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NMI M 11-1
Meters Intended for the Metering of Water in Open Channels and Partially Filled Pipes

Part 1: Metrological and Technical Requirements

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ABBREVIATIONS

b	width of the weir
C	discharge coefficient
g	acceleration due to gravity
h	height of water
EUT	equipment under test
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
MPE	maximum permissible error
OIML	International Organization of Legal Metrology
Q	flowrate
Q_1	minimum flowrate
Q_3	permanent flowrate
Q_4	overload flowrate
u_c	combined standard uncertainty
U	expanded uncertainty
U_l	lower limit mains voltage
U_{max}	upper limit (battery maximum)
U_{min}	lower limit (battery minimum)
U_{nom}	nominal voltage
U_u	upper limit mains voltage
V	voltage
V_a	actual volume
V_i	indicated volume

AMENDMENTS

Erratum	Date	Page	Location	Details of change
1	01/08/2009	3	clause 2.1.16	Added definition for flow straightener
2	01/08/2009	6	clause 2.6.14	Added definition for certified maintainer
3	01/08/2009	7	clause 3.1	Added Note
4	01/08/2009	10	clause 4.3	Added clause about software and firmware
5	01/08/2009	12	clause 5.5.5	Expanded clause on flow straighteners
6	01/08/2009	12	clause 5.8	Added 'year of manufacture as optional' to marks and inscriptions
7	01/08/2009	20	clause 6.2.10	Added maintenance test
8	01/08/2009	27	clause A.5.8	Added reference IEC 61000-4-20
9	01/08/2009	28	clause A.5.10	Added reference IEC 60068-2-68
10	01/08/2009	throughout	throughout	Minor editorial corrections

CONTENTS

PREFACE

NMI M 11-1 is based on *NMI R 49-1. Water Meters Intended for the Metering of Cold Potable Water and Hot Water. Part 1: Metrological and Technical Requirements* (which in turn is based on OIML R 49-1:2006). Some of the requirements and procedures have never previously been tested or enforced within Australia.

This second edition of NMI 11-1 differs from the first edition in that:

(1) The title has changed and the term 'non-urban' has been removed. Water meters previously designated as 'non-urban' are now designated as accuracy class 2.5 meters.

Note: Water meters approved against NMI R 49-1 are designated as either as accuracy class 1 or accuracy class 2 meters.

(2) To clarify the scope, the following paragraph has been added to clause 1:

> This document is not intended to cover the pattern approval, evaluation or testing of metering systems, although provision is made to allow for the testing and approval of individual modules or sensors.

(3) Clause 3.2 has been expanded to clarify the requirements for different metering arrangements.

(4) The following sentence has been added to clauses 4.2.2 and 4.2.3 to specify the requirements of battery-powered meters:

> Alternatively, provision shall be made to allow this date to be recorded in the memory of the meter upon replacement of the battery and installation of the meter by a certified person.

(5) Clause 5.5 has been expanded to clarify the requirements for different installation conditions.

(6) There is now a requirement that the meter be tested for maximum head loss as specified in clause 5.7.

(7) To specify the requirements of digital indicating devices, the following paragraph has been added to clause 5.9.2.2:

> For electronic devices:
> - either permanent or non-permanent displays are permitted; for non-permanent displays the volume shall be able to be displayed at any time for at least 10 s; and
> - it shall include a feature that enables the correct operation of the display to be checked, e.g. by successive display of the various characters; each step of the sequence shall last at least 1 s.

(8) Clause 5.11 has been amended to clarify the requirements for specific technologies.

(9) Clause 6.2 has been expanded to give a more complete description of the testing required.

(10) Clauses 6.2.3 and 6.2.4 outline the requirements for the meter (if designed to operate under partially filled pipe conditions) to be tested under low-flow and full-flow conditions.

(11) Clause 6.2.6 requires the meter to be tested for accuracy under the influence of standard disturbances.

(12) Clause 6.2.7 requires that the meter be tested for maximum head loss.

(13) Clause 6.2.8 outlines the new endurance testing requirements. A meter is no longer required to be subjected to accelerated wear or endurance regimes under laboratory conditions. Instead, manufacturers shall submit a sample of meters that have registered a volume of water corresponding to at least 1000 hours of continuous flow at a flowrate of Q_3. The meters will be tested to determine the intrinsic errors of indication.

(14) Clause 6.2.9 outlines the requirements for a meter that is to be tested in a certain installation configuration, as specified by the manufacturer.

(15) Annex A has been expanded to include two extra tests for electronic devices, namely water and dust.

1. SCOPE

This document specifies the metrological and technical requirements for the pattern approval and verification of water meters (subsequently referred to as meters) used for trade*, which measure the actual volume of water flowing through open channels and partially filled closed conduits. Such meters shall incorporate devices which indicate the integrated volume. Meters approved against this document are designated as accuracy class 2.5 water meters.

This document also applies to meters based on electrical or electronic principles, and to meters based on mechanical principles incorporating electronic devices, used to meter the actual volume flow of water. It also applies to electronic ancillary devices. As a rule, ancillary devices are optional.

Meters which are essentially self-contained units with their own geometry are normally pattern approved as a single unit. However, modular metering systems consisting of one or more measurement transducers which are pattern approved separately and whose output is used with computational methods as detailed in existing Australian standards to determine flow rate and volume are usually calibrated after installation.

This document is not intended to cover the pattern approval, evaluation or testing of metering systems, although provision is made to allow for the testing and approval of individual modules or sensors.

The metrological characteristics and operating conditions listed in this document apply to self-contained meters and metering systems.

Individual modules (measuring instruments) that form part of a metering system may directly measure and display quantities that are not listed within this document such as water level or flow velocity. Individual modules may also be subject to operating conditions other than those listed in this document.

Appropriate metrological characteristics and operating conditions shall be taken into account during the pattern approval process of such modules.

NMI M 11-2 [1] specifies the methods of examination and testing procedures and NMI M 11-3 [2] contains the model test report.

Requirements for meters for water flowing in full flowing pipes are contained in NMI M 10-1 [3] or NMI R 49-1 [4].

2. TERMINOLOGY

Many of the definitions used in this document conform with the *International Vocabulary of Basic and General Terms in Metrology* [5], the *International Vocabulary of Terms in Legal Metrology* [6] and *AS 3778.1 Measurement of Water Flow in Open Channels. Part 1: Vocabulary and Symbols* [7]. In addition, for the purposes of this standard, the following definitions shall apply:

2.1 Water Meter and its Constituents

2.1.1 Water Meter

An instrument intended to measure continuously, memorise and display the volume of water passing through the measurement transducer or measurement section at metering conditions. A meter is a self contained instrument, of a defined geometry and will be evaluated for pattern approval as a single unit.

Note: A water meter includes at least one measurement transducer, a calculator (including adjustment or correction devices if present) and an indicating device. These three devices may be in different housings. Where the term meter is used in this document it may equally be read as water meter.

* Under the *National Measurement Act 1960* 'used for trade' means use of a measuring instrument for either:

- determining the consideration in respect of a transaction; or
- determining the amount of a tax.

2.1.2 Metering System

A metering system may consist of a number of measuring instruments or modules, which may have been separately pattern approved. These modules may be combined with a structure or emplacement and a calculation methodology to derive a measurement of the volume of water passing through the metering system.

2.1.3 Measurement Transducer

A part of the meter which transforms the flow or the volume of the water to be measured into signals which are passed to the calculator. It can be based on a mechanical, electrical or electronic principle. It may be autonomous or use an external power source.

Note: For the purposes of these requirements, the measurement transducer includes the flow sensor or volume sensor.

2.1.4 Flow Sensor or Volume Sensor

Transducer consisting of one or more components from which is derived a mechanical or electrical output related to the flowrate or another property, such as liquid level, flow velocity or differential pressure between two points, from which the flowrate or volume may be computed.

2.1.5 Non-contact Sensor

Sensor for open channel level measurement, which mounts above the fluid surface and makes no contact with the fluid under normal operation.

2.1.6 Non-invasive Sensor

Sensor for application to pipes which attaches to the outside of a pipe and requires no tapping, drilling or cutting of the pipe to install.

2.1.7 Transmitter

Device which takes the signal from the sensor and converts it into a visual or electrical output proportional to the flowrate or totalised volume.

Note: The sensor and transmitter may be incorporated in a single housing.

2.1.8 Calculator

A part of the meter which receives the output signals from the transducer(s) and, possibly, associated measuring instruments, transforms them and, if appropriate, stores the results in memory until they are used. In addition, the calculator may be capable of communicating both ways with ancillary devices.

2.1.9 Indicating Device

A part of the meter which displays the measurement results either continuously or on demand.

Note: A printing device which provides an indication at the end of the measurement is not an indicating device.

2.1.10 Adjustment Device

A device incorporated in the meter, that only allows the error curve to be shifted generally parallel to itself, with a view to bringing errors of indication within the MPEs.

2.1.11 Correction Device

A device connected to or incorporated in the meter for automatically correcting the volume at metering conditions, by taking into account the flowrate and/or the characteristics of the water to be measured (e.g. temperature and pressure) and the pre-established calibration curves. The characteristics of the water to be measured may either be measured using associated measuring instruments or be stored in memory in the instrument.

2.1.12 Ancillary Device

A device intended to perform a particular function, directly involved in elaborating, transmitting or displaying measurement results.

The main ancillary devices are:

- zero setting device;
- repeating indicating device;
- printing device;
- memory device;
- tariff control device;
- presetting device.

Note: Ancillary devices are only subject to metrological control if they are used for trade.

2.1.13 Tariff Control Device

A device that allocates measurement results into different registers depending on tariff or other criteria, each register having the possibility to be displayed individually.

2.1.14 Presetting Device

A device which permits the selection of the quantity to be measured and which automatically stops the flow of the water at the end of the measurement of the selected quantity.

2.1.15 Associated Measuring Instruments

Instruments connected to the calculator, the correction device or the conversion device, for measuring certain quantities which are characteristic of water, with a view to making a correction and/or conversion.

2.1.16 Flow Straightener

Any device installed into the pipe or channel work intended to minimise or eliminate flow disturbances and create smooth, uniform flow.

2.2 Metrological Characteristics

2.2.1 Actual Volume, V_a

Total volume of water passing through the meter, disregarding the time taken. This is the measurand.

2.2.2 Indicated Volume, V_i

Volume of water indicated by the meter, corresponding to the actual volume.

2.2.3 Primary Indication

An indication (displayed, printed or memorised) which is subject to legal metrological control.

2.2.4 Error of Indication

Indicated volume minus the actual volume.

2.2.5 Relative Error of Indication

Error of indication divided by the actual volume.

2.2.6 Maximum Permissible Error (MPE)

The extreme values of the relative error of indication of a meter, permitted by these requirements.

2.2.7 Intrinsic Error

The error of indication of a meter determined under reference conditions.

2.2.8 Initial Intrinsic Error

The intrinsic error of a meter as determined prior to all performance tests.

2.2.9 Fault

The difference between the error of indication and the intrinsic error of a meter.

2.2.10 Significant Fault

A fault the magnitude of which is greater than half of the MPE.

The following are not considered to be significant faults:

- faults arising from simultaneous and mutually independent causes in the meter itself; and
- transitory faults being momentary variations in the indication which cannot be interpreted, memorised or transmitted as a measurement result.

2.2.11 Durability

The capability of a meter to keep its performance characteristics over a period of use.

2.2.12 Metering Conditions

The conditions of the water, of which the volume is to be measured, at the point of measurement (example: temperature and pressure of water).

2.2.13 First Element of an Indicating Device

The element which, in an indicating device comprising several elements, carries the graduated scale with the verification scale interval.

2.2.14 Verification Scale Interval

The lowest value scale division of the first element of an indicating device.

2.2.15 Resolution (of an Indicating Device)

The smallest difference between indications of an indicating device that can be meaningfully distinguished.

Note: For a digital device, this is the change in the indication when the least significant digit changes by one step.

2.3 Operating Conditions

2.3.1 Flowrate, Q

Quotient of the actual volume of water passing through the meter and the time taken for this volume to pass through the meter expressed in megalitres per day, litres per second, cubic metres per hour or kilolitres per hour.

2.3.2 Permanent Flowrate, Q_3

The highest flowrate expressed in megalitres per day, litres per second, cubic metres per hour or kilolitres per hour, within the rated operating conditions, at which the meter is required to operate in a satisfactory manner within the MPE.

2.3.3 Overload Flowrate Q_4

The highest flowrate expressed in megalitres per day, litres per second, cubic metres per hour or kilolitres per hour, at which the meter is required to operate, for a short period of time, within its MPE, whilst maintaining its metrological performance when it is subsequently operated within its rated operating conditions.

2.3.4 Minimum Flowrate, Q_1

The lowest flowrate expressed in megalitres per day, litres per second, cubic metres per hour or kilolitres per hour, at which the meter is required to operate within the MPE.

2.3.5 Open Channel Flow

Flow in a channel or conduit where there is always a free surface, i.e. air/water interface.

2.3.6 Partially Filled Pipe

A closed conduit in which, under normal operating conditions, the flow has a free surface but under some circumstances may become surcharged and behave as a pressurised pipe.

2.3.7 Maximum Admissible Temperature

The maximum water temperature that a meter can withstand permanently, within its rated operating conditions, without deterioration of its metrological performance.

2.3.8 Maximum Admissible Pressure

The maximum internal pressure that a meter for a partially filled pipe can withstand permanently, within its rated operating conditions, without deterioration of its metrological performance.

2.3.9 Working Temperature, T_w

The average water temperature in the pipe or channel measured upstream and downstream of the meter.

2.3.10 Working Pressure

The average water pressure in the pipe measured upstream and downstream of a close conduit meter when the pipe is surcharged and behaving as a pressurised pipe.

2.3.11 Head Loss

The head loss, at a given flowrate, caused by the presence of the meter in the pipeline or channel.

2.4 Test Conditions

2.4.1 Influence Quantity

A quantity that is not the measurand but which affects the result of the measurement.

2.4.2 Influence Factor

An influence quantity having a value within the rated operating conditions of the meter, as specified in these requirements.

2.4.3 Disturbance

An influence quantity having a value within the limits specified in these requirements, but outside the specified rated operating conditions of the meter.

Note: An influence quantity is a disturbance if for that influence quantity the rated operating conditions are not specified.

2.4.4 Rated Operating Conditions

Conditions of use giving the range of values of the influence factors, for which the errors of indication of the meter are required to be within the MPEs.

2.4.5 Reference Conditions

A set of reference values, or reference ranges of influence quantities, prescribed for testing the performance of a meter, or for the inter-comparison of the results of measurements.

2.4.6 Limiting Conditions

The extreme conditions, including flowrate, temperature, pressure, humidity and electromagnetic interference, that a meter is required to withstand without damage, and without degradation of its error of indication, when it is subsequently operated within its rated operating conditions.

2.4.7 Performance Test

A test intended to verify whether a meter is capable of accomplishing its intended functions.

2.4.8 Endurance Test

A test intended to verify whether the meter is able to maintain its performance characteristics over a period of use.

2.5 Electronic and Electrical Equipment

2.5.1 Electronic Device

A device employing electronic sub-assemblies and performing a specific function. Electronic devices are usually manufactured as separate units and are capable of being tested independently.

Note: Electronic devices, as defined above, may be complete meters or parts of meters, in particular such as those mentioned in clauses 2.1.1 to 2.1.10 and clause 2.1.13.

2.5.2 Electronic Sub-assembly

A part of an electronic device, employing electronic components and having a recognisable function of its own.

2.5.3 Electronic Component

The smallest physical entity which uses electron or hole conduction in semi-conductors, gases, or in a vacuum.

2.5.4 Power Supply Device

A device which provides the electronic devices with the required electrical energy, using one or several sources of AC or DC.

2.6 Terms in Metrology

2.6.1 Accuracy (of Measurement)

The closeness of the agreement between the result of a measurement and a true (conventional) value of the measured quantity.

2.6.2 Error (of Measurement)

The result of a measurement minus a true (conventional) value of the measured quantity.

2.6.3 Relative Error (of Measurement)

The error of measurement divided by a true value of the measured quantity.

2.6.4 True Value (of a Quantity)

A value consistent with the definition of a given particular quantity.

Notes:

1. This is the value that would be obtained by a perfect measurement.
2. True values by nature are indeterminate.
3. The indefinite article 'a', rather than the definite article 'the', is used in conjunction with 'true value' because there may be many values consistent with the definition of a given particular quantity.

2.6.5 Conventional True Value (of a Quantity)

A value attributed to a particular quantity and accepted, sometimes by convention, as having an uncertainty appropriate for a given purpose.

2.6.6 Uncertainty of Measurement

A parameter associated with the result of a measurement that characterises the dispersion of the values that could reasonably be attributed to the measured value.

Notes:

1. The parameter may be, for example, a standard deviation (or a given multiple of it), or the half-width of an interval having a stated level of confidence.
2. Uncertainty of measurement comprises, in general, many components. Some of these components may be evaluated from the statistical distribution of the results of a series of measurements and can be characterised by experimental standard deviations. The other components, which can also be characterised by standard deviations, are evaluated from assumed probability distributions based on experience or other information.
3. It is understood that the result is best estimate of the value of the measurand, and that all components of uncertainty, including those arising from systematic effects, such as components associated with corrections and reference standards, contribute to the dispersion.
4. Both 'Type A' and 'Type B' uncertainties are used in this documentation; for further information see the *Guide to the Expression of Uncertainty in Measurement* [8].

2.6.7 Expanded Uncertainty

Expanded uncertainty shall be determined in accordance with the *Guide to the Expression of Uncertainty in Measurement* [8].

2.6.8 Pattern Approval

The process whereby an impartial body examines the pattern of an instrument against a set of national or international metrological specifications. This determines whether an instrument is capable of retaining its calibration over a range of environmental and operating conditions and ensures that the instrument is not capable of facilitating fraud.

2.6.9 Pattern of an Instrument

The definitive design of a measuring instrument of which all components affecting its metrological properties are suitably defined.

2.6.10 Verification

The process whereby instruments are inspected to ensure that they comply with the approved pattern, calibrated to ensure that they are operating within the MPEs, and stamped or certified as evidence of conformity.

2.6.11 Initial Verification

Verification, by an approved person, of a new instrument which does not bear a verification mark and has never been verified before.

2.6.12 Subsequent Verification

Any verification of an instrument by an approved person because the mark is no longer valid due to such reasons as:

- repairs or adjustments have been made that affect metrological performance; or
- the mark has been defaced or removed.

2.6.13 In-service Inspection

The examination of an instrument by an approved person to check that:

- the verification mark is valid; and
- the instrument has not been modified in any way since verification.

2.6.14 Certified Maintainer

A person certified by an accredited organisation to undertake meter maintenance activities in accordance with best industry practices and Australian standards or technical specifications.

Certified persons may include but are not limited to water service provider staff, State/Territory government officers and irrigation industry contractors.

3. METROLOGICAL REQUIREMENTS

3.1 Values of Q_1, Q_3 and Q_4

The flowrate characteristics of a meter shall be defined by the values of Q_1, Q_3 and Q_4 expressed in megalitres per day, litres per second, cubic metres per hour or kilolitres per hour.

A meter shall be designated by the numerical value of Q_3 and the ratio Q_3/Q_1.

The value of Q_3 shall be nominated by the manufacturer.

The value of the ratio Q_3/Q_1 shall be chosen from the following list:

10	12.5	16	20	25	31.5	40	50	63	80
100	125	160	200	250	315	400	500	630	800

The list may be extended to higher or lower values in the series.

The ratio Q_4/Q_3 shall be 1.25.

Note: Some meters may be designated by numerical values of other characteristics such as velocity. In this case the manufacturer is required to nominate numerical values and ratios analogous to those specified above.

3.2 Maximum Permissible Error

3.2.1 General

This section outlines the MPEs for all types of meters and systems. In order for a meter to comply with this documentation, the meter must satisfy all relevant acceptance criteria.

3.2.2 Error of Indication

The error of indication is expressed as a percentage, and is equal to:

$$[(V_i - V_a) / V_a] \times 100$$

Where: V_a is actual volume
V_i is indicated volume

3.2.3 Self-contained Meters

Meters which are essentially self-contained units with their own geometry and which are normally pattern approved and verified as single units shall be designed and manufactured such that their errors of indication do not exceed ±2.5% across the flowrate range ($Q_1 \leq Q \leq Q_4$) under rated operating conditions. Alternatively, individual elements of self-contained units may be calibrated to ensure that the overall expanded uncertainty for the self-contained meter once assembled does not exceed ±2.5%.

3.2.4 Meters with Separable Calculator and Transducer

For meters with separable calculator and measurement transducer:

- the calculator (including indicating device) and the measurement transducer (including flow sensor or volume sensor) of a meter, where they are separable and interchangeable with other calculators and measurement transducers of the same or different designs, may be the subject of separate pattern approvals; and
- the MPEs of the combined indicating device and measurement transducer shall not exceed ±2.5%.

3.2.5 Insertion Devices

Where insertion velocity measuring devices are tested for pattern approval and initial verification they shall be tested in pipe sections whose measurements have been determined to the extent that such dimensions contribute no more than 0.1% to the expanded uncertainty in the determination of volume. In this case, MPE of the insertion velocity measuring device plus the pipe section shall not exceed ±2.5% across the flowrate range ($Q_1 \lesssim Q \lesssim Q_4$) under rated operating conditions.

3.2.6 Additional Requirements

The requirements relating to the MPEs shall be met for all temperature variations occurring within the rated operating conditions of the meter.

The meter totalisation shall not change when the flowrate is zero.

3.3 Maximum Permissible Uncertainty

Modular metering systems, consisting of one or more measurement transducers and a computational device which are separately pattern approved shall be installed such that the maximum expanded uncertainty in the determination of the volume of water shall not exceed ±5%.

Uncertainty shall be determined in accordance with *Guide to the Expression of Uncertainty of Measurement* [8]. An example of an uncertainty calculation is given in Annex B.

3.4 Requirements for Meters and Ancillary Devices

3.4.1 Connections between Electronic Parts

The connections between the measurement transducer, the calculator and the indicating device shall be reliable, durable and tamper protected in accordance with clause 5.9.2.

3.4.2 Adjustment Device

Adjustment devices may be either electronic or mechanical. Such devices shall be tamper protected in accordance with clause 5.9.

3.4.3 Correction Device

Meters may be fitted with correction devices; such devices shall be considered as an integral part of the meter and shall be tamper protected in accordance with clause 5.9. All requirements which apply to the meter, in particular the MPE (±2.5%) or maximum expanded uncertainty (±5%) specified in clause 3.2, are therefore applicable to the corrected volume at metering conditions.

In normal operation, non-corrected volume shall not be displayed.

The aim of a correction device is to reduce the errors of indication to as close to zero as possible. Meters with electronic correction devices shall satisfy the performance tests of Annex A.5.

All the parameters which are not measured and which are necessary for correcting shall be contained in the calculator at the beginning of the measurement operation. The pattern approval certificate may prescribe the possibility of checking parameters which are necessary for correctness at the time of verification of the correction device.

The correction device shall not allow the correction of a pre-estimated drift, e.g. in relation to time or volume.

Associated measuring instruments, if any, shall comply with the applicable international standards or recommendations. Their accuracy should be good enough to permit the requirements on the meter to be met, as specified in clause 3.2.

Correction devices shall not be used for adjusting the error of indication of a meter to values other than as close as practical to zero, even when these values are within the MPEs.

3.4.4 Calculator

All parameters necessary for the elaboration of indications that are subject to legal metrological control, such as a calculation table or correction polynomial, shall be present in the calculator at the beginning of the measurement operation.

The calculator may be provided with interfaces permitting the coupling of peripheral equipment. When these interfaces are used, the meter's hardware and software shall continue to function correctly and its metrological functions shall not be capable of being affected.

3.4.5 Electronic Indicating Device

The continuous display of volume during the period of measurement is not mandatory.

3.4.6 Ancillary Devices

The relevant requirements of NMI R 117 [9] shall be applied when the meter is equipped with any of the following devices:

- zero setting device;
- printing device;
- memory device;
- presetting device.

4. METERS EQUIPPED WITH ELECTRONIC DEVICES

4.1 General Requirements

Meters with electronic devices shall be designed and manufactured in such a way that significant faults do not occur when they are exposed to the disturbances specified in Annex A.5.

These requirements shall be met durably.

The meter shall also provide visual checking of the entire display which shall have the following sequence:

- displaying all elements (e.g. an ‘eights’ test); and
- blanking all the elements (a ‘blanks’ test).

Each step of the sequence shall last at least 1 s.

4.2 Power Supply Device

Three different kinds of basic power supplies for meters with electronic devices are covered by these requirements:

- external power supply;
- non-replaceable battery; and
- replaceable battery.

These three types of power supplies may be used alone or in combination. The requirements for each type of power supply are covered by the following paragraphs.

4.2.1 External Power Supply

Meters with electronic devices shall be designed such that in the event of an external power supply failure (AC or DC), the meter indication of volume just before failure is not lost, and remains accessible for a minimum of one year.

The corresponding memorisation shall occur at least either once per day or for every volume equivalent to 10 min of flow at Q_3.

Any other properties or parameters of the meter shall not be affected by an interruption of the electrical supply.

Note: Compliance with this clause will not necessarily ensure that the meter will continue to register the volume consumed during a power supply failure.

The power supply shall be secured from tampering or any such tampering will be evident.

4.2.2 Non-replaceable Battery

The manufacturer shall ensure that the indicated lifetime of the battery exceeds the operational lifetime of the meter by one year. Therefore, guaranteeing that the meter functions correctly for at least one year longer than the nominal operational lifetime of the meter.

The latest date by which the meter is to be replaced shall be indicated on the meter. Alternatively, provision shall be made to allow this date to be recorded in the memory of the meter upon installation by a certified person.

Note: It is anticipated that a combination of maximum allowable volume, displayed volume, indicated operational lifetime, remote reading and extreme temperature will be considered when specifying a battery and during pattern approval. Alternative means of indicating impending battery failure may be allowed.

4.2.3 Replaceable Battery

Where the electrical power supply is a replaceable battery, the manufacturer shall give precise rules for the replacement of the battery.

The replacement date of the battery shall be indicated on the meter. Alternatively, provision shall be made to allow this date to be recorded in the memory of the meter upon replacement of the battery and installation of the meter by a certified person.

The properties and parameters of the meter shall not be affected by the interruption of electrical supply when the battery is replaced.

Note: It is anticipated that a combination of maximum allowable volume, displayed volume, indicated operational lifetime, remote reading and extreme temperature will be considered when specifying a battery and during pattern approval. Alternative means of indicating impending battery failure may be allowed.

The operation of replacing the battery shall be carried out in a way which does not necessitate breaking the seal required for metrological verification.

The battery compartment shall be secured from tampering or any such tampering will be evident.

4.2.4 Combination of External Power Supply and Rechargeable Battery

Where an external power source such as solar energy is used to recharge batteries, meters shall be designed such that in the event of failure of the solar power through damage or shading, the meter indication of volume just before battery failure is not lost, and remains accessible for a minimum of one year.

The corresponding memorisation shall occur once per day or for every volume equivalent to 10 min of flow at Q_3.

4.2.5 Frequency of Measurement

For meters operating at constant flowrate with only periodic measurement in order to conserve battery life, flow measurement shall occur at least every 5 min.

4.3 Software and Firmware

Details of any software and/or firmware used in the meter shall be specified in the pattern approval application form. The applicant shall advise NMI of any subsequent modifications to software and/or firmware which may affect the metrology of the meter.

5. TECHNICAL REQUIREMENTS

5.1 Materials and Construction of Meters

The meter shall be manufactured from materials of adequate strength and durability for the purpose for which the meter is to be used.

The meter shall be manufactured from materials which shall not be adversely affected by water temperature variations, within the working temperature range (see clause 5.6).

The meter shall be manufactured from materials which are resistant to corrosion or which are protected by a suitable surface treatment.

The indicating device of the meter shall be protected by a transparent window which is resistant to ultraviolet radiation. A cover of suitable type may also be provided as additional protection.

The meter shall incorporate devices for elimination of condensation, where there is a risk of the condensation forming on the underside of the window of the indicating device of the meter.

5.2 Environmental Requirements

5.2.1 General

The rated ranges of use for ambient conditions are divided into two classes. Meters shall be tested at the severity level indicated in Table A.1, according to the environmental class.

Note: The individual components of a meter may belong to different environmental classes. In this case, the cable between them and any interface device should be suitable for the higher rated of the two classes.

The manufacturer shall state the environmental class(es) of the meter or its individual components. The approving authority shall determine the test requirements for the meter or its individual components.

5.2.2 Environmental Class B

This class applies to enclosed locations whose temperature and humidity are not controlled. Heating may be used to raise low temperatures, especially when there is a large difference between the conditions of this class and the open air conditions. Meters may be exposed to solar and heat radiation and draughts and may be subject to condensed water, water from sources other than rain and to ice formations. Vibration and shock will be of low significance.

5.2.3 Environmental Class C

This class applies to open locations with average climatic conditions, excluding polar and desert environments. Levels of vibration and shock will be of low significance.

5.3 Enclosure

All mechanical and electrical equipment and connections shall be protected against the ingress of dust and water and shall meet or exceed the requirements of one of the following rated ranges of use in accordance with IEC 60529 (IP Code) [10]:

- Class B — IP54;
- Class C — IP65 or IP68 for non-submersible and submersible components respectively.

For meters or individual components specified to IEC 60529 IP65 or IP68, the degree of protection for all electrical equipment and connections shall not be degraded below their original rating after routine maintenance procedures or during normal calibration and verification. Where this is not possible, the meter or component shall be clearly marked to indicate that all care must be taken when any procedure is being undertaken.

The minimum degree of protection provided for an electrical flow sensor, including any electrical equipment or termination section provided as part of the sensor unit, shall conform to the requirements of IEC 60529 IP65.

The degree of protection provided for a submersible or insertion electrical flow sensor shall conform to the requirements of IEC 60529 IP68 at a depth to be stated by the manufacturer.

Any electrical equipment or termination section provided with a submersible or insertion electrical sensor unit as part of the sensor unit, but not intended to be immersed, shall conform to the requirements of IEC 60529 IP65 and be clearly marked with a warning that this equipment is not to be immersed.

5.4 Adjustment and Correction

The meter may be fitted with an adjustment device, and/or correction device.

If these devices are mounted on the outside of the meter, provision for sealing by the appropriate authority shall be made (see clause 5.10).

5.5 Installation Conditions

5.5.1 General

Meters shall be installed in the manner for which they have been approved. During pattern approval, meters and meter modules will be tested for the affects of influence factors likely to be encountered after installation. The pattern approval certificate will state the conditions and limitations of installation, if any.

5.5.2 Partially Filled Pipes

A meter approved for operation in partially filled pipes shall be installed so that conditions of approval are met.

5.5.3 Open Channels

A meter approved for operation in an open channel shall be installed so that conditions of that approval relating to upstream and downstream water levels are met.

5.5.4 Strainers and Filters

If the accuracy of the meter is likely to be affected by the presence of solid particles in the water, it shall be provided with a strainer or filter, fitted at its inlet or in the upstream pipeline.

5.5.5 Straight Lengths of Pipe or Channel

If the accuracy of the meter is affected by disturbances in the upstream pipeline or channel (e.g. due to the presence of bends, valves, gates or pumps) the meter shall be provided with a sufficient number of straight lengths of pipe or channel (with or without a flow straightener) as specified by the manufacturer, so that the indications of the installed meter meet the requirements of clause 3.2.

Applicants shall submit full details and technical drawings of external flow straighteners to NMI (e.g. model, technical characteristics, position relative to the meter). The details and use of such devices will be included in the pattern approval certificate and listed as a condition of installation.

5.5.6 Specified Installations

The meter may be tested in specified installation conditions such as certain piping configurations in accordance with the requirements of clause6.2.9.

5.6 Rated Operating Conditions

The rated operating conditions for a meter shall be as follows:

- flowrate range: Q_1 to Q_3 inclusive;
- ambient air temperature range: –5 to +55°C;
- ambient humidity range: 0 to 100% except for remote indicating devices where the ranges shall be 0 to 93%;
- working water temperature range: 0.1 to 30°C (the maximum admissible temperature is 50°C; this is a limiting condition for the meter).

5.7 Head Loss

The meter shall be tested to determine the maximum head loss through the meter at any flowrate between Q_1 and Q_3. The head loss will be indicated in the manufacturer's documentation (see clause 6.2.7).

5.8 Marks and Inscriptions

The following information shall either be clearly and indelibly marked on the meter (either grouped or distributed on the casing, the indicating device dial, an identification plate or on the meter cover if it is not detachable), or recorded in the meter's memory and be easily accessible:

(a) unit of measurement: megalitre, cubic metre or kilolitre (see clause 5.8.1.1);

(b) numerical value of Q_3 and the ratio Q_3/Q_1;

(c) pattern approval mark;

(d) name or trade mark of the manufacturer;

(e) serial number (as near as possible to the indicating device);

(f) year of manufacture (optional);

(g) direction of flow (the direction of flow arrow shall be easily visible under all circumstances);

(h) maximum head loss;

for meters designed to operate in partially filled pipes:

(i) maximum admissible pressure;

(j) minimum water level;

for meters with electronic devices, the following additional inscriptions where appropriate:

(k) for an external power supply: the voltage and frequency;

(l) for a replaceable battery: the latest date that the battery is to be replaced; alternatively, provision shall be made to allow this date to be recorded in the memory of the meter upon replacement of the battery and installation of the meter by a certified person;

(m) for a non-replaceable battery: the latest date by which the meter is to be replaced; alternatively, provision shall be made to allow this date to be recorded in the memory of the meter upon installation by a certified person; and

(n) the IP rating of the meter and/or its constituent parts.

5.9 Indicating Device

5.9.1 General Requirements

The indicating device or display:

- shall provide an easily read, reliable and unambiguous visual indication of the indicated volume;
- shall include visual means of testing and calibration;
- may include additional elements for testing and calibration by other methods, e.g. for automatic testing and calibration;
- may display other parameters such as instantaneous or average flowrate.

5.9.1.1 Unit of Measurement, Symbol and its Placement

The indicated volume of water shall be expressed in megalitres, cubic metres or kilolitres. The symbol ML, m^3 or kL shall appear on the dial or immediately adjacent to the numbered display.

5.9.1.2 Indicating Range

The indicating device shall be able to record the indicated volume in megalitres, cubic metres or kilolitres corresponding to at least 200 days of operation at the permanent flowrate Q_3, without passing through zero. Examples of compliance are shown in Tables 1 and 2.

Table 1. Volumetric (ML) indicating range of a water meter

Q_3 (ML/d)	Indicating range (ML) (minimum values)
$Q_3 \leq 50$	9 999
$50 < Q_3 \leq 500$	99 999
$500 < Q_3 \leq 5\,000$	999 999

Table 2. Volumetric (m^3 or kL) indicating range of a water meter

Q_3 (L/s)	Indicating range (m^3 or kL) (minimum values)
$Q_3 \leq 0.5$	9 999
$0.5 < Q_3 \leq 5$	99 999
$5 < Q_3 \leq 50$	999 999

Note: 5 ML/d is approximately equal to 60 L/s.

5.9.1.3 Colour Coding of Indicating Devices

The colour black should be used to indicate megalitres, cubic metres or kilolitres and its multiples.

The colour red should be used to indicate sub-multiples of a megalitre, cubic metre or kilolitre.

These colours shall be applied to either the pointers, indexes, numbers, wheels, discs, dials or aperture frames.

Other means of indicating the megalitre, cubic metre or kilolitre its multiples and its sub-multiples may be used, provided there is no ambiguity in distinguishing between the primary indication and alternative displays, e.g. sub-multiples for verification testing.

5.9.2 Types of Indicating Device

5.9.2.1 Type 1 – Analogue Device

The indicated volume is indicated by continuous movement of either:

- one or more pointers moving relative to graduated scales; or
- one or more circular scales or drums each passing an index.

The value expressed in megalitres, cubic metres or kilolitres for each scale division shall be of the form 10^n, where n is a positive or negative whole number or zero, thereby establishing a system of consecutive decades. Each scale shall be either graduated in values expressed in megalitres, cubic metres or kilolitres accompanied by a multiplying factor ($\times$ 0.001; $\times$ 0.01; $\times$ 0.1; $\times$ 1; $\times$ 10; $\times$ 100; $\times$ 1000 etc.).

Rotational movement of the pointers or circular scales shall be clockwise.

Linear movement of pointers or scales shall be left to right.

5.9.2.2 Type 2 – Digital Device

The indicated volume is given by a line of adjacent digits appearing in one or more apertures. The advance of a given digit shall be completed while the digit of the next immediately lower decade changes from 9 to 0. The apparent height of the digits shall be at least 4 mm.

For non-electronic devices:

- movement of numbered roller indicators (drums) shall be upwards; and
- if the lowest value decade has a continuous movement, the aperture shall be large enough to permit a digit to be read unambiguously.

For electronic devices:

- either permanent or non-permanent displays are permitted; for non-permanent displays the volume shall be able to be displayed at any time for at least 10 s; and
- it shall include a feature that enables the correct operation of the display to be checked, e.g. by successive display of the various characters; each step of the sequence shall last at least 1 s.

5.9.2.3 Type 3 – Combination of Analogue and Digital Devices

The indicated volume is given by a combination of an analogue and a digital device and the respective requirements of each shall apply.

5.9.3 Supplementary Devices

In addition to the indicating devices described in clause 5.9.2, the meter may include supplementary devices which may be permanently incorporated or added temporarily.

The device may be used to detect movement of the flow sensor before this is clearly visible on the indicating device. The device may be used for testing and verification and for remote reading of the meter, provided that other means guarantee the satisfactory operation of the meter.

Meters shall be fitted with a device or devices capable of communicating data to a location remote from the meter. This may take the form of a reed switch with each contact closure representing a known volume of water.

5.9.4 Verification Devices – First Element of an Indicating Device – Verification Scale Interval

5.9.4.1 General

Every indicating device shall provide means for visual, non-ambiguous verification testing and calibration.

The visual verification scale may have either a continuous or discontinuous movement.

In addition to the visual verification display, an indicating device may include provisions for rapid testing by inclusion of complementary elements (e.g. star wheels or discs) providing signals through externally attached sensors.

5.9.4.2 Value of the Verification Scale Interval

The value of the verification scale interval (expressed in megalitres, cubic metres or kilolitres) shall be of the form 1×10^n, or 2×10^n, or 5×10^n, where n is a positive or negative whole number, or zero.

For analogue and digital indicating devices with continuous movement of the first element, the verification scale may be formed from the division into 2, 5 or 10 equal parts of the interval between two consecutive digits of the first element. Numbering shall not be applied to these divisions.

For digital indicating devices with discontinuous movement of the first element the verification scale interval is the interval between two consecutive digits or incremental movements of the first element.

5.9.4.3 Form of the Verification Scale

On indicating devices with continuous movement of the first element, the apparent scale spacing shall not be less than 1 mm and not more than 5 mm. The scale shall consist of either:

- lines of equal thickness not exceeding one-quarter of the scale spacing and differing only in length; or
- contrasting bands of a constant width equal to the scale spacing.

The apparent width of the pointer at its tip shall not exceed one-quarter of the scale spacing and in no case shall it be greater than 0.5 mm.

5.9.4.4 Resolution of the Indicating Device

The subdivisions of the verification scale shall be small enough to ensure that the resolution error of the indicating device does not exceed 0.5% of the actual volume passed during 1 h 30 min at the minimum flowrate, Q_1.

Note: When a display of the first element is continuous, an allowance should be made for a maximum error in reading of not more than half the verification scale interval.

When the display of the first element is discontinuous, an allowance should be made for a maximum error in each reading of not more than one digit of the verification scale.

5.10 Verification Marks and Protection Devices

A place shall be provided on meters for affixing the main verification mark, which shall be visible without dismantling the meter.

5.10.1 Mechanical Sealing Devices

Meters shall include protection devices which can be sealed so as to prevent, both before and after correct installation of the meter, dismantling or modification of the meter, its adjustment device or its correction device, without damaging these protection devices.

5.10.2 Electronic Sealing Devices

(a) When access to parameters that influence the determination of the results of measurements is not protected by mechanical sealing devices, the protection shall fulfil the following provisions:

- Access shall only be allowed to authorised people, e.g. by means of a code (key word) or of a special device (e.g. a hard key). The code shall be capable of being changed.
- It shall be possible for at least the last intervention to be memorised. The record shall include the date and a characteristic element identifying the authorised person making the intervention (see above). The traceability of the last intervention shall be assured for at least two years, if it is not overwritten on the occasion of a further intervention. If it is possible to memorise more than one intervention and if deletion of a previous intervention must occur to permit a new record, the oldest record shall be deleted.

(b) For meters with parts which may be disconnected one from another and which **are** interchangeable, the following provisions shall be fulfilled:

- it shall not be possible to access parameters that participate in the determination of results of measurements through disconnected points unless the provisions of clause 5.10.2(a) are fulfilled; and
- interposing any device which may influence the accuracy shall be prevented by means of electronic and data processing securities or, if this is not possible, by mechanical means.

(c) For meters with parts which may be disconnected one from another and which **are not** interchangeable, the provisions in clause 5.10.2(b) shall apply. Moreover, these meters shall be provided with devices which do not allow them to operate if various parts are not connected according to the manufacturer’s configuration.

Note: Disconnections which are not allowed may be prevented, e.g. by means of a device that prevents any measurement after disconnecting and reconnecting.

5.11 Requirements Related to Specific Metrological Techniques

For meters which calculate the volume and/or flowrate based upon predetermined measurements (diameter, length, height, depth, angle or other physical quantity), such predetermined measurements shall be traceable to Australia's national standards of measurement. The uncertainty associated with these measurements shall be incorporated in the overall uncertainty of measurement for the meter.

5.11.1 Self-contained Meters

Self-contained meters shall be approved as complete meters. The MPEs of such meters shall not exceed the value given in clause 3.2 (±2.5%).

5.11.1.1 Metering of Partially Filled Pipes

Meters for partially filled pipes include devices for measuring water velocity and height. The output from these devices coupled with the geometry of the meter or pipe section is used to calculate the flow rate which, when integrated over time, results in measured volume. The height and velocity measurement devices may be one device.

Meters for partially filled pipes shall be tested from a minimum height nominated by the manufacturer to full pipe condition. Meters shall indicate when flow has occurred below the minimum height specified by the manufacturer. The duration of such flow shall be recorded.

If meters for partially filled pipes are not designed to measure under full pipe condition a visual or audible alarm shall occur and the duration of full pipe condition shall be recorded.

5.11.1.2 Metering of Open Channels

Self-contained meters for open channels are factory assembled and contain all elements required to determine the volume of water. They may be verified in a flow rig, in which case they shall be calibrated to ensure that they are within an MPE of ±2.5%. Alternatively, individual elements shall be calibrated to ensure that the overall expanded uncertainty for the self-contained meter once assembled does not exceed ±2.5%. All verification requirements are to be approved by NMI and listed on the pattern approval certificate.

The individual elements, instruments, sensors and measurement devices may be contained in one device.

5.11.2 Modular Metering Systems

This document is not intended to cover the pattern approval, evaluation or testing of modular metering systems, although provision is made to allow for the testing and approval of individual modules or sensors such as those defined in clauses 2.1.3 to 2.1.9. The overall expanded uncertainty of measurement of modular metering systems shall be determined in accordance with the *Guide to the Expression of Uncertainty in Measurement* [8] and shall not exceed ±5%. An example of an uncertainty calculation is given in Annex B.

5.11.2.1 Installation

The installation and putting into service of modular metering systems may involve taking measurements of length (diameter, depth, height, width), angle, time or other quantity. Instruments used to make such measurements shall have a calibration certificate from a NATA-accredited facility showing the accuracy, uncertainty and traceability of the instruments to Australia's primary standards of measurement.

Modular metering systems for open channel flow shall be designed and installed in accordance with AS 3778.2.2 [11].

5.11.2.2 Level Sensors

Level sensors used to determine the surface height of water relative to a fixed datum shall meet the requirements of NMI M 12-1 [12].

If level sensors incorporate temperature measuring devices they shall be tested at the temperatures given in Annexes A.5.1 and A.5.2.

If level sensors incorporate electronic devices they shall be tested in accordance with the tests outlined in Annex A.

5.11.2.3 Weirs and Flumes

Weirs and flumes shall be designed and constructed in accordance with AS 3778.4.1 [13] and AS 3778.4.7 [14]. The determination of flowrate shall be made using the formulae and coefficients of these standards. NMI may issue a general certificate for the design and construction of weirs and flumes. Weirs and flumes purporting to comply with any such general certificate shall comply with the conditions of the certificate.

5.11.2.4 Velocity Measurement Devices

Velocity measurement devices shall be designed and constructed in accordance with either AS 3778.6.1 [15] or AS 3778.6.7 [16].

5.11.2.5 Flow Computer

Flow shall be computed in accordance with AS 3778.2.3 [17], AS 3778.3.1 [18], AS 3778.3.7 [19] or AS 3778.3.8 [20].

Where a flow computer computes flowrate and volume from inputs of one or more properties, the flow computer and the manufacturer's documentation shall be examined to determine whether the flow computer incorporates means to perform these computations.

All of the parameters which are not measured and which are necessary for computation shall be contained in the flow computer at the beginning of the measurement operation.

Flow computers shall be tested for accuracy over the range of input parameters and reference conditions and shall be tested for the effects of the applicable influence factors and disturbances listed in Annex A. During these tests, measured input parameters may be actual or simulated.

Where total volume is determined by averaging flowrate and multiplying by time, the time interval over which the flowrate is averaged shall be suitable to ensure that the overall maximum uncertainty for the metering system is not exceeded.

The uncertainty associated with this averaging process shall be incorporated in the overall uncertainty of measurement for the meter.

Where total volume is determined by extrapolating velocity measurements which are taken intermittently to infer velocity over the time period, such extrapolation process shall be clearly defined and such meters shall not be installed where this process would lead to the MPEs being exceeded due to this process. The uncertainty associated with this extrapolation process shall be incorporated in the overall uncertainty of measurement for the meter.

6. METROLOGICAL CONTROLS

6.1 Reference Conditions

When meters and modules are tested under laboratory conditions, all influence quantities, except for the influence quantity being tested shall be held to the following values during pattern approval tests on the meter or module. NMI can provide guidance on any issues related to permissible reference conditions.

6.1.1 Flowrate and Power Supply

Flowrate:
$0.7 \times (Q_1 + Q_3) \pm 0.03 \times (Q_1 + Q_3)$

Module measurement parameter:
0.7 × (min + max) ± 0.03 (min + max) where min and max are the minimum and maximum boundaries of the range over which the module is claimed to be within accuracy limits

Power supply voltage (mains AC):
nominal voltage (U_{nom}) ±5%

Power supply frequency:
nominal frequency (f_{nom}) ±2%

Power supply voltage (battery):
a voltage V in the range $U_{min} \leq V \leq U_{max}$

6.1.2 Temperature

The ambient and working temperature ranges given below allow for seasonal and climatic variations. However during all performance testing the ambient and working temperature shall not vary by more than ±5°C over the period of the testing.

Working water temperature: 20 ± 10°C
Ambient air temperature: 20 ± 10°C

6.1.3 Humidity and Pressure

The values given below for ambient relative humidity and atmospheric pressure are the recommended ranges over which pattern approval testing should be conducted. These conditions shall be recorded appropriately.

Ambient relative humidity: 60 ± 15%
Ambient atmospheric pressure: 86 to 106 kPa

6.2 Pattern Approval

Meters and modules shall undergo the pattern approval tests indicated below. Pattern approval shall be carried out by an approving authority appointed in accordance with the National Measurement Regulations.

In the case of open channel devices such as weirs or flumes, NMI may issue a general certificate based upon an agreed Australian or ISO standard. Such general certificates will only apply to the weir or flume. All other devices such as counters, transducers, calculators, flow computers or indicating devices must be approved separately.

The calculator (including indicating device) and the measurement transducer (including flow sensor or volume sensor) of a meter, where they are separable and interchangeable with other calculators and measurement transducers of the same or different designs, may be the subject of separate pattern approvals. The MPEs of the combined indicating device and measurement transducer shall not exceed the values given in clause 3.2 (±2.5%).

Before undergoing pattern approval tests, each pattern of meter or module submitted shall be inspected externally to ensure that it complies with the provisions of the relevant preceding clauses of these requirements.

The approval tests shall be made on the minimum number of samples of each pattern shown in Table 3 as a function of the meter designation Q_3 of the pattern presented. In general, where the approval tests are for a module, only one module is required to be submitted.

The service responsible for pattern approval may request further specimens.

Table 3. Number of meters to be tested

Meter designation Q_3 (L/s equivalent)	Minimum number of meters
$Q_3 \leq 44$	3
$44 < Q_3 \leq 1\,440$	2
$1\,440 < Q_3$	1

Note: Additional samples are required for meters equipped with electronic devices.

The requirements of clause 3.2 shall apply to all the meters tested.

6.2.1 Static Pressure Test

A meter designed for operation in partially filled pipes shall be capable of withstanding the following test pressures without leakage or damage:

- 1.6 times the maximum admissible pressure applied for 15 min; and
- twice the maximum admissible pressure applied for 1 min.

6.2.2 Errors of Indication

The errors of indication of the meter (in the measurement of the actual volume) shall be determined for at least the following flowrates, the error at each flowrate being measured twice:

- between Q_1 and $1.1Q_1$;
- between $0.33\,(Q_1 + Q_3)$ and $0.37\,(Q_1 + Q_3)$;
- between $0.67\,(Q_1 + Q_3)$ and $0.74\,(Q_1 + Q_3)$;
- between $0.9\,Q_3$ and Q_3; and
- between $0.95\,Q_4$ and Q_4.

If the meter is designed to operate in open channels then tests shall also be conducted under the following conditions:

- free overfall – the meter shall be tested at each of the above flowrates under free overfall conditions; and
- submerged flow – the meter shall be tested at a range of flowrates to be established under different downstream conditions which shall include 5–15%, 40–50% and 80–90% of the upstream level/head.

The errors of indication observed for each of the flowrates shall not exceed the MPEs given in clause 3.2 (±2.5%). If the error of indication observed on one or more meters is greater than the MPE at one flowrate only, the test at that flowrate shall be repeated. The test shall be declared satisfactory if two out of the three results lie within the MPE and the arithmetic mean of the results for the three tests at that flowrate is less than or equal to the MPE.

If all the errors of indication of the meter have the same sign, at least one of the errors shall not exceed one-half of the MPE.

It is recommended that the characteristic error curve for each meter be plotted in terms of error against flowrate, so that the general performance of the meter over its flowrate range can be evaluated.

6.2.3 Low Flow Test

Meters that are designed for operation in partially filled pipes shall be tested to verify the minimum water level (nominated by the manufacturer) of the meter.

The meter shall indicate when flow has occurred below the minimum water level and that the duration of such flow is recorded.

6.2.4 Full Flow Test

Meters designed to operate in partially filled pipes that are not designed to measure under full flowing pipe conditions must be fitted with a visual or audible alarm. If the meter is subjected to full flowing pipe conditions then that alarm shall automatically occur and the duration of the full flowing pipe conditions will be recorded by the meter.

Meters designed to operate in partially filled pipes that are also designed to measure at full flowing pipe conditions will be tested under such conditions to verify that they do not exceed the maximum permissible error given in clause 3.2.

6.2.5 Wave Disturbance Test

The meter shall be subjected to wave disturbances and tested to verify that the meter complies with the requirements of clause 3.2.

6.2.6 Flow Disturbance Test

The meter will be subjected to a number of standard disturbances. The relative error of indication of the meter shall not exceed the MPE given in clause 3.2 for any of the tests, and the error shift shall be less than one-third of the MPE given in clause 3.2 (the expanded uncertainty of the test method plus an allowance for the repeatability of the meter under test).

6.2.7 Head Loss Test

The meter shall be tested to determine the maximum head loss through the water meter at any flowrate between Q_1 and Q_3.

6.2.8 Endurance Test

Meters are required to maintain their performance characteristics and a required level of metrological accuracy over an extended period of operation. However due to cost and time constraints, subjecting meters to accelerated wear or endurance regimes under laboratory conditions shall not form part of the pattern approval process.

Manufacturers will be required to submit a sample of meters (see Table 3) that have registered a volume of water corresponding to at least 1000 hours of continuous flow at a flowrate of Q_3.

Meters that form part of the sample will be tested to determine the intrinsic errors of indication.

The following acceptance criteria will apply to meters in the sample:

- the difference between the error of indication at the initial test and the test following the endurance regime shall not exceed 2.5% at each point on the curve;
- the error of indication curve shall not exceed a maximum error limit of ±4%.

6.2.9 Specified Installation Tests

The meter may be tested in a certain installation configuration (as specified by the manufacturer) in which case the error of indication shall be determined in accordance with clause 6.2.2 and shall not exceed the MPE given in clause 3.2 for any of the tests.

6.2.10 Maintenance Tests

The policy paper *National Framework for Non-urban Water Metering* [21] allows a manufacturer to test a specified maintenance activity on the meter under test as part of the pattern approval process.

The pattern approval certificate will list the specified maintenance procedures that have been tested and are deemed to have no adverse affect on the metrological performance of a meter when undertaken by a suitably trained and certified maintainer. Any and all other maintenance procedures that are performed on a meter, that are not listed on the pattern approval certificate (which require the verification seal(s) to be broken), are deemed to affect the metrological performance of the meter and therefore subsequent verification is required.

All information included on a pattern approval certificate relating to the maintenance of a meter is intended as guidance only.

6.2.11 Pattern Approval of a Meter or Module with Electronic Device

In addition to the examinations or tests described in the preceding paragraphs, a meter or module with electronic devices shall be subject to the following examinations and tests.

6.2.11.1 Design Inspection

This examination of documents aims at verifying that the design of electronic devices and their checking facilities, if applicable, comply with the provisions of these requirements, in particular clause 4. It includes:

- an examination of the mode of construction and of the electronic subsystems and components used, to verify their appropriateness for their intended use; and
- consideration of faults likely to occur, to verify that in all considered cases these devices comply with the provisions of clause 4.1.

6.2.11.2 Performance Tests

The performance tests specified in Annex A aim at verifying that the meter complies with the provisions of clauses 3.2 and 4.1 with regard to influence quantities.

(a) Performance under the Effect of Influence Factors

When subjected to the effect of influence factors as provided for in Annex A, the equipment shall continue to operate correctly and the errors of indication shall not exceed the MPEs.

For modules which will subsequently form part of a modular metering system, the effect of the influence factors shall be recorded for subsequent use in the determination of the uncertainty of measurement of the modular metering system.

(b) Performance under the Effect of Disturbances

When subjected to external disturbances as provided for in Annex A, the equipment shall continue to operate correctly and significant faults shall not occur.

6.2.11.3 Equipment under Test (EUT)

Where the electronic devices form an integral part of the meter, tests shall be carried out on the complete meter.

If the electronic devices of a meter or module are in a separate housing, their electronic functions may be tested independently of the measurement transducer of the meter by simulated signals representative of the normal operation of the meter or module, in which case the electronic devices shall be tested in their final housing.

In all cases, ancillary equipment may be tested separately.

6.2.12 Documentation

Application for approval of a pattern of a meter shall be made according to NMI P 106 [22].

In accordance with the National Measurement Regulations:

- a certificate of approval shall be issued in accordance with Regulation 63; and
- under Regulation 59 an approval holder shall make application to vary such approval following any modification or addition which concerns such approved pattern.

6.3 Initial Verification

Meters and modules shall undergo initial verification tests. This verification shall be carried out by a verifying authority appointed in accordance with section 18ZC of the National Measurement Act. Requirements for verification are given in section 18V of the Act.

The errors of indication of the meters in the measurement of actual volume shall be determined for at least the following three flowrates:

- between Q_1 and $1.1Q_1$;
- between $0.5Q_3$ and $0.6Q_3$; and
- between $0.9Q_3$ and Q_3.

However, depending on the shape of the error curve, the design and specifications of the meter and typical installation conditions, alternative flowrates (or flowrate ranges) may be specified in the pattern approval certificate.

The errors of indication ascertained at each of the above flowrates shall not exceed the MPEs given in clause 3.2 (±2.5%).

7. TEST METHOD AND MODEL TEST REPORT

7.1 Test Method

The methods of examination and testing described in NMI M 11-2 [1] shall apply to pattern approval and verification of a meter.

In addition, the performance tests in Annex A shall apply to meters with electronic devices.

When a test is conducted, the expanded uncertainty in the determination of the actual volume passing through the meter shall not exceed one-fifth of the applicable MPE for pattern approval and one-third of the applicable MPE for verification.

The expanded uncertainty shall be estimated according to *Guide to the Expression of Uncertainty in Measurement* [8] with a coverage factor, k = 2.

7.2 Model Test Report

The results of pattern approval and verification examinations and tests shall be presented in the format given in NMI M 11-3 [2].

ANNEX A. PERFORMANCE TESTS FOR METERS AND MODULES WITH ELECTRONIC DEVICES (MANDATORY)

A.1 General

This annex defines the performance tests intended to verify that meters and modules with electronic devices perform and function as intended in a specified environment and under specified conditions. Each test indicates, where appropriate, the reference conditions for determining the intrinsic error.

These tests supplement any other prescribed test.

When the effect of one influence quantity is being evaluated, all other influence quantities are to be held relatively constant, at values close to reference conditions (see clause 6.1 and Annex A.3).

A.2 Environmental Classification (see [23] and clause 5.2)

For each performance test, typical test conditions are indicated which correspond to the climatic and mechanical environmental conditions to which meters and modules are usually exposed.

Meters and modules with electronic devices are divided into two classes according to climatic and mechanical environmental conditions:

- class B for fixed meters and modules installed in a building; and
- class C for fixed meters and modules installed outdoors.

They are also divided into two electromagnetic environment classes:

- class E1 residential, commercial and light industrial; and
- class E2 industrial.

Following consultation and agreement with NMI, the pattern approval applicant may also indicate specific environmental conditions in the documentation supplied to the approving authority, based on the intended use of the meter. In this case, the approving authority will carry out performance tests at severity levels corresponding to these environmental conditions.

If pattern approval is granted, the data plate shall indicate the corresponding limits of use. Manufacturers shall inform potential users of the conditions of use for which the meter or module is approved. The approving authority shall verify that the conditions of use are met.

A.3 Reference Conditions

Ambient air temperature: 20°C ± 5°C
Ambient relative humidity: 60% ± 15%
Ambient atmospheric pressure:
  86 kPa to 106 kPa
Power voltage:
  nominal voltage (U_{nom}) ±5%
Power frequency:
  nominal frequency (f_{nom}) ±2%

During each test, the temperature and relative humidity shall not vary by more than 5°C or 10% respectively within the reference range.

Note: The reference conditions given in this section differ from those that apply to the testing in clauses 6.2 and 6.3 (see clause 6.1).

A.4 Pattern Approval of a Module

When an electronic module is submitted for separate pattern approval, pattern approval tests shall be conducted on the module (including indicating device) alone, simulating different inputs with appropriate standards.

Tests include an accuracy test on the indications of measurement results. For this purpose, the error obtained on the indication of the result is calculated considering that the true value is the one which takes into account the value of the simulated quantities applied to inputs of the module and using standard methods for calculation. The MPEs are those given in clause 3.2.

The examinations and tests for electronic instruments described in clause 6.2.11 shall be performed.

Table A.1 Tests involving the electronic part of the meter or its devices

Test	Nature of the influence quantity [23]	Severity level for the class	
		B	C
A.5.1 Dry heat	Influence factor	3	3
A.5.2 Cold	Influence factor	1	2
A.5.3 Damp heat, cyclic	Influence factor	1	2
A.5.4 Power voltage variation	Influence factor	1	1
A.5.5 Short time power reductions	Disturbance	1a and 1b	1a and 1b
A.5.6 Bursts	Disturbance	2 or 3	2 or 3
A.5.7 Electrostatic discharge	Disturbance	1	1
A.5.8 Electromagnetic susceptibility	Disturbance	2 or 3	2 or 3
A.5.9 Enclosure — water	Disturbance	—	—
A.5.10 Enclosure — dust	Disturbance	—	—

A.5 Performance Tests

The tests indicated in Table A.1 involve the electronic part of the meter or its devices and may be carried out in any order.

The following rules shall be taken into consideration for these performance tests:

(1) Test Volumes

Some influence quantities should have a constant effect on measurement results and not a proportional effect related to the measured volume. The value of the significant fault is related to the measured volume; therefore, in order to be able to compare results obtained in different laboratories, it is necessary to perform a test on a volume corresponding to that delivered in 10 min at the overload flowrate Q_4. Some tests, however, may require more than 10 min, in which case they shall be carried out in the shortest possible time taking into consideration the measurement uncertainty.

(2) Influence of the Water Temperature

Temperature tests concern the ambient temperature and not the temperature of the water used. It is therefore advisable to use a simulation test method so that the temperature of the water does not influence the test results.

A.5.1 Dry Heat

Test Method

Dry heat (non-condensing)

Object of the Test

To verify compliance with the provisions in clause 3.2 under conditions of high ambient air temperature.

References

IEC 60068-2-2 [24]
IEC 60068-3-1 [25]
IEC 60068-1 [26]

Test Procedure in Brief

The test consists of exposure of the EUT to a temperature of 55°C under free air conditions for a 2 h period, after the EUT has reached temperature stability.

The EUT shall be tested at the reference flowrate (or simulated flowrate) and:

- at the reference temperature of 20°C following conditioning;
- at the temperature of 55°C, 2 h after temperature stabilisation; and
- after recovery of the EUT at the reference temperature of 20°C.

Test Severities

Temperature: severity level 3: 55°C
Duration: 2 h

Number of Test Cycles

One cycle

Maximum Allowable Variations

All functions shall operate as designed and all the errors of indication measured during the application of the influence factor shall be within the MPE.

A.5.2 Cold

Test Method

Cold

Object of the Test

To verify compliance with the provisions in clause 3.2 under conditions of low ambient air temperature.

References

IEC 60068-2-1 [27]
IEC 60068-3-1 [25]
IEC 60068-1 [26]

Test Procedure in Brief

The test consists of exposure of the EUT to a temperature of either –10°C (class C) or +5°C (class B) under free air conditions for a 2 h period after the EUT has reached temperature stability. The EUT shall be tested at the reference flow rate (or simulated flow rate):

- at the reference temperature of 20°C following conditioning;
- at a temperature of –10°C or +5°C, 2 h after temperature stabilisation; and
- after recovery of the EUT at the reference temperature of 20°C.

Test Severities

Temperature: severity level 1: + 5°C
severity level 2: –10°C
Duration: 2 h

Number of Test Cycles

One cycle

Maximum Allowable Variations

All functions shall operate as designed and all the errors of indication measured during application of the influence factor shall be within the MPE.

A.5.3 Damp Heat, Cyclic

Test Method

Damp heat, cyclic (condensing)

Object of the Test

To verify compliance with the provisions in clause 3.2 under conditions of high humidity when combined with cyclic temperature changes.

References

IEC 60068-2-30 [28]
IEC 60068-3-4 [29]

Test Procedure in Brief

The test consists of exposure of the EUT to cyclic temperature variations between 25°C and the upper temperature of 55°C (class C) or 40°C (class B), maintaining the relative humidity above 95% during the temperature changes and during the phases at low temperature, and at 93% at the upper temperature phases.

Condensation should occur on the EUT during the temperature rise.

A standard stabilising period before and recovery after the cyclic exposure is indicated in IEC 60068-2-30 [28].

The power supply is turned off when the influence factor is applied.

Test Severities

Upper temperature: severity level 1: 40°C
severity level 2: 55°C
Duration: 24 h

Number of Test Cycles

Two cycles

Maximum Allowable Variations

After the application of the influence factor and recovery, all functions shall operate as designed and all the errors of indication measured shall be within the MPE.

A.5.4 Power Voltage Variation

A.5.4.1 Meters Powered by Direct AC or AC/DC Converters

Test Method

Variation in AC mains power supply (single phase)

Object of the Test

To verify compliance with the provisions in clause 3.2 under conditions of varying AC mains power supply.

References

IEC 61000-4-11 [30]
IEC 61000-2-1 [31]
IEC 61000-2-2 [32]
IEC 61000-4-1 [33]
IEC 60654-2 [34]
IEC 61000-2-12 [35]

Test Procedure in Brief

The test consists of exposure of the EUT to power voltage variations, while the EUT is operating under normal atmospheric conditions.

Test Severities

Single voltage: mains voltage
upper limit: U_{nom} +10%
lower limit: U_{nom} –15%

Voltage range: mains voltage
upper limit: U_u +10%
lower limit: U_l –15%

Maximum Allowable Variations

All functions shall operate as designed and all errors of indication measured during the application of the influence factor shall be within the MPEs.

A.5.4.2 Meters Powered by Primary Batteries

Test Method

Variation in DC primary battery power supply

Objective of the Test

To verify compliance with the provisions in clause 3.2 under conditions of varying DC power supply.

References

None available

Test Procedure

The meter error of indication shall be measured with the maximum and the minimum operating voltages of the battery, as specified by the meter supplier, applied throughout the test.

Test Severities

Voltage: upper limit (battery maximum): U_{max}
lower limit (battery minimum): U_{min}

Maximum Allowable Variations

All functions shall operate as designed and all errors of indication measured during the application of the influence factor shall be within the MPEs.

A.5.5 Short Time Power Reductions

Test Method

Short time interruptions and reductions in mains voltage

Object of the Test

To verify compliance with the provisions in clause 3.2 under conditions of short time mains voltage interruptions and reductions.

References

IEC 61000-4-11 [30]
IEC 61000-2-1 [31]
IEC 61000-2-2 [32]
IEC 61000-4-1 [33]

Test Procedure in Brief

The test consists of subjecting the EUT to voltage interruptions from nominal voltage to zero voltage for a duration equal to half a cycle of line frequency (severity level 1a), and reductions from nominal voltage to 50% of nominal for a duration equal to one cycle of line frequency (severity level 1b). The mains voltage interruptions and reductions shall be repeated 10 times with a time interval of at least 10 s.

Test Severities

100% voltage interruption for a period equal to half a cycle. 50% voltage reduction for a period equal to one cycle.

Number of Test Cycles

At least 10 interruptions and 10 reductions, each with a minimum of 10 s between tests.

The interruptions and reductions are repeated throughout the time necessary to perform the whole test. For this reason, more than 10 interruptions and reductions may be necessary.

Maximum Allowable Variations

The difference between the error of indication during the test and the intrinsic error shall not exceed the value given in clause 2.2.10 or significant faults are detected and acted upon by means of a checking facility.

A.5.6 Bursts

Test Method

Electrical bursts

Object of the Test

To verify compliance with the provisions in clause 3.2 under conditions where electrical bursts are superimposed on the mains voltage.

References

IEC 61000-2-1 [31]
IEC 61000-2-2 [32]
IEC 61000-4-1 [33]
IEC 61000-4-4 [36]

Test Procedure in Brief

The test consists of subjecting the EUT to bursts of double exponential waveform transient voltages. Each spike shall have a rise time of 5 ns and a half amplitude duration of 50 ns. The burst length shall be 15 ms and the burst period (repetition time interval) shall be 300 ms. All bursts shall be applied asynchronously asymmetrical mode (common mode).

Test Severities

class E1 amplitude (peak value): 1 000 V
class E2 amplitude (peak value): 2 000 V

Test Duration

The bursts should be applied for at least 1 min during the measurement or simulated measurement for each polarity.

Maximum Allowable Variations

The difference between the error of indication during the test and the intrinsic error shall not exceed the value given in clause 2.2.10 or significant faults are detected and acted upon by means of a checking facility.

A.5.7 Electrostatic Discharge

Test Method

Electrostatic discharge

Object of the Test

To verify compliance with the provisions in clause 3.2 under conditions of direct and indirect electrostatic discharges.

References

IEC 61000-2-1 [31]
IEC 61000-2-2 [32]
IEC 61000-4-1 [33]
IEC 61000-4-2 [37]

Test Procedure in Brief

A capacitor of 150 pF is charged by a suitable DC voltage source. The capacitor is then discharged through the EUT by connecting one terminal to ground (chassis) and the other via 330 Ω to surfaces which are normally accessible to the operator. The test includes the paint penetration method, if appropriate.

For direct discharges the air discharge method shall be used where the contact discharge method cannot be applied.

Test Severities

8 kV for air discharges
6 kV for contact discharges

Number of Test Cycles

At each test point, at least 10 direct discharges shall be applied at intervals of at least 10 s between discharges, during the same measurement or simulated measurement.

For indirect discharges, a total of 10 discharges shall be applied on the horizontal coupling plane and a total of 10 discharges for each of the various positions of the vertical coupling plane.

Maximum Allowable Variations

The difference between the error of indication during the test and the intrinsic error shall not exceed the value given in clause 2.2.10 or significant faults are detected and acted upon by means of a checking facility.

Where a meter has been proven to be immune from electrostatic discharges, within the rated operating conditions for flowrate, the approving body shall be free to choose a flowrate of zero during the electrostatic discharge test. During a zero flowrate test the meter totalisation shall not change by more than the value of the verification scale interval.

A.5.8 Electromagnetic Susceptibility

Test Method

Electromagnetic fields (radiated)

Object of the Test

To verify compliance with the provisions in clause 3.2 under conditions of electromagnetic fields.

References

IEC 61000-2-1 [31]
IEC 61000-2-2 [32]
IEC 61000-4-1 [33]
IEC 61000-4-3 [38]
IEC 61000-4-20 [39]

Test Procedure in Brief

The EUT shall be exposed to the electromagnetic field strength as specified by the severity level.

The field strength can be generated in various ways:

- the strip line is used at low frequencies below 30 MHz (or in some cases 150 MHz) for small EUTs;
- the long wire is used at low frequencies (below 30 MHz) for larger EUTs;
- dipole antennas or antennas with circular polarisation placed 1 m from the EUT are used at high frequencies.

The specified field strength shall be established prior to the actual testing without the EUT in the field.

The field shall be generated in two orthogonal polarisations. If antennas with circular polarisation (i.e. log-spiral or helical antennas) are used to generate the electromagnetic field, a change in the position of the antennas is not required.

When the test is carried out in a shielded enclosure, to comply with international laws prohibiting interference to radio communications, care should be taken to handle reflections from the walls. Anechoic shielding may be necessary.

Test Severities

Frequency range:	26 to 1 000 MHz	
Field strength:	class E1	3 V/m
	class E2	10 V/m
Modulation:	80% AM, 1 kHz sine wave	

Maximum Allowable Variations

The difference between the error of indication during the test and the intrinsic error shall not exceed the value given in clause 2.2.10 or significant faults are detected and acted upon by means of a checking facility.

A.5.9 Water

Test Method

Spraying, splashing or immersion in water.

Object of the Test

To verify compliance with the provisions in clause 3.2 during spraying, splashing or immersion in water.

References

IEC 60068-2-18 [40]
IEC 60512-14-7 [41]
IEC 60529 [10]

Test Procedure in Brief

For classes B, C and I non-submersible components: mount the EUT on an appropriate fixture and subject it to impacting water generated from either an oscillating tube or a spray nozzle simulating spraying or splashing water.

For class C and I submersible components: immerse to a depth agreed to with the manufacturer.

Maximum Allowable Variations

The difference between the error of indication during the test and the intrinsic error shall not exceed the value given in clause 2.2.10 or significant faults are detected and acted upon by means of a checking facility.

A.5.10 Dust

Test Method

Application of dust laden atmospheres.

Object of the Test

To verify compliance with the provisions in clause 3.2 under dust-laden atmosphere.

References

IEC 60512-11-8 [42]
IEC 60529 [10]
IEC 60721-2-5 [43]
IEC 60068-2-68 [44]

Test Procedure in Brief

Mount the EUT in a dust chamber and whilst cycling the temperature between 30°C and 65°C in accordance with clause 3.2.3 in IEC 60512-11-8 [42] apply the dust conditions described in IEC 60529 [10].

Maximum Allowable Variations

The difference between the error of indication during the test and the intrinsic error shall not exceed the value given in clause 2.2.10 or significant faults are detected and acted upon by means of a checking facility.

ANNEX B. UNCERTAINTY EXAMPLE (INFORMATIVE)

B.1 Nature of Errors

All measurements have errors even after all corrections and calibrations have been applied. The errors may be positive or negative and may be of a variable magnitude. Many errors vary with time. Some have very short periods while others vary daily, weekly, seasonally or yearly.

Those errors which remain constant (or apparently constant) during a test are sometimes called systematic errors. The actual or systematic errors can be determined only when measurements are compared with the true value of the quantity, which is rarely possible. However, upper bounds on the errors can be estimated. The objective is to construct an uncertainty interval (sometimes referred to as a range) within which the true value will lie with a stated probability.

B.2 Explanation of Terms

B.2.1 Uncertainty of Measurement

A parameter associated with the result of a measurement that characterises the dispersion of the values that could reasonably be attributed to the measured value [5].

B.2.2 What is Uncertainty of Measurement?

Uncertainty of measurement is the doubt that exists about the result of any measurement. For every measurement, even the most careful, there is always a margin of doubt. Uncertainty of measurement tells us something about the quality of the measurement.

Uncertainty of measurement is expressed as ‘how big is the margin’ and ‘how bad is the doubt’? For example, the flowrate of water passing through a gate in a channel is 10 ML/day ± 0.05 ML/day at a level of confidence of 95%. This means we are 95% confident that the flowrate is between 9.95 ML/day and 10.05 ML/day.

B.2.3 Error versus Uncertainty

It is important not to confuse the terms ‘error’ and ‘uncertainty’. Error is the difference between the measured value and the true value of the thing being measured. Uncertainty is a quantification of the doubt about the measurement result.

B.2.4 True Value (of a Quantity)

A value consistent with the definition of a given particular quantity.

Notes:

1. This is the value that would be obtained by a perfect measurement.
2. True values by nature are indeterminate.
3. The indefinite article ‘a’, rather than the definite article ‘the’ is used in conjunction with ‘true value’ because there may be many values consistent with the definition of a given particular quantity.

B.2.5 Conventional True Value (of a Quantity)

A value attributed to a particular quantity and accepted, sometimes by convention, as having an uncertainty appropriate for a given purpose.

B.3 Error and Uncertainty

B.3.1 Making the Measurement

Water is measured by devices consisting of a transducer or multiple transducers which detect characteristics of the water flow and pass the results to a computational device which calculates flowrate or volume and the result is displayed. In a simple, full flowing pipe situation, a device (e.g. a propeller) detects water velocity, and the volume is calculated through a computational device (e.g. a gear train) and the result displayed on the register. At a bulk off-take, the velocity of the water at one or several parts of the flow profile may be measured using ultrasonic devices. The height of the surface may be measured using ultrasonic, pressure or float devices. These measurements, along with previously determined hydrographical details of the flow profile are used to calculate mean velocity, flowrate and volume.

B.3.2 Determination of True Value

In the first example above of a propeller-actuated meter, the true value of the measured quantity may be determined by placing the device in a laboratory test rig and flowing water through the propeller-actuated meter and into a calibrated collection vessel. The volume in the collection vessel can be considered as the true value because the collection vessel has been calibrated with traceability to Australia's standards of measurement. Alternatively, the propeller-actuated meter may be compared to a calibrated master meter either in a laboratory or in the field.

In the second example of bulk off-take metering, determination of true value of volume is not practical as flowing into a collection vessel or through a calibrated device is not feasible. Each of the devices providing input to the computation of flow can be calibrated against reference devices with traceability to Australia's standards of measurement. Each of those calibrations will have an error and an uncertainty associated with it. All of these errors and uncertainties along with other relevant factors contribute to the uncertainty associated with the computation of flow.

B.3.3 Error or Uncertainty

In the case of the propeller-actuated meter, it is possible to determine how much the value measured by the meter varies from the true value. This is the error and it is likely that the error will be different at various flowrates. For each determination of error there is an associated uncertainty. In an ideal world, corrections should be made to measured values in order to bring them as close as possible to true value. If corrections are not made the error is another source of uncertainty.

B.4 Example of Uncertainty Calculation

Below is an example which demonstrates the process of determining the uncertainty of measurement. It covers a broad-crested weir in accordance with AS 3778.4.2 [45].

The measurement model is:

$$Q = (2/3)^{3/2}.g^{1/2}.b.C.h^{3/2}$$

where:

Q is the flowrate in m^3/s

g (acceleration due to gravity) can be considered constant for a particular location and is taken as 9.81 m/s^2

b is the width of the weir which has an uncertainty associated with it (in this example the width is measured as 10 m with an uncertainty of ±0.01 m)

C is the discharge coefficient which has an uncertainty associated with it (in this example the coefficient is taken as 1.043 with an uncertainty of ±0.033), C is non-dimensional

h is the height of water measured at the appropriate point upstream of the weir (in this example h is taken as 0.4 m with an uncertainty of ±0.003 m)

The flow rate, Q, is calculated as follows:

$$Q = (2/3)^{3/2}.g^{1/2}.b.C.h^{3/2} = 4.50\ m^3/s$$

$g = 9.81\ m/s^2$

$b = 10\ m$

$C = 1.043$ non-dimensional

$h = 0.4\ m$

Sensitivity coefficients describe how the measurand (Q) changes with small changes in each of the variables and are calculated as the partial derivative of the measurand with respect to each of the particular variables:

$$\partial Q/\partial b = (2/3)^{3/2}.g^{1/2}.C.h^{3/2} = 0.449\,9$$

$$\partial Q/\partial C = (2/3)^{3/2}.g^{1/2}.b.h^{3/2} = 4.313\,1$$

$$\partial Q/\partial h = 3/2.(2/3)^{3/2}.g^{1/2}.b.C.h^{1/2} = 16.8695$$

Component	Component values				
	U_i	k_i	$u(x_i)$	c_i	$c_i.u(x_i)$
Width, b	0.010	2	0.005	0.449 9	0.002 249
Discharge coefficient, C	0.033	2	0.016 5	4.313 1	0.071 166
Measured head, h	0.003	2	0.001 5	16.869 5	0.025 304

As shown above, for each of the components, its expanded uncertainty (U_i) is divided by its coverage factor (k_i) to obtain the standard uncertainty for that measurement. The component standard uncertainty is multiplied by its sensitivity coefficient (c_i) to obtain the standard uncertainty (for that component) in the measurand ($c_i.u(x_i)$).

Each of these values is squared, added together and the square root taken to give the combined standard uncertainty (u_c) = 0.0755 64.

This value is multiplied by a coverage factor to obtain the expanded uncertainty (U). With a coverage factor of 2, U = 0.151 128 m^3/s.

Finally, the measured flow rate, Q = 4.5 m^3/s with an expanded uncertainty of ±3.36%.

This is by no means a comprehensive example as there are a number of other variables which could affect the uncertainty. For example, the coefficient, C, is a function of the ratios h/p and h/L where p is the height of the weir and L is the length of the weir in the direction of flow. Measurement of h, p and L will affect the determination of C. Further, all instruments used to make measurements would have been calibrated at a reference temperature. Variations in temperature will affect these instruments and, temperature will need to be measured to determine or estimate this effect. There will be an uncertainty associated with the temperature measurement.

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