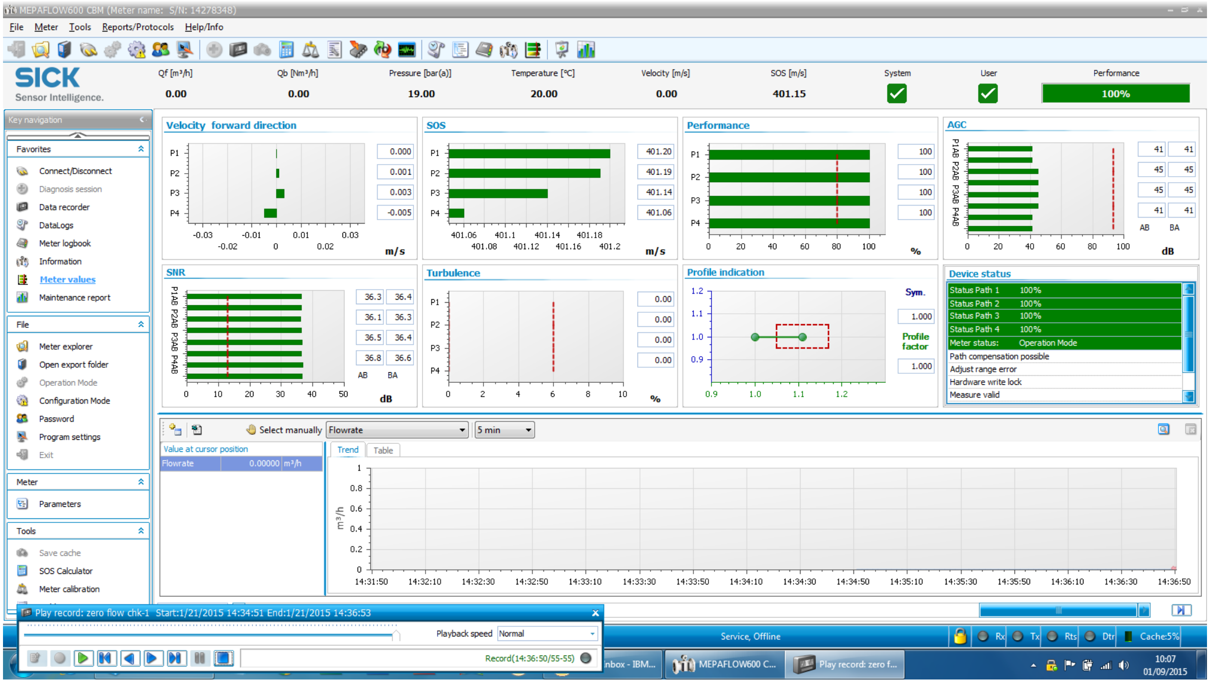


Figure 10 : Typical Zero Flow values at a test facility

A zero flow test can also be a useful indication of meter performance once the meter has been installed and is operational on site. The test situation will not be as stable as in the factory or at the high pressure calibration and a zero flow test can become a valve leakage test if valves are not fully sealing. Temperature effects will also be greater than the previous examples especially if the meter is exposed to direct sunlight or there is a high differential temperature between the gas temperature and the ambient temperature. Assuming that metering stream isolation valves are not leaking then it should be possible to meet a limit of <±0.012 m/s for each acoustic path however it will probably not be possible to meet a limit of <±0.006 m/s for each acoustic path.

Example of on site zero flow test with an 18" meter ; Table 1

Data from an 18" chordal meter, exposed to direct sun with a differential temperature of 15 degC (gas temperature lower than ambient temperature) shows that once flow is stopped the velocities for the 4 chords are ;

The meter would pass the limit of <±0.012 m/s for a period of 112 seconds and then 448 seconds once flow ceases.

But the meter would pass the limit of <±0.006 m/s for a period of only 11 seconds and then 32 seconds once flow ceases.

On this basis, this confirms that the limit of <±0.012 m/s is practical for in situ testing.

Flowing conditions	Path 1 m/s 4.628	Path 2 m/s 5.051	Path 3 m/s 5.054	Path 4 m/s 4.409	>0.012 m/s	>0.06 m/s
T=0s	-0.005	-0.012	0.01	0.01		
T=21s	0.004	-0.001	-0.003	0.005		
T=32s	0.002	-0.001	-0.007	0.004		
T=112s	0	-0.002	-0.002	0.015		
T=128s	0.006	-0.003	0.002	0.009		
T=249s	-0.003	0.006	0.001	0.001		
T=291s	0.001	0.007	0	0.001		
T=455s	0.007	0.004	-0.012	0.004		
T=576s	0.004	0.014	0.06	0.09		

Table 1 ; 18" meter zero test on site

For class 4 meters, typically flare gas meters, the zero flow test may take place using specialised test equipment such as a zero flow box. The function of a zero flow test box is to give a stable, controlled environment where transducer performance can be verified.

Zero Flow Test : Flare Gas Meters

For flare gas meters (typically class 4 meters) the transducers are usually removed and are subject to a test in a zero flow test box; see Figure 11. This gives a set path length and allows the air pressure and temperature to be measured. The measured speed of sound can be compared against a theoretical value as well as the gas velocity (zero) to be checked.

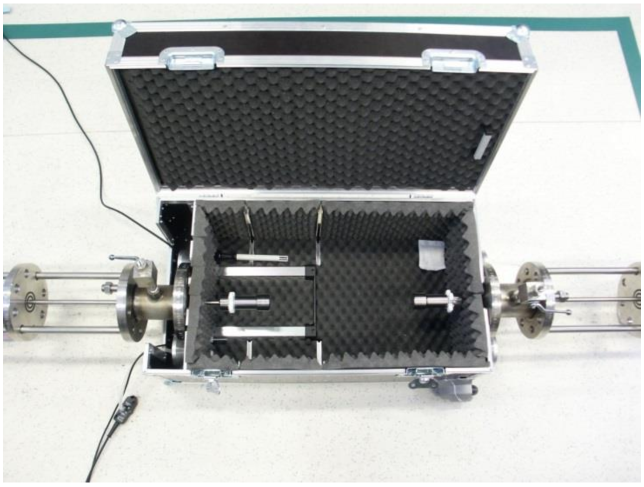


Figure 11 : Zero Flow Test Box

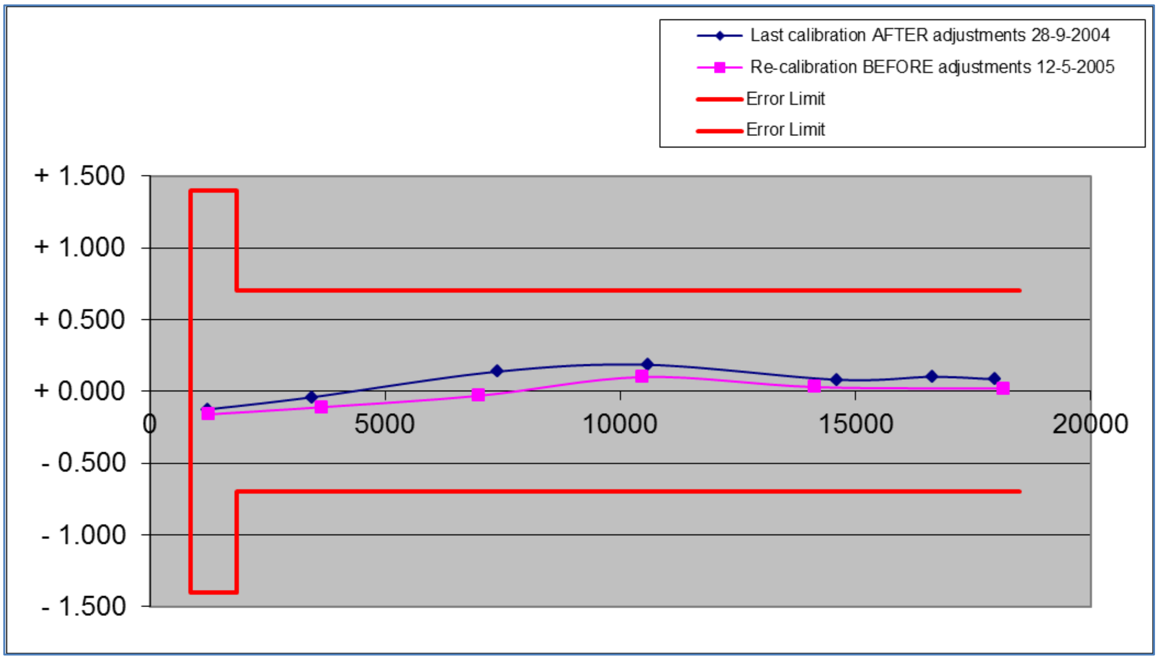
Shift between calibrations

BS7965: 2009 gave a maximum allowable shift between calibrations on ±0.3% of FWME. Experience showed that this figure was not always practical for small meters so the requirements were modified as follows ;

"For meters >4 in, a typical tolerance of ±0.3% of FWME (flow weighted mean error) should be allowed between subsequent calibrations. For meters ≤4 inches, the allowable shift is ±0.5% of FWME.

Examples for shifts in performance are given in figures 12,13 and 14, these show that the defined values for allowable changes in FWME can be met for the three sizes of meters.

Large Meter



2005 Calibration FWME :	+ 0.0187	%
2004 Calibration FWME :	+ 0.0985	%
Change in FWME :	- 0.0797	

Figure 12 : Shifts at Calibration for a Large Meter

For the large, 20" ; figure 12, we can see that the change in performance results in a change in FWME of less than ±0.3%. Although we show only one set of results the meter has been to subjected to multiple recalibrations and in all cases the change in performance has complied with requirements laid down in BS7965:2013

Medium Meter

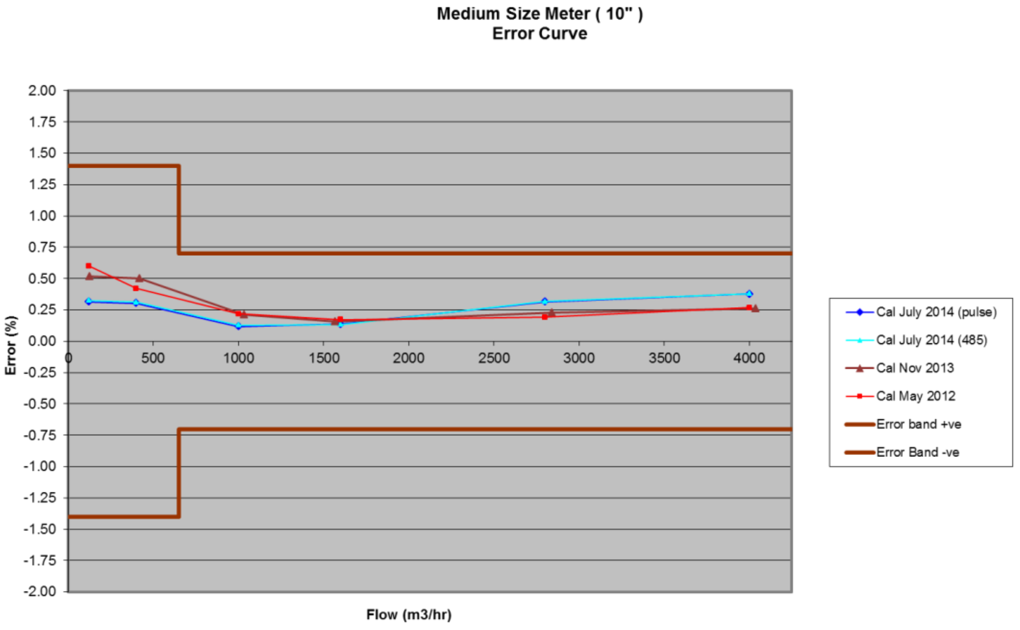


Figure 13 : Shifts at Calibration for a Medium Meter

For the medium, 10”, size meter there are 3 sets of results; figure 13. The worst case change occurs from the November 2013 to July 2014 calibration, a change in FWME of 0.24 to 0.28 (a change in FWME of 0.04) It can be seen that the change is less than ±0.3% of FWME so the results of the calibrations would be acceptable under BS7965:2013

Small Meter

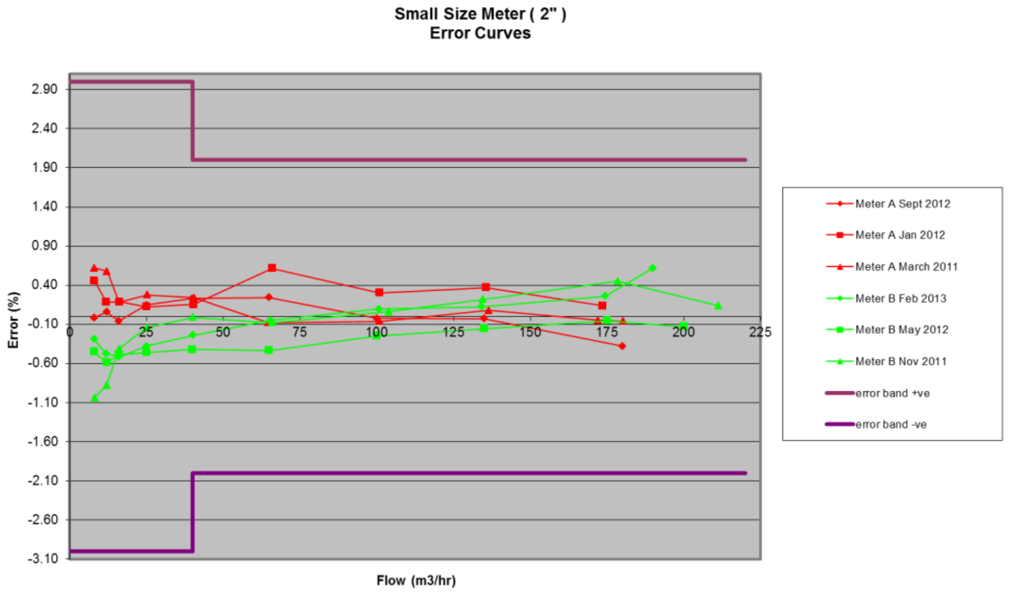


Figure 14 : Shifts at Calibration for a Small Meter

For the smallest size meter, 2”, there are results for two meters; Figure 14. When we look at repeat calibrations we see a range of change of between 0.08% of FWME to 0.43% of FWME with an average change of 0.28% of FWME). It can be seen that some of the changes would be greater than ±0.3% of FWME however the change is always less than ±0.5% of FWME so the results of all of the calibrations would be acceptable under BS7965:2013

For all sizes of meters there may be occasions where the change in FWME is greater than that allowed. There may be a number of reasons for this not limited to, but including the following;

1. Meter contamination, either through pipeline particulates, liquid or in the process of removing the meter from service. To this end it is recommended that a diagnostics file is taken from the meter prior to removing the meter from service. If a change in performance is due to contamination it should be possible, using logged data in the meter, flow computer or supervisory system to determine when this occurred,

2. Change in test site conditions, this can raise the following questions,
    a. Is the meter being calibrated at the same site ?
    b. Is the site set up the same, if a flow conditioning plate is being used is it the same type, at the same location and of in same orientation as for the previous calibration ?

3. Parameter check, if values have changed since the previous calibration this may result in a change in performance. This can usually be checked either through checksum comparisons or by comparing parameter list automatically.

Path failure simulation and exchange of components

“Where a Class 1 or Class 2 meter remains in service in the event of path failure, the effect of the failure should be determined during meter calibration by simulating the failure of one or more paths. The test should be carried out at or around the mid-point of the expected operating range of the meter. During the test, the flow rate should be varied by 20% of the flow rate to ensure that the meter responds appropriately.

The manufacturer should demonstrate the capability of the meter to replace or relocate transducers, electronic parts and software without a significant change in meter performance. This should be demonstrated for: the electronics; transducers of different path types.

When components are exchanged, the resulting shift in the FWME of the meter should not be more than 0.2%”.

This new section within BS7965:2013 seeks to address the effect of replacing a component in the field and to put a limit on the change in performance after such a replacement. Component failure may require the operator to change out either the electronics unit or a pair of transducers.

Results are shown for a 3” meter tested as part of a high pressure calibration carried out on natural gas at 50 Bar; Figure 15. Results show the initial calibration, three points repeated with one set of transducers exchanged (for a spare set) and the meter with the original transducers installed.

For all scenarios the resulting shift in the FWME of the meter is less than 0.2%, the meter would be compliant with the requirements of BS7965:2013 and this also shows that the procedure in the document is valid even for small meters.

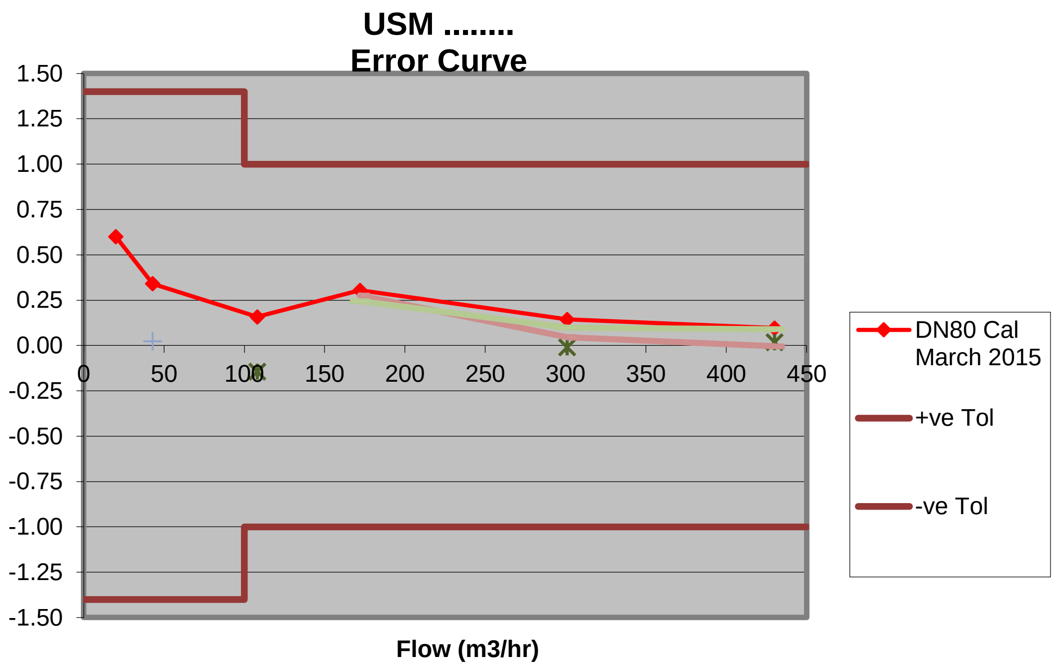


Figure 15 : Change in Performance with transducer change out for a Small Meter

FWME with original transducers (as found)	0.15
FWME with 1 pair of transducers replaced	0.05
FWME with original transducers replaced	0.12

CBM (Condition Based Maintenance / Monitoring)

UK offshore operators have, historically, calibrated meters using a time based maintenance philosophy. This has been followed independent of the value of product flowing through a meter and the level of diagnostics available in the metering system. The adoption of a risk based philosophy, using the diagnostics available either directly from the meter or the metering system addresses the following concerns [2];

- Safety concerns around the removal and handling of large pieces of equipment
- Planning and scheduling to ensure minimal down time without any gas deferral
- ETS legislation governing the venting and release of Hydrocarbon gases
- Availability of test slots, particularly for meter sizes above 10”
- The calibration facilities claiming uncertainties of approximately ± 0.23%, not the “order of magnitude” smaller uncertainty (± 0.03%) that fundamental metrological principles require for a true calibration.
- Potential for damage to the meters during removal, transportation or reinstallation .

Gas USFM meter diagnostics may be classified depending on the type of information that they provide:

- Functional (information on the physical operation of the meter)
- Process (information on the fluid properties, flow profile, etc.)
- System Performance (information on the overall measurement system)

This new section, covering CBM, was implemented based on information first included in DECC "Guidance Notes for Petroleum Measurement Issue 8". The section within the DECC document was formulated following a seminar hosted by DECC in Aberdeen in June 2011. Attendees were the main manufacturers of fiscal meters currently being used in the UK and meter operators. Latest advice from the OGA [3] recommends that operators of meters should adopt a combined "risk-based" and "conditioned base" rather than a simple "time based" approach to maintenance where possible.

The guidance was based on common values (listed below) that are generated by all recognised meters and does not include bespoke manufacturers solutions, the guidelines cover data such as ;

- Speed of Sound
- Automatic Gain Control
- Signal to Noise Ratios
- Performance
- Temperature

The approach to CBM is qualative rather than quantative. There is a recognition that there is an opportunity to add to this as ISO17089 part 1 is updated.

Summary

The BS7965:2013 working group believe that the document, which is based upon extensive end user experience, is practical, pragmatic and is performance focused. As a group our hope is that the industry will adopt the practices contained within the latest revision and that the work carried out will be a valuable input into other documents, especially the work being carried out to revise part 1 of ISO17089.

References

1. Experimental Research into the Measurement of Temperature in Natural Gas Transmission Metering Systems – Sarah Kimpton and Bob Ingram (Oil and Gas Focus Group ; April 2015)

2. On-line Condition Based Maintenance of Gas Ultrasonic Flow Meters – Stephen Peterson and Jan Peters (CEESI/VSL European Flow Measurement Workshop ; March 2014)

3. OGA Policy Statement – Maintenance Strategies on Fiscal Measurement Systems (August 2015)