Performance Standards and Test Procedures for Continuous Water Monitoring Equipment

Part 2 - Performance standards and test procedures for on-line monitors

Ammonia; COD; Conductivity; Dissolved Oxygen; Free Cyanide; Nitrates; Orthophosphate; pH; Temperature; TOC; Total Arsenic; Total Cadmium; Total Chlorine; Total Copper; Total Lead; Total Mercury; Total Nickel; Total Oxidised Nitrogen; Total Phosphorus; Turbidity

Environment Agency
Version 3.1

August 2010

Foreword

The Environment Agency established its 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 certain types of permanently installed continuous water monitors (CWMs) used for the monitoring of treated wastewater discharges from industrial processes, untreated wastewaters and receiving waters.

MCERTS for CWMs:

- 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 CWMs 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.

The determinands covered by this standard are some of the most important parameters when monitoring discharges from both waste water treatment works and other industrial processes as well as the monitoring of natural receiving waters. As MCERTS develops, the performance standards may be expanded to cover other determinands and industrial processes.

MCERTS for CWMs provides a formal scheme for the product certification of continuous monitoring systems 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 CWMs 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 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"**.

- 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
Crayford Road
Crayford
Dartford, Kent.
DA1 4AL

Tel: +44 (0) 1322 520500
email: mcerts@siraenvironmental.com

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

Environment Agency
National Monitoring Services
PO Box 519
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PR5 8GD
or visit our MCERTS website at www.mcerts.net.

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Record of amendments

Version number	**Date**	**Amendment**
2	Feb 2006	Amalgamation of former MCERTS performance standards and test procedures for continuous water monitoring equipment. Alignment of the determination of performance characteristics to relevant international standards.
2.1	July 2006	Amendment to foreword. Update tables 3 and 6. New clauses in sections 7, B1 and E4.
2.2	March 2008	Cover – Conductivity, Total chlorine and free cyanide added to list of determinands. Section 1.1 – Clause 1.1.11 added. Section 1.2 – Section on repairs, maintenance and modifications to certified CWMs added. Section 1.3 – Clause 1.3.1 amended, clauses 1.3.2, 1.3.3 and 1.3.4 added. Table 1 updated to include estuarine/coastal waters. Section 3.2 – Clauses 3.2.1, 3.2.5 and 3.2.9 added. Section 4 – Table 3 changed to 3A and 3B and updated. Notes amended. Section 6 - Interference effects renamed as sample matrix effects 6.3.4 and split into two sections with generic procedure. Note added to Incident light test 6.3.9. Section 7 – Clauses covered by Annex C and I removed and replaced with clauses 7.1.1, 7.1.2 and 7.1.3. Annex order changed to reflect new document. Annex A, B, C, D and F – updated Annex E – New. Contains guidance on usage groups (originally Table 4) Annex H – New. Guidance on test methods for interference effects. Annex I – New. Examples of evidence. Whole document: Reference to technical committee removed and replaced by Certification Committee.
3	June 2009	Cover – Orthophosphate, Temperature, Total Arsenic, Total Cadmium, Total Copper, Total Lead, Total Mercury and Total Nickel added to list of determinands. Section 1 – Table 1 amended with additional determinands Section 3 – Tables 3A and 3C added to give performance requirements for temperature and heavy metals. Presentation of lower limit values in tables 3A, 3B and 3C updated. Section 4 – Table 4 added and subsequent table numbers amended Section 6 – Amendment to 6.3.2 Section 7 – Note added Annexes B and F – updated for heavy metals. Annex H - updated

3.1	August 2010	Forward – List of determinands removed page i. Section 1 – Table 1 typical ranges moved to Annex G, all subsequent tables renumbered. Section 3 – Reporting of the limit of detection and range added as general requirements. TON added in Table 2B. Section 4 – Table 2A Performance requirements for Temperature updated. Note 3 moved to 7.4. Section 5 - Reporting 5.4.1 updated to reference model test report. Section 6 – Wording of the response time test 6.3.2 updated. 6.3.6 maximum output impedance vales added. Section 7 – New note added in 7.4.4 field test response time. Annex B – definition for limit of detection added. Annex G Format of test report removed and replaced with typical ranges for measurement.

Status of this document

This document may be subject to review and amendment following publication. The latest version of this document is available on our website at:
www.mcerts.net

Contents

Performance Standards and Test Procedures for Continuous Water Monitoring Equipment – On-line Monitors

1. Introduction

1.1 Background

1.1.1 This document describes the performance standards, test procedures and general requirements for the testing of continuous water monitors (CWMs) for compliance with the MCERTS performance standards.

1.1.2 The certification process is explained in Annex C.

1.1.3 The Environment Agency requires 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 CWM is appropriate to the application.

1.1.5 Continuous Water Monitors (CWMs) are instruments used for the determination of the value of specified parameters of water quality. CWMs are installed to measure continuously in a fixed location and without constant operator control.

1.1.6 A CWM comprises all components required to make the measurement.

1.1.7 The determinands currently covered are:

- ammonia
- COD
- conductivity
- dissolved Oxygen
- free Cyanide
- nitrates
- orthophosphate
- pH
- temperature
- TOC
- total Arsenic
- total Cadmium
- total Chlorine
- total Copper
- total Lead
- total Mercury
- total Nickel
- total Phosphorus
- turbidity

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

1.1.9 The overall ranges for measurements of each of the determinands covered by this standard that may be encountered in typical applications are given in Table G1, Annex G. It is recognised that the actual ranges required will be application specific including any regulatory and process needs. The MCERTS tests are designed to take these conditions into account. The certification range for a specific analyser will be agreed between the manufacturer and the Certification Body, see Annex C.

1.1.10 The data in Table G1 Annex G gives an indication of the conditions with which a CWM might have to contend, and the other components that may coexist with the determinand.

1.1.11 The performance standards cover a range of pollutant levels for waste water discharges from treatment works and industrial processes regulated under EPR and other legislation. The standards also cover receiving waters and natural waters.

1.2 Repairs, maintenance and modifications to certified CWMs

1.2.1 Any spares or replacement parts for certified CWMs 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 CWM manufacturer.

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

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

1.2.4 The Certification Body will conduct audits of the design changes to CWMs 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 CWM performance.

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

1.2.6 If there is evidence that a modification has only limited effects on the performance of the CWM, then it would not be necessary to retest a CWM 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 CWM 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 CWM'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 CWMs covers:

- Processes falling under the Environmental Permitting Regulations
- Processes that used to fall under the Integrated Pollution Prevention and Control Directive and PPC Regulations
- Consented discharges for processes that used to be regulated through provisions of the Water Resources Act,1991
- Sites falling under the Urban Wastewater Treatment Directive (UWWTD)
- Site falling under other relevant directives e.g. Water Framework Directive.

3. General CWM requirements

3.1 General requirements for all CWMs

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

3.1 The manufacturer shall state the measurement range of the CWM. The range (or ranges) over which the certification will be applied shall be agreed with the Certification Committee.

3.1.2 All MCERTS certified CWMs shall have a unique designation that unambiguously identifies the CWM as a certified model.

3.1.3 The CWM shall have a means of protection against inadvertent or unauthorised access to the control functions.

3.1.4 The CWM shall have an analogue or digital output signal.

3.1.5 The CWM shall have a means of displaying its operating status, for example, stand-by, maintenance mode or malfunction.

3.1.6 The CWM shall have a means of communicating fault conditions to a remote system.

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

3.1.8 A CWM operating from a battery shall incorporate a method of indicating when the power supply voltage is below its normal operating limit.

3.2 Manufacturer's 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 state the storage life and requirements of all scheduled spares and reagents.

3.2.3 The manufacturer shall identify any special equipment required for the storage of spares and reagents and a source of such equipment.

3.2.4 The manufacturer shall state any specific installation requirements.

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

3.2.6 The manufacturer shall state the rated operating conditions for the signal load impedance on the analogue output.

3.2.7 The manufacturer shall state the reference values and rated operating conditions for sample flow-rate, temperature and pressure, as appropriate.

3.2.8 The manufacturer shall give guidance on the time period over which the CWM shall operate continuously without requiring manual adjustment or intervention. This will be application specific.

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.

3.2.9 The manufacturer shall state any chemical, biological and physical interferents to the measurement method.

3.2.10 The manufacturer shall state the Limit of Detection for the CWM.

4. Performance requirements

4.1 Performance characteristics

4.1.1 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 1.

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

Table 1 Expression of performance characteristics

Characteristic	Symbol	Expression of requirement
Mean error	$\overline{x}$	The mean of the errors measured at each test point (see Annex D)
Repeatability	u_R	The standard deviation of the errors measured at each test point (see Annex D)
Linearity	X_L	The maximum deviation from a straight line fitted to the measured values across the certification range (see Annex D)
Drift	X_D	The maximum change in error observed during the drift test (see Annex D)
Interferents Output impedance Supply voltage Ambient temperature Relative humidity Incident light Sample temperature Sample flow-rate Sample pressure	X_{IN} X_O X_V X_T X_{RH} X_{LX} X_{ST} X_{SQ} X_{SP}	For any influence condition the performance requirement is half the range of any change in error resulting from varying the influence condition from a low to a high value (see Annex D).
Combined performance characteristic	U_C	An expanded uncertainty obtained by combining individual performance characteristics (see Annex D).

4.1.2 Tables 2A, 2B and 2C show the maximum value permitted for each performance characteristic. In order to achieve certification, an instrument must comply with all appropriate performance requirements. The values for individual determinands are expressed as a percentage of reading, except pH which is in pH units; temperature which is in ^{o}C; turbidity and conductivity which are expressed as percentage span. This is to reflect the ways in which instrument performance is typically specified by manufacturers for each parameter.

Table 2A Performance characteristics for CWMs

	Symbol	**Test**	**Temperature**	**pH**	**Conductivity**	**Turbidity**	**Dissolved oxygen**	**COD**	**TOC**
			^{o}C	**pH units**	**% of span**	**% of span**	**% of reading**	**% of reading**	**% of reading**
Mean error (see 4.1.3)	$\overline{x}$	6.3.3	0.3	0.2	1	2 (or 0.2 FTU)	5 (or 0.2 mg/l or 2% sat)	10 (or 10 mg/l)	10 (or 0.2 mg/l)
Linearity	X_L	6.3.3	0.2	0.1	0.2	1	2.5	5	5
Repeatability (see 4.1.3)	u_R	6.3.3	0.2	0.1	0.5	1 (or 0.1 FTU)	2.5 (or 0.1 mg/l or 1% sat)	5 (or 5 mg/l)	5 (or 0.1 mg/l)
Sample matrix effects (notes 1 and 2)	X_{IN}	6.3.4	-	-	-	-	2.5	5	3% span
Drift	X_D	6.3.5	0.2	0.1	0.5	1	2.5	5	5
Output impedance	X_O	6.3.6	0.2	0.05	0.5	0.5	1	2.5	2.5
Supply voltage	X_V	6.3.7	0.2	0.05	0.25	0.5	1	2.5	2.5
Ambient temperature	X_T	6.3.8	0.2	0.1	0.5	1	2.5	5	5
Relative humidity	X_{RH}	6.3.8	0.2	0.1	0.5	1	2.5	5	5
Incident light	X_{LX}	6.3.9	0.2	0.05	0.25	1	1	2.5	2.5
Sample temperature	X_{ST}	6.3.10	-	0.1	0.5	1	2.5	5	5
Sample flow-rate	X_{SQ}	6.3.11	-	0.05	0.2	0.5	1	2.5	2.5
Sample pressure	X_{SP}	6.3.12	-	0.05	0.2	0.5	1	2.5	2.5
Combined performance characteristic	U_C	Annex D	0.5	0.3	1.5	2.5	6	12	12
Response time		6.3.2	Value achieved in tests shall be reported (note 3)						
Initial warm up		6.1.2	Value achieved in tests shall be reported (note 3)						

Not all tests may be necessary. The certification committee, in consultation with the manufacturer, will make the decision as to which tests are required for an individual instrument.

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Table 2B Performance characteristics for CWMs

	Symbol	Test	Ammonia as N	NO_3, NO_2 and TON as N	Total phosphorus and Ortho-phosphate	Total chlorine	Free cyanide
			% of reading	**% of reading**	**% of reading**	**% of reading**	**% of reading**
Mean error(see 4.1.3)	$\bar{x}$	6.3.3	10 (or 0.03 mg/l - as N)	5 (or 0.2mg/l - as N)	10 (or 0.05 mg/l - as P)	10 (or 0.05 mg/l)	10 (or 0.05 mg/l)
Linearity	X_L	6.3.3	5	2.5	5	2	2
Repeatability (see 4.1.3)	u_R	6.3.3	5 (or 0.015 mg/l - as N)	2.5 (or 0.1 mg/l - as N)	5 (or 0.025 mg/l - as P)	5 (or 0.025 mg/l)	5 (or 0.025 mg/l)
Sample matrix effects (notes 1 and 2)	X_{IN}	6.3.4	5	2.5	5	5	5
Drift	X_D	6.3.5	5	2.5	5	2.5	2.5
Output impedance	X_O	6.3.6	2.5	1	2.5	1.5	1.5
Supply voltage	X_V	6.3.7	2.5	1	2.5	2.5	2.5
Ambient temperature	X_T	6.3.8	5	2.5	5	2.5	2.5
Relative humidity	X_{RH}	6.3.8	5	2.5	5	5	5
Incident light	X_{LX}	6.3.9	2.5	1	2.5	2.5	5
Sample temperature	X_{ST}	6.3.10	5	2.5	5	5	5
Sample flow-rate	X_{SQ}	6.3.11	2.5	1	2.5	2	2
Sample pressure	X_{SP}	6.3.12	2.5	1	2.5	2	2
Combined performance characteristic	U_C	Annex D	12	6	12	12	12
Response time		6.3.2	Value achieved in tests shall be reported (note 3)				
Initial warm up		6.1.2	Value achieved in tests shall be reported (note 3)				

Not all tests may be necessary. The certification committee, in consultation with the manufacturer, will make the decision as to which tests are required for an individual instrument.

Table 2C Performance characteristics for CWMs

	Symbol	Test	Total Arsenic	Total Copper	Total Mercury	Total Cadmium	Total Lead	Total Nickel
			% of reading	% of reading	% of reading	% of reading	% of reading	% of reading
Mean error (see 4.1.3)	$\bar{x}$	6.3.3	10 (or 7.5 µg/l)	10 (or 1.0 µg/l)	10 (or 0.01 µg/l)	10 (or 0.01 µg/l)	10 (or 1.0 µg/l)	10 (or 3.0 µg/l)
Linearity	X_L	6.3.3	5	5	5	5	5	5
Repeatability (see 4.1.3)	u_R	6.3.3	5 (or 3.75 µg/l)	5 (or 0.5 µg/l)	5 (or 0.005 µg/l)	5 (or 0.005 µg/l)	5 (or 0.5 µg/l)	5 (or 1.5 µg/l)
Sample matrix effects (notes 1 and 2)	X_{IN}	6.3.4	-	-	-	-	-	-
Drift	X_D	6.3.5	5	5	5	5	5	5
Output impedance	X_O	6.3.6	2.5	2.5	2.5	2.5	2.5	2.5
Supply voltage	X_V	6.3.7	2.5	2.5	2.5	2.5	2.5	2.5
Ambient temperature	X_T	6.3.8	5	5	5	5	5	5
Relative humidity	X_{RH}	6.3.8	5	5	5	5	5	5
Incident light	X_{LX}	6.3.9	2.5	2.5	2.5	2.5	2.5	2.5
Sample temperature	X_{ST}	6.3.10	5	5	5	5	5	5
Sample flow-rate	X_{SQ}	6.3.11	2.5	2.5	2.5	2.5	2.5	2.5
Sample pressure	X_{SP}	6.3.12	2.5	2.5	2.5	2.5	2.5	2.5
Combined performance characteristic	U_C	Annex D	12	12	12	12	12	12
Response time		6.3.2	Value achieved in tests shall be reported (note 3)					
Initial warm up		6.1.2	Value achieved in tests shall be reported (note 3)					

Not all tests may be necessary. The certification committee, in consultation with the manufacturer, will make the decision as to which tests are required for an individual instrument.

Notes to Tables 2A, 2B and 2C

1 *A dissolved oxygen CWM shall be tested to check for the effect of chlorides present in the sample. For dissolved oxygen instruments intended solely for freshwater use with no built in salinity compensation, this test may be omitted. See Annex H.*

2 *The scope of interference testing shall be agreed, on a case by case basis, between the manufacturer and the Certification Body. Interferents may be physical, e.g. colour, or chemical. When interference effects are not included in the combined uncertainty, this shall be stated on the certificate..*

3 *Where an instrument operates in a batch mode based on the development of a chemical reaction to the sample over a fixed period of time, the response time and warm-up drift tests may be omitted.*

4.1.3 The error requirements for the majority of parameters are expressed as a percentage of reading. As the value of the determinand becomes small it is increasingly difficult to determine the error of a measurement, expressed as a percentage of reading, in any meaningful way. This is caused by limitations on the resolution or accuracy of reference methods.

Where two values are given (e.g. Mean error for ammonia is shown as 10 (or 0.03 mg/l – as N), then the greater value apples to the test.

Example – If the test point for an ammonia instrument is 0.1 mg/l, then 10% of reading = 0.01 mg/l which is below 0.03 mg/l, therefore the mean error test requirement will be 0.03 mg/l and the repeatability requirement will be 0.015 mg/l.

4.1.4 The resolution of the reading displayed by a PWM shall be 0.1°C or better for temperature probes and 0.01 pH units or better for pH probes. Any different resolution shall be agreed with the Certification Committee.

4.1.5 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.

4.2 Environmental requirements

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

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

4.2.3 For usage groups II and III, the minimum rated operating conditions for ambient temperature shall be –5°C to +35°C. See Annex E for further details.

NOTE: The manufacturer shall state any additional installation requirements to *enable the CWM to operate over this temperature range, e.g. provision of frost protection to prevent freezing.*

4.3 Field test characteristics

Table 3 provides a summary of the field test requirements as detailed in section 7.

Table 3 Summary of field trial

Requirement	Reference	Requirements
Period of operation	7.2	At least 3 months recorded data demonstrating continuous operation
Error	7.3	A minimum of 24 reference measurements shall be taken. In at least 90% of these reference measurements the error shall be less than or equal to the combined performance characteristic as given in Table 2.
Response time	7.4	Measured at the beginning and end of the trial. Values achieved shall be reported.
Up-time	7.5	Greater than 95% as calculated in 7.5.1
Maintenance	7.6	Reported as detailed in 7.6.1 to 7.6.6

5. Provisions for test organisations

5.1 General requirements for test-houses

5.1.1 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 CWMs under MCERTS.

5.2 General requirements for testing

5.2.1 Standard reference methods for each determinand are described in Annex F. Where agreed by the Certification Body, simulated inputs or secondary standards may be used.

Note: Ideally, the uncertainty of the reference system should be no more than 1/5th of the performance requirement being tested.

5.2.2 With the prior agreement of the Certification Committee, fewer measurements than required by an 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.

5.2.3 The CWM shall 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.

5.2.4 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.

5.2.5 For dip sensors, during all tests that use more than one reference solution, the following sensor treatment shall be followed, unless stated in the test procedure and agreed with the Certification Committee.

The sensor shall be rinsed with demineralised water prior to the test, then rinsed with the new solution and finally immersed in fresh reference solution. The sensor will then be rinsed with the next value of wash and then immersed in the next value of the reference solution. In every case, measurements shall be made in continuously stirred solutions.

5.2.6 To carry out tests on the effect of influence quantities on discrete analysers it will be necessary to ensure that the full measurement cycle is carried out with the influence quantity at each required value. Thus if a change in an influence quantity is effected during a measurement cycle, the output from that cycle should be discarded, and that from the next cycle, where the influence quantity is being held at the required value for the full duration of the cycle, shall be used.

5.2.7 Readings should be allowed to stabilise after any change in influence condition or determinand value. Where response time is slow (> 2 minutes), the maximum time allowed for stabilisation of the readings should not exceed 4 times the response time of the CWM.

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

5.3 Test conditions

5.3.1 Table 4 shows the standard test points that should be used as required by each individual test. In situations where the following test points are not practical, alternative test points shall be agreed with the Certification Committee.

Table 4 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

5.3.2 Table 5 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 5 Reference conditions

Influence quantity	Reference value	Tolerance
Ambient temperature	20°C	±2°C
Ambient humidity at 20°C	<60%	-
Incident light	Existing local light level	-
Sample temperature	20°C	±5°C
Sample pressure	To be stated by the manufacturer	±5% of reference value
Sample flow-rate	To be stated by the manufacturer	±5% of reference value
Supply voltage (a.c.)	230 or 110V	±2%
Supply voltage (d.c.)	To be stated by the manufacturer	±2%
Output impedance	Manufacturer's specified maximum	±1Ω
Presence of known interferents	Below minimum detectable value	-
Conductivity (pH and instruments with ion selective electrodes only)	>200μS/cm	-

5.3.3 Tests for the effect of ambient temperature and relative humidity shall be carried out using a climatic chamber, which can vary the temperature and humidity over the range for which the CWM is to be certified.

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 CWM is set up, calibrated and adjusted in accordance with the manufacturer's instructions.

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

6.1.2 The CWM shall be allowed to warm up while being supplied with a zero or reference solution of known value. The time taken for the CWM 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 Section 3.1 are fulfilled, as appropriate to the CWM 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 an analogue or digital output are comparable to those shown on any local display on the CWM. (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 Section 3.2, as appropriate to the CWM under test.

6.3 Performance tests

6.3.1 Loss of power

Record the values of all pre-set data, calibration data and alarm set points. Disconnect the CWM 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 or alarm set points.

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

6.3.2 Response time

Provide means to apply a step change in the determinand to be applied to the sensor. For flow cell mounted sensors, this may be achieved using a three way diverter valve on the inlet to the cell. For dip sensors, two continuously stirred solutions of known determinand value contained in beakers may be used. When transferring the sensor unit from one beaker to the other, shake off the test solution from the sensor unit but do not wipe or rinse. This action should be completed as quickly as possible in order to provide a single step change in the determinand.

Provide the means of recording the measurement during the test, either by activating an internal memory or attaching a recording device to the instrument output. Results can be recorded manually but must be sufficiently frequent to reproduce the instrument response curve.

Provide the CWM with a solution having a determinand value of 5 – 25% of the certification range until a constant output reading is obtained.

Apply a step change by switching to a solution having a determinand value of 75% - 95% of the certification range. Record the time of switching.

Record the instrument output and continue to supply this solution until the measurement is stable.

Apply a decreasing step change by reverting to the lower value solution recording a second event marker at the instant of switching. Record the instrument output and continue to supply this solution until the measurement is stable.

From the instrument record, calculate the size of the step change and the response time.

The response time is the time required for the instrument output to reach and remain within a band between the initial value *plus* (for an increasing step) or *minus (*for a decreasing step) 90% and 110% of the step change.

Repeat the procedure twice more and report the mean response times for an increasing and a decreasing step change.

NOTE: The solutions used for the response time test need not be certified standards so long as the solutions are of known values and stable over the period of the test. Should the reading fail to maintain a value within the 90% to 110% band for the increasing or decreasing changes, report the value which it does reach. In such cases, it will not be possible to calculate the response time.

6.3.3 Mean error, linearity and repeatability

Expose the sensor unit, in turn, to five reference solutions at test points 1 to 5 (see Table 4) in ascending order. Allow sufficient time for each reading to stabilise and record the readings from each output, e.g. local display, analogue output signal and/or digital output signal. Repeat the series of test points in descending order. Repeat the sequence of ascending and descending points twice more to give six discrete readings at each test point.

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

6.3.4 Sample matrix effects

6.3.4.1 General interference tests

The scope of the interference testing shall be agreed between the manufacturer and the Certification Body, based on knowledge and experience relevant to the nature of the water, the instrument, the operating method and the determinand. If several potential interferents are identified, the instrument shall be tested for the effect of at least two interferents.

Testing is based on the method described in BS EN ISO 15839:2006 and involves spiking calibration solutions at 50% and 100% of the expected interference level at test points 2 and 4 (see Table 4).

A generic procedure is described below.

Expose the sensor to a blank calibration solution (where a blank is not possible the level of determinand in the solution should be below the limit of detection) and record the CWM response, y_0. Prepare two further blank calibration solutions spiked with the selected interferent at 50% and 100% of the expected interference level. Record the CWM responses as y_1 and y_2 respectively.

Prepare three calibration solutions at test point 2, the first unspiked, the second spiked with the selected interferent at 50% of the expected interference level and the third at 100% of the expected interference level. Record the CWM responses as $y_{3,}$ $y_{4,}$ y_5 respectively.

Prepare three calibration solutions at test point 4, the first unspiked, the second spiked with the selected interferent at 50% of the expected interference level and the third at 100% of the expected interference level. Record the CMW responses as $y_{6,}$ $y_{7,}$ y_8 respectively.

Calculate and report the change in the reading at zero determinand and interferent at 50% (y_1-y_0) and interferent at 100% (y_2-y_0). Calculate and report the change in the reading at determinand test point 2 with the interferent at 50% (y_4-y_3) and with the interferent at 100% (y_5-y_3). Also calculate and report the change in the reading at determined test point 4 with the interferent at 50% (y_7-y_6) and with the interferent at 100% (y_8-y_6). Identify the maximum change as the error due to interferents, X_{IN}.

The highest value of X_{IN} shall be used to calculate the combined performance characteristic.

NOTE: Example test methods are given in Annex H for specifically identified interferences. For some determinands the above approach may not be appropriate. Annex H contains examples of how an alternative simplified testing approach may be adopted for these determinands.

6.3.4.2 Salinity compensation for dissolved oxygen instruments

For instruments intended solely for freshwater use with no salinity compensation this test may be omitted. This shall be reported on the MCERTS certificate.

Prepare two solutions using distilled water, the first containing chloride at an approximate concentration of 25-30 g l^{-1} NaCl using sea salts, and the second un-modified. Aerate both to ensure they are at 100% saturation. This should be confirmed using a calibrated reference dissolved oxygen meter with in built salinity compensation.

Expose the sensor firstly to the un-modified solution at 100% saturation. Once stabilised, record the instrument response as percentage saturation and as mg/l $O_{2.}$ Move the sensor to the ‘sea water’ reference solution at 100% saturation and, once stabilised, record the instrument response as percentage saturation and as mg/l O_2.

Repeat a further two times, carefully washing the sensor with distilled water between measurements. The manufacturer’s instructions should be followed with regard to positioning and movement of the sensors during measurement.

Calculate and report the change in error, X_{sc}, for both percent saturation and mg/l ranges. Confirm change using Table A.1 in ISO 5814: 1990.

6.3.5 Drift

CWMs without automatic maintenance or calibration facilities shall be assessed for drift over the manufacturer's stated maintenance interval or one week, whichever is the shorter.

During the test period, the CWM shall be continuously supplied with a reference solution at test point 4 (see Table 4), or 100% saturation for a dissolved oxygen instrument, and the output logged.

CWMs which incorporate automatic maintenance or calibration facilities shall have such facilities enabled to operate at a frequency agreed with the manufacturer. The frequency of operation shall be reported. A minimum of three automatic maintenance or calibration cycles should occur within the test period. Drift shall be assessed between automatic calibration cycles and over the manufacturer's stated maintenance interval or one week, whichever is the shorter.

Expose the sensor to a reference solution at test point 4 (see Table 4). For dissolved oxygen instruments expose the sensor to a reference solution of 100% saturation. Allow the reading to stabilise and record the reading. Make two further determinations and calculate the average error of the reading, x_0.

Repeat after a period of 24 hours with 6 further determinations to be carried out at approximately equal intervals of time over the test period ($x_1 \ldots x_6$).

For each determination $x_1 \ldots x_6$, calculate the difference from x_0. Identify and report the maximum difference as the drift error X_D.

For CWMs incorporating automatic calibration or maintenance routines, additional readings shall be taken immediately before and immediately after the operation of the automatic routine. Any step changes that occur following automatic calibration shall be reported.

NOTE: Some reference solutions are known to be unstable and have a short shelf life e.g. formazine suspensions. Limitations on the shelf life of the reference solutions may require that fresh solutions are prepared for each error determination. Alternatively, for a CWM where a secondary standard is available, that may be used for this test.

6.3.6 Output impedance

Connect the analogue output from the CWM to a variable resistance load initially set to the reference value. Expose the sensor unit to a reference solution having a determinand value at test point 4 (see Table 4). For dissolved oxygen instruments expose the sensor to a reference solution of 100% saturation. Alternatively, using an appropriate simulator, apply an electronic signal representing (75% ± 0.5%) of the certification range to the secondary electronics. 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. In each case, record the value of the analogue output signal. Repeat the procedure a further two times.

Calculate and report the change in error due to output impedance, X_O.

NOTE: If no minimum or maximum limit, or zero, is specified, a value of 20Ω and 500Ω shall be used for the minimum and maximum values.

6.3.7 Supply voltage

6.3.7.1 Mains powered CWMs: Expose the sensor unit to a reference solution having a determinand value at test point 4 (see Table 4). For dissolved oxygen instruments expose the sensor to a reference solution of 100% saturation. Record the value of the analogue output signal. Vary the supply voltage to the CWM using an isolating transformer, in steps of 10V from 230 V (or 110 V) to the upper and lower limits. In each case, record the value of the analogue output signal.

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

6.3.7.2 DC powered instruments: Expose the sensor unit to a reference solution having a determinand value at test point 4 (see Table 4). For dissolved oxygen instruments expose the sensor to a reference solution of 100% saturation. Vary the supply voltage to the CWM using a variable DC power supply, in steps of 5V from the manufacturer’s stated reference voltage to the upper and lower limits in turn. At each voltage, record the value of the analogue output signal and report the change in error from that at the reference supply voltage.

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

6.3.7.3 Battery powered CWMs, the batteries shall be removed and power supplied from a variable DC power supply, initially set to the nominal supply voltage. Expose the sensor unit to a reference solution having a determinand value at test point 4 (see Table 4). 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 CWM switches off)
- the voltage at which the CWM switches off.

Identify and report the maximum change in error due to supply voltage, $X_{V,}$ prior to activation of the low battery alarm.

6.3.8 Ambient temperature and relative humidity

During environmental testing, where practicable, the CWM shall be continuously supplied with a reference solution of known value at sample reference conditions.

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

The CWM shall be placed in a climatic chamber, the temperature of which is set to 20°C. The CWM must be allowed to warm up and be calibrated, if required.

The following conditions shall be set in the climatic chamber in the order given in Table 6, where Tmin and Tmax are the minimum and maximum values for ambient temperature over which the CWM is to be certified. The transitional temperatures (steps 2 and 5) may be omitted.

Table 6 Test cycle for environmental conditions

Steps	**Temperature °C**	**Humidity**	**Minimum exposure time**
1. Reference	20	Reference	2 hours
2. Transition	*(Tmax+ref)/2*	*Reference*	*2 hours*
3. High T dry	Tmax	Dry	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

At each step, after a sufficient stabilisation period, the CWM shall be provided with a reference solution having a determinand value at test point 4 (see Table 4) and the output recorded. For dissolved oxygen instruments expose the sensor to a reference solution of 100% saturation. 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 change in error due to ambient temperature, X_T, from steps 3, 4 and 6.

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

6.3.9 Incident light test

NOTE: This test shall be applied to all CWMs using optical measurements methods.

The need to test CWMs utilising other measurement methods will be considered by the Certification Committee on a case by case basis.

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

Expose the sensor to a reference solution having a determinand value at test point 4 (see Table 4). For dissolved oxygen instruments expose the sensor to a reference solution of 100% saturation.

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 change in error, X_{LX}, due to incident light.

NOTE: Further guidance on solar radiation testing can be found in BS EN 60068-2-9:2000 and BS EN 60068-2-5:2000.

6.3.10 Sample temperature

Expose the sensor unit to a reference solution having a determinand value at test point 4 (see Table 4). For dissolved oxygen instruments expose the sensor to a reference solution of 100% saturation. Record the value of the output with the sample temperature at the lower limit of the rated operating conditions, the reference value and at the upper limit of the rated operating conditions. Take three discrete measurements at each value of sample temperature.

Calculate and report the change in error due to sample temperature, X_{ST}.

NOTE: Stability of reference standards with temperature variations should be considered. Care should be taken in selecting suitable standards for this test.

6.3.11 Sample flow-rate

Expose the sensor unit to a reference solution having a determinand value at test point 4 (see Table 4). For dissolved oxygen instruments expose the sensor to a reference solution of 100% saturation. Record the value of the output with the sample flow-rate at the lower limit of the rated operating conditions, the reference value and at the upper limit of the rated operating conditions. Take three discrete measurements at each value of sample flow-rate.

Calculate and report the change in error due to sample flow-rate, X_{SQ}.

6.3.12 Sample pressure

Expose the sensor unit to a reference solution having a determinand value at test point 4 (see Table 4). For dissolved oxygen instruments expose the sensor to a reference solution of known value. Record the value of the output with the sample pressure at the lower limit of the rated operating conditions, the reference value and at the upper limit of the rated operating conditions. Take three discrete measurements at each value of sample pressure.

Calculate and report the change in error due to sample pressure, X_{SP}.

7. Guidance on field tests

NOTE: Table 3 (section 4.3) summarises field trial requirements.

7.1 Objective of field test

7.1.1 The objectives of the field test are to demonstrate that the performance of a CWM is maintained under representative 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 CWM being tested
- The intended applications for the CWM
- The presence of existing manufacturer and / or customer data.

Annex I gives guidance in the form of examples of different approaches used to meet the requirement of the field trial.

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 range of determinand
- Reference method
- Traceability
- Installation environment.

NOTE: A check sheet 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 CWM 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 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.

7.2.3 The output of the CWM shall be logged continuously over the period of the field test.

7.2.4 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.

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

7.2.6 During the field test, the performance characteristics of the CWM shall be determined under representative operational conditions. This means that the reference measurements (see 7.3.3) shall only be taken when the process is operating normally and all parameters are within the rated operating conditions of the CWM.

7.2.7 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 conditions

7.3.1 The error of a CWM is determined by comparing the measurement obtained by the CWM with that from a standard reference method (SRM). SRMs for the determinands covered by this Standard are listed in Annex F.

7.3.2 If a second CWM is being used for the reference measurement then this should be a certified measurement technique suitable for the application.

7.3.3 A minimum of 24 pairs of reference measurements (simultaneous determinations from the CWM 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 determinand values 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 CWM.

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

7.3.5 The proportion of errors less than or equal to the value for the combined performance characteristic (see Table 2) shall be calculated and reported.

7.4 Response time

7.4.1 Two response time tests shall be carried out according to clause 6.3.2. The first shall be carried out at the start of the field test and the second at the end. The test at the end of the field tests shall be carried out prior to any scheduled manual or automatic maintenance and without any cleaning.

7.4.2 For the test at the end of the field test, care shall be taken with dip or insertion sensors not to disturb or remove any fouling during removal from the test fluid and transfer between solutions. Stirring of the solution of known determinand value should also not disturb any fouling material on the sensor.

7.4.3 For the test at the end of the field test on flow cell mounted sensors, the test fluid supply shall be shut off and a solution of known determinand value providing a step change of at least 20% of the certification range, introduced as quickly as possible without any purging of the pipes.

7.4.4 For the test at the end of the field test on discrete analysers the step change shall be applied at the point in the operating cycle immediately following a sampling action. The test fluid supply shall be shut off and a solution of known determinand value providing a step change of at least 20% of the certification range, introduced as quickly as possible without any purging of the pipes.

Note: It should be noted that low conductivity in some upland raw waters can give rise to drift and slow response on pH meters.

Note: The results from the laboratory response time test may be used as the start response time value but this may increase the likelihood of failing to meet this performance requirement.

7.5 Up-time

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

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

where

$V =$ up-time

$t_G =$ total operating time

$t_A =$ total outage time

7.5.2 The outage time shall be summarised in a table, as shown in Table 7.

Table 7 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 ($1-t_A/t_G$)	%

7.6 Maintenance

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

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

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

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

7.6.5 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 CWM was not operational, i.e. time from point of failure to the CWM coming back on line.

7.6.6 If the total time while the CWM 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.

7.7 Reporting of field test

7.7.1 The field test shall be summarised in the MCERTS test report. This should be forwarded to the certification committee for consideration.

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Annex B – 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 equipment on site but which does not normally form part of the CWM package. Examples include sampling systems, external data loggers or telemetry equipment, power conditioning devices, lightning protection, external pumps or compressors required for automatic cleaning systems.

Arsenic: A highly toxic metal released naturally into the aquatic environment as a result of weathering of arsenic-containing rocks or from industrial and agricultural pollution. Total arsenic includes dissolved arsenic and arsenic attached to matter.

Cadmium: A heavy metal that accumulates in the environment. Cadmium and several cadmium-containing compounds are known carcinogens and can induce many types of cancer. Total cadmium refers to the preparation of the sample for analysis. Total cadmium includes dissolved cadmium and cadmium attached to matter.

Certification range: Range over which the CWM is certified.

Chemical Oxygen Demand (COD): The COD of a water or wastewater is a measure of the quantity of oxygen required to completely oxidise all the organic and inorganic material in the water under standard empirical conditions. The COD value, also known as the Dichromate Value, is determined by measuring the quantity of acidic dichromate consumed by a sample of the water under standard conditions.

Chlorine: A powerful oxidant used for disinfection of water and wastewaters. Free chlorine is defined as the concentration of residual chlorine in water present as dissolved gas (Cl2), hypochlorous acid (HOCl), and/or hypochlorite ion (OCl-). Combined chlorine is defined as the residual chlorine existing in water in chemical combination with ammonia or organic amines which can be found in natural or polluted waters. Total chlorine is the sum of free and combined chlorine.

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

Conductivity: The ability of a material to conduct electrical current. For aqueous samples conductivity is measured in µSiemens and mSiemens. Temperature compensation is required to remove the effect of liquid temperature. Commonly used as a surrogate for TDS.

Copper: A metal released into the environment by both natural sources and human activities. Soluble copper compounds form the largest threat to human health. High uptakes of copper may cause liver and kidney damage. Total copper includes soluble copper and insoluble copper (attached to matter).

Cyanide: A highly toxic chemical which is characterised by the presence of a cyano functional group, CN-. Inorganic compounds include simple salts of cyanide with various metals such as sodium cyanide NaCN(s) and potassium cyanide KCN(s). These simple salts are highly soluble in water.

Continuous analyser: CWM which makes continuous measurements of the determinand or successive discrete measurements at very short time intervals such that they appear continuous, except whilst undergoing automatic cleaning and calibration routines.

CWM: Acronym for a *continuous water monitor*.

Determinand: The property that is required to be measured.

Dip sensor: Sensor designed to be located directly in a channel or tank and in contact with the process fluid.

Discrete analyser: CWM which operates on a batch rather than continuous basis.

Drift: Measure of the CWM's response to a defined reference material over a period of time.

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

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.

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

Flow cell: Sensor housing designed to be mounted directly in series with a process line or sample line.

Insertion sensor: Sensor unit designed to be inserted directly into a process pipe.

Interferent: Property of the fluid, other than the determinand, which influences the measurement.

Lead: A highly dangerous metal which is found in the environment as a result of human activities. It is one metal with the most damaging effects on human health, entering human body through uptake of food, water and air. Unwanted effects include brain damage or behavioural disruptions of children. Lead has poisoning effects for humans but also on shellfish even at low concentration. Total lead includes dissolved lead ($PbCO_3$ or $Pb(CO_3)_2^{2-}$) and lead attached to matter.

Limit of detection (Instrument detection limit): is the lowest quantity of the determinand that the CWM can be distinguished from the absence of that substance (a *blank value*) within a stated confidence limit (generally 1%). Detection limits are affected by the sample matrix and may therefore be application specific.

Linearity: Measure of fit of the CWM's response to a straight line using a number of values of a determinand.

Lower limit value: Limit value for errors as the measurement approaches zero and expression as percentage of value becomes meaningless.

Mercury: Mercury occurs in deposits throughout the world and it is harmless in an insoluble form, such as mercuric sulfide, but it is poisonous in soluble forms such as mercuric chloride. Total mercury includes dissolved mercury and mercury attached to matter.

Nickel: A metal which organic matter has a strong ability to absorb. Uptake in large quantities increases the risk of many types of cancer. Total nickel includes dissolved nickel and nickel attached to matter.

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

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

Rated operating conditions: The minimum to maximum values of any environmental, fluid or electrical parameter within which the CWM 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 material: A substance or mixture of substances, with a known composition within specified limits. One or more of the properties of the reference material are sufficiently well established over a stated period of time to be used for the calibration of an apparatus, for the assessment of a measuring method, or for assigning values to materials. Reference materials appropriate to the determinands covered by this standard are given in Annex F.

Reference method: Method to be used to obtain the determinand value of the test fluid to a stated uncertainty, against which the readings from the CWM under test can be compared. Reference methods appropriate to the determinands covered by this standard are given in Annex F.

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

Response time: The time interval between the instant when a sensor is subjected to an abrupt change in determinand value and the instant when the readings cross the limits of (and remain inside) a band defined by the 90% and the 110% of the difference between the initial and final value of the abrupt change.

Sample preconditioning equipment: A piece of equipment that is fitted prior to the inlet of a CWM that is designed to modify or condition the fluid in some way prior to its input into the CWM and is necessary for the normal operation of the CWM. Examples include filters, macerators and de-bubbling chambers.

Sampling system: A mechanism for transporting a sample from the bulk fluid to the inlet of the CWM, usually comprising an arrangement of tubes or pipe work and / or pumps and valves.

Secondary turbidity standard: Material having a fixed value for turbidity based on a substance other than formazine. Such standards are often specific to an individual instrument and are provided by manufacturers for calibration purposes.

Sensor: Transducer consisting of one or more components from which is derived an electrical output related to the value of the determinand in the sample.

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

Total ammonia: The total ammonia concentration is the sum of ammonia in the forms of unionised (free) ammonia (NH_3) and ammonium ions present in a sample. Total ammonia concentration may be expressed in terms of nitrogen converted to the equivalent concentration of ammonium ions (NH_4^+), in units of milligrams per litre (mg l^{-1}). Unless otherwise stated, all references to total ammonia in this document are expressed in terms of milligrams per litre of nitrogen, often referred to as ammoniacal nitrogen.

Total organic carbon (TOC): The TOC of a water or wastewater sample is a measure of the total concentration of organic material (i.e. compounds based on carbon) present in the water. It includes all the carbon that is present in an organic form, regardless of its oxidation state. TOC therefore represents the difference between the total carbon (TC) and the total inorganic carbon (TIC).

Total Oxidised Nitrogen: Total Oxidised Nitrogen (TON) is the total concentration, in compatible units, of nitrate and nitrite ions in a sample of water or wastewater, expressed as mgl^{-1} N.

Informative note: Nitrate and nitrite provide the greatest contribution to TON in most waters. Other forms of 'oxidised nitrogen', chiefly hydroxylamine, have occasionally been detected in some waters. However, hydroxylamine is not detected by many of the methods used to measure TON. (Methods for the examination of waters and associated materials. Oxidised Nitrogen in Waters 1981. HMSO. ISBN 0 11 751593 0).

Total phosphorus: Total phosphorus includes all chemical and physical forms of phosphorus present in a sample e.g. orthophosphates, condensed phosphates and organic phosphates.

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

Turbidity: The optical property of particles suspended in a fluid that causes light to be scattered and absorbed rather than transmitted through the fluid without change. For the purpose of this specification all measurements of turbidity shall be expressed in formazine turbidity units (FTU). One formazine turbidity unit (FTU) equals 1/400th of the Stock Turbidity of the suspension prepared by the method as set out in 'Methods for the Examination of Waters and Associated Materials - Colour and Turbidity of Waters 1981.

Informative note: Other systems of units are in common use for turbidity measurement. The nephelometric turbidity unit (NTU) is the turbidity of the sample measured by a detector at 90° from the source light. BS EN ISO 7027:2000 Water Quality – Determination of turbidity, uses formazine nephelometric units (FNU) and formazine attenuation units (FAU). There is no direct relationship between any of these units.

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

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

Annex C - Certification Process

C1 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 CWM under consideration.

Only a complete CWM shall be certified. Where a CWM can be supplied with a number of options, for example where more than one sensor or sensor configuration can be used to cover different ranges, or where different sensor mounting arrangements are available, one complete CWM shall undergo the full conformity tests. In selecting the options to be tested, consideration should be given to the options likely to be used in the identified applications. For additional sensors or sensor configurations, it may be possible to extend certification by carrying out a subset of the full test programme. Similarly, where different electronics units having different facilities may be used with a single sensor, one complete example of the CWM 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.

Multi-parameter instruments may be certified for one or more of the determinands covered by this standard. The test certificate shall make clear for which determinands the instrument is certified. Any reference by the manufacturer to certification shall make clear for precisely which determinands the instrument is certified.

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 CWM 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 accuracy, repeatability, linearity and response time.

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, and will be reported on the MCERTS certificate.

C2 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.

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
- Manufacturer’s 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 applications, provided that there is some way of validating measurements by one of the reference methods described in Annex F. 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 application is used in support of an MCERTS certification, it should be from a CWM 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 CWM, including details of any maintenance or repairs. Corroboration may be sought from the equipment owner via a confidential questionnaire.

The field test shall be summarised in the MCERTS test report, see Annex G. This should be forwarded to the certification committee for consideration.

C3 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.

C4 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.

C5 Modifications to certified CWMs

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

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

The Certification Body will conduct audits of the design and software changes to a CWM 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 D - Determination of performance characteristics

D1 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
- Fit for purpose.

D2 Errors

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

Note: In this standard, errors are expressed as a percentage of reading, except for pH where they are expressed in pH units and turbidity where they are expressed as a percentage of span.

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

$$\overline{x} = \frac{\sum_{1}^{n} x_i}{n} \qquad \text{Equation D1}$$

D3 Repeatability

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

$$u_R = \sqrt{\frac{\sum_{i=1}^{n} (\overline{x} - x_i)^2}{n-1}} \qquad \text{Equation D2}$$

As the MCERTS test for repeatability (see 6.3.3) requires the test point to be approached from both higher and lower values, the calculation of repeatability here includes any effect due to hysteresis.

D4 Linearity

Linearity is a measure of the deviation of the instrument response from a straight line over the measurement range. It is calculated by using the method of least squares to fit a straight line to the mean measurement values obtained at each test point over the range. The maximum deviation from the best fit line is taken as the linearity error, X_L, to be compared with the MCERTS performance characteristic for linearity.

Ideally, where an instrument would be expected to have a zero response to a determinand value of zero, a zero-based linearity should be calculated, i.e. the best fit line should be forced through the origin. Where this is inappropriate, e.g. where there is an offset at zero, or for pH, a terminal based linearity may be used. The test report shall state whether a terminal or zero based linearity calculation has been used.

D5 Drift

The performance characteristic for drift, X_D, is expressed as the maximum change in error over the period of the test.

D6 Effect of influence conditions

The performance requirement for the effect of an influence condition, X_I, is the half range of any change in error resulting from varying the influence condition from a low to a high value, including the reference value, expressed as a percentage of reading, i.e. referring to Figure D1:

$$X_I = \left(\frac{\left| \overline{X}high - \overline{X}ref \right| + \left| \overline{X}low - \overline{X}ref \right|}{2} \right) \qquad \text{Equation D3}$$

Note 1: In the sample matrix tests (6.3.4) and the relative humidity test (6.3.8) the reference conditions and the low influence conditions are the same, hence $(\overline{X}low - \overline{X}ref)$ is zero.

Note 2: In cases where the response is U shaped, see Figure D2, calculate X_I as half the maximum difference, i.e. in the example shown in Figure D2:

$$X_I = \left(\frac{\left| \overline{X}high - \overline{X}ref \right|}{2} \right) \qquad \text{Equation D4}$$

Note 3: For tests conducted at more than one measurement point (6.3.4.2 and 6.3.4.4), calculate the half range of the error change at each measurement point and take the maximum value as X_I.

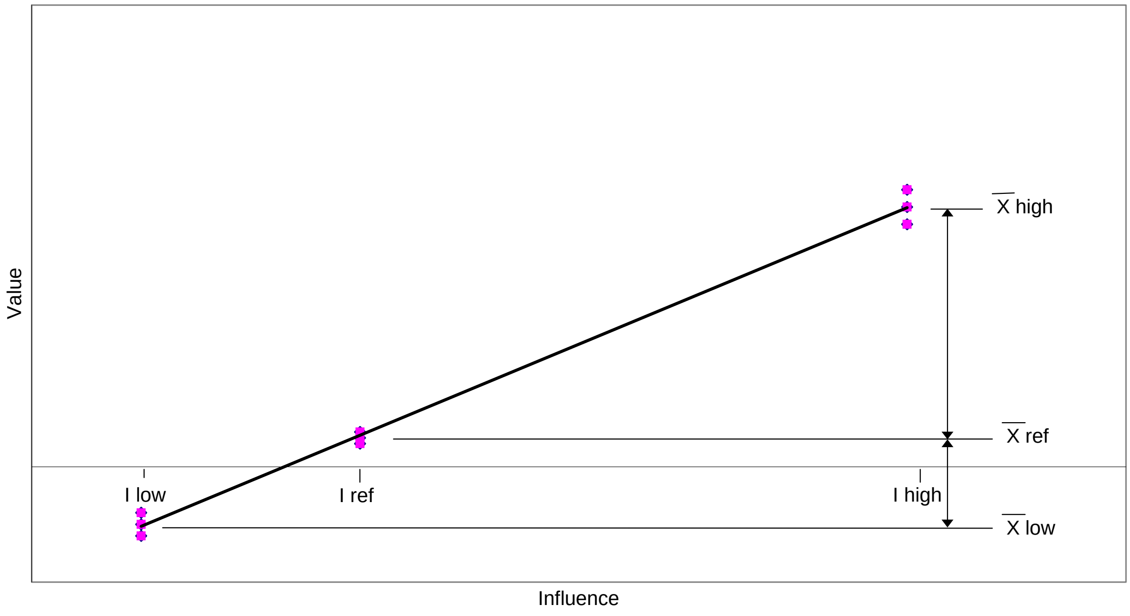

Figure D1 Effect of influence conditions – linear response

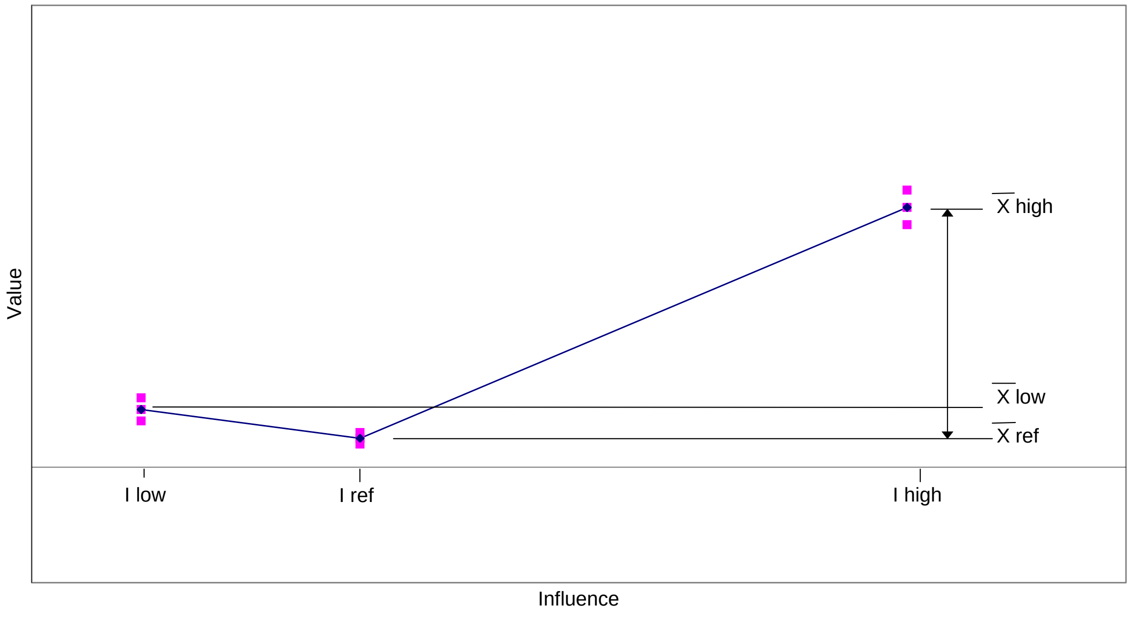

Figure D2 Effect of influence conditions – U shaped response

D7 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, 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:

$$u = \frac{X}{\sqrt{3}} \qquad \text{Equation D5}$$

Repeatability has been calculated as a standard deviation at each test point (Equation D2) 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:

$$U_C = 2 \times u_C \qquad \text{Equation D6}$$

Table D1 shows the components which are to be combined when determining the combined performance characteristic, U_c. Specific components depend on the type of CWM, although some are common to all types of CWM.

Table D8 Components for the combined performance characteristic

Performance characteristic	**Symbol**	**Test**
(Mean error – see Note)	u_A	6.3.3
Repeatability	u_R	6.3.3
Linearity	u_L	6.3.3
Interferents	u_{IN}	6.3.4
Drift	u_D	6.3.5
Output impedance	u_O	6.3.6
Supply voltage	u_V	6.3.7
Ambient temperature	u_T	6.3.8
Incident light	u_{LX}	6.3.9
Sample temperature	u_{ST}	6.3.10
Sample flow-rate	u_{SQ}	6.3.11
Sample pressure	u_{SP}	6.3.12

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 6.3.3 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.:

$$u_A = \frac{(\max \bar{x})}{\sqrt{3}}$$

Equation D7

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.

$$\mathrm{U_c} = 2 \times \sqrt{u_A^2 + u_R^2 + u_L^2 + u_{IN}^2 + u_D^2 + u_O^2 + u_V^2 + u_T^2 + u_{LX}^2 + u_{ST}^2 + u_{SQ}^2 + u_{SP}^2}$$

Equation D8

D8 Worked example

A CWM is to be certified over the range 0-50 mg/l. It is subjected to the test procedure in 6.3.3 and the readings in Table D2 are obtained (in mg/l).

Table D2 Example measurement results

Test point:	1	2	3	4	5
Ref. value	2.55	13.50	25.50	37.30	47.40
Run 1	2.52	12.98	25.02	37.10	48.20
Run 2	2.48	12.97	25.03	37.01	47.96
Run 3	2.48	12.95	25.00	36.90	47.80
Run 4	2.45	12.95	25.02	37.02	47.95
Run 5	2.48	12.97	25.01	36.85	47.96
Run 6	2.47	12.99	25.03	37.15	48.01

The errors (in mg/l) 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 D3. The mean error at each test point is calculated from Equation D1.

Table D3 Errors from example measurement data

Test point	1	2	3	4	5
Run 1	-1.19%	-4.01%	-1.92%	-0.54%	1.66%
Run 2	-2.82%	-4.09%	-1.88%	-0.78%	1.17%
Run 3	-2.82%	-4.25%	-2.00%	-1.08%	0.84%
Run 4	-4.08%	-4.25%	-1.92%	-0.76%	1.15%
Run 5	-2.82%	-4.09%	-1.96%	-1.22%	1.17%
Run 6	-3.24%	-3.93%	-1.88%	-0.40%	1.27%
Mean error	-2.83%	-4.10%	-1.93%	-0.80%	1.21%

The mean errors at each test point are compared with the MCERTS requirement for mean error.

The certification committee decides that as the instrument requires user calibration in the field against synthesised solutions provided by the manufacturer, a mean error component shall be incorporated into the combined performance characteristic.

This is calculated from Equation D7 as (-4.10)/√3 = 2.37%.

The repeatability at each test point is calculated from Equation D2 as shown in Table D4.

Table D4 Example repeatability values

Test point	1	2	3	4	5
Standard deviation	0.94%	0.13%	0.05%	0.31%	0.27%

The repeatability values at each test point are compared with the MCERTS requirement for repeatability.

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 0.31%.

The mean measurement values at each test point are plotted against the reference values and a best fit line is calculated by method of least squares. In this case, it is assumed that the best fit line would pass through the origin. The equation of the best fit line is therefore y= 0.9993x. The deviation from the best fit line at each test point is calculated in engineering units and as a percentage of reading, see Table D5.

Table D5 Linearity example

Test point	1	2	3	4	5
Deviation from best fit	-0.068	-0.522	-0.464	-0.269	0.613
As % reading	-2.75%	-4.03%	-1.85%	-0.73%	1.28%

The maximum non-linearity error is identified as that at test point 2, and compared with the MCERTS requirement for linearity.

The component for linearity to be included in the combined performance characteristic is calculated from Equation D5 as (-4.03)/√3 = 2.33%.

The instrument is then subjected to a test for the effect of supply voltage. Three measurements are taken at test point 3 with the supply voltage at its reference value, then 3 more with the supply voltage at its lower limit and 3 more with the supply voltage at its upper limit. The data points in Table D6, in mg/l, are obtained.

Table D6 Example influence condition results

Reference value	Lower limit	Reference conditions	Upper limit
25.00	24.95	25.05	25.10
25.10	25.00	25.17	25.18
24.80	24.88	25.00	25.00

The errors, as percentage of reading, are as shown in Table D7.

Table D7 Influence condition errors

	Lower limit	Reference conditions	Upper limit
1st measurement	-0.20%	0.20%	0.40%
2nd measurement	-0.40%	0.28%	0.32%
3rd measurement	0.32%	0.80%	0.80%
Average	-0.09%	0.43%	0.51%

The effect of supply voltage is calculated from Equation D3 as:

$$X_V = \frac{|0.51 - 0.43| + |-0.09 - (0.43)|}{2} = 0.3\%$$

X_V is compared with the MCERTS performance characteristic for the influence of supply voltage. From Equation D5, the component to be included in calculation of U_C is 0.3/√3 = 0.17%.

The instrument undergoes all remaining MCERTS performance tests with the results as shown in Table D8.

Table D8 Example performance characteristics

Performance characteristic	**Symbol**	**Value**
Mean error	u_A	2.37%
Repeatability	u_R	0.31%
Linearity	u_L	2.33%
Interferents	u_{IN}	0.45%
Drift	u_D	0.33%
Output impedance	u_O	0.15%
Supply voltage	u_V	0.17%
Ambient temperature	u_T	0.25%
Incident light	u_{LX}	N/A (not an optical sensor)
Sample temperature	u_{ST}	0.67%
Sample flow-rate	u_{SQ}	0.28%
Sample pressure	u_{SP}	0.13%

The combined performance characteristic is then calculated from Equation D8.

$U_C = 2 \text{ x } (2.37^2+0.31^2+2.33^2\ 0.45^2+0.33^2+0.15^2+0.17^2+0.25^2+0.67^2+0.28^2+0.13^2)^{1/2}$

$= 6.96\%$

This value is compared with the MCERTS requirement for the combined performance characteristic.

Annex E – Guidance on usage groups

Table E1 gives guidance on the operating conditions to which CWMs are likely to be subjected (see BS EN 60746-1 Expression of performance of electrochemical analysers: General.). The extent of environmental testing will be agreed between the manufacturer and the Certification Body, taking into account the intended usage group of the instrument.

Table E1 Usage groups (for guidance)

Usage group	**Explanation**	**Recommended rated operating conditions**
I	For indoor use under conditions that are normally found in laboratories and factories and where apparatus will be handled carefully, this includes kiosks with full temperature control and ventilation. In this type of environment the ambient temperature will normally remain within fairly narrow limits. The CWM will not be exposed to water sprays or drips, high humidity or significant concentrations of airborne dust.	Ambient temperature: +5°C to +40°C Relative humidity: Up to 95% RH including condensation
II	For use in environments having protection from the full extremes of environment and under conditions of handling between those of groups I and III. Examples of this type of installation are: GRP kiosks and brick or concrete outbuildings which do not have a satisfactory means of maintaining the temperature inside the building within a controlled range. If frost protection is required to reduce the risk of the temperature dropping below a preset lower limit and prevent freezing, e.g. in reagent vessels, the manufacturer shall clearly state this in the installation instructions. In this type of environment the CWM may be exposed to water sprays from all directions, high humidity with condensation and large variations in temperature.	Ambient temperature: -10°C to +55°C Relative humidity: Up to 95% RH including condensation
III	For outdoor use and in areas where the apparatus may be subjected to rough handling. CWMs in this category will be exposed to the full range of outdoor environmental conditions without additional protection from extremes other than the provision of a sun shade or canopy to prevent direct solar heating of the enclosure. The equipment may be exposed to heavy rainfall and high power water jets from all directions for long periods of time.	Ambient temperature: -25°C to +70°C Relative humidity: Up to 95% RH including condensation

Annex F - Standard reference methods

GUIDANCE NOTE: Other methods may be accepted e.g. a portable water monitor (PWM) of known and demonstrable uncertainty.

If samples are taken for laboratory analysis then appropriate sample preservation procedures must be observed to minimise any changes in sample composition between sampling and laboratory analysis.

pH

A specific reference analytical technique has not been specified in this document for the determination of pH. For the field test the reference values for field test error measurements may be derived by having a second pH meter in line which is maintained and calibrated to a known and demonstrable uncertainty.

Ammonia

The method is given in Methods for the Examination of Waters and Associated Materials Ammonia in Waters 1981 for analysis used to obtain the ammonia as N concentration of the test fluid to a stated uncertainty, or producing a reference solution. For the field test, suitable reference methods are a second ammonia instrument of known and demonstrable uncertainty or laboratory analysis of samples.

COD

The recommended reference technique for the determination of COD is method A in the publication Chemical Oxygen Demand (Dichromate Value) of Polluted Waters 1986 (Second Edition) Methods for the Examination of Waters and Associated Materials. HMSO, London. ISBN 011 7519154. Details are also given for the preparation of a solution with a known COD value. For the field test, the reference values for field test error measurements may be derived from samples taken and measured by a laboratory that is accredited for the determination of COD in the value range of interest under quality assured conditions to a known uncertainty, or alternatively, by use of a process COD analyser which is maintained and calibrated to a known and demonstrable uncertainty.

TOC

There are several different recognised analytical methods for the determination of TOC. A specific reference analytical technique has not been specified because the most suitable approach varies according to the concentration range and sample matrix of interest. A method for preparing TOC solutions to a known value is described in Standard Methods for the Examination of Water and Wastewater. APHA. The reference values for field test error measurements may be derived from samples taken and measured in the laboratory under quality assured conditions to a known uncertainty, or by having a second TOC analyser in line which is maintained and calibrated to a known and demonstrable uncertainty.

Dissolved oxygen

Details of the reference analytical method can be found in the following publication: Methods for the Examination of Waters and Associated Materials - Dissolved Oxygen in Natural and

Waste Waters 1979. Method A - Winkler titration. A method is described for preparation of solutions of different dissolved oxygen concentrations. It should be noted that these solutions are not stable. The reference values for field test error measurements may be derived from samples taken and measured using the Winkler titration method, under quality assured conditions to a known uncertainty (though the Winkler titration may have a higher uncertainty than an electrochemical DO sensor), or by having a second dissolved oxygen analyser in line which is maintained and calibrated to a known and demonstrable uncertainty. In high ionic strength samples, there is a disparity between Winkler titration and electrode methods. This needs to be taken into account if seawater or high salinity estuarine samples are of interest. Tables providing an indication of the effects of ionic strength and temperature on oxygen solubility are included in BS EN 25814.

Total phosphorous

The recommended reference method is method A in the publication Methods for the Examination of Waters and Associated Materials. Phosphorus and Silicon in Waters. Effluents and Sludges 1992.

A series of reference solutions may be prepared by serial dilution of a stock solution containing a known quantity of phosphorus. The formulation of the stock reference solution for total phosphorus consists of an aqueous solution of the following compounds in equal proportions as phosphorus.

- disodium hydrogen orthophosphate
- sodium beta-glycerophosphate
- sodium tetrametaphosphate
- sodium tripolyphosphate.

The reference values for field test error measurements may be derived from samples taken and measured in the laboratory under quality assured conditions to a known uncertainty, or by having a second total phosphorus analyser in line which is maintained and calibrated to a known and demonstrable uncertainty. The recommended reference method is method A in the publication Methods for the Examination of Waters and Associated Materials. Phosphorus and Silicon in Waters. Effluents and Sludges 1992.

Nitrate

There are several different recognised analytical methods for the determination of nitrate. A specific reference analytical technique has not been specified in this document for the determination of nitrate because the most suitable approach varies according to the concentration range and sample matrix of interest. However the laboratory undertaking the analysis should be accredited for the determination of nitrate or TON in the matrix of interest. A method for preparation of reference solutions is described in Methods for the Examination of Waters and Associated Materials - Oxidised Nitrogen in Waters 1981. HMSO. The reference values for field test error measurements may be derived from samples taken and measured in the laboratory under quality assured conditions to a known uncertainty, or by having a second nitrate or TON analyser in line which is maintained and calibrated to a known and demonstrable uncertainty.

Turbidity

A specific reference analytical technique has not been specified in this document for the determination of turbidity. For the field test, the reference method shall be to expose the sensor to reference solutions. Formazine may be used, made up in accordance with BS EN ISO7027:2000 under quality assured conditions to a stated uncertainty. BS EN ISO7027:2000 also includes data on a synthetic polymer which shows good correlation to the formazine standard. This may be preferred as the production of formazine requires the use of chemicals which are known to be carcinogenic. Proprietary secondary standards may be used for routine calibration activities or determining the effect of various influence conditions, which are not sample dependent, in line with manufacturer's instructions but cannot be used to derive field test error values.

Conductivity

A specific reference analytical technique has not been specified in this document for the determination of conductivity. For the field test the reference values for field test error measurements may be derived by having a second conductivity meter which is maintained and calibrated to a known and demonstrable uncertainty.

Chlorine

Methods for the determination of Total available Chlorine by Iodometric Titration and chlorine, chloramines using the Diethyl-p-phenylendiamine (DPD) method are described in Methods for the Examination of Waters and Associated Materials. Chemical Disinfecting agents in water and effluents, and chlorine demand (1980).

Cyanide

Methods for the Examination of Waters and Associated Materials. The determination of cyanide in waters and associated materials, (EA update 2007) describes several analytical methods for the determination of cyanide, in various forms, in water.

An alternative method is the EPA Method 335.1, Cyanides Amenable to Chlorination is based on visible spectroscopy. This method incorporates two determinations of total cyanide. One determination is done after free cyanide in the sample has been chlorinated to CNCl, which degrades quickly, and a second is done without chlorination. The concentration of free cyanide is given by the difference of the two measurements of total cyanide.

Arsenic, copper, cadmium, lead and nickel

Methods for the determination of arsenic, copper, cadmium, lead and nickel are given in the 21st edition of Standard Methods for the Examination of Water and Wastewater. Method 3120 B Inductively coupled plasma (ICP) emission spectroscopy and method 3125 Metals by Inductively coupled plasma / mass spectrometry are both suitable for arsenic, copper, cadmium, lead and nickel.

Mercury

Methods for the determination of mercury are given in the 21st edition of Standard Methods for the Examination of Water and Wastewater. Method 3112 Metals by Cold-Vapor Atomic Absorption Spectrometry is the method to analyze mercury. Method 3125 Inductively coupled plasma/mass spectrometric method can also apply, even though mercury is not listed in the method.

Annex G – Typical ranges for measurement

Table G1 Typical ranges for measurement (As guidance –certification range to be agreed with the certification body)

Determinand	**Units**	**Untreated wastewater**	**Treated wastewater**	**Surface waters**	**Groundwater** (Note 4)	**Estuarine / Coastal Waters** (Note 1)
Ammonia (Note 3)	mgl^{-1}NH$_4$	< 300	< 20	< 5	< 5	<0.2
Chlorine (total)	mgl^{-1}	N/A	< 1	< 0.1	< 0.1	N/A
Chlorophyll *a*	µgl^{-1}Chl *a*	N/A	N/A	< 200	N/A	<100
COD	mgl^{-1}Oxygen	< 4000	< 250	N/A	N/A	N/A
Conductivity (Note 2)	µS/cm	< 500	< 500	< 1000	< 1000	*<0.1-40 mS/cm*
Dissolved oxygen	% saturation	< 100	< 100	< 200	< 200	<200
Free cyanide	mgl^{-1}	< 1	< 1	< 1	< 1	N/A
Nitrate	mgl^{-1}N	< 350	< 50	< 50	< 25	<1
Nitrite	mgl^{-1}N	< 10	< 10	< 2	< 2	<0.05
Orthophosphate	mgl^{-1}P	< 50	< 5	< 2	< 2	<0.1
pH	pH units	2-12	4-10	< 10	< 10	<10
Temperature	^{o}C	< 50	< 30	< 30	< 20	<25
TOC	mgl^{-1}C	< 1000	< 100	< 20	< 5	<20
Total Arsenic	µgl^{-1}	< 100	< 10	< 5	< 200	<6
Total Cadmium	µgl^{-1}	< 20	< 1	< 1	< 20	<1
Total Copper	µgl^{-1}	< 120	< 50	< 40	< 200	< 40
Total Lead	µgl^{-1}	< 60	< 5	< 5	< 500	<1
Total Mercury	µgl^{-1}	< 1	< 1	< 1	< 1	<0.2
Total Nickel	µgl^{-1}	< 100	< 50	< 20	< 50	<5
Total phosphorus	mgl^{-1}P	< 50	< 5	< 2	< 2	<0.1
Total oxidised nitrogen	mgl^{-1}N	< 350	< 50	< 50	< 25	<1
Turbidity	FTU	< 2000	< 50	< 500	N/A	<500

Note 1: Estuarine and coastal tidal environments can be physically and chemically demanding on water quality monitors. Instrumentation challenges in these waters include changes in salinity over the tidal cycle, high suspended sediment which creates an abrasive environment, highly variable water velocities due to tides and biological fouling.

Note 2: Conductivity in the mS/cm range may be common in saline waters.

Note 3: Ammonia as total ammoniacal nitrogen.

Note 4: Mine water may contain significantly elevated levels of some determinands compared to other groundwaters.

Annex H – Test Methods for Interference Effects

This section provides an example method suitable for determining the interference effects. This example may be used to develop methods specific to other interferences.

Colour effects to turbidity measurement

Colour effects shall be assessed at two colour levels which relate to 50% and 100% of the expected interference level. In this example these have been selected at 15 and 30 colour units.

Test samples y_0 to y_5 shall be prepared as given in table H1.

Potassium chloroplatinate shall be used to prepare the colour standards, as described in Method 2120 B Standard Methods for the Examination of Water and Wastewater, APAH. 20th edition. SDVB beads are recommended to provide the required turbidity.

Table H1 Samples required for colour effects to turbidity testing.

Test sample	Colour (Colour units)	Turbidity (Test point)
y_0	0	0
y_1	15	0
y_2	30	0
y_3	0	Test point 2
y_4	15	Test point 2
y_5	30	Test point 2

Measure each of test samples y_0 to y_5 with the CWM under test and record the turbidity reading.

Calculate and report the change in the reading at zero turbidity and 15 colour units (y_1-y_0) and 30 colour units (y_2-y_0). Also calculate and report the change in the reading at turbidity test point 2 with 15 colour units (y_4-y_3) and 30 colour units (y_5-y_3).

Identify the maximum change as the error due to interferents, X_{IN}.

Effect of chloride on COD measurements

Expose the sensor to reference solutions at test points 1 to 5 (see Table 4) in turn, to each of which 450 to 500 mgl^{-1} chloride has been added (using sodium chloride as the source of chloride). At each point, allow sufficient time for the reading to stabilise and record the reading. Repeat the series of test points a further two times.

Identify the maximum change as the error due to interferents, X_{IN}.

Annex I – 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

Prior to installation of the instrument on the site, the test house carried out a response time test. The instrument was installed at the site and 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 sample of the process fluid. During the field trial 24 paired measurements were made. Each pair comprised a reading from the instrument and the results from laboratory analysis of the sample taken. The analysis was carried out in a UKAS accredited laboratory. The timing of the 24 measurements was arranged so as to cover a range of determined concentrations, as wide a range in sample matrix as practicable at the location and at a number of different points within the maintenance cycle of the instrument.

For the selected application the test instrument required a sample filter unit to condition the sample prior to analysis. Therefore, with the agreement of the Certification Body, for the first month of the trial samples were taken and analysed from both upstream of the sample filter unit and immediately prior to the analyser inlet. These data confirmed the sample filter unit had no effect on the determinand concentration. For the remaining two month of the trial samples were taken and analysed only from upstream of the filter unit.

In addition to recording the values given by the instrument under test several hand held instruments were used to record ambient and water conditions e.g. pH and temperature. 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 and carried out the final response time test. 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 collect a number of samples for laboratory analysis as paired measurements. 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. Samples taken by the customer were analysed in a UKAS accredited laboratory and compared with the readings recorded at the time they were taken. 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.

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 their current on-line analyser from a different manufacturer. The calibration and response time of the instrument was checked each week in their laboratory against brought in standard solutions.

Available existing data

The customer had in excess of 6 months records of laboratory calibrations on the instrument, together with continuous records of the readings from the test instrument and the other on-line instrument.

Approach

The user's laboratory was not UKAS accredited though had defined and rigorous procedures for their laboratory work and the standards used were traceable. The user agreed to release the records 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

The calibration records provided the paired readings from which performance was assessed, and also the response time data. The continuous data from both instruments proved the operation of the test instrument over the trial period. Up-time was determined from the customer records.

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. An instrument was installed and the customer agreed that a technician from the manufacturer could visit site twice a week, each week for a period of twelve weeks to take reference measurements. The reference measurements were made using a portable instrument, which was calibrated at the start of the trial against a recognised standard and checked weekly using secondary standards. At the end of the trial, the reference instrument was recalibrated against the primary standard.

How the data requirements were met

The performance was assessed by comparing the readings taken by the instrument with those from the reference instrument whose performance was known. Up-time was determined at the end of the trial using the data from the test instrument.

Case study 5 – Instrument with multiple determinands

Background

The instrument under test was a multi parameter continuous monitoring device with different probes for each determinand and an in-built data logger.

Available existing data

None which met the requirements of MCERTS.

Approach

It was agreed that the field test could be conducted on all probes simultaneously. The instrument was suspended in a typical flow and left for a period of three months making measurements from each probe every 15 minutes. At the start of the trial, a series of 6 samples were collected over a day. This was repeated at the end of month 1, 2 and 3. The samples were sent for analysis against each determinand under evaluation. Data from the instrument was downloaded every week onsite using the telemetry link. Response time was assessed at the start and end of the trial by setting the data logger to its minimum interval and immersing the probes first in a bucket of clean water, then transferring it to a bucket of sample water which had been spiked to raise the levels of each determinand under test.

How the data requirements were met

Performance was assessed from a comparison of the logged readings against the values obtained from the samples taken. The weekly downloaded data confirmed the continuous operation of the instrument over the full period of the trial. The response time was assessed from the rapidly logged values. Up-time was determined at the end of the trial using the data from the test instrument.