Performance Standards and Test Procedures for Continuous Water Monitoring Equipment

Part 3: Performance standards and test procedures for water flowmeters

Environment Agency
Version 2.4

February 2013

Foreword

We established our Monitoring Certification Scheme (MCERTS) to deliver quality environmental measurements. The scheme is based on international standards and provides for the product certification of instruments, the competency certification of personnel and the accreditation of laboratories.

This document contains the performance standards and test procedures for flowmeters used for the monitoring of raw water abstraction, treated wastewater discharges from industrial processes, ultraviolet disinfection processes and industrial processes.

MCERTS for flowmeters:

- makes available a certification scheme that is formally recognised within the UK and is acceptable internationally
- gives confidence to regulatory authorities that instrumentation, once certified, is fit for purpose and capable of producing results of the required quality and reliability
- gives confidence to users that the instrumentation selected is robust and conforms to performance standards that are accepted by UK regulatory authorities
- supports the supply of accurate and reliable data to the public
- provides instrument manufacturing companies with an independent authoritative endorsement of their products, which will facilitate their access to international markets and increase the take-up of their products in the UK.

The MCERTS performance standards for flowmeters described in this document are based on relevant sections of a number of international ISO or CEN standards, as well as taking into account other relevant national standards.

This standard covers flowmeters making measurements of volumetric flow-rate or total volume passed in closed pressurised pipes, partially filled pipes and open channels. It also covers instruments that make measurements of fluid velocity, differential pressure or liquid level from which the instrument calculates, and outputs, a value for volumetric flow-rate or total volume passed.

MCERTS for flowmeters provides a formal scheme for the product certification of flowmeters conforming to these standards. We have appointed Sira Certification Service (the Certification Body) to operate MCERTS on our behalf.

Product certification comprises three phases. These are:

- **Laboratory testing** – used to determine performance characteristics, where such testing requires a highly controlled environment
- **Field testing** – carried out on processes representative of the intended industrial sectors and applications
- **Surveillance - initial and continuing** – which comprises an audit of the manufacturing process to confirm that the manufacturer has provisions to ensure manufacturing reproducibility and to control any design changes to ensure that they do not degrade performance below the MCERTS standards.

Test organisations shall demonstrate to the satisfaction of the Certification Body that they comply with the relevant requirements of ISO/IEC 17025 for the testing of flowmeters under MCERTS.

The results of previous performance tests may be acceptable to the Certification Body, if equivalent to MCERTS and carried out independently. Manufacturers' own test data may also be considered. This is applicable to both laboratory and field tests.

Certification Committee

- The role of the Certification Body is to assess and certify compliance with the MCERTS standard for defined applications and/or conditions.

- In performing this role the MCERTS scheme requires the Certification Body to consider the relevance of the procedures defined in the MCERTS standard to the specific product to be certified. The technology or defined application of a specific product may make certain of the documented tests inappropriate. The Certification Body is required by the MCERTS scheme to exercise its technical judgement when considering these matters.

- Any decision based on technical judgement of the standard shall be taken by an appropriately independent, competent person or group of persons, who in this MCERTS standard are referred to as the "Certification Committee".

- Any certificate issued by the Certification Body shall identify any variations from the normative MCERTS standard.

If you have any questions regarding the certification process, or would like further information on how to make an application, please contact:

Sira Certification Service
12 Acorn Industrial Park
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DA1 4AL

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You can get more information on MCERTS from our website at www.mcerts.net

If you have any general questions about MCERTS, please contact:

Environment Agency
Email: paul.wiggins@environment-agency.gov.uk
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Record of amendments

Version number	Date	Amendment
2	Feb 06	Amalgamation of former MCERTS performance standards and test procedures for flowmeters
2	June 06	Role of Certification Committee added to Foreword
2.1	March 08	Section 1 – 1.2 Section on repairs, maintenance and modifications to certified flowmeters added. New clauses in 1.3 Section 4 – Tables 6 Mean error limits reduced. Table 7 Combined performance characteristic limits increased. 4.6.5 New note Section 5 – Alternative test points added in Table 10 Section 6 - 6.3.9 Test replaced, 6.3.20 New note Section 7 – Field test requirements simplified Annexes – Reordered to reflect order of references in main text Annex E – New. Contains guidance on usage groups (originally Table 4) Annex H – New. Examples of evidence Whole document: Reference to technical committee removed and replaced by Certification Committee
2.2	Sept 11	Section 1 – 1.1.11 Reference added to new Annex G Section 4 – 4.2.1 and 4.3.1 Wording clarified Section 5 – 5.4.1 Removed reference to V2.1 Annex G V2.1 Annex A Bibliography deleted V2.1 Annex G Format of the Report deleted Remaining Annexes renamed A to F Annex E Standard Reference Methods – Standards numbers updated Annex G – New annex on Certification of non-standard flow gauging structures Whole document: References to Annexes updated
2.3	August 12	Annex G removed
2.4	Feb 13	Section 3.2.2 Mandatory advice on cleaning added Section 3.2.13 Example of sunshades given for shielding. Section 6.3.10 New test titled Direct solar radiation to replace Sonic velocity compensation (and references throughout document).

Status of this document

This document may be subject to review and amendment following publication. The latest version of this document is available on the Environment Agency's website at:

www.mcerts.net

Contents

Performance Standards and Test Procedures for Continuous Water Monitoring Equipment - Flowmeters

1. Introduction

1.1 Background

1.1.1 This document describes the performance standards, test procedures and general requirements for the testing of flowmeters for compliance with the MCERTS performance standards.

1.1.2 The certification process is explained in Annex B.

1.1.3 We require operators of regulated processes to utilise MCERTS certified equipment unless otherwise agreed in writing.

1.1.4 It is the responsibility of the user to ensure that the selection, installation and operation of a flowmeter are appropriate to the application.

1.1.5 The determinands covered are:

- volumetric flow-rate
- total volume passed.

NOTE: All flowmeters will be tested across a range of flow-rates.

1.1.6 The requirements in this document are intended to be technology transparent and allow the certification of any technical solution that meets the requirements.

1.1.7 Guidance on the requirements for specific determinands in certain applications is given in Table 1.

Table 1 Requirement for indication of volume or flow-rate

Application	Indication required
Raw water abstraction metering	Total volume passed (note)
Effluent discharge monitoring	Total volume passed and flow-rate
Ultraviolet disinfection monitoring	Flow-rate
Industrial process monitoring	No specific requirement

Note: Some abstraction licences also place limits on the rate of abstraction, in which case flow-rate shall also be required.

1.1.8 The standard covers all technologies of flowmeters intended to operate in:

- closed pressurised pipes
- open channels
- partially filled pipes.

1.1.9 The following flow measurement systems may be submitted for certification under this standard:

- A complete flowmetering system such as:
  - A flow sensor and transmitter
  - A mechanical flowmeter including any ancillary device required to derive an electronic output
  - A velocity-area flowmeter comprising a fluid velocity sensor with a liquid level sensor, associated electronics and flow computer
  - A gauging structure with a liquid level sensor, associated electronics and flow computer
  - A non-standardised primary device with a differential pressure sensor, associated electronics and flow computer.
- A liquid level sensor with associated electronics and flow computer, intended for use with a gauging structure
- A differential pressure sensor, associated electronics and flow computer intended for use with a standardised primary device.

NOTE: The general term "flowmeter" is used in this standard to apply to any of the above flow measurement systems.

1.1.10 Ideally, where a flowmeter is to be used with a primary device or gauging structure for which there is a relationship between flow-rate and measured flow property then the structure will comply with an ISO, CEN or a national standard. Specific concessions from the recognised standards are permissible albeit with an increased uncertainty in the flow measurement, e.g. MCERTS "Minimum Requirements for the Self Monitoring of Effluent Flow" Appendix 2. In such a case a specific assessment may be required to validate the in situ performance of the entire flow measurement systems.

1.1.11 A non-standard device or structure is acceptable provided that the discharge characteristic for the device or structure is well established. Annex G of this Standard describes a route to facilitate the certification, under the MCERTS product certification scheme, of pre-fabricated gauging structures for flow measurement in open channels where there is no current British, European or International Standard covering such a structure.

1.1.12 Where a flowmeter is used with a primary device or gauging structure, the uncertainty of that device or structure and the relationship of the measured parameter with flow-rate must be taken into account when calculating the uncertainty of the complete flow measurement system, which should be done according to the principles of the ISO Guide to the Expression of Uncertainty in Measurement (GUM).

1.1.13 The overall ranges of flow-rates, which might be encountered in a number of typical applications, are given in Table 2. It is recognised that the actual range required in any individual application will be specific to that application including any regulatory and process needs. Typically, on an individual application, a flowmeter should be able to measure up to 3 times the average daily flow, expressed in appropriate units. For water abstractions a meter should be able to record 5 times the annual licensed abstraction before the totaliser rolls over.

The certification range for a flowmeter will be agreed between the manufacturer and the Certification Body, see Annex B.

Table 2 Overall ranges for measurement (for guidance)

Application	Meter configuration	Size range (nominal bore / fluid depth)	Flow-rates (l/s)
Abstraction			
Agricultural and domestic	Mostly closed pipe	15-40 mm	0.002 to3.5
Spray irrigation	Closed pipe	15-100 mm	0.002 to 30
Power industry	Mostly closed pipe	500-2000 mm	15 to 5500
Water supply	Mostly closed pipe	50-1000 mm	0.08 to 1660
Industrial and commercial	Mostly closed pipe	40-1000 mm	0.015 to 1660
Effluent discharge			
Intermittent measurement	Mostly open channel	>0-100 mm depth	0.06 to 1.2
Continuous measurement	Mostly open channel	50-2000 mm depth	0.4+
	Closed pipe	50-600mm	0.4+
Ultraviolet disinfection			
Waste water	Open channel	200-1000 mm depth	0.4+
Industrial processing			
Dosing	Closed pipe	2-20 mm	0.0005 to 1.4
In process	Closed pipe	20-200 mm	0.05 to 140
Bulk transfer	Mostly closed pipe	150-1500 mm	1.3 to 3500

1.1.14 Guidance on the typical flow measurement uncertainty requirements, which incorporate all components of uncertainty of the flow measurement system, for these applications is given in Table 3.

Table 3 Typical performance requirements by application

Application	Typical performance requirements
Raw water abstraction metering	2% to 10% as required by individual license conditions
Effluent discharge monitoring	8% total daily volume
Ultraviolet disinfection monitoring	8% flow-rate
Industrial monitoring	as required by the specific application.

1.2 Repairs, maintenance and modifications to certified flowmeters

1.2.1 Any spares or replacement parts for certified flowmeters must meet the same performance standards as the original parts. Operators and equipment suppliers may be required to provide evidence that the replacement parts meet the required performance standards of the original equipment as specified by the flowmeter manufacturer.

1.2.2 Modifications to certified flowmeters are allowable so long as manufacturers can demonstrate that these design changes do not degrade the performance of the flowmeter below the MCERTS performance standards.

1.2.3 Manufacturers must keep detailed records and drawings of all design changes to flowmeters, and have provisions for design verification, inspection and testing to ensure that the flowmeters still meet the required performance standards.

1.2.4 The Certification Body will conduct audits of the design changes to flowmeters to meet the requirements of product certification. Manufacturers must notify the Certification Body of any modifications to equipment that may have a significant effect on flowmeter performance.

1.2.5 Design modifications or extensions to the range of application of a flowmeter may require renewed testing. The extent of this renewed testing will depend upon the nature of the modifications to the flowmeter.

1.2.6 If there is evidence that a modification has only limited effects on the performance of the flowmeter, then it would not be necessary to retest a flowmeter completely. In such cases, only a supplementary test would be required to the applicable MCERTS performance standards.

1.2.7 In the case of modifications to software – particularly in measuring instruments – documentation must be presented to the Certification Body indicating the nature of the modification as well as resultant effects on operation and functionality. The Certification Body will then decide if further testing is required.

1.3 Performance tests

1.3.1 Performance tests for certification of a flowmeter against the MCERTS requirements should normally be carried out in accordance with the procedures defined in this document.

1.3.2 The results of previous performance tests may be acceptable to the Certification Body, if equivalent to MCERTS and carried out independently. Manufacturers' own test data may also be considered. This is applicable to both laboratory and field tests.

1.3.3 Variations to the performance tests described in this standard may be acceptable provided that they demonstrate to the satisfaction of the Certification Body the flowmeter's performance against the requirements. Any such variations shall be agreed with the Certification Body.

1.3.4 The decision of the MCERTS Certification Committee on matters of data is final.

2. Scope of the MCERTS scheme

2.1.1 MCERTS is designed to support the requirements of EU Directives and the standards cited within these Directives.

2.1.2 MCERTS for flowmeters includes:

- Sites with permits issued under the Environmental Permitting Regulations (EPR) including:
  - industrial sites previously regulated under the Pollution Prevention and Control Regulations
  - Water Utility sewage treatment works previously regulated under the Water Resources Act
  - other sites with permits transferred to EPR if the flow monitoring arrangements are significantly changed
  - new installations with permits issued under EPR
- Sites falling under the Urban Wastewater Treatment Directive (UWWTD) (91/271/EEC and 98/15/EEC).
- Sites with permits issued under the Radioactive Substance Regulations.

3. General requirements

3.1 General requirements for all flowmeters

The following requirements will be assessed by inspection or manufacturer's statement for all flowmeters.

3.1.1 All MCERTS certified flowmeters shall have a unique designation that unambiguously identifies the flowmeter as a certified model.

3.1.2 The flowmeter shall have a means of protection against inadvertent or unauthorised access to control and calibration functions.

3.1.3 The flowmeter shall incorporate an indicating device and/or an analogue or digital output signal.

3.1.4 The indicating device or output shall show either the totalised volume and / or volumetric flow-rate.

3.1.5 A flowmeter intended for abstraction metering and / or effluent discharge monitoring shall have a means for preventing unauthorised resetting of the total recorded volume.

3.1.6 The indicating device and output shall be scaled in metric units.

3.1.7 The units of measurement shall be displayed on the indicating device.

3.1.8 The indicating device on a bi-directional flowmeter shall incorporate a symbol to show the flow direction.

NOTE: A pointer rotating clockwise with increasing flow and counter-clockwise with *reverse flow is acceptable but reliance on an increasing or decreasing total is not.*

3.1.9 The direction of forward flow shall be clearly marked on the sensor.

NOTE: In the case of a bi-directional flowmeter this should be the direction of flow which gives an increase in the total flow recorded. For a flowmeter which has been wet calibrated, this should be the direction of flow in which the flowmeter has been calibrated.

3.1.10 For a bi-directional flowmeter, the reverse flow volume shall either be subtracted from the indicated volume or it shall be separately recorded.

3.1.11 An open channel flowmeter computing flow from a level measurement shall incorporate a facility for a user defined water level (stage) - discharge curve to be entered.

3.1.12 Where a manufacturer recommends an upstream strainer or filter to protect the flowmeter, this shall be available from the manufacturer.

3.1.13 Attaching an ancillary device shall not reduce the rated operating conditions for a mechanical flowmeter for any environmental parameter.

3.1.14 For electromagnetic flowmeters, the minimum rated operating conditions for fluid conductivity shall be 50 $\mu S\ cm^{-1}$ to 1200 $\mu S\ cm^{-1}$.

3.1.15 For level sensors the resolution shall be as shown in Table 4.

Table 4 Resolution requirements for level sensors

Certification range	Class 1	Class 2	Class 3
≤ 1.0m	≤ 1mm	≤ 2mm	≤ 10mm
1.0 to 5.0m	≤ 2mm	≤ 5mm	≤ 20mm
5.0 to 20.0m	≤ 10mm	≤ 50mm	≤ 200mm

The resolution u_{RES} shall be reported and included in the combined performance characteristic, (See Annex C).

3.2 Manufacturers' published documentation

The following guidance or statements shall be incorporated into the manufacturer's published literature.

3.2.1 The manufacturer shall provide operating instructions which cover the full functionality of the instrument.

3.2.2 The manufacturer shall give guidance on the time period over which the flowmeter shall operate continuously without requiring manual adjustment or intervention. This shall be application specific. The guidance shall include advice on how to clean the flow meter.

NOTE: Automatic routines for cleaning, maintenance or recalibration may be used to maintain performance within the required limits between manual interventions. It is up to the user to ensure that a suitable regime is adopted for an individual application.

3.2.3 For a flowmeter intended for use with a primary device, the manufacturer shall state the types of primary device for which the flowmeter can compute flow-rate without the input of data other than the type and dimensions of the structure and a zero datum.

3.2.4 The manufacturer shall state whether the flowmeter is designed to measure flow in both forward and reverse directions.

3.2.5 The manufacturer shall state minimum up and downstream straight lengths of conduit adjacent to the sensor required to meet the performance characteristics of this standard.

3.2.6 The manufacturer shall state any limitations on the material of conduit into or onto which the flowmeter sensor can be installed.

3.2.7 The manufacturer shall state any limitations on the conduit dimensions or shape (including wall thickness or pipe schedule if appropriate), into or onto which the flowmeter sensor can be installed.

3.2.8 For non-contact level sensors, the manufacturer shall state the minimum separation distance from the sensor face to the fluid surface.

NOTE: It is assumed that the maximum separation distance will be the certification range of the level sensor plus the minimum separation distance.

3.2.9 For non-contact velocity sensors, the manufacturer shall state the minimum and maximum separation distances from the sensor face to the fluid surface.

3.2.10 For flowmeters intended to operate in partially filled pipes, the manufacturer shall state the minimum measurable fluid depth under free surface conditions (the maximum measurable fluid depth is assumed to be full bore).

3.2.11 Where appropriate, the manufacturer shall state the rated operating conditions for fluid pressure.

3.2.12 The manufacturer shall state the nature and quantity of particulate or other material that the meter can pass whilst maintaining its performance within the limits of this standard. If a minimum level of particulate is required for operation of the flowmeter, this too shall be stated.

3.2.13 The manufacturer shall state any specific requirements relating to the location or shielding of components necessary to maintain performance within the limits of this standard under varying environmental conditions, for example, the use of sunshades for air firing ultrasonics.

3.3 Additional requirements for electronic flowmeters

The following additional requirements will be assessed by inspection or manufacturer's statement for an electronic flowmeter.

3.3.1 The flowmeter shall have a means of displaying its operating status, for example, normal operation, stand-by, maintenance mode or malfunction.

3.3.2 The flowmeter shall have a means of communicating fault conditions to a remote system.

3.3.3 A flowmeter operating from an external power supply shall have the facility to incorporate an alarm indicating loss of supply.

3.3.4 A flowmeter operating from a battery shall incorporate a method of indicating when the power available is insufficient to maintain the measurement within the performance requirements of this standard.

3.4 Additional manufacturers’ statements for electronic flowmeters

The following additional guidance or statements shall be incorporated into the manufacturer’s published literature for an electronic flowmeter.

3.4.1 The manufacturer shall state the rated operating conditions for the power supply.

3.4.2 The manufacturer shall state the rated operating conditions for the signal load impedance on the analogue output, if present.

4. Performance Requirements

4.1 Performance characteristics

Performance characteristics have been defined in such a way that they can be calculated from test data in accordance with the principles contained within the ISO Guide to the Expression of Uncertainty in Measurement (GUM).

Specific characteristics are expressed as error (x), change in error (X), standard deviation (u) or expanded uncertainty (U) as shown in Table 5.

Annex C describes in detail how the values are calculated for each characteristic.

NOTE: Not all characteristics will apply to every flowmeter.

Table 5 Expression of performance characteristics

Characteristic	Symbol	Expression of requirement
Mean error	$\bar{x}$	The mean of the errors measured at each test point (see Annex C)
Repeatability	u_R	The standard deviation of the errors measured at each test point (see Annex C)
Resolution	u_{RES}	See clause 3.1.15
Output impedance Supply voltage Ambient air temperature Relative humidity Incident light Direct solar radiation Fluid temperature Sensor location Stray currents Computation accuracy User defined curve	X_O X_V X_T X_{RH} X_{LX} X_{SV} X_{FT} X_{SL} X_{SC} x_{AC} x_U	For any influence quantity the performance requirement is half the range of the change in error measured as the influence quantity is varied from its minimum to its maximum values (see Annex C).
Combined performance characteristic	U_C	An expanded uncertainty obtained by combining individual performance characteristics (see Annex C).

4.2 Performance characteristics for complete flowmetering systems

4.2.1 Table 6 shows the maximum value for each performance characteristic of a complete flowmetering system. In order to achieve certification for a given class, an instrument must comply with the combined performance characteristic for that class. The values for individual and combined performance characteristics are expressed as a percentage of reading of volumetric flow-rate or totalised volume passed.

Table 6 Performance characteristics for complete flowmetering systems

Performance class	Symbol	Test	Class 1	Class 2	Class 3	Class 4
			% reading			
Mean error	$\bar{x}$	6.3.2	±1.5	±4	±6.5	±8
Lower limit value for mean error (note 1)		6.3.2	±5	±10	±10	±10
Repeatability	u_R	6.3.2	1	2	4	5
Supply voltage	X_V	6.3.3	0.5	1	2	2.5
Output impedance	X_O	6.3.4	0.5	1	2	2.5
Fluid temperature	X_{FT}	6.3.5	0.5	1	2	2.5
Ambient air temperature	X_T	6.3.6	0.5	1	2	2.5
Relative humidity	X_{RH}	6.3.6	0.5	1	2	2.5
Incident light	X_{LX}	6.3.7	0.5	1	2	2.5

Performance class	Symbol	Test	Class 1	Class 2	Class 3	Class 4
Sensor location	X_{SL}	6.3.8	0.5	1	2	2.5
Stray currents	X_{SC}	6.3.9	0.5	1	2	2.5
Direct solar radiation	X_{SV}	6.3.10	1	2	4	5
Combined performance characteristic	U_C		2	5	8	10
Maximum response time	-	6.3.19	30 seconds (note 2)			
Warm up	-	6.1.2	Value shall be reported			

Notes to Table 6:

1. The lower limit value for mean error is only applicable in the region Q1 ≤ q < Q2, (see under *flow-rate* in Annex A for definitions of Q1 and Q2).

2. The response time of a flowmeter will be assessed over a change in flow-rate of at least 20% of the certification range.

4.2.2 A bi-directional flowmeter shall meet the requirements for mean error and repeatability with both forward and reverse flows.

4.2.3 The mean error and repeatability of a flowmeter not designed to measure reverse flow shall meet the requirements for mean error and repeatability following an accidental short-term reversal of flow.

4.2.4 A mechanical flowmeter shall meet the requirements for mean error and repeatability with and without any ancillary device used to derive an electronic output.

4.3 Performance characteristics for level sensors

4.3.1 Table 7 shows the maximum value for each performance characteristic for level sensors intended to be used with a gauging structure. In order to achieve certification for a given class, an instrument must comply with the combined performance characteristic for that class. The values for individual and combined performance characteristics are expressed as a percentage of range (where *range* is taken as applying to the fluid depth range for which certification is sought).

Table 7 Performance characteristics for level sensors

Performance class	Symbol	Test	Class 1	Class 2	Class 3
			% certification range		
Mean error	$\bar{x}$	6.3.2	±0.1	±0.3	±1
Repeatability	u_R	6.3.2	0.05	0.15	0.5
Supply voltage	X_V	6.3.3	0.025	0.075	0.25
Output impedance	X_O	6.3.4	0.025	0.075	0.25
Fluid temperature	X_{FT}	6.3.5	0.025	0.075	0.25

Ambient air temperature	X_T	6.3.6	0.025	0.075	0.25
Relative humidity	X_{RH}	6.3.6	0.025	0.075	0.25
Incident light	X_{LX}	6.3.7	0.025	0.075	0.25
Direct solar radiation	X_{SV}	6.3.10	0.05	0.15	0.5
Computation accuracy	X_{AC}	6.3.11	0.025	0.075	0.25
User defined equation	X_U	6.3.12	0.025	0.075	0.25
Combined performance characteristic	U_C	-	0.2	0.5	1.5
Maximum response time	-	6.3.19	30 seconds (note 1)		
Warm up	-	6.1.2	Value shall be reported		

Notes to Table 7:

1. The response time of a level sensor shall be assessed over a change in level of at least 20% of the certification range.

4.4 Performance requirements for differential pressure sensors

4.4.1 Performance characteristics for differential pressure sensors will be agreed by discussion between a manufacturer and the Certification Body to meet specific application requirements.

4.5 Data retention

4.5.1 All pre-set data, including calibration and alarm set points and adjustments, shall be retained for a minimum period of 30 days after disconnection of the power supply.

4.5.2 For raw water abstraction and effluent discharge monitoring the totalised volume shall be retained for a minimum period of 30 days after disconnection of the power supply.

4.6 Environmental requirements

4.6.1 Guidance on the operating conditions to which flowmeters are likely to be subjected is given in Annex D. The rated operating conditions have been divided into three usage groups for typical operating environments.

4.6.2 The extent of the environmental testing will be agreed between the manufacturer and the Certification Body, taking into account the intended usage class of the instrument, see Annex D.

4.6.3 For usage group B, the minimum rated operating conditions for ambient air temperature shall be +5°C to +40°C.

4.6.4 For usage groups C and I, the minimum rated operating conditions for ambient air temperature shall be –10°C to +35°C.

4.6.5 The mean error and repeatability of flowmeters with an environmental class I shall remain within the limits defined in this standard after exposure to random vibration.

Note: A sinusoidal vibration test may be acceptable to demonstrate compliance, see 6.3.20.

4.7 Fluid requirements

4.7.1 The minimum rated operating conditions for fluid temperature shall be +1°C to +30°C.

4.8 Site installation influences

4.8.1 Flowmeters with insertion electromagnetic sensors shall meet the requirements in Table 6 for mean error, repeatability and combined performance characteristic when installed in plastic or metal conduits.

4.8.2 Flowmeters with non-invasive ultrasonic sensors shall meet the requirements in Table 6 for mean error, repeatability and combined performance characteristic when installed on pipes constructed from commonly used plastic and metal materials including lined pipes.

4.8.3 Flowmeters with insertion or non-invasive sensors shall meet the requirements in Table 6 for mean error, repeatability and combined performance characteristic when installed in conduits within the manufacturer's specified size range.

4.8.4 Flowmeters for partially filled pipes sensors shall meet the requirements in Table 6 for mean error, repeatability and combined performance characteristic under both free surface and surcharged flow conditions.

4.9 Field test characteristics

4.9.1 For a complete flowmetering system, during the field test, the error shall be less than or equal to the value of the combined performance characteristic, as given in Table 6, in at least 90% of the paired readings taken.

4.9.2 For a level sensor during the field test, the error shall be less than or equal to the value of the combined performance characteristic, as given in Table 7, in at least 90% of the paired readings taken.

4.9.3 During the field test the flowmeter shall have an up-time greater than 95%.

5. Provisions for test organisations

5.1 General requirements for test-houses

5.1.1 For the testing of flowmeters under MCERTS test organisations shall demonstrate to the satisfaction of the Certification Body that they comply with the relevant requirements of ISO/IEC 17025 General Requirements For The Competence Of Testing And Calibration Laboratories.

5.2 General requirements for testing

5.2.1 Example reference methods for flowmeter tests are given in Annex E.

Note: Ideally, the errors associated with any test equipment or reference measurements should be no more than 1/5th of the mean error requirement for the performance class against which the instrument is being tested.

5.2.2 Level measurement instruments and differential pressure instruments may be tested using a direct input of level or pressure generated by means other than a flow of water, for example a plate, static water column or surface, or pressure calibrator.

5.2.3 With the prior agreement of the Certification Committee, fewer measurements than required by the individual test may be made, if this can be justified, e.g. where a pattern of low variability is supported by statistical analysis. This shall be shown in the test report.

5.2.4 The flowmeter may be maintained, cleaned or recalibrated in line with manufacturer's instructions prior to any test, but adjustments shall not be carried out during the course of the test.

5.2.5 Any self cleaning mechanisms or other automatic maintenance functions shall be disabled during any laboratory test unless these are part of the normal measurement cycle or the test procedure states otherwise.

5.2.6 Insertion sensors may be cleaned between tests by rinsing with demineralised water.

5.2.7 Readings shall be allowed to stabilise after any change in an influence quantity or determinand value.

5.2.8 Data from tests shall be processed in accordance with the calculation methods summarised in Annex C.

5.3 Test conditions

5.3.1 For flowmeters with a narrow measurement range (≤ 100:1) and level sensors for open channel flow measurement, the flow-rate test points given in Table 9 shall be used as required by each individual test.

Table 9 Test point values

Test point	Limits of determinand value
1	(5% ± 2.5%) of the certification range
2	(25% ± 5%) of the certification range
3	(50% ± 5%) of the certification range
4	(75% ± 5%) of the certification range
5	(95% ± 5%) of the certification range

For closed pipe flowmeters with a wide measurement range (>100:1), the test schedule defined in EN 14154 Part 3 Water meters Test methods and Equipment and shown in Table 10 shall be used.

Table 10 EN 14154 test point values

Test point	Limits of determinand value
1	Between Q1 and 1.1 Q1
1a*	Between 0.5(Q1+Q2) and 0.55(Q1+Q2)
2	Between Q2 and 1.1 Q2
3	Between 0.33(Q2+Q3) and 0.37(Q2+Q3)
4	Between 0.67(Q2+Q3) and 0.74(Q2+Q3)
5	Between 0.9 Q3 and Q3
6	Between 0.95 Q4 and Q4

** Test point to be included if Q2/Q1 > 1.6*

5.3.2 Table 11 gives the reference conditions for possible influence quantities. Tests shall be carried out with all influence quantities at their reference values, including tolerances, unless where specifically varied in any one test.

Table 11 Reference conditions

Influence quantity	Reference value	Tolerance
Ambient air temperature (note 1)	20°C	±5°C
Ambient humidity at 20°C (note 2)	<60%	-
Incident light	Existing local light level	-
Fluid temperature	20°C	±5°C
Fluid pressure (closed pipes)	≥ maximum head loss across meter + 0.5 bar	-
Fluid conductivity (note 3)	50 < conductivity < 5000μS/cm	-
Supply voltage (a.c.)	230 or 110V	±2%
Supply voltage (d.c.)	To be stated by the manufacturer	±2%
Output impedance	Manufacturer's stated maximum	+0, -2Ω
Sensor location for non-contact velocity sensors	Mean of maximum and minimum limits stated by manufacturer	±10%
Water quality	Public potable water supply or equivalent. The water should be free of debris and entrained gas, unless specifically required for the functioning of the instrument, e.g. devices using the Doppler effect.	

Notes to Table 11:

1. During any one test, the ambient air temperature shall not vary by more than 5°C.

2. During any one test, the relative humidity shall not vary by more than 10%.

3. Only applicable when testing instruments incorporating electromagnetic sensors.

5.4 Reporting

5.4.1 The test-house shall produce a report using the model test report provided by the Certification Body.

6. Laboratory test procedures

6.1 Initial checks

6.1.1 The test-house shall ensure that the flowmeter is set up, calibrated and adjusted in accordance with the manufacturer’s instructions.

NOTE: The manufacturer may install and set up the flowmeter.

6.1.2 The flowmeter shall be allowed to warm up while being supplied with a zero or reference input of known value. The time taken for the flowmeter to stabilise shall be reported.

6.1.3 The test house shall verify by inspection or by a statement from the manufacturer that the general requirements listed in Sections 3.1 and 3.3 are fulfilled, as appropriate to the flowmeter under test. The means by which each requirement is fulfilled shall be reported.

6.1.4 The test house shall verify and report that measurements obtained from any analogue or digital outputs are comparable to those shown on any local display on the flowmeter. (Readings will rarely be identical due, for example, to small errors between devices, different refresh rates or numbers of significant figures.)

6.1.5 The test house shall verify and report that the displayed operational status is correct.

6.2 Manufacturer’s published documentation

6.2.1 The test house shall verify and report that the manufacturer’s published documentation includes the relevant statements required in Sections 3.2 and 3.4, as appropriate to the flowmeter under test.

6.3 Performance tests

6.3.1 Loss of power for electronic flowmeters

Record the values of all pre-set data, calibration data, alarm set points and total recorded volume (note: this must be a non-zero value). Disconnect the equipment from the power supply. After a period of 30 days reconnect the power supply and report any changes in the values of the pre-set data, calibration data, alarm set points and total recorded volume.

For instruments where user-programmed data is stored in non-volatile memory, the test period may be reduced to 48 hours. Instruments with battery back-up will still be required to undergo the full 30 day test.

6.3.2 Mean error and repeatability

Provide the sensor unit with a reference input at each test point, see 5.3.1. At each test point, record the reading and calculate the error. Repeat the measurements to obtain six discrete readings at each test point.

Where the EN14154 test points used, three determinations shall be carried out at test points 1a (if used), 3, 5 and 6 with six determinations carried out at test points 1, 2 and 5. Repeatability shall be determined at points 1, 4 and 5.

Calculate and report the mean error, $\bar{x}$, and repeatability, u_R, for each test point.

NOTE 1: To ensure that discrete readings are obtained and that any hysteresis effects are captured, the input shall be varied between each reading with the test point approached from both higher and lower values.

NOTE 2: For flowmeters with insertion and non-invasive sensors, see also 6.3.16 and 6.3.17. For flowmeters intended for partially filled pipes, see also 6.3.18.

6.3.3 Supply voltage

6.3.3.1 Mains powered instruments: Provide the sensor with a reference input at test point 4, see 5.3.1, and record the value of the analogue output signal. Vary the supply voltage to the flowmeter using an isolating transformer, in steps of 10V from 230V (or 110V) to the upper and lower limits of the rated operating conditions. At each voltage, record the value of the analogue output signal.

Identify and report the maximum change in error due to supply voltage, X_V.

6.3.3.2 DC powered instruments: Provide the sensor with a reference input at test point 4, see 5.3.1, and record the value of the analogue output signal. Vary the supply voltage to the flowmeter using a variable DC power supply, in steps of 5V from the manufacturer's stated reference voltage to the upper and lower limits of the rated operating conditions. At each voltage, record the value of the analogue output signal.

Identify and report the maximum change in error due to supply voltage, X_V.

6.3.3.3 Battery powered instruments: The batteries shall be removed and power supplied from a variable DC power supply, initially set to the nominal supply voltage. Provide the sensor with a reference input at test point 4, see 5.3.1. Reduce the supply voltage in 0.5V steps. Record and report:

- the voltage at which the low battery alarm occurs;
- the voltage at which the reading changes by more than 10% (if this occurs before the instrument switches off);
- the voltage at which the instrument switches off.

Identify and report the maximum change in error due to supply voltage, X_V, from the readings taken before the low battery alarm is activated.

6.3.4 Output impedance

Connect the analogue output from the flowmeter to a variable resistance load initially set to the reference value. Provide the sensor with a reference input at test point 4, see 5.3.1, and record the reading. Adjust the value of the load resistance to the mean of the upper and lower limits of the rated operating conditions, then to the lower limit. At each value of impedance record the value of the analogue output signal. Repeat the procedure a further two times.

NOTE: If no minimum limit, or zero, is specified, a value of 50Ω shall be used for the minimum impedance value.

Calculate and report the effect on error due to output impedance, X_O.

6.3.5 Fluid temperature

Provide the sensor with a reference input at test point 3, see 5.3.1. Take readings with the fluid at a temperature in the ranges 1°C to 5°C (low limit), 15°C to 20°C (reference) and 25°C to 30°C (upper limit). Take 3 discrete readings in each temperature range.

Calculate and report the effect on error due to fluid temperature, X_{FT}.

6.3.6 Ambient air temperature and relative humidity

During environmental testing, where practicable, the flowmeter shall be continuously supplied with a reference input of known value at fluid reference conditions.

The outputs shall be monitored continuously to identify any transient effects. Data shall also be reported graphically.

Place the flowmeter in a climatic chamber, the temperature of which is set to 20°C. The flowmeter shall be allowed to warm up, if required.

The following conditions shall be set in the climatic chamber in the order given in Table 12, where Tmin and Tmax are the minimum and maximum values for the ambient air temperature range over which the flowmeter is to be certified. The transitional temperatures (steps 2 and 5) may be omitted.

At each step, after a sufficient stabilisation period, the flowmeter shall be provided with a reference input at test point 4, see 5.3.1, and the output recorded. The measurement shall be repeated three times to give three discrete readings.

During each exposure period (steps 3, 6 and 8), any self-cleaning or auto-calibration routines shall be operated at least once, after the 3 reference measurements have been taken. Three further measurements shall then be taken to identify any systematic shifts brought about by operating such routines under different conditions.

NOTE: It is preferable that any automatic cleaning or calibration routines are initiated remotely to avoid opening the chamber and affecting the climatic conditions.

Calculate and report the effect on error due to ambient air temperature, X_T, from steps 3, 4 and 6.

Calculate and report the effect on error due to high humidity and temperature, X_{RH}, from steps 7 and 8.

Table 12 Test cycle for environmental conditions

	Temperature °C	Humidity	Minimum exposure time
1. Reference	20	Reference	2 hours
2. Transition	*(Tmax+20)/2*	*Reference*	*2 hours*
3. High T dry	Tmax	Reference	2 hours
4. Reference	20	Reference	2 hours
5. Transition	*(20+Tmin)/2*	*Reference*	*2 hours*
6. Low T	Tmin	Reference	2 hours
7. Reference	20	Reference	2 hours
8. High T humid	Tmax	≥95% RH	6 hours
9. Reference	20	Reference	2 hours

6.3.7 Incident light

This test shall only be applied to flowmeters using optical measurement methods.

The light source shall be chosen to simulate the spectrum of natural sunlight, for example a high pressure xenon arc lamp. Illuminate the sensor from above.

Provide the sensor with a reference input at test point 3, see 5.3.1.

Cover the instrument to prevent any ambient light reaching the sensor. Record the measurement value given by the instrument.

Illuminate the sensor with an intensity of 1.120 kW/m^2 and record the measurement value given by the instrument.

Repeat the procedure a further two times.

Calculate and report the effect error due to incident light, X_{LX}.

NOTE: Further guidance on solar radiation testing can be found in BS EN 60068-2-5: 2011 Environmental testing. Tests. Test Sa. Simulated solar radiation at ground level and guidance for solar radiation testing.

6.3.8 Sensor location

This test shall only be applied to non-contact velocity sensors.

Mount the sensor above a fluid surface which is flowing at test point 3, see 5.3.1. Tests shall be carried out with the sensor mounted in three locations:

- Upper limit: 95% ± 5% of the maximum separation distance from the surface;
- Reference: Mean of the minimum and maximum separation distances, ±5%;
- Lower limit: 105% ± 5% of the minimum separation distance.

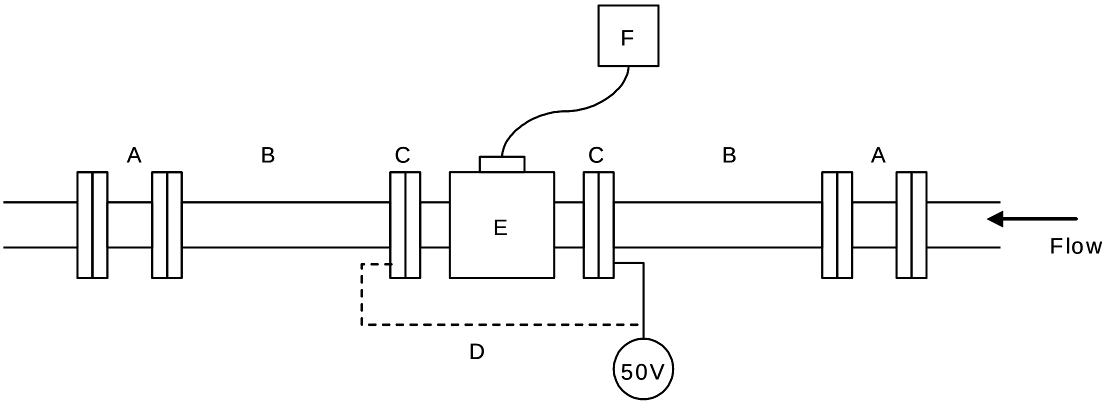
Take three discrete readings with the sensor at each location.

Calculate and report the effect on error due to sensor location, X_{SL}.

6.3.9 Presence of stray currents

This test shall only be applied to flowmeters utilising for electromagnetic sensors.

Install the flowmeter sensor according to manufacturer's instructions between two lengths of metal pipe, which should be unlined and not painted internally to ensure good metal to water contact. Particular attention should be paid to the manufacturer's requirements for potential equalisation. The lengths of metal pipe should be at least 5D long and electrically insulated from the rest of the test rig via rubber couplings or non-conductive pipe. The preferred test configuration is shown in Figure 1.



A Insulating sections

B Metal pipe ≥ 5D

C Ensure any cross bonding and potential equalisation rings (if required) are installed to manufacturer's instructions

D Additional link if required (see text)

E Sensor

F Transmitter (may be integral with sensor)

Figure 1Test configuration

Pass flow through the meter at test point 2, see 5.3.1, and record the reading.

Apply a voltage of 50V (r.m.s.) to the pipe upstream of the flowmeter and record the reading.

Repeat the procedure a further two times.

Calculate and report the effect on error due to stray currents, X_{SC}.

If the manufacturer does not specify bonding for the equalisation of potential both up and downstream of the sensor, then the test shall be repeated with the up and downstream lengths of metal pipe joined electrically (link D in Figure 1).

6.3.10 Direct solar radiation

This test shall be applied to all air firing ultrasonic level sensors.

NOTE 1: If a manufacturer recommends that a sunshade should be fitted over or around the ultrasonic transducer and/or external temperature sensor (if used) when installing the instrument in an exposed location, this test shall be conducted with the sunshade in place.

NOTE 2: When monitoring temperature within the ultrasonic path, the temperature monitoring device shall be small and offset from the direct line between transducer and target to avoid interference with the ultrasonic signal.

NOTE 3: Experimentation has shown that a 500W metal halide lamp (colour temperature 5000 to 5200K) and a 500W tungsten halogen lamp (colour temperature 3000 to 3300K) used together provide sufficient intensities in the visible and infrared parts of the spectrum to simulate the effect of solar radiation on an ultrasonic transducer. The lamps should be in floodlight housings mounted side by side approximately 0.55 m above the transducer.

Install the flowmeter in an enclosed test space with a controlled environment.

The test space shall meet the following requirements while the test is being conducted:

- There shall be a source of radiant energy supplied by a lamp or combination of lamps that simulate the solar spectrum (see Note 3)
- The mean ambient temperature within the test space shall be within the range 15 to 25°C with a maximum deviation of ±2.5°C around the mean
- There shall be negligible draughts or air currents within the test space other than the convection currents that naturally occur as the air beneath the lamps is heated
- There shall be no other sources of radiant energy (e.g. lights or radiant heaters) operating in the test space during the test
- In order to simulate the transducer being in an open environment:
    - there shall be at least 600mm of free space above the lamps
    - the test space shall be at least 1.5 m square

Position the transducer at 50% ±5% of the certification range plus the minimum separation distance from a fixed target surface. The design of the transducer support bracket shall be such that any shading of the transducer by the bracket is minimised.

Apply radiant energy directed at what would be the topmost surface of the transducer in its normal installation configuration. The intensity of the radiation at the topmost surface of the transducer shall be 1 kW/m^2 ± 10%.

Set the lamps on an automatic timer such that the test space can be closed and conditions allowed to stabilise for at least 6 hours before the lamps are illuminated.

Operate the lamps continuously for a period of 8 hours. At the end of this period, the lamps shall switch off automatically. The test space shall remain closed for a further minimum period of 6 hours to allow the instrument to reach equilibrium.

Perform at least two complete cycles; each cycle comprising unlit, lit and unlit conditions.

During each test cycle, log the instrument output, ambient and mid-path temperature and light intensity at a minimum frequency of 5 minutes.

Repeat the test with the distance between the transducer face and the target set at the minimum separation distance plus 100 mm.

For each test cycle, calculate the instrument reading under lit conditions as the average value during the final hour with the lamps on, and the instrument reading under unlit conditions as the average value during the final hour with the lamps off. Calculate the change in the instrument output as the difference between these two values.

Identify the maximum change from the completed test cycles and use this value to calculate the effect due to solar radiation, *Xsv*.

6.3.11 Accuracy of computation

This test shall only be applied to level sensors used for open channel flow.

Test the in-built calculations for three structures, chosen from those offered on the flowmeter, which should include:

- a long throated flume
- a V notch thin plate weir
- a broad crested weir, or other structure typical of the intended application.

Provide a reference input at test point 1, see 5.3.1, and record the level measurement given by the instrument, h.

Configure the flowmeter to compute the flow-rate based on each selected structure in turn. Record the flow-rate indicated by the flowmeter.

Calculate the reference flow-rate from the measured level, h, using the appropriate discharge equation and/or the tabulated values in the relevant British or International Standard.

Repeat or reference inputs at test points 3 and 5, see 5.3.1.

Calculate and report the maximum error observed, X_{AC}.

6.3.12 User defined stage-discharge equation

This test shall only be applied to level sensors used for open channel flow.

In turn, enter two stage-discharges characteristics, applicable within the certification range of the flowmeter.

The two characteristics shall be of the general form:

$$Q = f\left(h^n\right)$$

where Q is discharge (flow) as volume per unit time; and h is measured head and where the function includes one or more variable discharge co-efficients. For one user defined curve, the value of n shall be in the range 1.5 to 1.6 as for a flume or flat weir. For the second curve, the value of n shall be 2.5, such as for a V-notch weir.

Alternatively stage-discharge tables or equations provided by manufacturers of non-standard gauging structures may be used.

For each user defined characteristic, provide reference inputs at test points 1, 3 and 5, see 5.3.1, in turn, and record the level measurement, h.

Configure the flowmeter to compute the flow-rate based on that curve.

NOTE: If the curve is entered as a look up table, the test points shall not be co-incident with the values in the look up table such that the flowmeter is forced to interpolate between points.

At each point, record the flow-rate indicated by the flowmeter and calculate the reference flow-rate manually using the defined discharge characteristic and the measured height, h.

Calculate and report the maximum error observed, $X_{U.}$

6.3.13 Bi-directional flow

Provide the sensor with reference inputs at test points 1, 3 and 5, see 5.3.1, but with flow in the reverse direction. At each test point record the reading and calculate the error. Repeat the measurements to obtain three discrete readings at each test point.

Calculate and report the mean error, $\bar{x}$, and repeatability, u_R, for each test point.

NOTE: To ensure that discrete readings are obtained and that any hysteresis effects are captured, the input shall be varied between each reading with the test point approached from both higher and lower values.

6.3.14 Flow reversal

Flowmeters which are not designed to measure reverse flows shall be subjected to a flow at test point 4, see 5.3.1, in the reverse direction for a period of 1 minute. Forward flow shall then be restored. Provide the sensor with flows at test points 1 and 5, see 5.3.1, and make at least three discrete measurements at each point.

Calculate and report the mean error, $\bar{x}$, and repeatability, u_R, for each test point.

6.3.15 Ancillary devices

This test shall only be applied to mechanical meters.

Provide the sensor with flows at test points 1 and 5, see 5.3.1, and make at least 3 discrete measurements at each point, with and without the ancillary device attached.

Calculate and report the mean error, $\bar{x}$, and repeatability, u_R, for each test point with and without the ancillary device attached.

6.3.16 Effect of conduit material

This test shall only be applied to insertion electromagnetic and non-invasive ultrasonic sensors.

Carry out the test in 6.3.2 on three conduits of different materials (see list below), each conduit having a similar nominal bore.

For electromagnetic insertion flowmeters, the pipe materials shall be:

- Plastic (which is electrically non-conducting and non-magnetic);
- Steel (which is electrically conducting and magnetic); and
- Stainless steel (which is electrically conducting and non-magnetic).

For clamp-on ultrasonic flowmeters, the pipe materials shall be:

- Plastic, e.g. MDPE, HPPE, or PVC;
- Metal, e.g. ductile iron, stainless steel or carbon steel; and
- A composite or lined pipe, e.g. cement lined ductile iron.

For each material, calculate and report the mean error, $\bar{x}$, and repeatability, u_R, at each test point.

NOTE: The Certification Body will decide which results shall be incorporated into the calculation of the combined performance characteristic.

6.3.17 Effect of conduit size

*This test shall only be applied to insertion and non-invasive sensors***.**

Test 6.3.2 shall be repeated on a number of conduits over the range of sizes for which certification is being sought, as given in Table 13. These conduits shall be of the same, or similar, material and schedule.

Table 13 Conduit test sizes for insertion or non-invasive sensors

	Ratio D_{max}/D_{min} (note 1)		
Test conduit size	**$D_{max}/D_{min} \leq 5$**	**$5 < D_{max}/D_{min} < 40$**	**$D_{max}/D_{min} \geq 40$**
Small	D_{min} to 1.5 x D_{min}	D_{min} to D_{min} + 0.1 x (D_{max}-D_{min})	D_{min} to 2 x Dmin
Medium 1	-	0.4 x (D_{min} + D_{max}) to 0.6 x (D_{min} + D_{max})	0.2 x (D_{min} + D_{max}) to 0.35 x (D_{min} + D_{max})

Medium 2	-	-	0.5 x (D_{min} + D_{max}) to 0.7 x (D_{min} + D_{max})
Large	0.8D_{max} to D_{max}	0.8D_{max} to D_{max}	0.8D_{max} to D_{max}

Notes for Table 13:

1. Where D_{min} and D_{max} are the minimum and maximum conduit sizes for which certification is being sought.

For each conduit size, calculate and report the mean error, $\bar{x}$, and repeatability, u_R, at each test point.

NOTE: The Certification Body will decide which results shall be incorporated into the calculation of the combined performance characteristic.

6.3.18 Fill level

This test shall only be applied to partially filled flowmeters.

Carry out the test in 6.3.2 under each of the following conditions:

- Varying liquid depth with mean fluid velocity constant at 15%, 50% and 85%, each ± 5%, of the velocity operating range;
- Varying fluid velocity with the fill depth constant at 15%, 50% and 85%, each ± 5%, of pipe bore;
- Under surcharged conditions.

For each fill level, calculate and report the mean error, $\bar{x}$, and repeatability, u_R, at each test point.

NOTE: The Certification Body will decide which results shall be incorporated into the calculation of the combined performance characteristic.

6.3.19 Response time

NOTE: MCERTS recognises that flowmeter response time is difficult to measure on a flow rig where there may be a significant period of stabilisation for the rig itself when the flow-rate is changed which may impact on the apparent response of the flowmeter under test. The following procedure may be varied at the discretion of the Certification Body. The test report shall explain how the test was conducted.

Provide a reference input at a known value. Monitor the input value and the flowmeter response. Increase the input value by at least 20% of the certification range to a point Ref_2. Record a time T_0 when the change in input starts. Record time T_1 as the point where the input value reaches Ref_2. The change should be effected in no more than 30 seconds, i.e. T_1-T_0 ≤ 30. Maintain the input at Ref_2 until a constant reading between 90% and 110% of Ref_2 is reached. Record this point as T_2.

Calculate response time as T_2-T_1.

Repeat the procedure reducing the input from Ref_2 by at least 20% of the certification range.

Repeat the procedure twice more.

Calculate and report the mean response times for an increasing and decreasing change.

NOTE: Should the reading fail to maintain a value within 90% to 110% of the input value after the change, report the value that is reached. In such cases it will not be possible to calculate a response time.

6.3.20 Vibration

This test shall only be applied to flowmeters intended for usage Class I.

Follow the procedures in BS EN 60068-2-64:2008 Environmental Testing Tests. Test Fh. Vibration, broad-band random (digital control) and guidance, summarised as follows:

- Mount the flowmeter on a rigid fixture by its normal mounting means, such that the gravitational force acts in the same direction as it would in normal use;
- Apply random vibrations, over the frequency range 10 to 150Hz, to the flowmeter, in three mutually perpendicular axes in turn, for a period of at least 2 minutes per axis;
- During the application of vibrations the following conditions shall be met:
  - The flowmeter shall be empty of water;
  - Power supply to the flowmeter shall be switched off;
- Total RMS level of vibration shall be 7 ms^{-2};
- ASD level from 10Hz to 20Hz shall be $1m^2s^{-3}$;
- ASD level from 20Hz to 150Hz shall be –3dB/octave.

Following the application of vibration, provide the sensor with flows at test points 1 and 5, see 5.3.1, and make at least three discrete measurements at each point.

Calculate and report the mean error, $\bar{x}$, and repeatability, u_R, for each test point.

Note: Due to the complexity and cost of a random vibration test, a sinusoidal vibration test in accordance with BS EN 60068-2-6 may be acceptable to demonstrate compliance. If a sinusoidal test is used it should be to the following minimum requirements:

- *Frequency range: 10 to 150Hz*
- *Maximum acceleration level: 20 m/s^2*
- *Number of sweep cycles/axis: 20*

- *Sweep rate: 1 octave/minute*
- *Number of axes tested: 3*
- *Duration per axis: 2 minutes*

7. Field test requirements

7.1 Objective of field test

7.1.1 The objectives of the field test are to demonstrate that the performance of a flowmeter is maintained under operational conditions and allow an assessment of the proportion of time for which usable measurement data can be obtained.

It is recognised that no two field trials will be identical and the nature of the trial will depend on many factors such as:

- The flowmeter being tested;
- The intended applications for the flowmeter;
- The availability of existing manufacturer and / or customer data.

Annex F gives guidance in the form of examples of different approaches that may be used to meet the requirements of the field test.

7.1.2 A test plan detailing the proposed field trial shall be submitted to the Certification Body for consideration by the Certification Committee. This shall include:

- Nature of site and specific application;
- Typical flow range;
- Reference method;
- Traceability;
- Installation environment.

NOTE: A questionnaire is available from the Certification Body to assist in collating the information the Certification Committee will need to establish whether data from an existing installation would be acceptable as a basis for certification.

7.1.3 The decision of the Certification Committee on matters of the test plan and data is final.

7.2 Requirements of the field trial

7.2.1 The flowmeter under test shall be the same model as for the laboratory testing. Any differences between to the instrument shall be justified and agreed with the Certification Body.

7.2.2 For all instruments, the field test shall be carried out on a complete flow measurement system, i.e. the field test for a level measurement instrument shall be carried out with the sensor installed on an appropriate gauging structure, similarly a differential pressure sensor shall be field tested with an appropriate primary device.

7.2.3 At least 3 months continuous operation is required. Only in exceptional cases, which must be fully justified (for example, in the case of operation-related interruptions or process breakdown), will it be possible to count shorter testing periods towards the three-month period.

7.2.4 The output of the flowmeter shall be logged continuously over the period of the field test.

7.2.5 Details of ambient conditions pertaining during the field test facilitate the understanding of field test data. Where possible, field test data should be supported by any such relevant data on ambient conditions.

7.2.6 Similarly, details of the process fluid can also facilitate understanding of field test data and provide an indication of the conditions under which the flowmeter was operating. Where possible, field test data should be supported by any such relevant data on process conditions.

7.2.7 During the field test, the performance characteristics of the flowmeter shall be determined under representative operational conditions. This means that the reference measurements shall only be taken when the process is operating normally and all parameters are within the rated operating conditions of the flowmeter.

7.2.8 Data obtained when conditions are outside the rated operating conditions can be reported to demonstrate performance in excess of the MCERTS requirements.

7.3 Error under field test conditions

7.3.1 The error of a flowmeter is determined by comparing the flowmeter's readings with those from a standard reference method (SRM). Possible SRMs for flow are listed in Annex E.

NOTE: It is recognised that some of the methods listed in Annex E may have a greater uncertainty than some of the flowmeters being submitted for certification. The Certification Body shall take such factors into account when assessing data from the field test.

7.3.2 If a second flowmeter is being used for the reference measurement then, where possible, it should be a certified instrument suitable for the application.

7.3.3 A minimum of 24 pairs of readings (simultaneous determinations from the flowmeter and the SRM) shall be taken over the duration of the field test. The timing of readings shall be chosen such that:

- they are spread throughout the field test period;
- the determinand value is stable (i.e. does not change by more than ±5% whilst each pair of readings is being taken);
- they are carried out at a number of different times during the normal operating cycle(s) for the site whether these be diurnal, weekly or monthly;
- they are spread across as wide a range of flow-rates encountered on the test

site as possible;

- they encompass as wide a range of the variations occurring in the test fluid as practicable;

- they are carried out at a number of different points during the maintenance cycle of the instrument.

7.3.4 For each pair of reference measurements the error shall be determined, see Annex C, and reported.

7.3.5 The proportion of errors less than or equal to the value for the combined performance characteristic (see 5.3.1) shall be calculated and reported.

7.4 Up-time

7.4.1 Up-time is the fraction of the total time for which usable measuring data are available from the flowmeter. It is calculated using equation (1).

$$V = 100\left(\frac{t_G - t_A}{t_G}\right) \qquad (1)$$

Where

V = up-time;

t_G= total operating time;

t_A = total outage time.

7.4.2 The outage time shall be summarised and reported in a table, as shown in Table 14.

Table 14 Summary of up-time test results

Time	TOTAL
Total operating time (t_G)	minutes
Outage time: • automatic maintenance and calibration times • scheduled manual interventions • device malfunction and repairs • other servicing, adjustment Total outage time (t_A)	 minutes minutes minutes minutes minutes
Up-time	%

7.5 Maintenance

7.5.1 Any maintenance activities, scheduled or otherwise, required during the field test shall be recorded.

7.5.2 Settings and frequency of any automatic maintenance or calibration routines shall be recorded.

7.5.3 Any changes to the frequency of any automatic or scheduled manual maintenance activities during the field test period shall be reported.

7.5.4 If one or more major components (for example, the entire sensor or transmitter) of the flowmeter are replaced during the field test period, the matter shall be referred to the Certification Body who shall consider whether additional data is required.

7.5.5 The following shall be reported with regards to each unscheduled maintenance event:

- nature of the fault;
- actions required to remedy fault;
- time taken in man-hours to remedy the fault;
- any problems or difficulties experienced in following the manufacturer's recommendations for fault diagnosis and repair;
- requirement for manufacturer's attendance on site;
- any components replaced;
- total time while the flowmeter was not operational, i.e. time from point of failure to the flowmeter coming back on line.

7.5.6 If the total time while the flowmeter is not operational due to failure is more than two weeks, the Certification Body may require an extension of the test to ensure that sufficient operational data are collected.

7.6 Reporting of field test

7.6.1 The field test shall be summarised in the MCERTS test report.

Annex A – Definitions

NOTE: Underlined terms within a definition are themselves defined in this Annex.

Ancillary equipment: Any additional equipment which may be required for operation of the flowmeter on site but which does not normally form part of the flowmeter package. Examples include external data loggers or telemetry equipment, power conditioning devices, lightning protection, external pumps or compressors required for automatic cleaning systems.

Bi-directional flow: Flow of fluid which may be in either direction through a pipe or channel.

Certification range: Range over which the flowmeter is tested.

Combined performance characteristic: Combination of individual performance characteristics, see Annex C.

Conduit: Pipe or channel through which water is flowing.

Determinand: The property that is required to be measured.

Error (x): Difference between the value given by the flowmeter and the conventional true value, see Annex C.

Expanded uncertainty (U): Quantity defining a level of confidence about the result of a measurement that may be expected to encompass a specific fraction of the distribution of values that could reasonably be attributed to a measurement, see Annex C.

NOTE: The level of confidence would typically be 95%.

Flowmeter: An instrument which measures the flow-rate or totalised volume of fluid passing along a conduit, or computes such quantities from measurements of one or more properties which have a defined relationship with the flow-rate.

Flow-rate (q): The volume of fluid passing through the flowmeter per unit time.

NOTE: EN14154-1 Water meters. General requirements defines a number of flow-rate points to define the range of a water flowmeter. These are:

Q1 (minimum flow-rate), the lowest flow-rate at which the flowmeter is required to operate within the maximum permissible error defined in the standard.

Q2 (transitional flow-rate), flow-rate which occurs between Q1 and Q3 that divides the flow-rate range into the upper zone and the lower zone, each characterised by its own maximum permissible errors.

Q3 (permanent flow-rate), the highest flow-rate at which the flowmeter is required to operate in a satisfactory manner within the maximum permissible error.

Q4 (overload flow-rate), the highest flow-rate at which the meter is required to operate for a short period of time, within its maximum permissible error, whilst maintaining its metrological performance when subsequently operated at lower flow-rates.

EN 14154-1 Water Meters: General Requirements defines the measuring range of a flowmeter as the ratio Q3/Q1 (taken from a table of fixed values), and fixes the ratio Q4/Q3 as 1.25 and Q2/Q1 as 1.6.

Gauging structure: A constriction installed in a channel which ensures that the fluid depth at a predetermined point upstream has a known relationship with volumetric flow-rate.

Indicating device: Visual display incorporated into the flowmeter showing the measured value of the determinand.

Influence quantity: Any quantity, generally external to the equipment, which may affect the performance of the equipment.

Insertion sensor: Sensor designed to be inserted into a process pipe, suspended in a channel or mounted internally in a pipe or channel directly in contact with the fluid. Examples include electromagnetic insertion sensors, floor mounted ultrasonic sensors for partially filled pipes or channels and retro-fit (wetted) ultrasonic sensors for pressurised pipes.

Lower zone: The part of a meter's flow-rate range between Q1 and Q2 (see note under *flow-rate*).

Non-contact sensor: Sensor for level or fluid velocity measurement, which mounts above a fluid surface and makes no contact with the fluid under normal operation.

Non-intrusive sensor: Sensor which is in contact with the fluid but does not present any obstruction or intrusion into the flow. Examples are a full bore electromagnetic flowmeter or a spool piece ultrasonic flow meter.

Non-invasive sensor: Sensor for application to a pipe which attaches to the outside of a pipe and requires no tapping, drilling or cutting of the pipe to install, for example clamp-on ultrasonic transducers.

NOTE: In hydrometry, the term non-invasive is frequently used for ultrasonic or electromagnetic gauges which may, though not always, be installed in a dedicated section of the channel. In other applications and for the purposes of this specification, these are considered as non-intrusive sensors.

Output: A reading, or a digital or analogue electrical signal, generated by an instrument in response to a determinand.

Partially filled pipe: A closed conduit in which, under normal operating conditions, there is free surface flow but, under some circumstances may become surcharged, and behave as a pressurised pipe.

Performance characteristic: One of the quantities (described by values, tolerances, range) assigned to a flowmeter in order to define its performance.

Primary device: Restriction placed in a flow which generates a change in a property of the flow having a known relationship to volumetric flow-rate.

Range [for level sensors]: The minimum to maximum fluid depth that can be measured by the flowmeter.

Rated operating conditions: The minimum to maximum values of any environmental, fluid or electrical parameter within which the flowmeter is designed to operate without adjustment, with errors within the required uncertainty.

Reference conditions: A specified set of values (including tolerances) of influence variables, delivering representative values of performance characteristics.

Reference method: Method to be used to obtain the determinand value to a stated uncertainty, against which the readings from the equipment under test can be compared.

Repeatability: The ability of a flowmeter to provide closely similar indications for repeated applications of the same determinand under the same conditions of measurement.

Sensor: Transducer consisting of one or more components from which is derived an electrical or mechanical output related to the flow-rate or another property, such as liquid level, flow velocity or differential pressure from which the flow-rate may be computed.

NOTE: The sensor and transmitter may be incorporated within a single housing.

Spool piece sensor: Sensor unit in which the measurement mechanism is incorporated into a discrete length of tube which is installed as a continuous part of the pipeline.

Stage-discharge characteristic: The relationship between the upstream liquid level (stage) and the discharge (flow-rate) through a gauging structure.

Standard uncertainty (u): Uncertainty of the result of a measurement expressed as a standard deviation.

Surcharged conditions: Surcharged conditions occur when a pipe which normally runs part-filled backs up to the extent that it becomes full and a pressure head develops upstream to drive the flow.

Totalised volume: The total volume of fluid which has been measured by the flowmeter over a period of time which commenced when the totaliser was set to zero.

Totaliser: Indicating device showing the totalised volume.

Transmitter: Device which takes the signal from the sensor and converts it into a visual or electrical output proportional to the determinand. The transmitter may include a user interface with the instrument.

Uncertainty: The parameter associated with the result of a measurement that characterises the dispersion of the values that could reasonably be attributed to the determinand.

Upper zone: The part of a flowmeter's flow-rate range between Q2 and Q4 (see *flow-rate*).

Up-time: The fraction of the total time for which usable measuring data are available from the flowmeter.

Annex B – Certification Process

B1 Certification process

Product certification comprises three phases. These are:

- **Laboratory testing** – used to determine performance characteristics, where such testing requires a highly controlled environment.

- **Field testing** – carried out on processes representative of the intended industrial sectors and applications.

- **Surveillance - initial and continuing** – which comprises an audit of the manufacturing process to confirm that the manufacturer has provisions to ensure manufacturing reproducibility and to control any design changes to ensure that they do not degrade performance below the MCERTS standards.

Manufacturers seeking certification should contact the Certification Body who will advise on any specific requirements for the flowmeter under consideration.

Where a flowmeter can be supplied with a number of options, for example different liner or electrode materials, remote or integrated transmitter, flanged, screwed or clamp couplings, or is available in different sizes, or where more than one sensor or sensor configuration can be used to cover different ranges, one complete flowmeter shall undergo the full conformity tests. In selecting the options to be tested, consideration should be given to the selections for that flowmeter type likely to be used for each of the identified applications. For additional sensors, sensor configurations or other options, it may be possible to extend certification by carrying out a subset of the full test programme or selected additional tests in cases where the options are likely to have a significant effect on the performance of the flowmeter. Similarly, where different transmitters having different facilities may be used with a single sensor, one complete flowmeter shall undergo the full conformity tests. For additional transmitters, it may be possible to extend certification by carrying out a subset of the full test programme.

When the performance of a certified product is likely to be invalidated by use of alternative equipment, e.g. non-certified sensors, an appropriate reminder to users of the product may be included on the certificate.

Certification Committee

- The role of the Certification Body is to assess and certify compliance with the MCERTS standard for defined applications and or conditions.

- In performing this role the MCERTS scheme requires the Certification Body to consider the relevance of the procedures defined in the MCERTS standard to the specific product to be certified. The technology or defined application of a specific product may make certain of the documented tests inappropriate. The Certification Body is required by the MCERTS scheme to exercise its technical judgement when considering these matters.

- Any certification decision based on technical judgement of the standard shall be taken by an appropriately independent, competent person or group of persons, who in this MCERTS standard are referred to as the “Certification Committee”.

- When the Certification Committee exercises its technical judgement the rationale supporting any such decision shall be appropriately documented.

- Any certificate issued by the Certification Body shall identify any variations from the normative MCERTS standard.

- On request the Certification Body shall provide the MCERTS scheme owner with the rationale for any decision based on technical judgement, within the relevant confidentiality constraints.

Certification range

A flowmeter will be certified over the measurement range for which it is tested. If a manufacturer wishes to demonstrate performance over one or more supplementary ranges some additional testing will be required over those ranges. This additional testing shall at least include evaluations of the mean error and repeatability.

The extent of the environmental testing will be agreed between the manufacturer and the Certification Body, taking into account the intended usage class of the instrument. Similarly for flowmeters with insertion or non-invasive sensors, certification will cover a range of conduit sizes agreed between the manufacturer and the Certification Body which will be reported on the MCERTS certificate. Testing will be carried out on a range of conduit sizes within that range.

B2 Testing

Manufacturers may commission testing from any organisation, provided that the requirements for testing organisations can be met (see 5.1.1). Manufacturers' own test data may also be acceptable. This applies to both laboratory and field tests.

Certain tests may present practical difficulties for certain flowmeters, e.g. 6.3.5 which requires variations in fluid temperature may present difficulties when testing a very large flowmeter. In such cases, manufacturers should discuss such matters with the Certification Body to determine the most appropriate course of action.

Field test

The field test requirements take into account two scenarios:

- Established products that have a track record of use in a variety of applications;

- Products that are new onto the market and as such do not have data to demonstrate use in a real environment.

In keeping with the European new approach directives, MCERTS sets out some essential requirements, (see Section 7) written in general terms which must be met before products can be certified as meeting MCERTS.

Emphasis will be placed upon the manufacturer setting out a case justifying, with appropriate evidence, why the product will meet the field test requirements.

Acceptable data might include:

- Field test reports from qualified laboratories;

- Validated reports from users of the equipment;

- Manufacturers' data validated by an independent third party.

This data will be augmented by a rigorous assessment of maintenance and service records carried out during the manufacturing audit. More emphasis will also be placed on continued compliance of the products to the general requirements and this will be carried out during the regular surveillance audits.

The field test requirements are intended to be sufficiently flexible to allow manufacturers to utilise existing installations, provided that there is some way of validating measurements by one of the reference methods described in Annex E. Alternative methods may also be acceptable but in such cases, the manufacturer is advised to discuss the matter with the Certification Body to ensure that the proposed method is acceptable.

Where data from an existing installation is used in support of an MCERTS certification, it should be from a flowmeter of the same type for which certification is sought. Any options included in the field test device shall be reported, as shall any modifications or differences between it and the device used in the laboratory testing stage. The Certification Body may require the full history of the flowmeter since its installation, including details of any maintenance or repairs. Corroboration may be sought from the site owner via a confidential questionnaire.

B3 Auditing and surveillance

An audit of the manufacturing process shall be conducted by the Certification Body to confirm that the manufacturer has provisions to ensure manufacturing reproducibility and to control any design changes that may affect product performance.

Subsequent surveillance audits are normally conducted annually until sufficient evidence of a well-proven, robust system has been collected. Once this has been established the Certification Body may extend the interval between audits or require submission of specific audit data for review off site.

B4 Certificate validity

MCERTS certificates are valid for five years. After this time, the certification is reviewed and any necessary retesting will be identified to maintain the certification. Assessment for recertification shall be carried out against the MCERTS standards current at the time of recertification.

B5 Modifications to certified flowmeters

Modifications to a certified flowmeter are allowable so long as manufacturers can demonstrate to the Certification Body that these design changes do not degrade the performance of the flowmeter below the MCERTS performance standards.

Manufacturers must keep detailed records and drawings of all design changes to a flowmeter, and have provisions for design verification and inspection to ensure that the flowmeter still meets the required performance standards.

The Certification Body will conduct audits of the design and software changes to a flowmeter to meet the requirements of product certification. Manufacturers must inform the Certification Body of any modification affecting any of the documents, drawings or other information referred to in the certificate.

Annex C - Determination of performance characteristics

C1 Introduction

The approach to specifying performance requirements and analysing data from product testing to be used in the certification of water monitoring equipment against the MCERTS performance requirements has been developed to be:

- Internationally acceptable, i.e. based on the principles of the ISO Guide to the Expression of Uncertainty in Measurement (GUM);
- Consistent with the approach taken across the MCERTS business;
- Applicable across the range of different equipment types and technologies covered by MCERTS product certification; and
- Fit for purpose.

C2 Errors

For any individual test point, the error, *x*, is the difference between the value given by the flowmeter and the conventional true value.

Note: In this standard, errors are expressed as a percentage of reading, except for level sensors which are expressed as percentage of range.

The mean error, $\overline{x}$, from a series of *n* measurements is:

$$\overline{x} = \frac{\sum_{1}^{n} x_i}{n}$$ Equation C1

C3 Repeatability

Repeatability is standard deviation of the measurements taken at reference conditions.

$$u_R = \sqrt{\frac{\sum_{i=1}^{n} (\overline{x} - x_i)^2}{n-1}}$$ Equation C2

As the MCERTS test for repeatability (see 6.3.2) requires the test point to be approached from both higher and lower values, the calculation of repeatability here includes any effect due to hysteresis.

C4 Effect of influence quantities

The performance requirement for the effect of an influence quantity, X_I, is the half range of any change in error resulting from varying the influence quantity from a low to a high value, including the reference value, expressed as a percentage of reading, i.e. referring to Figure C1:

$$X_I = \left(\frac{\left| \overline{X}high - \overline{X}ref \right| + \left| \overline{X}low - \overline{X}ref \right|}{2} \right)$$ Equation C3

Note 1: In the relative humidity test (6.3.8) the reference condition and the low value for the influence quantity are the same, hence $(\overline{X}low - \overline{X}ref)$ is zero.

Note 2: In cases where the response is U shaped, see Figure C2, calculate X_I as half the maximum difference, i.e. in the example shown in Figure C2:

$$X_I = \left(\frac{\left| \overline{X}high - \overline{X}ref \right|}{2} \right)$$ Equation C4

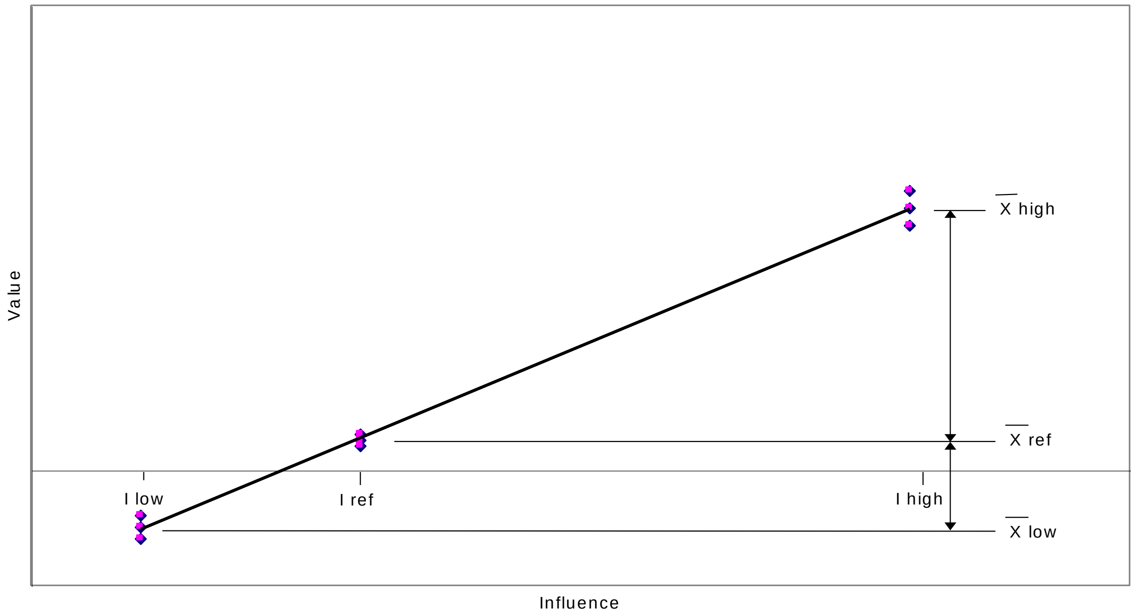


Figure C1 Effect of influence quantities – linear response

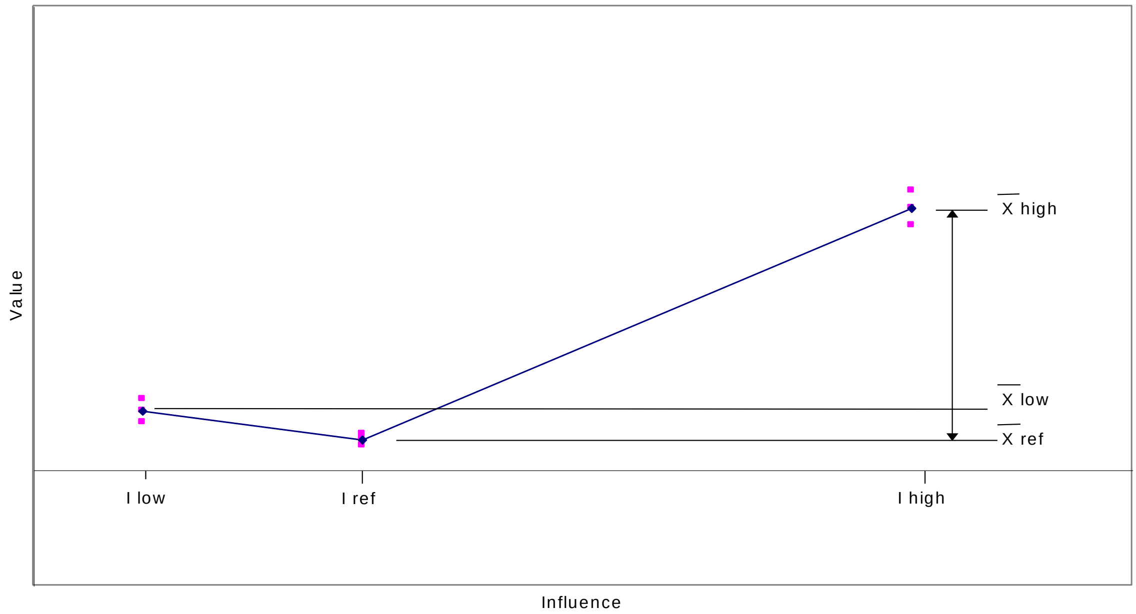


Figure C2 Effect of influence quantities – U shaped response

C5 Combined performance characteristic

It is frequently convenient to have a single value for an instrument's uncertainty under any circumstances. MCERTS therefore defines a combined performance characteristic by combining the components measured in the individual tests. To combine the characteristics in accordance with the GUM it is necessary to convert them to standard uncertainties (*u*) which take account of the probable distribution of errors.

For the purposes of this standard, resolution and all measured characteristics (except repeatability) are assumed to have a rectangular probability distribution, i.e. there is an equal chance of any value of error occurring within the range that has been measured in any individual test. In the case of a rectangular distribution the standard uncertainty is calculated as:

$$u = \frac{X}{\sqrt{3}}$$ Equation C5

Repeatability has been calculated as a standard deviation at each test point (Equation C2) and hence represents a normal distribution of errors. The value to be used in the calculation of the combined performance characteristic shall be the maximum value measured, excluding that taken at test point 1.

In the GUM, standard uncertainties are combined using a root square sum with due account taken of the contribution of each component through the use of sensitivity co-efficients. To determine sensitivity co-efficients, it is necessary to know the analytical functions by which each component contributes to the overall error. In the case of instrument testing this will rarely be known. Hence for the purposes of this standard, the sensitivity co-efficients are all taken as 1. However, in specific cases, the certification committee may require particular weighting to be given to certain components and hence require other values of sensitivity co-efficients to be used.

The requirement for the combined performance characteristic is expressed as an expanded uncertainty. The expanded uncertainty, *U*, is obtained by multiplying the standard uncertainty by a coverage factor. The coverage factor is determined by the confidence level required. For MCERTS, a 95% confidence is used with a coverage factor assumed to be 2. Thus:

$$U_C = 2 \times u_C \qquad \text{Equation C6}$$

Table C1 shows the components which are to be combined when determining the combined performance characteristic, U_c. Specific components depend on the type of flowmeter, although some are common to all types of flowmeter.

Table C1 Components for the combined performance characteristic

Performance characteristic	**Symbol**	**Test**
(Mean error – see below)	u_A	6.3.2
Repeatability	u_R	6.3.2
Resolution	u_{RES}	3.1.15 (requirement)
Supply voltage	u_V	6.3.3
Output impedance	u_O	6.3.4
Fluid temperature	u_{FT}	6.3.5
Ambient air temperature	u_T	6.3.6
Incident light	u_{LX}	6.3.7
Sensor location	u_{SL}	6.3.8
Presence of stray currents	u_{SC}	6.3.9
Direct solar radiation	u_{SV}	6.3.10
Computation accuracy; or User defined curve [1]	u_{AC} or u_U	6.3.11 or 6.3.12

1: The larger of u_U and u_{AC} shall be used in the calculation of U_C.

Inclusion of Mean Error

The certification committee shall decide on a case by case basis whether the mean error shall be included in the calculation of U_C. A net mean error in test 6.3.2 could indicate a number of things, for example:

- For a factory calibrated instrument a net mean error could be due to a systematic offset between the test house facility and the manufacturer's calibration facility, both of which could have demonstrable traceability routes. In such cases it would be unfair to include it in U_C.

- For a user calibrated instrument, a net mean error could be the result of deficiencies in the calibration routine or the calibration standards supplied by the manufacturer. In these cases the mean error should be included in U_C.

The certification committee shall take such factors into account and be able to justify the inclusion or otherwise of the mean error component in U_C.

Where a mean error component is included, it shall be as a standard uncertainty with an assumed rectangular distribution, i.e.:

$$u_A = \frac{(\max \ \bar{x})}{\sqrt{3}} \qquad \text{Equation C7}$$

The combined performance characteristic, U_C, is therefore calculated by summing the components as a root sum of their squares and multiplying by the coverage factor, 2, i.e.

$$U_c = 2 \times \sqrt{u_A^2 + u_R^2 + u_{RES}^2 + u_V^2 + u_O^2 + u_{FT}^2 + u_T^2 + u_{LX}^2 + u_{SL}^2 + u_{SC}^2 + u_{SV}^2 + u_{AC}^2}$$

Equation C8

NOTE: u_U may be substituted for u_{AC} if it is larger value.

C6 Worked example

An electromagnetic flowmeter is to be certified over the range 0-60 l/s. It is subjected to the test procedure in 6.3.2 and the readings in Table C2 are obtained (in l/s).

Table C2 Example measurement results

Test point:	1	2	3	4	5
Ref. value	3.00	15.60	28.80	46.20	58.18
Run 1	2.98	15.58	28.78	46.14	58.17
Run 2	2.97	15.56	28.77	46.24	58.12
Run 3	2.99	15.57	28.78	46.22	58.00
Run 4	3.00	15.59	28.82	46.17	58.22
Run 5	3.01	15.59	28.83	46.15	57.80
Run 6	2.98	15.62	28.85	46.25	57.75

The errors (in l/s) for each measurement are determined by subtracting the reference value from each reading, then converted to percentage of reading to obtain the values shown in Table C3. The mean error at each test point is calculated from Equation C1.

Table C3 Errors from example measurement data

Test point	1	2	3	4	5
Run 1	-0.67%	-0.13%	-0.07%	-0.13%	-0.02%
Run 2	-1.01%	-0.26%	-0.10%	0.09%	-0.10%
Run 3	-0.33%	-0.19%	-0.07%	0.04%	-0.31%
Run 4	0.00%	-0.06%	0.07%	-0.06%	0.07%
Run 5	0.33%	-0.06%	0.10%	-0.11%	-0.66%
Run 6	-0.67%	0.13%	0.17%	0.11%	-0.74%
Mean error	-0.39%	-0.10%	0.02%	-0.01%	-0.29%

The mean errors at each test point are compared with the MCERTS requirement for mean error for a performance Class 1 flowmeter.

The certification committee decides that as the instrument has been calibrated by the manufacturer on a UKAS accredited rig, no component of mean error shall be incorporated into the combined uncertainty calculation.

The repeatability at each test point is calculated from Equation C2 as shown in Table C4.

Table C4 Example repeatability values

Test point	1	2	3	4	5
Standard deviation	0.49%	0.13%	0.11%	0.10%	0.34%

The repeatability values at each test point are compared with the MCERTS requirement for repeatability and are also within the requirements for a Class 1 flowmeter.

The value for repeatability to be carried through to the calculation of the combined performance characteristic is the maximum, excluding test point 1, in this case 0.34%.

The instrument is then subjected to a test for the effect of output impedance. Three measurements are taken at test point 4 with the output impedance at its reference value, then 3 more with the output impedance at its lower limit and 3 more with the output impedance at its upper limit. The data points in Table C5, in l/s, are obtained.

Table C5 Example influence quantity results

Reference value	Lower limit	Reference conditions	Upper limit
28	27.85	27.91	28.15
27.8	27.76	27.90	27.91
28.6	28.42	28.58	28.71

The errors, as percentage of reading, are as shown in Table C6.

Table C6 Influence quantity errors

	Lower limit	Reference conditions	Upper limit
1st measurement	-0.54%	-0.32%	0.53%
2nd measurement	-0.14%	0.36%	0.39%
3rd measurement	-0.63%	-0.07%	0.38%
Average	-0.44%	-0.01%	0.44%

The effect of output impedance is calculated from Equation C3 as:

$$X_O = \frac{|0.44 - (-0.01)| + |-0.44 - (-0.01)|}{2} = 0.44\%$$

X_O is compared with the MCERTS performance characteristic for the influence of output impedance. From Equation C5, the component to be included in calculation of U_C is 0.44/√3 = 0.25%.

The instrument undergoes all remaining MCERTS performance tests with the results as shown in Table C7.

Table C7 Example performance characteristics

Performance characteristic	Symbol	Value
Repeatability	u_R	0.34%
Output impedance	u_O	0.25%
Supply voltage	u_V	0.45%
Ambient air temperature	u_T	0.25%
Incident light	u_{LX}	N/A (not an optical sensor)
Fluid temperature	u_{FT}	0.00%
Presence of stray currents	u_{SC}	0.28%

The combined performance characteristic is then calculated from Equation C8.

$U_C = 2 \times (0.34^2+0.25^2+0.45^2+0.25^2+0.00^2+0.28^2)^{1/2}$

$= 1.44\%$

This value is compared with the MCERTS requirement for the combined performance characteristic and the flowmeter is within the Class 1 limits for all requirements, including U_C.

Annex D – Usage groups

Table D1 gives guidance on the operating conditions to which flowmeters are likely to be subjected (see BS EN 14154-1:2004). The extent of environmental testing shall be agreed between the manufacturer and the Certification Body, taking into account the intended usage group of the flowmeter.

Table D1 Usage groups (for guidance)

Usage group	Explanation	Recommended rated operating conditions
B	For fixed meters inside a building. This class applies to enclosed locations where temperature and humidity are not necessarily controlled. Heating may be used to raise low temperatures, e.g. for frost protection. Flowmeters may be exposed to solar and heat radiation and draughts and may be subject to condensed water and water from sources other than rain. Vibration and shocks will be of low significance.	Ambient air temperature: +5°C to +55°C See 4.6.2 for minimum Relative humidity: 5% to 95% RH including condensation
C	For fixed meters installed outdoors. This class applies to open locations with average climatic conditions, excluding polar and desert environments. Flowmeters are likely to be exposed to solar and heat radiation and draughts and may be subject to condensed water, water from sources other than rain and to ice formations. Vibration and shocks will be of low significance.	Ambient air temperature: -25°C to +55°C See 4.6.3 for minimum Relative humidity: 5% to 95% RH including condensation
I	For mobile meters. This class applies to open locations with average climatic conditions, excluding polar and desert environments. Levels of vibration and shock may be high, for example flowmeters mounted directly on machinery, such as irrigation reels, mobile pumps and tankers.	Ambient air temperature: -25°C to +55°C See 4.6.3 for minimum Relative humidity: 5% to 95% RH including condensation

Different usage groups may apply to individual components of the flowmeter.

Annex E - Standard reference methods

(Normative)

E1 Laboratory methods

Laboratory determinations of total volume passed may be based on weigh tanks, volumetric methods or transfer standard reference meters. For flow-rate determination, the volume shall be divided by the flow duration. Reference meters may provide flow-rate directly, depending on their type.

For level sensors, fixed targets may be used (unless the test procedure requires a flowing surface), the distance from the sensor being established by a traceably calibrated length measurement device.

There are various methods for establishing the position of a fluid surface relative to a datum which would be acceptable to MCERTS, provided that they have been calibrated in such a way as to be traceable to National standards and provide a resolution and uncertainty commensurate with the requirements of the test being undertaken. These include pressure transducers, float and shaft encoders, mechanical gauges (e.g. hook gauges) and solid state devices (e.g. radar gauges).

E2 In situ methods

There are a number of techniques by which flow measurements may be verified in-situ. The choice of technique will be largely influenced by site conditions. However, it is recognised that the errors associated with some of these techniques may be higher than the errors claimed for some of the types of meters under test. This should be borne in mind when selecting which technique to use and when interpreting field test data. The most appropriate method for the site should be used which minimises testing uncertainty. Methods which measure volume passed will also need a flow duration to compute flow-rate.

Possible methods are:

- Reference meter – a second flowmeter of known and demonstrable uncertainty in series with the meter under test (volume passed or flow-rate);

- Dilution methods – the introduction of a tracer into the flow and its subsequent detection downstream (see BS 5857 Part 1 for closed pipe flows and BS 3680 Part 2 for open channel) (flow-rate);

- Volumetric methods (drop tests) – the diversion of the flow into a vessel of known volume, or the release of fluid from a tank of known volume through the flowmeter (volume passed);

- Velocity area methods (insertion flowmeters) – the integration from a number of point velocity measurements spaced across the flow (see BS 1042 Part 2 Measurement Of Fluid Flow In Closed Conduits. Velocity Area Methods for closed pipe applications and BS EN ISO 748:2007 Hydrometry. Measurement of liquid flow in open channels using current-meters or floats, for open channel applications);

- Thermodynamic methods – measurement of the changes in fluid temperature and pressure across a pump to infer flow-rate (flow-rate);

- Fixed targets for level sensors.

To monitor whether there have been any changes to a flowmeter, or drift, which might be undetectable by the reference method during a field test it may be preferable to do a laboratory calibration immediately before and immediately after the field test. Care should be taken when removing the meter and carrying out the second calibration not to disturb any fouling on the sensor. A reference would still be required for the duration of the field test to enable the determination of up-time.

Annex F – Examples of evidence

The MCERTS Certification Body can accept evidence from a variety of sources. The following examples may be used as guidance when determining an approach to meet the field trial requirements. The proposed approach shall be agreed with the Certification Body whose decision on the acceptability of the any approach is final.

Case study 1 – New instrument with a full field trial run by test house

Background

The instrument under test was a new model. Therefore only limited data existed from product development testing.

Available existing data

None which met the MCERTS requirements for field test data.

Approach

One new fully serviced instrument was supplied for the field trial. This was the same model, although not the same instrument, as that used for the laboratory testing. The trial was run in conjunction with a user known to the test house. The trial consisted of three months continuous operation of the instrument in a typical application acceptable to the Certification Body.

How the data requirements were met

The manufacturer and the test house agreed the method by which reference measurements could be taken. The reference method was checked in the laboratory against a traceable standard. The instrument was operated continuously for a period of three months. The instrument output was logged by a dedicated data logger. Twice a week, the test house visited the site, downloaded the logger and took a reference measurement. During the field trial 24 paired measurements were made. Each pair comprised a reading from the instrument and the reference measurement. The timing of the 24 measurements was arranged so as to cover a range of flow-rates.

In addition to recording the values given by the instrument under test, measurements of fluid temperature and other background parameters were made. All maintenance activities both scheduled and otherwise were recorded and the Certification Body kept informed of any deviations from the schedules given in the test plan. At the end of the test period, the test house removed the instrument. Up-time was determined at the end of the trial using the data from the test instrument. All the information collected was recorded in a log book which was made available to the Certification Body when the trial finished.

Case study 2 – Existing instrument, field test run by manufacturer

Background

The instrument under test was an existing instrument in use with a number of customers.

Available data

Whilst users had records of readings taken over an extended period, no formal validation of any of those readings was available.

Approach

The manufacturer approached a customer with whom they had a good relationship. The customer agreed to have the instrument installed on their site, to operate the instrument as part of a field trial and also to carry out a number of flow checks using a second method. The customer was also happy to release records of all readings taken during this period and respond to any questions raised by the Certification Body. It was made clear to the customer that the records would be used solely for the purpose of MCERTS certification. At the start of the test, the manufacturer serviced the instrument and checked response time.

How the data requirements were met

The test instrument was operated continuously for a three month period without interruption. The readings obtained with the second method were compared with those obtained from the flowmeter under test. This provided 24 paired readings for assessment of field performance. The reading records proved the test instrument had operated continuously for a three month period and met the up-time requirement. The Certification Body put some brief questions to the user to ensure that the trial, though run by the manufacturer, had been conducted in a fair and unbiased manner. It was acknowledged that the reference method used by the customer was inferior in its potential accuracy to that of the flowmeter under test. However, it was shown to be repeatable and was checked against a primary standard and found to be operating within its own performance limits. As the difference between the readings from the flowmeter under test and the reference method was consistently within the uncertainty envelope of the reference method, the Certification Committee took the view that the instrument under test had maintained its performance for the duration of the field trial.

Case study 3 – Existing instrument using customer records

Background

The instrument under test was an existing model in use with a number of customers on different applications. One customer was evaluating the instrument against another flowmeter from a different manufacturer. Prior to the evaluation, the reference instrument had been calibrated at a UKAS accredited facility.

Available existing data

The customer had in excess of 6 months continuous records of the readings from the test instrument and the other instrument.

Approach

The user agreed to release the calibration records of the reference instrument and the 6 months of readings from both instruments for the purpose of MCERTS certification. The data was shown to be robust and no further field trial was required.

How the data requirements were met

A random selection of paired readings was taken that were spread throughout the trial period and covering the full range of flows experienced at the site. These were used to calculate the field test error. The continuous data from both instruments proved the operation of the test instrument over the trial period and enabled calculation of the up-time.

Case study 4 – Existing instrument carried out by manufacturer using a second instrument

Background

The instrument under test was an existing model but with no field test data available.

Available existing data

None which met the requirements of MCERTS.

Approach

The manufacturer agreed with a customer to run the site trial on their site. Two flowmeters of different models were calibrated on a UKAS accredited flow-rig prior to installation on a customer's site. The two instruments were operated over a period of 3 months during which time they were continuously logged on a dedicated data logger. At the end of the trial the two instruments were removed from the site and re-tested on the UKAS rig.

How the data requirements were met

Comparison of the UKAS calibrations from the start and end of the trial showed that there had been no change in performance from either instrument. The difference between the readings obtained by the two instruments was plotted against time and shown to be consistent over time and in line with the expectations of the process operator. As two different models of meter were used, it was deemed unlikely that they would respond identically to any changes in the site or process conditions and so the consistent difference was taken to show that the flowmeter under test had continued to perform reliably throughout the trial period.