Australian Government
National Measurement Institute

NMI M 11-2
Meters Intended for the Metering of Water in Open Channels and Partially Filled Pipes

Part 2: Test Methods

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CONTENTS

PREFACE

NMI M 11-2 is based on *NMI R 49-2. Water Meters Intended for the Metering of Cold Potable Water and Hot Water. Part 2: Test Methods* (which in turn is based on OIML R 49-2:2006). Some of the requirements and procedures have never previously been tested or enforced within Australia.

1. SCOPE

NMI M 11-2 specifies test methods for the pattern approval and verification of water meters intended for the metering of water in full flowing pipes. Meters approved against this document are designated as accuracy class 2.5 water meters.

The corresponding parts 1 and 3 of this document are:

- NMI M 11-1 Metrological and Technical Requirements [1]; and
- NMI M 11-3 Test Report Format [2].

2. TERMINOLOGY

The terms and definitions in NMI M 11-1 [1] shall apply.

Some of the definitions used in this document conform to terminology used in IEC 60068-1 [3] and are adopted where necessary.

2.1 Full Flowing Pipe Conditions

Specific to meters designed to operate in partially filled pipes. Full flowing pipes conditions arise when the pipe, pipe section or meter are completely filled with flowing water.

2.2 Water Level

Elevation of the free surface of water relative to a specified datum. The relative height of the water in the pipe or channel system. Water level is given the symbol 'h' with minimum and maximum values given as h_{min} and h_{max}. Indications of level shall be in legal units of length.

2.3 Specified Straight Lengths of Pipe or Channel

The number of straight lengths of pipe or open channel, specified by the manufacturer, to be placed immediately upstream of the meter. Forms part of the installation conditions.

2.4 Test Flowrate

Mean flowrate during a test, calculated from the indications of a calibrated reference device. The quotient of the actual volume passing through the meter divided by the time for that volume to pass through the meter. Flowrate is expressed in megalitres per day, litres per second, cubic metres per hour or kilolitres per hour.

2.5 Equipment under Test (EUT)

Complete meter, a part of a meter or an ancillary device.

2.6 Flow Sensor or Volume Sensor

Part of the meter (such as a disc, piston, wheel, turbine element, ultrasonic sensor or electromagnetic coil) that senses the velocity, flow rate or volume of water passing through the meter.

2.7 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 or an electrical or an electronic principle. It may be autonomous or use an external power source.

Note: The measurement transducer includes the flow sensor or volume sensor.

2.8 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; and
- presetting device.

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

2.9 Temperature Stability

Temperature stability has been reached when all parts of the EUT are within 3°C of each other, or as otherwise specified in the

relevant specification of its final temperature.

2.10 Pre-conditioning

Treatment of the EUT, with the object of removing, or partly counteracting, the effects of its previous history. Where called for, it is the first process in the test procedure.

2.11 Conditioning

Exposure of the EUT to an environmental condition (influence factor or disturbance) in order to determine the effect of such a condition on it.

2.12 Recovery

Treatment of the EUT, after conditioning, in order that the properties of the EUT may be stabilised before measurement.

2.13 Flow Straightener

A device installed into the pipe work intended to minimise or eliminate flow disturbances and create smooth, uniform flow. In the context of this document a flow straightener may be used by:

(a) The testing laboratory in order to eliminate any flow disturbances caused by the configuration of the test rig itself (caused by pumps, bends, valves etc) to ensure the confidence, repeatability and inter-laboratory comparison of test results.

(b) The meter manufacturer, used as a component of the meter installation, in order to achieve the level of accuracy and performance required by this document. In this case, the details and use of such a device will be included in the pattern approval certificate and listed as a condition of installation.

3. REFERENCE CONDITIONS

3.1 General

All applicable influence quantities, except for the influence quantity being tested, shall be held at the following values during pattern approval tests on a meter. However, for influence factors and disturbances for electronic meters, it is permissible to use the reference conditions defined in the applicable IEC standard. NMI can provide guidance on any issues related to permissible reference conditions.

3.2 Flowate and Power Supply

Flowrate:

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

Module measurement parameter:

$0.7 \times (\text{min} + \text{max}) \pm 0.03\ (\text{min} + \text{max})$ 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 $U_{min} \le V \le U_{max}$

3.3 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 temperature: 20 ± 10°C
Ambient temperature: 20 ± 10°C

3.4 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

4. CALCULATION OF ERROR

Equations, symbols and their units, concerning the calculation of the error of indication of a meter used in this document, are given in Annex A.

5. EXTERNAL EXAMINATION

During the external examination, all relevant values, dimensions and observations shall be recorded. For presentation of the results of pattern examinations see 10.

5.1 Object of Examination

To verify that the meter meets the requirements of NMI M 11-1 with respect to the design of the indicating device, the marking of the meter and the application of protection devices.

5.2 Preparation

Linear measurements that have to be taken from the meter shall be made using traceable, calibrated measuring devices.

The actual or apparent dimensions of the scales of the indicating device shall be taken without removing the meter lens or disassembling the meter.

Note: A travelling microscope (cathetometer) may be used to measure the width, spacing and height of the scale divisions and the height of numerals.

5.3 Examination Procedures

Each of the following aspects of the meter design shall be examined on at least one meter from the sample.

Either the same meter sample may be used for all the external examinations or different meters from the samples submitted may be used for some of the examinations.

5.3.1 Marks and Inscriptions (NMI M 11-1, 5.8)

1. Verify that the meter is clearly and indelibly marked with the following information (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:
   (a) unit of measurement : megalitre (ML), cubic metre (m^3) or kilolitre (kL);
   (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 (shown on both sides of the body; or on one side only provided the direction of flow arrow is 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.
2. Complete the test report (NMI M 11-3, section 4.1, 5.8).

5.3.2 Indicating Device or Display

5.3.2.1 General Requirements (NMI M 11-1, 5.9.1)

1. Verify that the indicating device provides an easily read, reliable and unambiguous visual indication of the indicated volume.
2. Verify that the indicating device includes visual means for testing and calibration.
3. If the indicating device includes additional elements for testing and calibration by other methods, e.g. for automatic testing and calibration, record the type(s) of device.
4. If the indicating device displays other parameters such as instantaneous or average flowrate, record the parameters.
5. Complete the test report (NMI M 11-3, section 4.1, 5.9.1).

5.3.2.2 Unit of Measurement, Symbol and its Placement (NMI M 11-1, 5.9.1.1)

1. Verify that the indicated volume of water is expressed in megalitres, cubic metres or kilolitres.
2. Verify that the symbol ML, m^3 or kL appears on the dial or immediately adjacent to the numbered display.
3. Complete the test report (NMI M 11-3, section 4.1, 5.9.1.1).

5.3.2.3 Indicating Range (NMI M 11-1, 5.9.1.2)

1. Verify that the indicating device is 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 Table 1 and Table 2.

Table 1. Volumetric (ML) indicating range

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

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

2. Calculate the indicated volume (V_i) corresponding to 200 days of operation.

   If Q_3 is the numerical value of the permanent flowrate Q_3:
   - in ML/d, $V_i = Q_3 \times 200$ ML;
   - in L/s, $V_i = Q_3 \times 17\,280$ m^3 or kL

   where Q_3 is the numerical value of the permanent flowrate Q_3 in ML/d (or L/s).
3. Complete the test report (NMI M 11-3, section 4.1, 5.9.1.2).

5.3.2.4 Colour Coding for Indicating Devices (NMI M 11-1, 5.9.1.3)

1. Verify that either:
   - the colour black is used to indicate the megalitre, cubic metre or kilolitre and its multiples; the colour red is used to indicate sub-multiples of a megalitre, cubic metre or kilolitre; and the colours are applied either to the pointers, indexes, numbers, wheels discs, dials or aperture frames; or
   - other means of indicating the megalitre, cubic metre or kilolitre are used in which there is no ambiguity in distinguishing between the primary indication and alternative displays, e.g. sub-multiples for verification and testing.
2. Complete the test report (NMI M 11-3, section 4.1, 5.9.1.3).

5.3.2.5 Types of Indicating Device

5.3.2.5.1 Type 1 – Analogue Device (NMI M 11-1, 5.9.2.1)

1. If a type 1 indicating device has been used verify that volume is indicated by either:
   - continuous movement of one or more pointers moving relative to graduated scales; or
   - continuous movement of one or more circular scales or drums each passing an index.
2. Verify that the value expressed in megalitres, cubic metres or kilolitres for each scale division is of the form 10^n, where n is a positive or a negative whole number or zero, thereby establishing a system of consecutive decades.
3. Verify that each scale is either graduated in values expressed in megalitres, cubic metres or kilolitres or accompanied by a multiplying factor (× 0.001; × 0.01; × 1; × 10; × 100; × 1000 etc).
4. Verify that rotational movements of the pointers or circular scales are clockwise.
5. Verify that linear movement of pointers or scales is from left to right.
6. Verify that movement of numbered roller indicators is upwards.
7. Complete the test report (NMI M 11-3, section 4.1, 5.9.2.1).

5.3.2.5.2 Type 2 – Digital Device (NMI M 11-1, 5.9.2.2)

1. Verify that the indicated volume is given by a line of digits, appearing in one or more apertures.
2. Verify that the advance of one digit is completed while the digit of the next immediately lower decade changes from 9 to 0.
3. For non-electronic devices:
   - verify that the movement of numbered roller indicators (drums) is upwards; and
   - if the lowest value decade has a continuous movement, verify that the aperture is large enough to permit a digit to be read without ambiguity.
4. For electronic devices:
   - note whether the electronic display is either permanent or non-permanent;
   - where a non-permanent display is used, verify that the volume is able to be displayed at any time for at least 10 s;
   - verify that the electronic device includes 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. Verify that the actual or apparent height of the digits is at least 4 mm.
6. Complete the test report (NMI M 11-3, section 4.1, 5.9.2.2).

5.3.2.5.3 Type 3 – Combination of Analogue and Digital Devices (NMI M 11-1, 5.9.2.3)

1. If the indicating device is a combination of types 1 and 2 devices, verify that the respective requirements of each apply (5.3.2.5.1 and 5.3.2.5.2).
2. Complete the test report (NMI M 11-3, section 4.1, 5.9.2.3).

5.3.2.6 Verification Devices – First Element of an Indicating Device – Verification Interval

5.3.2.6.1 General Requirements (NMI M 11-1, 5.9.4.1)

1. Verify that the indicating device has the means for visual, non-ambiguous verification testing and calibration.
2. Note whether the visual verification display has a continuous or a discontinuous movement.

3. Note whether, in addition to the visual verification display, the indicating device includes provisions for rapid testing by the inclusion of complementary elements (e.g. star wheels or discs) providing signals through externally attached sensors. Note the relationship, stated by the manufacturer, between the visual indication of volume and the signals emitted by these complementary devices.
4. Complete the test report (NMI M 11-3, section 4.1, 5.9.4.1).

5.3.2.6.2 Value of the Verification Scale Interval (NMI M 11-1, 5.9.4.2)

1. Verify that the value of the verification scale interval, expressed in megalitres, kilolitres or cubic metres, is 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.
2. For analogue and digital indicating devices with continuous movement of the first element, verify that the verification scale interval is formed from the division into 2, 5 or 10 equal parts of the interval between two consecutive digits of the first element.
3. For analogue and digital indicating devices with continuous movement of the first element, verify that numbering is not applied to the divisions between consecutive digits of the first element.
4. For digital indicating devices, including electronic 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. Complete the test report (NMI M 11-3, section 4.1, 5.9.4.2).

5.3.2.6.3 Form of the Verification Scale (NMI M 11-1, 5.9.4.3)

1. If the indicating device has continuous movement of the first element, check that the apparent scale spacing is not less than 1 mm and not more than 5 mm.

   Note: This does not apply to devices with discontinuous movement.
2. Verify that the scale consists 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.
3. Verify that the apparent width of the pointer at its tip does not exceed one-quarter of the scale spacing.
4. Verify that the apparent width of the pointer at its tip does not exceed 0.5 mm.
5. Complete the test report (NMI M 11-3, section 4.1, 5.9.4.3).

5.3.2.6.4 Resolution of the Indicating Device (NMI M 11-1, 5.9.4.4)

1. Note the value of the verification scale interval, δV ML or m^3 or kL.
2. Calculate the actual volume V_a passed during 1 h 30 min at the minimum flowrate, Q_1:
   $V_a = Q_1 \times 1.5$ ML or m^3or kL
3. Calculate the resolution error of the indicating device, ε_r.
4. For continuous movement of the first element:
   $\varepsilon_r = 100 \times (\frac{1}{2}\,\delta V + \frac{1}{2}\,\delta V)/\ V_a\% = 100 \times \delta V/\ V_a\%$
5. For discontinuous movement of the first element:
   $\varepsilon_r = 100 \times (\delta V + \delta V)/\ V_a\% = 100 \times 2\delta V/\ V_a\%$
6. Verify that the verification scale interval is small enough to ensure that the resolution error, ε_r, of the indicating device does not exceed 0.5% of the actual volume required during 1 h 30 min at the minimum flow rate, Q_1:
   $$\varepsilon_r \leq 0.5\%$$
7. Complete the test report (NMI M 11-3, section 4.1, 5.9.4.4).

Notes:

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

5.3.3 Verification Marks and Protection Devices

1. Verify that a place has been provided on the meter for affixing the main verification mark, which is visible without dismantling the meter (NMI M 11-1, 5.10).
2. Verify that the meter includes either provision for mechanical sealing or electronic security as described in point 3, to prevent, both before and after correct installation, dismantling or modification of the meter or its adjustment device, without damaging these devices (NMI M 11-1, 5.10.1).
3. When access to parameters that influence the determination of the results of measurements is not protected by mechanical sealing devices, verify that the protection fulfils the following provisions (NMI M 11-1, 5.10.2(a)):
   (a) access is only allowed to authorised people;
   (b) where an access code is used, it is capable of being changed;
   (c) the last intervention is stored in memory;
   (d) the record stored in memory also includes the date and the identity of the authorised person;
   (e) the last record stored in memory is accessible for at least two years;
   (f) 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 is deleted.
4. Where meters have parts that can be disconnected from one another and which **are** interchangeable (NMI M 11-1, 5.10.2(b)), verify that:
   (a) it is not possible to access parameters that participate in the determination of results of measurements through disconnected points unless the provisions tested in 5.3.3, point 3 are fulfilled; and
   (b) interposing any device which may influence the accuracy is prevented by means of electronic and data processing securities or, if this is not possible, by mechanical means.
5. Where meters have parts that can be disconnected from one another by the user and which **are not** interchangeable (NMI M 11-1, 5.10.2(c), verify that:
   (a) it is not possible to access parameters that participate in the determination of results of measurements through disconnected points unless the provisions tested in 5.3.3, point 3 are fulfilled;
   (b) interposing any device which may influence the accuracy is prevented by means of electronic and data processing securities or, if this is not possible, by mechanical means;
   (c) they are provided with devices that prevent them from operating if the various parts are not connected according to the manufacturer's configuration;
   (d) they are provided with a device that prevents any measurement after any unauthorised disconnection and subsequent reconnection by the user.
6. Complete the test report (NMI M 11-3, section 4.1 — 5.10, 5.10.1 and 5.10.2).

6. PERFORMANCE TESTS

During the performance tests, all relevant values, dimensions and observations shall be recorded. For presentation of the results of pattern examinations see 10.

6.1 Requirements Common to all Tests

6.1.1 Water Quality

Tests shall be carried out using water. The water shall not contain any substance which might damage the EUT or adversely affect its operation. Filtering systems may be used to achieve the desired level of water quality.

At the time of each test the water quality shall be measured and recorded.

Note: If water is being recycled, measures shall be taken to prevent residual water from becoming harmful to human beings.

6.1.2 General Rules Concerning Test Installation and Location

6.1.2.1 Freedom from Spurious Influences

Test rigs shall be so designed, constructed and used, that the performance of the rig itself shall not contribute significantly to the test error. To this end, high standards of rig maintenance and adequate supports and fittings are necessary to prevent vibration of the meter, the test rig and its accessories.

The test rig environment shall be such that the reference conditions of the test are met (see 3).

It shall be possible to carry out test readings rapidly and easily.

As part of the validation process, periodic intercomparisons between test rigs shall be carried out.

6.1.2.2 Group Testing

Meters are tested either individually or in groups. In the latter case the individual characteristics of the meters shall be precisely determined. Interaction between meters, and between meters and test rigs, shall be eliminated.

When meters are tested in series, the pressure at the exit of each meter shall be sufficient to prevent cavitation.

6.1.2.3 Location

The environment chosen for tests shall be free from disturbing influences, e.g. extreme ambient temperature, vibration.

6.2 Static Pressure Test

Refer to NMI M 11-1, 6.2.1.

6.2.1 Object of Test

To verify that the meter can withstand the specified hydraulic test pressure for the specified time without leakage or damage.

6.2.2 Preparation

1. Install the meters in the test rig either singly or in groups.
2. Bleed the test rig pipework and the meters of air.
3. Ensure that the test rig is free from leaks.
4. Ensure that the supply pressure is free from pressure pulsations.

6.2.3 Test Procedure

1. Increase the hydraulic pressure to 1.6 times the maximum admissible pressure of the meter and hold it for 15 min.
2. Examine the meters for physical damage, for external leaks and for leaks into the indicating device.
3. Increase the hydraulic pressure to twice the maximum admissible pressure and hold this pressure level for 1 min.
4. Examine the meters for physical damage, for external leaks and for leaks into the indicating device.
5. Complete the test report (NMI M 11-3, section 5.1).

Additional requirements:

(a) Increase and decrease the pressure gradually without pressure surges.

(b) Apply only the reference temperatures for this test.

(c) For an insertion meter, attach the meter to a piece of pipe capable of meeting these pressure test requirements and test as per the above procedure.

6.2.4 Acceptance Criteria

There shall be no leakage from the meter, leakage into the indicating device or physical damage, resulting from any of the pressure tests.

6.3 Determination of Intrinsic Errors of Indication and the Effects of Meter Orientation

Refer to NMI M 11-1, 6.2.2.

6.3.1 Object of Test

To determine the intrinsic errors of indication of the meter and the effects of meter orientation on the error of indication.

6.3.2 Preparation

6.3.2.1 Description of the Test Rig

Two methods of determining the errors of indication of a meter are described here, however other methods may be used, provided the requirements of 6.3.2.2.6.1 are met.

1. One method is the collection method, in which the quantity of water passed through the meter is collected in one or more collecting vessels and the quantity determined volumetrically or by weighing. Errors of indication are then calculated by comparing the volume indications given by the meter operating at reference conditions against the calibrated reference device.
2. Another method consists of installing at least one calibrated reference meter in the test rig and passing the quantity of water through the EUT and the reference meter(s); the water may be re-circulated through the system. Errors of indication are then calculated by comparing the volume indications given by the meter operating at reference conditions against the calibrated reference meter.

For the purpose of these tests, a meter should be tested without its temporary supplementary devices attached (if any).

The test rig consists, typically, of:

(a) a water supply (non-pressurised tank, pressurised tank, pump etc);

(b) pipework;

(c) a calibrated reference device (calibrated volumetric tank, weighing system, reference meter etc);

(d) means for measuring the time of the test;

(e) devices for automating the tests (if required);

(f) means for measuring water temperature;

(g) means for measuring water pressure and/or head.

6.3.2.2 Pipework

6.3.2.2.1 Description

Pipework shall include:

(a) a test section in which the meter(s) is (are) placed;

(b) means for establishing the desired flowrate;

(c) one or two isolating devices;

(d) means for determining the flowrate;

and if necessary:

(e) means for checking that the pipework is filled to a datum level before and after each test;

(f) one or more air bleeds;

(g) a non-return device;

(h) an air separator;

(i) a filter (if required).

During the test, flow leakage, flow input and flow drainage shall not be permitted either between the meter(s) and the reference device or from the reference device.

The pipework shall be such that in the upper, internal part of the meter, a positive pressure exists, even at zero flowrate.

6.3.2.2.2 Test Section

The test section shall include, in addition to the meter(s):

(a) one or more pressure tappings for the measurement of pressure, of which one pressure tapping is situated upstream of, and close to, the (first) meter;

(b) means for measuring the temperature of the water close to the entry of the (first) meter.

The presence of any pipe components or devices placed in or near the measuring section shall not cause cavitation or flow disturbances capable of altering the performance of the meters or causing errors of indication.

6.3.2.2.3 Precautions to be Taken

1. Check that the operation of the test rig is such that, during a test, the actual volume of water that flows through the meter(s) is equal to that measured by the reference device.
2. Check that the pipe or open channel system (e.g. the swan-neck in the outlet pipe) is filled to the same datum level at the beginning and at the end of the test.
3. Take all precautions necessary to avoid the effects of vibration and shock.
4. For meter designed to operate in partially filled pipes, check that the lead-in/lead-out pipe has the same internal diameter as the meter under test. If an exact match of internal diameters cannot be achieved, it is acceptable to use piping that has a slightly larger internal diameter than the meter. However, any difference in the internal diameter should be kept to an absolute minimum.

6.3.2.2.4 Special Arrangements for the Installation of Meters

6.3.2.2.4.1 Avoidance of Erroneous Measurements

The recommendations in 6.3.2.2.4.2 to 6.3.2.2.4.5 address the most frequent causes of erroneous measurements and the necessary precautions for the installation of meters on the test rig, and are intended to achieve a test installation in which:

(a) the hydrodynamic flow characteristics cause no discernible difference to the meter functioning when compared with hydrodynamic flow characteristics which are undisturbed;

(b) the overall error of the method employed does not exceed the stipulated value (see 6.3.2.2.6.1).

6.3.2.2.4.2 Need for Straight Lengths of Pipe or a Flow Straightener

The accuracy of non-volumetric meters can be affected by upstream disturbance caused, e.g. by the presence of bends, tees, valves or pumps.

It is important to eliminate any such disturbances caused by the configuration of the test rig itself in order to ensure the repeatability and inter-laboratory comparison of test results. In order to counteract these disturbances:

- the meter shall be installed in accordance with the manufacturer's instructions;
- the connecting pipework shall have an internal diameter matched to the relevant meter connection;
- if necessary, a flow straightener shall be installed upstream of the straight pipe length and the standard disturbances defined in 6.7.

6.3.2.2.4.3 Common Causes of Flow Disturbance

A flow can be subject to two types of disturbance: velocity-profile distortion and swirl, both of which may affect the errors of indication of a meter.

Velocity-profile distortion is typically caused by an obstruction partially blocking

the pipe, for instance the presence of a partly closed valve or a misaligned flange joint. This can easily be eliminated by careful application of installation procedures.

Swirl can be caused either by two or more bends in different planes or a single bend in combination with a reducer or partially closed valve. This effect can be controlled either by ensuring an adequate length of straight pipe upstream of the meter, or by installing a flow straightening device, or by a combination of the two. However, where possible, these types of pipework configurations should be avoided.

6.3.2.2.4.4 Volumetric Meters

Volumetric meters (that is, involving measuring chambers with mobile walls) such as oscillating piston or nutating disc meters, are considered insensitive to upstream installation conditions; hence no special conditions are required.

6.3.2.2.4.5 Meters Employing Electromagnetic Induction

Meters employing electromagnetic induction as a measuring principle may be affected by the conductivity of the test water.

The conductivity of the water used for testing this type of meter should be within the operational range of conductivity specified by the meter manufacturer.

6.3.2.2.4.6 Other Measuring Principles

Other types of meter may require flow conditioning when measuring the errors of indication and in such cases the manufacturer's recommended installation requirements shall be followed (see 6.7).

These installation requirements should be reported in the pattern approval certificate for the meter.

6.3.2.2.5 Errors of Test Commencement and Termination

Adequate precautions shall be taken to reduce the uncertainties resulting from operation of test rig components during the test.

Details of the precautions to be taken are given in 6.3.2.2.5.1 and 6.3.2.2.5.2 for two cases encountered in the collection method.

If testing is being conducted using a reference meter, readings can easily be taken using a variation of the flying-start-and-finish method (see 6.3.2.2.5.2). However it must be ensured that the reference meter and EUT can be synchronised such that they both accurately register the beginning and end of each test. This could be done retrospectively by matching up the time stamps of their pulse outputs once the desired flowrate had been established.

6.3.2.2.5.1 Tests with Readings taken with the Meter at Rest

This method is generally known as the standing-start-and-finish method.

Flow is established by fully opening a valve, preferably situated downstream of the meter, and it is stopped by closure of this valve. The meter is read when the registration is stationary.

Time is measured between the beginning of the movement of the valve at opening and at the end of closure.

Whilst flow is beginning (and during the period of running at the specified constant flowrate) the error of indication of the meter varies as a function of the changes in flowrate (the error curve).

Whilst the flow is being stopped, the combination of the inertia of the moving parts of the meter and the rotational movement of the water inside the meter may cause an appreciable error to be introduced in certain types of meter and for certain test flowrates.

It has not been possible, in this case, to determine a simple empirical rule which lays down conditions so that this error may always be negligible.

In case of doubt, it is advisable:

(a) to increase the volume and duration of the test;

(b) to compare the results with those obtained by one or more other methods, and in particular the method described in 6.3.2.2.5.2, which eliminates the causes of uncertainty given above.

For some types of electronic meters with pulse outputs that are used for testing, the response of the meter to changes in flowrate may be such that valid pulses are emitted after closure of the valve. In this case means shall be provided to count these additional pulses.

Where pulse outputs are used for testing meters, it shall be checked that the volume indicated by the pulse count corresponds to the volume displayed on the indicating device.

6.3.2.2.5.2 Tests with Readings taken under Stable Flow Conditions and Diversion of Flow

This method is generally known as the flying-start-and-finish method.

The measurement is carried out when flow conditions have stabilised.

A switch diverts the flow into a calibrated vessel at the beginning of the measurement and diverts it away at the end.

The meter is read whilst in motion.

The reading of the meter is synchronised with the movement of the flow switch.

The volume collected in the vessel is the actual volume passed.

The uncertainty introduced into the volume may be considered negligible if the times of motion of the flow switch in each direction are identical within 5% and if this time is less than 1/50 of the total time of the test.

6.3.2.2.6 Calibrated Reference Device

6.3.2.2.6.1 Overall Uncertainty of the Value of Measured Actual Volume

When a test is conducted, the expanded uncertainty of the value of measured actual volume shall not exceed one-fifth of the MPE for pattern approval-and one-third of the MPE for initial verification.

The estimated uncertainty shall be made according to the Guide to the Expression of Uncertainty in Measurement [4] with a coverage factor, k = 2.

6.3.2.2.6.2 Minimum Volume of the Calibrated Reference Device

The minimum volume permitted depends on requirements determined by the test start and end effects (timing error), and the design of the indicating device (value of the verification scale interval).

6.3.2.2.6.3 Cyclic Distortion of the Meter

The effects of a possible cyclic distortion on the reading of the meter (visual or automatic) shall be negligible.

6.3.2.2.7 Major Factors Affecting the Measurement of Errors of Indication

6.3.2.2.7.1 General

Variations in the pressure, flowrate and temperature in the test rig, and uncertainties in the precision of measurement of these physical quantities, are the principal factors affecting the measurement of the errors of indication of a meter.

6.3.2.2.7.2 Supply Pressure

The supply pressure shall be maintained at a constant value throughout the test at the chosen flowrate.

When testing meters which are designated $Q_3 \leq 4$ L/s, at test flowrates $\leq 0.1\ Q_3$, constancy of pressure at the inlet of the meter (or at the inlet of the first meter of a group being tested) is achieved if the test rig is supplied through a pipe from a constant head tank. This ensures an undisturbed flow.

Any other methods of supply shown not to cause pressure pulsations exceeding those of a constant head tank may be used, e.g. a pressurised tank.

For all other tests, the pressure upstream of the meter shall not vary by more than 10%.

The maximum uncertainty (k = 2) in the measurement of pressure shall be 5% of the measured value.

Pressure at the entrance to the meter shall not exceed the maximum admissible pressure for the meter.

6.3.2.2.7.3 Flowrate

A constant flowrate shall be maintained throughout the test.

The relative variation in the flowrate during each test (not including starting and stopping) shall not exceed ±5.0% from Q_1 (inclusive) to Q_4.

The flowrate value is the actual volume passed during the test divided by the time.

This flowrate variation condition is acceptable if the relative pressure variation (in flow to free air) or the relative variation of pressure loss (in closed circuits) does not exceed ±10% from Q_1 (inclusive) to Q_4.

6.3.2.2.7.4 Temperature

During a test, the temperature of the water shall not change by more than 5ºC.

The maximum uncertainty (k = 2) in the measurement of temperature shall not exceed 1ºC.

6.3.2.2.7.5 Orientation of Meter(s)

1. If the meters are marked 'H', mount the connecting pipework with the flow axis in the horizontal plane during the test.
2. If the meters are marked 'V', mount the connecting pipework with the flow axis in the vertical plane during the test.
3. If the meters are not marked with either 'H' or 'V':
   (a) at least one meter from the sample shall be mounted with the flow axis vertical, with flow direction from bottom to top;
   (b) at least one meter from the sample shall be mounted with the flow axis vertical, with flow direction from top to bottom;
   (c) at least one meter from the sample shall be mounted with the flow axis at an intermediate angle to the vertical and horizontal (chosen at the discretion of the approving authority);
   (d) the remaining meters from the sample shall be mounted with the flow axis horizontal.
4. Where the meters have an indicating device which is integral with the body of the meter, at least one of the horizontally mounted meters shall be oriented with the indicating device positioned at the side and the remaining meters shall be oriented with the indicating device positioned at the top.
5. The tolerance on the position of the flow axis for all meters, whether horizontal, vertically or at an intermediate angle, shall be $\pm 5^{o}$.

6.3.3 Test Procedure

1. Determine the intrinsic errors of indication of the meter (in the measurement of the actual volume), for at least the following flowrates, the error at each flowrate being measured twice:
   (a) between Q_1 and 1.1 Q_1;
   (b) between 0.33 ($Q_1 + Q_3$) and 0.37 ($Q_1 + Q_3$);
   (c) between 0.67 ($Q_1 + Q_3$) and 0.74 ($Q_1 + Q_3$);
   (d) between 0.9 Q_3 and Q_3; and
   (e) between 0.95 Q_4 and Q_4.
2. Test the meter without its supplementary devices attached (if any).
3. 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.

4. During a test hold all other influence factors at reference conditions.
5. Measure the errors of indication at other flowrates if the shape of the error curve indicates that the MPE may be exceeded.
6. Calculate the relative error of indication for each flowrate in accordance with Annex A.
7. Complete the test report (NMI M 11-3, section 5.2).

Note: Where the initial error curve is close to the MPE at a point other than at Q_1 or Q_3, if this error is shown to be typical of the meter type, the approving authority may choose to define an alternative flowrate for verification to be included in the pattern approval certificate.

6.3.4 Acceptance Criteria

1. The relative errors of indication for each of the flowrates shall not exceed the MPE in 3.2 of NMI M 11-1. If the error 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.
2. If all the relative errors of indication of the meter have the same sign, at least one of the errors shall not exceed half the MPE. In all cases this requirement shall be applied equitably with respect to the water supplier and the consumer (NMI M 11-1, 3.4.3, paragraphs 3 and 7).

6.4 Low Flow Test

Only applies to meters designed for operation in partially filled pipes.

Refer to NMI M 11-1, 6.2.3.

6.4.1 Object of Test

To verify the minimum water level (nominated by the manufacturer) of the meter. To verify that the meter indicates when flow has occurred below the minimum water level and that the duration of such flow is recorded. This test only applies to meters that are designed for operation in partially filled pipes.

6.4.2 Preparation

The installation and operational requirements described in 6.3.2 shall apply.

6.4.3 Test Procedure

1. Establish a water level in the pipework of between h_{min} and 1.1 h_{min} at a flowrate greater than Q_1.
2. Calculate the relative error of indication in accordance with Annex A.
3. Establish a water level in the pipework of between 0.9 h_{min} and 0.95 h_{min} at a flowrate greater than Q_1.
4. Verify that the meter indicates that flow has occurred below h_{min} and that the duration of such flow is recorded.
5. During each test, all other influence factors shall be maintained at reference conditions.
6. Complete test report (NMI M 11-3, section 5.3).

6.4.4 Acceptance Criteria

1. The relative errors of indication of the EUT shall not exceed the MPE in 3.2 of NMI M 11-1.
2. The EUT shall indicate that flow has occurred below h_{min}.
3. The duration of flow below h_{min} shall be recorded.

6.5 Full Flow Test

Only applies to meters designed for operation in partially filled pipes.

Refer to NMI M 11-1, 6.2.4.

6.5.1 Object of Test

To verify that meters operate as intended (see 6.2.4 in NMI M 11-1) when subjected to full flowing pipe conditions.

6.5.2 Preparation

The installation and operational requirements described in 6.3.2 shall apply. In addition, the following requirements shall apply:

1. Install the meter(s) in the test rig.
2. Completely fill the pipework with water.
3. Bleed the test rig pipework and the water meter(s) of air.
4. Ensure that the test rig is free from leaks.
5. Ensure that the supply pressure is free from pressure pulsations.

6.5.3 Test Procedure

6.5.3.1 Meters Designed to Measure at Full Flow Conditions

1. Measure the error of indication of at least one meter at each of the following flowrates:
   (a) between Q_1 and 1.1 Q_1; and
   (b) between 0.9 Q_3 and Q_3.
2. During each test, all other influence factors shall be maintained at reference conditions.
3. Calculate the relative error of indication for each flowrate in accordance with Annex A.
4. Complete test report (NMI M 11-3, section 5.4.1)

6.5.3.2 Meters **Not** Designed to Measure at Full Flow Conditions

1. Subject the meter to the reference flowrate for at least 1 min.
2. During each test, all other influence factors shall be maintained at reference conditions.
3. Note whether an alarm occurred and also whether the meter recorded the duration of the full flow conditions.
4. Complete test report (NMI M 11-3, section 5.4.2)

6.5.4 Acceptance Criteria

In the test described in 6.5.3.1, the relative error of indication of the meter shall not exceed the applicable MPE given in 3.2 of NMI M 11-1. In the test described in 6.5.3.2, the meter will have a visual or audible alarm and will record the duration of the full flow conditions.

6.6 Wave Disturbance Tests

Refer to NMI M 11-1, 6.2.5.

6.6.1 Object of Tests

To verify that the meter complies with the requirements of 3.2 in NMI M 11-1 when subjected to wave disturbances.

6.6.2 Preparation

In addition to the installation and operational requirements described in 6.3.2, the conditions described in 6.7.3 shall be applied.

6.6.3 Test Procedure

1. Establish a flow through the meter at the reference flowrate.
2. Place a wave generator in the upstream section of the pipework/open channel system.
3. Ensure that the wave generator is positioned such that the waves generated shall have a height of no more than 100 mm with a period of 2 s at the entrance of the specified straight lengths of pipe or channel upstream of the meter.
4. The wave generator shall not be placed in the specified straight lengths of pipe or channel upstream of the meter.

5. Determine the error of indication of the meter in accordance with Annex A.
6. During each test, all other influence factors shall be maintained at reference conditions.
7. Complete test report (NMI M 11-3, 5.5)

6.6.4 Acceptance Criteria

The relative error of indication of the meter shall not exceed the MPE given in 3.2 of NMI M 11-1.

6.7 Flow Disturbance Tests

Refer to NMI M 11-1, 6.2.6.

6.7.1 Object of Test

To verify that the meter does not exceed the relevant MPE when subjected to specified types of disturbed upstream flow. Meters are subjected to disturbances generated by a quarter pipe blockage and a device that induces swirl (see Annex B).

6.7.2 Preparation

In addition to the installation and operational requirements in 6.3.2, the conditions in 6.7.3 apply.

6.7.3 Test Procedure

1. Using the flow disturbances and methods specified in Annex B, determine the error of indication of the meter (in accordance with Annex A) at a flowrate between 0.9 Q_3 and Q_3.
2. During each test, all other influence factors shall be maintained at reference conditions.
3. Complete the test report (NMI M 11-3, section 5.6).

Additional requirements

(a) For meters where the manufacturer has specified installation lengths of straight pipe/channel of at least 15 × DN upstream and 5 × DN downstream of the meter, no external flow straighteners are allowed.

(b) Where meter installations with external flow straighteners are to be used, the manufacturer shall specify the straightener model, its technical characteristics and its position in the installation relative to the meter. The details and use of such a device will be included in the pattern approval certificate and listed as a condition of installation.

(c) Devices within the meter having flow straightening functions shall not be considered to be a 'straightener' in the context of these tests.

6.7.4 Acceptance Criteria

1. The relative error of indication for each of the flow disturbance tests shall not exceed the MPE in 3.2 of NMI M 11-1. The error shift, as defined in B.3.1, shall be less than one-third of the MPE of 3.2 (the expanded uncertainty of the test method plus an allowance for the repeatability of the EUT).
2. The minimum upstream and downstream pipe lengths required for the meter to achieve the above acceptance criteria shall be recorded.

6.8 Head Loss Test

Refer to NMI M 11-1, 6.2.5.

6.8.1 Object of Test

To determine the maximum head loss through the meter at any flowrate between Q_1 and Q_3. The head loss is defined as the level difference created by the flowing water passing through the EUT into a flooded discharge.

6.8.2 Preparation

The installation and operational requirements described in 6.3.2 shall apply.

6.8.3 Test Procedure

1. Flood the discharge to zero level difference and establish zero flow.
2. Decrease the outlet level until the desired flow is achieved.

3. Each flow shall then be maintained within tolerance specified below for a suitable period of time to minimise uncertainty in the head loss reading.
4. The head loss shall be determined at the following flows:
   (a) between Q_1 and 1.1 Q_1;
   (b) between 0.5 (Q_1 + Q_3) and 0.6 (Q_1 + Q_3);
   (c) between 0.9 Q_3 and Q_3; and
   (d) between 0.95 Q_4 and Q_4 (or the highest flowrate recorded at the maximum head loss available).
5. Each test shall be carried out for a minimum of 30 min.
6. Complete test report (NMI M 11-3, section 5.7).

6.8.4 Acceptance Criteria

The head loss across the meter shall be determined and recorded for the above flowrates. Accordingly, this value shall be marked on the meter casing, the indicating device dial, the identification plate or the meter cover if it is not detachable. Alternatively, the maximum head loss may be recorded in the memory of the meter provided it is made easily accessible (see 5.3.1).

6.9 Endurance Tests

Refer to NMI M 11-1, 6.2.7.

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 does not form part of the pattern approval process.

Instead, manufacturers shall submit a sample of meters that have registered a volume of water corresponding to at least 1000 h of continuous flow at a flowrate of Q_3, e.g. meters which have been operating in the field. Details of all meter operations and calibrations shall be submitted to NMI.

Given that the numbers and use of meters will vary from approval to approval, specific sample sizes will be discussed and agreed upon on a case-by-case basis (see Table 4 for an indication of the required sample size).

As well, all such meters in the sample MUST bear their initial verification/ calibration seal(s).

If no suitable meters are available a provisional certificate may be issued (see 4.3 in NMI P 106 [5]) and the manufacturer shall be required to submit a sample of meters for testing before the provisional certificate expires. Upon the successful completion of testing a pattern approval certificate will be issued.

6.9.1 Object of Test

To verify the durability of the meter after an extended period of in-field operation.

6.9.2 Preparation

The installation and operational requirements described in 6.3.2 shall apply.

6.9.3 Test Procedure

1. Determine the intrinsic errors of indication of the meter for at least the following flowrates, the error at each flowrate being measured twice:
   (a) between Q_1 and 1.1 Q_1;
   (b) between 0.33 (Q_1 + Q_3) and 0.37 (Q_1 + Q_3);
   (c) between 0.67 (Q_1 + Q_3) and 0.74 (Q_1 + Q_3);
   (d) between 0.9 Q_3 and Q_3; and
   (e) between 0.95 Q_4 and Q_4.
2. During a test hold all other influence factors at reference conditions.
3. Measure the errors of indication at other flowrates if the shape of the error curve indicates that the MPE (see 6.8.4) may be exceeded.

4. Calculate the relative error of indication for each flowrate in accordance with Annex A.
5. Complete the test report (NMI M 11-3, section 5.7).

6.9.4 Acceptance Criteria

1. The difference between the error of indication at the initial test and the test following the endurance test shall not exceed 2.5% at each point on the curve. For the purpose of determining these requirements the mean values of the errors of indication at each flowrate shall apply.
2. The error of indication curves shall not exceed a maximum error limit of ±4%.

Note: The MPEs in 3.2 of NMI M 11-1 do **not** apply.

6.10 Installation Test

Refer to NMI M 11-1, 6.2.8.

6.10.1 General

A manufacturer may wish to test a meter in a specific installation design that the meter may commonly be subject to in the field, such as particular piping or channel configurations. While this is not a requirement of pattern approval, provided that the testing is performed in accordance with the requirements below, recognition of such testing may form part of the pattern approval certificate.

The manufacturer shall submit detailed technical drawings and diagrams of the installation to NMI and the approving authority and these may form part of the pattern approval certificate.

6.10.2 Object of Test

To verify that a meter operating in a specified installation complies with the requirements of 3.2 in NMI M 11-1.

6.10.3 Preparation

The installation and operational requirements described in 6.3.2 shall apply. In addition, the test section shall include the specified installation configuration; with the meter installed as specified.

6.10.4 Test Procedure

1. Determine the errors of indication of the meter, for at least the following flowrates, the error at each flowrate being measured twice:
   (a) between Q_1 and 1.1 Q_1;
   (b) between 0.33 (Q_1 + Q_3) and 0.37 (Q_1 + Q_3);
   (c) between 0.67 (Q_1 + Q_3) and 0.74 (Q_1 + Q_3);
   (d) between 0.9 Q_3 and Q_3;
   (e) between 0.95 Q_4 and Q_4.
2. Test the meter without its supplementary devices attached (if any).
3. During a test hold all other influence factors at reference conditions.
4. Measure the errors of indication at other flowrates if the shape of the error curve indicates that the MPEs may be exceeded.
5. Calculate the relative error of indication for each flowrate in accordance with Annex A.
6. Complete the test report (NMI M 11-3, section 5.9).

6.10.5 Acceptance Criteria

1. The relative errors of indication observed for each of the flowrates shall not exceed the MPE in 3.2 of NMI M 11-1. If the error observed on the meter 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.
2. If all the relative errors of indication of the meter have the same sign, at least one of the errors shall not exceed half of the MPE. In all cases this requirement shall be applied equitably

with respect to the water supplier and the consumer (NMI M 11-1, 3.4.3, paragraphs 3 and 7).

6.11 Maintenance Tests

Refer to NMI M 11-1, 6.2.9.

6.11.1 General

The policy paper *National Framework for Non-urban Water Metering* [6] allows a pattern approval certificate to provide guidance on common types of maintenance activities which:

(a) do not and cannot affect the metrological performance (and therefore can be undertaken by an uncertified person operating under established work practices and/or maintenance plan);

(b) do not affect the metrological performance when undertaken by a suitably trained and certified maintainer (and therefore trigger the need for subsequent verification when undertaken by an uncertified maintainer);

(c) may affect the metrological performance even when undertaken by a trained and certified maintainer (and therefore trigger the need for subsequent verification).

Any maintenance activity which does not require the verification seal(s) to be broken will not typically affect the metrological performance of the meter. There are exceptions that exist in some meter types and these will be noted in the individual pattern approval certificates.

Any maintenance activity which does require the verification seal(s) to be broken will typically be deemed to have affected the metrological performance of a meter and therefore that meter will require subsequent verification.

However, if it can be proven that a specified maintenance activity, when performed by a suitably trained and certified maintainer, does not affect the metrological performance of a meter, an exception may be made.

6.11.2 Documentation

A manufacturer may test a specified maintenance activity as part of the pattern approval process. While this is not a requirement of pattern approval, provided that the testing is performed in accordance with NMI requirements, recognition of successful test results may form part of the pattern approval certificate.

For any maintenance activity that is tested, the applicant shall provide:

(a) reference to appropriate maintenance instructions that form part of a publication related directly to the meter; such as an instruction booklet or product manual; and/or

(b) detailed instructions and procedures outlining how the maintenance is to be performed.

This information will be included as part of the pattern approval certificate.

6.11.3 Certification

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.

Note: Maintenance procedures that are listed on the pattern approval certificate are specific to that meter only. Maintenance procedures listed

on one pattern approval certificate cannot be used as guidance to perform maintenance on a meter with a different certificate; any such maintenance will be deemed to have affected the metrology of the meter and therefore subsequent verification is required.

6.11.4 Object of Test

To verify that a specified maintenance procedure does not affect the metrological performance of the meter.

6.11.5 Preparation

The installation and operational requirements described in 6.3.2 shall apply. The meter shall have subsequently been tested in accordance with 6.3.2.

6.11.6 Test Procedure

1. Perform the specified maintenance procedure.
2. If the meter has been removed (as a result of maintenance), re-install the meter into the test rig as per 6.3.2.
3. Determine the errors of indication of the meter, for at least the following flowrates, the error at each flowrate being measured twice:
   (a) between Q_1 and 1.1 Q_1;
   (b) between 0.33 (Q_1 + Q_3) and 0.37 (Q_1 + Q_3);
   (c) between 0.67 (Q_1 + Q_3) and 0.74 (Q_1 + Q_3);
   (d) between 0.9 Q_3 and Q_3;
   (e) between 0.95 Q_4 and Q_4.
4. During a test hold all other influence factors at reference conditions.
5. Calculate the relative error of indication for each flowrate in accordance with Annex A.
6. Complete test report (NMI M 11-3, section 5.10).

6.11.7 Acceptance criteria

The relative errors of indication observed for each of the flowrates shall not deviate from the corresponding relative errors of indication observed in 6.3.3 by more than the uncertainty associated with the test method itself (see NMI M 11-1, 7.1).

7. PERFORMANCE TESTS FOR ELECTRONIC METERS AND MECHANICAL METERS FITTED WITH ELECTRONIC DEVICES

7.1 General Requirements

Refer to NMI M 11-1, A.1.

This section defines the performance tests which are intended to verify that meters 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 performance tests are additional to the tests described in 6 and apply to complete meters, to separable parts of a meter, and, if required, to ancillary devices.

When the effect of one influence quantity is being evaluated, all other influence quantities are to be held at the reference conditions (see 7.1.2).

Note: The reference conditions in this section differ from those in 3 which apply to the testing in 6 (see 3).

The pattern approval tests specified in this section may be carried out in parallel with the tests specified in 6, using examples of the same model of the meter, or its separable parts.

7.1.1 Environmental Classification

Refer to NMI M 11-1, A.2.

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

Meters with electronic devices are divided into three classes according to these environmental conditions:

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

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, approving authority will carry out performance tests at severity levels corresponding to these environmental conditions. These severity levels must not be less than class B. See NMI 11-1, Table A.1 for more details of severity levels.

In all cases the approving authority shall verify that the conditions of use are met.

Note: Meters which are approved at a given severity level are also suitable for lower severity levels.

7.1.2 Reference Conditions

Refer to NMI M 11-1, 6.1 and A.3.

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

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

7.1.3 Test Volumes for Measuring the Error of Indication

Refer to NMI M 11-1, A.5(1).

Some influence quantities should have a constant effect on the error of indication of a meter and not a proportional effect related to the measured volume.

In other tests the effect of the influence quantity applied to a meter is related to the measured volume. In these cases, in order to be able to compare results obtained in different laboratories, the test volume for measuring the error of indication of the meter shall correspond to that delivered in 10 min at the over-load flowrate, Q_4.

However, some tests 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.

7.1.4 Influence of the Water Temperature

Refer to NMI M 11-1, A.5(2).

Dry heat, cold and damp heat tests are concerned with measuring the effects of ambient air temperature on the performance of the meter. However, the presence of the measurement transducer, filled with water, may also influence heat dissipation in electronic components.

A simulation of the measurement transducer may be used for testing all electronic components. Where simulated tests are used, they shall replicate the effects caused by the presence of water for those electronic devices which are normally attached to the flow sensor, and the reference conditions shall be applied during the tests.

7.1.5 Requirements for Environmental Tests

The following requirements are associated with the environmental tests and the

relevant standards to be applied are listed in the appropriate sections:

(a) pre-conditioning of the EUT;
(b) any deviations in the procedure from the relevant standard;
(c) initial measurements;
(d) state of the EUT during conditioning;
(e) severity levels, values of the influence factor and duration of exposure;
(f) measurements required and/or the loading during conditioning;
(g) recovery of the EUT;
(h) final measurements;
(i) the acceptance criteria for the EUT passing a test.

Where no standard exists for a specific test, the essential requirements for the test are given in this document.

7.1.6 Categorisation of the EUT

Refer to NMI M 11-1, 6.2.10.3.

7.1.6.1 General

For the purpose of testing, the EUT shall be categorised as one of the cases, A to E, as described below.

Case A No performance test (as mentioned in this section) is required.

Case B The EUT is the complete meter: the test shall be carried out with water flowing in the volume or flow sensor and the meter operating as designed.

Case C The EUT is the measurement transducer (including flow or volume sensor): the test shall be carried out with water flowing in the volume or flow sensor and the meter operating as designed.

Case D The EUT is the electronic calculator (including the indicating device) or the ancillary device: the test shall be carried out with water flowing in the volume or flow sensor and the meter operating as designed.

Case E The EUT is the electronic calculator (including the indicating device) or the ancillary device: the test may be carried out with simulated measurement signals without water in the volume or flow sensor.

Note: The approving authority may apply an appropriate category, A to E, for approval testing of meters having technology which is not included in 7.1.6.2 to 7.1.6.5.

7.1.6.2 Turbine Meters

(a) The meter is not fitted with electronic devices: Case A.

(b) The measurement transducer and the electronic calculator including the indicating device are in the same housing: Case B.

(c) The measurement transducer is separate from the electronic calculator, but **not** fitted with electronic devices: Case A.

(d) The measurement transducer is separate from the electronic calculator, and fitted with electronic devices: Case C.

(e) The electronic calculator including the indicating device is separate from the measurement transducer and simulation of the measurement signals is **not** possible: Case D.

(f) The electronic calculator including the indicating device is separate from the measurement transducer and simulation of the measurement signals is possible: Case E.

7.1.6.3 Electromagnetic Meters

(a) The measurement transducer and the electronic calculator including the indicating device are in the same housing: Case B.

(b) The flow sensor, consisting only of the pipe/channel, the coil and the two meter electrodes, is without any additional electronic devices: Case A.

(c) The measurement transducer including the flow sensor is separate from the electronic calculator, and in one housing: Case C.

(d) The electronic calculator including the indicating device is separate from the measurement transducer and simulation of the measurement signals is **not** possible: Case D.

(e) The electronic calculator including the indicating device is separate from the measurement transducer and simulation of the measurement signals is possible: Case E.

7.1.6.4 Ultrasonic Meters, Coriolis Meters, Fluidic Meters

(a) The measurement transducer and the electronic calculator including the indicating device are in the same housing: Case B.

(b) The measurement transducer is separate from the electronic calculator and fitted with electronic devices: Case C.

(c) The electronic calculator including the indicating device is separate from the measurement transducer and simulation of the measurement signals is **not** possible: Case D.

(d) The electronic calculator including the indicating device is separate from the measurement transducer and simulation of the measurement signals is possible: Case E.

7.1.6.5 Ancillary devices

(a) The ancillary device is part of the meter, a part of the measurement transducer or part of the electronic calculator: Cases A to E.

(b) The ancillary device is separate from the meter, but not fitted with electronic devices: Case A.

(c) The ancillary device is separate from the meter, and simulation of the input signals is **not** possible: Case D.

(d) The ancillary device is separate from the meter, and simulation of the input signals is possible: Case E.

7.2 Dry Heat (Non-condensing)

Refer to NMI M 11-1, A.5.1.

7.2.1 Object of Test

To verify that the EUT complies with the provisions of 3.2 in NMI M 11-1 during the application of high ambient temperatures.

7.2.2 Preparation

Test arrangements: IEC 60068-2-2 [7].

Guidance on test arrangements:
IEC 60068-3-1 [8] and IEC 60068-1 [3].

7.2.3 Test Procedure

1. Do not pre-condition the EUT.
2. Measure the error of indication of the EUT at the reference flowrate and at the following test conditions:
   (a) at the reference air temperature of 20 ± 5°C, before conditioning the EUT;
   (b) at an air temperature of 55 ± 2°C, after the EUT has been stabilised at this temperature for a period of 2 h;
   (c) at the reference air temperature of 20 ± 5°C, after recovery of the EUT.
3. Calculate the relative error of indication for each test condition.
4. During the application of the test conditions, check that the EUT is functioning correctly.
5. Complete the test report (NMI M 11-3, section 6.1).

Additional requirement:

When measuring the errors of indication, the installation and operational conditions described in 6.3.2 shall be followed and the reference conditions shall be applied unless otherwise specified.

7.2.4 Acceptance Criteria

During the application of the test conditions on the EUT:

1. All functions shall operate as designed.
2. The relative error of indication shall not exceed the MPE (NMI M 11-1, 3.2).

7.3 Cold

Refer to NMI M 11-1, A.5.2.

7.3.1 Object of Test

To verify that the EUT complies with the provisions of 3.2 in NMI M 11-1 during the application of low ambient temperatures.

7.3.2 Preparation

Test arrangements: IEC 60068-2-1 [9].

Guidance on test arrangements:
IEC 60068-3-1 [8] and IEC 60068-1 [3].

7.3.3 Test Procedure

1. Do not pre-condition the EUT.
2. Measure the error of indication of the EUT at the reference flowrate and at the reference air temperature.
3. Stabilise the air temperature at either -10°C (classes C and I) or +5°C (class B) for a period of 2 h.
4. Measure the error of indication of the EUT at the reference flowrate at an air temperature of either –10°C (classes C and I) or +5°C (class B).
5. After recovery of the EUT, measure the error of indication of the EUT at the reference flowrate and at the reference air temperature.
6. Calculate the relative error of indication for each test.
7. During the application of the test conditions, check that the EUT is functioning correctly.
8. Complete the test report (NMI M 11-3, section 6.2).

Additional requirements:

(a) If it is necessary to have water in the flow sensor, the water temperature shall be held at the reference temperature.

(b) When measuring the errors of indication, the installation and operational conditions described in 6.3.2 shall be followed and the reference conditions shall be applied unless otherwise specified.

7.3.4 Acceptance Criteria

During the application of the stabilised test conditions on the EUT:

1. All functions shall operate as designed.
2. The relative error of indication shall not exceed the MPE (NMI M 11-1, 3.2).

7.4 Damp Heat, Cyclic (Condensing)

Refer to NMI M 11-1, A.5.3.

7.4.1 Object of Test

To verify that the EUT complies with the provisions of 3.2 in NMI M 11-1 after applying conditions of high humidity combined with cyclic temperature changes.

7.4.2 Preparation

Test arrangements: IEC 60068-2-30 [10].

Guidance on test arrangements:
IEC 60068-3-4 [11].

7.4.3 Test Procedure

1. Pre-condition the EUT.
2. Expose the EUT to cyclic temperature variations between the lower temperature of 25°C and the upper temperature of either 55°C (classes C and I) or 40°C (class B). Maintain 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 during the temperature rise.
3. Allow the EUT to recover.

4. After recovery, check that the EUT is functioning correctly.
5. Measure the error of indication of the EUT at the reference flowrate.
6. Calculate the relative error of indication.
7. Complete the test report (NMI M 11-3, section 6.3).

Additional requirements:

(a) The power supply to the EUT is switched off during steps 1 to 3.

(b) When measuring the error of indication, the installation and operational conditions described in 6.3.2 shall be followed and the reference conditions shall be applied unless otherwise specified.

7.4.4 Acceptance Criteria

After the application of the influence factor and recovery on the EUT:

1. All functions shall operate as designed.
2. The relative error of indication at the reference conditions shall not exceed the MPE (NMI M 11-1, 3.2).

7.5 Power Voltage Variation

Refer to NMI M 11-1, A.5.4.

7.5.1 Meters Powered by Direct AC and AC/DC Converters (NMI M 11-1, A.5.4.1)

7.5.1.1 Object of Test

7.5.1.1.1 Single Voltage

To verify that electronic devices which operate at a single nominal value of mains voltage (U_{nom}) at a nominal frequency (f_{nom}) comply with the provisions of 3.2 in NMI M 11-1 during static deviations of the AC (single-phase) mains power supply, applied in accordance with the requirements of NMI M 11-1 (A.5.4.1).

7.5.1.1.2 Voltage Range

To verify that electronic devices which operate within a nominal range of mains voltage, having an upper limit U_u and a lower limit U_l, at a nominal frequency (f_{nom}) comply with the provisions of 3.2 in NMI M 11-1 during static deviations of the AC (single-phase) mains power supply, applied in accordance with the requirements of NMI M 11-1 (A.5.4.1).

7.5.1.2 Preparation

Test arrangements:

- IEC 61000-4-11 [12]
- IEC 61000-2-1 [13]
- IEC 61000-2-2 [14]
- IEC 61000-4-1 [15]
- IEC 60654-2 [16]
- IEC 61000-2-12 [17]

7.5.1.3 Test Procedure

1. Expose the EUT to power voltage variations, while the EUT is operating under reference conditions.
2. Measure the error of indication of the EUT during the application of the upper mains voltage limit U_{nom} + 10% (single voltage) or U_u +10% (voltage range).
3. Measure the error of indication of the EUT during the application of the lower mains voltage limit U_{nom} – 15% (single voltage) or U_l – 15% (voltage range).
4. Calculate the relative error of indication for each test condition.
5. Check that the EUT is functioning correctly during the application of each power supply variation.
6. Complete the test report (NMI M 11-3, section 6.4.1).

Additional requirements:

(a) During the measurement of the error of indication the EUT shall be subjected to the reference flowrate (NMI M 11-1, 6.1).

(b) When measuring the errors of indication, the installation and operational conditions described in 6.3.2 shall be followed and the reference conditions shall be applied unless otherwise specified.

7.5.1.4 Acceptance Criteria

During the application of the influence factor on the EUT:

1. All functions shall operate as designed.
2. The relative error of indication shall not exceed the MPE (NMI M 11-1, 3.2).

7.5.2 Meters Powered by Primary DC Batteries (NMI M 11-1, A.5.4.2)

7.5.2.1 Object of Test

To verify that battery powered electronic devices comply with the provisions of 3.2 in NMI M 11-1 during static deviations of the DC, primary battery, power supply voltage.

7.5.2.2 Preparation

No references to standards for test methods can be given.

7.5.2.3 Test Procedure

1. Expose the EUT to power voltage variations, while the EUT is operating under reference conditions.
2. Measure the error of indication of the EUT during the application of the upper battery voltage limit U_{max}.
3. Measure the error of indication of the EUT during the application of the lower battery voltage limit U_{min}.
4. Calculate the relative error of indication for each test condition in accordance with Annex B.
5. Check that EUT is functioning correctly during the application of each power supply variation.
6. Complete the test report (NMI M 11-3, section 6.4.2).

Additional requirement:

(a) During the measurement of the error of indication the EUT shall be subjected to the reference flowrate.

When measuring the errors of indication, the installation and operational conditions described in 6.3.2 shall be followed and the reference conditions shall be applied unless otherwise specified.

7.5.2.4 Acceptance Criteria

During the application of the voltage variations on the EUT:

1. All functions shall operate as designed.
2. The relative error of indication shall not exceed the MPE (NMI M 11-1, 3.2).

7.6 Short-time Power Reductions

Refer to NMI M 11-1, A.5.7.

7.6.1 Object of Test

To verify that EUT which is mains powered, complies with the provisions of 3.2 in NMI M 11-1 during the application of short time, mains voltage interruptions and reductions.

7.6.2 Preparation

Test arrangements:

- IEC 61000-4-11 [12]
- IEC 61000-2-1 [13]
- IEC 61000-2-2 [14]
- IEC 61000-4-1 [15]

7.6.3 Test Procedure

1. Measure the error of indication of the EUT before applying power reduction test.
2. Measure the error of indication of the EUT during the application of at least ten voltage interruptions and ten voltage reductions.
3. Calculate the relative error of indication for each test condition.
4. Subtract the error of indication of the meter measured before applying the power reductions from that measured during the application of the power reductions.
5. Examine the EUT for correct functioning.
6. Complete the test report (NMI M 11-3, section 6.7).

Additional requirements:

(a) Voltage interruptions and voltage reductions are applied throughout the

period required to measure the error of indication of the EUT.

(b) Voltage interruptions: the supply voltage is reduced from its nominal value (U_{nom}) to zero voltage, for a duration equal to half a cycle of line frequency.

(c) Voltage interruptions are applied in groups of ten.

(d) Voltage reductions: the supply voltage is reduced from nominal voltage to 50% of nominal voltage for a duration equal to one cycle of the power supply frequency.

(e) Voltage reductions are applied in groups of ten.

(f) Each individual voltage interruption or reduction is initiated, terminated and repeated at zero crossings of the supply voltage.

(g) The mains voltage interruptions and reductions are repeated at least ten times with a time interval of at least 10 s between each group of interruptions and reductions. This sequence is repeated throughout the duration of the measurement of the error of indication of the EUT.

(h) During the measurement of the error of indication the EUT shall be subjected to the reference flowrate.

(i) When measuring the errors of indication, the installation and operational conditions described in 6.3.2 shall be followed and the reference conditions shall be applied unless otherwise specified.

(j) When the EUT is designed to operate over a range of supply voltage, voltage reductions and interruptions shall be initiated from the mean voltage of the range.

7.6.4 Acceptance Criteria

After the application of the short time power reductions on the EUT:

1. All functions shall operate as designed.
2. The difference between the relative error of indication obtained **during** the test and that obtained at the same flowrate **before** the test under reference conditions, shall not exceed half of the MPE (NMI M 11-1, 3.2).

7.7 Bursts

Refer to NMI M 11-1, A.5.8.

7.7.1 Object of Test

To verify that the EUT (including its external cables) complies with the provisions of 3.2 in NMI M 11-1 during the application of voltage spikes, superimposed on the mains voltage.

7.7.2 Preparation

Test arrangements:

- IEC 61000-2-1 [13]
- IEC 61000-2-2 [14]
- IEC 61000-4-1 [15]
- IEC 61000-4-4 [18]

7.7.3 Test Procedure

1. Measure the error of indication of the EUT before applying the electrical bursts.
2. Measure the error of indication of the EUT during the application of bursts of transient voltage spikes, of double exponential waveform.
3. Calculate the relative error of indication for each test condition.
4. Subtract the error of indication of the meter measured before applying the bursts from that measured during the application of the bursts.
5. Examine the EUT for correct functioning.
6. Complete the test report (NMI M 11-3, section 6.8).

Additional requirements:

(a) Each spike shall have an amplitude (positive or negative) of 1000 V for class E1 instruments, or 2000 V for class E2 instruments (see 7.1.1), phased randomly, with a rise time of 5 ns and a half amplitude duration of 50 ns.
(b) The burst length shall be 15 ms, the burst period (repetition time interval) shall be 300 ms.
(c) All bursts shall **not** be applied asynchronously in common mode (asymmetrical voltage) during the measurement of the error of indication of the EUT.
(d) During the measurement of the error of indication the EUT shall be operated at the reference flowrate.
(e) When measuring the error of indication, the installation and operational conditions of the EUT, described in 6.3.2, shall be followed and the reference conditions shall be applied unless otherwise specified.

7.7.4 Acceptance Criteria

After the application of the disturbance on the EUT:

1. All functions shall operate as designed.
2. The difference between the relative error of indication obtained **during** the test and that obtained at the same flowrate **before** the test under reference conditions, shall not exceed half of the MPE (NMI M 11-1, 3.2).

7.8 Electrostatic Discharge

Refer to NMI M 11-1, A.5.9.

7.8.1 Object of Test

To verify that the EUT complies with the provisions of 3.2 in NMI M 11-1 during the application of direct and indirect electrostatic discharges.

7.8.2 Preparation

Test arrangements:

- IEC 61000-2-1 [13]
- IEC 61000-2-2 [14]
- IEC 61000-4-1 [15]
- IEC 61000-4-2 [19]

7.8.3 Test Procedure

1. Measure the error of indication of the EUT before applying the electrostatic discharges.
2. Charge a capacitor of 150 pF capacitance by means of a suitable DC voltage source. Then discharge the capacitor through the EUT by connecting one terminal of the supporting chassis to ground and the other via a 330 Ω resistor, to surfaces of the EUT which are normally accessible to the operator. The following conditions shall be applied:
   (a) include the paint penetration method, if appropriate;
   (b) for each contact discharge, a voltage of 6 kV shall be applied;
   (c) for each air discharge, a voltage of 8 kV shall be applied;
   (d) for direct discharges, the air discharge method shall be used where the manufacturer has declared a coating to be insulating;
   (e) at each test location, at least ten direct discharges shall be applied at intervals of at least 10 s between discharges, during the same measurement or simulated measurement;
   (f) for indirect discharges, a total of ten discharges shall be applied on the horizontal coupling plane and a total of ten discharges for each of the various positions of the vertical coupling plane.
3. Measure the error of indication of the EUT during the application of electrostatic discharges.
4. Calculate the relative error of indication for each test condition in accordance with Annex B.

5. Determine if the significant fault has been exceeded by subtracting the error of indication of the meter measured before applying the electrostatic discharges from that measured after applying the electrostatic discharges.
6. Examine the EUT for correct functioning.
7. Complete the test report (NMI M 11-3, section 6.9).

Additional requirements:

(a) When measuring the error of indication the EUT shall be subjected to the reference flowrate.

(b) When measuring the error of indication, the installation and operational conditions described in 6.3.2 shall be followed and the reference conditions shall be applied unless otherwise specified.

(c) In cases where a specific meter design has been proven to be immune to electrostatic discharge, within the rated operating conditions for flowrate, the approving authority shall be free to choose a flowrate of zero during the electrostatic discharge test.

7.8.4 Acceptance Criteria

After the application of the disturbance on the EUT:

1. All functions shall operate as designed.
2. The difference between the relative error of indication obtained **during** the test and that obtained **before** the test at the same flowrate under reference conditions, shall not exceed half of the MPE (NMI M 11-1, 3.2).
3. For tests at zero flowrate the meter totalisation shall not change by more than the value of the verification interval.

7.9 Electromagnetic Susceptibility

Refer to NMI M 11-1, A.5.10.

7.9.1 Object of Test

To verify that the EUT complies with the provisions of 3.2 in NMI M 11-1 during the application of radiated electromagnetic fields.

7.9.2 Preparation

Test arrangements:

- IEC 61000-2-1 [13]
- IEC 61000-2-2 [14]
- IEC 61000-4-1 [15]
- IEC 61000-4-3 [20]
- IEC 61000-4-20 [21]

However, the test procedure described below is a modified procedure applicable to integrating instruments which totalise the measurand.

7.9.3 Test Procedure

1. Measure the intrinsic error of indication of the EUT at reference conditions before applying the electromagnetic field.
2. Apply the electromagnetic field in accordance with the requirements of (a) to (e) below.
3. Start a new measurement of the error of indication for the EUT.
4. Step the carrier frequency until the next carrier frequency in Table 3, is reached in accordance with requirements of (e).
5. Stop the measurement of the error of indication for the EUT.
6. Calculate the relative error of indication of the EUT in accordance with Annex B.
7. Calculate the significant fault as the difference between the intrinsic error of indication from step 1 and the error of indication from step 6.
8. Change the polarisation of the antenna.
9. Repeat steps 2 to 8.

10. Examine the EUT for correct functioning.
11. Complete the test report (NMI M 11-3, section 6.10).

Table 3. Start and stop carrier frequencies

MHz	MHz	MHz
26	150	435
40	160	500
60	180	600
80	200	700
100	250	800
120	350	934
144	400	1000

Additional requirements:

(a) The EUT, and its external cables of at least 1.2 m length, shall be subjected to radiated electromagnetic fields at field strengths of either 3 V/m for class E1 instruments, or 10 V/m for class E2 instruments (see above).

(b) The preferred transmitting antennae are a bi-conical antenna for the frequency range 26 MHz to 200 MHz and a log-periodic antenna for the frequency range 200 MHz to 1000 MHz.

(c) The test is performed as 20 partial scans with vertical antenna and 20 partial scans with horizontal antenna. The start and stop frequencies for each scan are listed in Table 3.

(d) Each intrinsic error of indication is determined by commencing at a start frequency and terminating when the next highest frequency of Table 3 is reached.

(e) During each scan, the frequency shall be stepped in steps of 1% of actual frequency, until the next frequency of Table 3 is reached. The dwell time at each 1% step must be identical. The dwell time will depend on the test equipment used and the resolution of the reference values of measurement measurements. However, the dwell time shall be equal for all carrier frequencies in the scan and shall be sufficient for the EUT to be exercised and able to respond at each frequency.

(f) The error of indication measurements shall be carried out with all of the scans, listed in Table 3.

(g) When measuring the error of indication, the EUT shall be subjected to the reference flowrate.

(h) When measuring the error of indication, the installation and operational conditions described in 6.3.2 shall be followed and the reference conditions shall be applied unless otherwise specified.

(i) If a specific meter design has been proven to be immune to radiated electromagnetic fields described in 7.11.1, within the rated operating conditions for flowrate, the approving authority shall be free to choose a flowrate of zero during the electromagnetic susceptibility test.

7.9.4 Acceptance Criteria

After the application of the disturbance on the EUT:

1. All functions shall operate as designed.
2. The difference between the relative error of indication measured **during** the test, and that obtained at the same flowrate **before** the test under reference conditions, shall not exceed half the MPE (NMI M 11-1, 3.2).
3. During tests applied at zero flowrate, the meter totalisation shall not change by more than the value of the verification interval.

7.10 Water

Refer to NMI M 11-1, A.5.11.

7.10.1 Object of Test

To verify that the EUT complies with the provisions of 3.2 in NMI M 11-1 during the spraying or splashing of or immersion in, water.

7.10.2 Preparation

Test arrangements:

- IEC 60068-2-18 [22]
- IEC 60512-14-7 [23]
- IEC 60529 [24]

7.10.3 Test Procedure

1. Do not pre-condition the EUT.
2. Measure the error of indication of the EUT at the reference flowrate and at the reference air temperature.
3. 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 (class B and class C and I for non-submersible components) or immerse components to a depth agreed to with the manufacturer (class C and I submersible components).
4. After recovery of the EUT, measure the error of indication of the EUT at the reference flowrate and at the reference air temperature.
5. Calculate the relative error of indication for each test.
6. During the application of the test conditions, check that the EUT is functioning correctly.
7. Complete the test report (NMI M 11-3, section 6.11).

Additional requirements:

(a) If it is necessary to have water in the flow sensor, the water temperature shall be held at the reference temperature.

(b) When measuring the errors of indication, the installation and operational conditions described in 6.3.2 shall be followed and the reference conditions shall be applied unless otherwise specified.

7.10.4 Acceptance Criteria

After the application of the test conditions on the EUT:

1. All functions shall operate as designed.
2. The relative error of indication shall not exceed the MPE (NMI M 11-1, 3.2).

7.11 Dust

Refer to NMI M 11-1, A.5.12.

7.11.1 Object of Test

To verify that the EUT complies with the provisions of 3.2 in NMI M 11-1 during the application of dust laden atmospheres.

7.11.2 Preparation

Test arrangements:

- IEC 60512-11-8 [25]
- IEC 60529 [24]
- IEC 60721-2-5 [29]
- IEC 60068-2-68 [28]

7.11.3 Test Procedure

1. Do not pre-condition the EUT.
2. Measure the error of indication of the EUT at the reference flowrate and at the reference air temperature.
3. Mount the EUT in a dust chamber as described in IEC 60529 [24].
4. Whilst cycling the temperature between 30°C and 65°C in accordance with 3.2.3 in IEC 60512-11-8 [25] apply the dust conditions described in IEC 60529 [24].
5. After recovery of the EUT, measure the error of indication of the EUT at the reference flowrate and at the reference air temperature.
6. Calculate the relative error of indication for each test.
7. During the application of the test conditions, check that the EUT is functioning correctly.
8. Complete the test report (NMI M 11-3, section 6.12).

Additional requirements:

(a) If it is necessary to have water in the flow sensor, the water temperature shall be held at the reference temperature.

(b) Dust/talc particles shall be adequately suspended within the test chamber throughout the test.

(c) When measuring the errors of indication, the installation and operational conditions described in 6.3.2 shall be followed and the reference conditions shall be applied unless otherwise specified.

7.11.4 Acceptance Criteria

After the application of the test conditions on the EUT:

1. All functions shall operate as designed.
2. The relative error of indication shall not exceed the MPE (NMI M 11-1, 3.2).

8. TEST PROGRAM FOR PATTERN APPROVAL

8.1 Number of Samples Required

8.1.1 All Meters

For each meter pattern, the numbers of complete meters or their separable parts, to be tested during pattern examination shall be as shown in Table 4.

8.1.2 Meters Equipped with Electronic Devices

In addition to the number of samples specified in Table 4, one additional sample shall be submitted for pattern examination when the meter is equipped with electronic devices.

Table 4. Minimum 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: The approving authority may require more meters to be submitted

8.2 Tests Applicable to all Meters

Table 5 gives a program for testing all meters for pattern evaluation. The tests shall be carried out in the sequence shown on at least the number of samples given in Table 4, according to the meter designation.

Table 5. Performance tests for all meters

Clause	Test
6.2	Static pressure
6.3	Errors of indication
6.4	Low flow
6.5	Full flow
6.6	Wave disturbance
6.7	Flow disturbance
6.8	Head loss
6.9	Endurance

Table 6. Performance tests for electronic parts of meters

Clause	Test
7.2	Dry heat
7.3	Cold
7.4	Damp heat, cyclic
7.5	Power voltage variation
7.6	Short time power reductions
7.7	Bursts
7.8	Electrostatic discharge
7.9	Electromagnetic susceptibility
7.10	Water
7.11	Dust

8.3 Tests Applicable to Electronic Meters, Mechanical Meters Fitted with Electronic Devices and their Separable Parts

In addition to the tests listed in Table 5, the performance tests listed in Table 6 shall be applied to electronic meters and mechanical meters fitted with electronic devices. The tests listed in Table 6 may be carried out in any order.

8.4 Pattern Approval of Separable Parts

The compatibility of separable parts of a meter shall be evaluated by the approving authority and the following rules shall be applied.

1. The pattern approval certificate for a:
   - **separately approved measurement transducer** (including flow or volume sensor) shall state the model or models of approved calculator (including indicating device) with which it can be combined;
   - **separately approved calculator** (including indicating device) shall state the model or models of approved measurement transducer (including flow or volume sensor) with which it can be combined;
   - **combined meter** shall state which model or models of approved calculator (including indicating device) and approved measurement transducer (including flow or volume sensor) which can be combined.
2. The MPEs for the calculator (including indicating device) or measurement transducer (including flow or volume sensor) shall be declared by the manufacturer when it is submitted for pattern examination.
3. The arithmetic sum of the MPEs of an approved calculator (including indicating device) and an approved measurement transducer (including flow or volume sensor) shall not exceed the MPEs for a complete meter (NMI M 11-1, 3.2).
4. Measurement transducers (including flow or volume sensor) of mechanical meters, mechanical meters fitted with electronic devices and electronic meters, shall be subjected to the applicable performance tests listed in Tables 5 and 6.
5. Calculators (including indicating device) of mechanical meters, mechanical meters fitted with electronic devices and electronic meters, shall be subjected to the applicable performance tests listed in Tables 5 and 6.
6. Wherever possible, the test conditions applied during the pattern evaluation of a complete meter shall be applied to the separable parts of a meter. Where this is not possible for certain test conditions, simulated conditions, of equivalent severity and duration, shall be applied.
7. The performance test requirements of 6 and 7 shall be met where applicable.
8. The results of the pattern evaluation tests of separable parts of a meter shall be declared in a report of similar format to that for a complete meter (see NMI M 11-3).

8.5 Families of Meters

When a family of meters is submitted for pattern approval, the criteria in Annex C shall be applied by the approving authority in deciding if the meters conform to the definition of ‘a family’ and in selecting which meter sizes are to be tested.

9. TESTS FOR INITIAL VERIFICATION

In general, only meters which have been approved either as complete meters or as separately approved, calculator (including indicating device) and measurement transducer (including flow or volume sensor), and subsequently assembled into a combined meter shall be eligible for initial verification.

However, NMI may allow substitution in service of separately approved calculators (including indicating device) and measurement transducers (including flow or volume sensor), if it has been proven during pattern evaluation that such substitutions will not result in the combined MPEs exceeding the respective MPEs for a complete meter.

Any special requirements for initial verification testing which have been detailed in the pattern approval certificate, shall be applied.

9.1 Water Meter

9.1.1 Object of Test

To verify that the relative errors of indication of the meter are within the MPEs in 3.2 of NMI M 11-1.

9.1.2 Preparation

The errors of indication of the meter shall be measured using equipment and principles described in 6.1 and 6.3.

9.1.3 Test Procedure

1. Install the meters for testing either singly or in series.
2. Apply the procedures given in 6.3.
3. Ensure that there is no significant interaction between meters installed in series.
4. Ensure that outlet pressure of any meter is not less than 0.03 MPa (0.3 bar).
5. Ensure that working water temperature range is: $20 \pm 10^{o}C$.
6. Ensure that all other influence factors are held within the rated operating conditions of the meter.
7. Unless alternative flowrates are specified in the pattern approval certificate, measure the errors of indication at the following flowrates:
   (a) between Q_1 and 1.1 Q_1;
   (b) between 0.5 Q_3 and 0.6 Q_3;
   (c) between 0.9 Q_3 and Q_3.
8. Calculate the error of indication, in accordance with Annex A, for each flowrate.
9. Complete test report NMI M 11-3, Example 1.

9.1.4 Acceptance Criteria

1. The errors of indication of the EUT shall not exceed the MPEs in 3.2 of NMI M 11-1.
2. If all the errors of indication of the meter have the same sign, at least one of these errors shall not exceed half the MPE. In all cases this requirement shall be applied equitably with respect to the water supplier and the consumer (NMI M 11-1, 3.4.3 paragraphs 3 and 7).

9.2 Separable Parts

9.2.1 Object of Test

To verify that the errors of indication of the measurement transducer (including volume or flow sensor) or the calculator (including indicating device) are within the MPEs stated in the pattern approval certificate.

Measurement transducers (including flow or volume sensors) shall be subjected to the initial verification tests listed in 9.1.

Calculators (including indicating devices) shall be subjected to the initial verification tests listed in 9.1.

9.2.2 Preparation

The errors of indication of separable approved parts of a meter shall be measured using equipment and principles described in 6.1 and the performance test requirements of 6.3 shall be met where applicable.

Where possible, the test conditions applied during the pattern evaluation of a complete meter shall be applied to the separable parts of a meter. Where this is not possible for certain test conditions, simulated conditions, of equivalent characteristics, severity and duration shall be applied.

9.2.3 Test Procedure

The test procedure in 9.1.3 shall be followed except where simulated testing is necessary.

Complete test report NMI M 11-3, Example 2 and/or Example 3.

9.2.4 Acceptance Criteria

The errors of indication of separable parts of the meter shall not exceed the MPEs stated in the pattern approval certificate.

10. PRESENTATION OF RESULTS

10.1 Object of Reports

To record and present the work carried out by the testing laboratory, including the results of the tests and examinations and all relevant information accurately, clearly and unambiguously, in the format given in NMI M 11-3 [2].

10.2 Identification and Test Data to be Included in Records

10.2.1 Pattern Evaluation

The record of a pattern evaluation shall contain:

(a) a precise identification of the test laboratory and the meter tested;

(b) the calibration history of all instrumentation and measuring devices used for the tests;

(c) exact details of the conditions during which the various tests were carried out, including any specific test conditions advised by the manufacturer;

(d) the results and conclusions of the tests, as required in this document;

(e) The limitations applying to the application of separately approved measurement transducers and calculators.

10.2.2 Initial Verification

The record of an initial verification or subsequent verification test for an individual meter shall include as a minimum:

(a) identification of testing laboratory, i.e. name and address;

(b) identification of meter tested:
- name and address of the manufacturer or the trademark used;
- the meter designation Q_3;
- the ratios Q_3/Q_1;
- the maximum head loss (and corresponding flowrate);
- year of manufacture and the serial number of the meter tested;
- type or model;

(c) the results and conclusions of the tests.

ANNEX A.
CALCULATING THE RELATIVE ERROR OF INDICATION (MANDATORY)

A.1 General

This Annex defines the formulae to be applied during pattern approval and verification tests, when calculating the error of indication of a:

- complete meter;
- separable calculator (including indicating device);
- separable measurement transducer (including flow or volume sensor).

A.2 Error of Indication

When either a measurement transducer (including flow or volume sensor) or a calculator (including indicating device) of a meter is submitted for separable pattern approval, error of indication measurements are carried out only on these separable parts of the meter.

For a measurement transducer (including flow or volume sensor), the output signal (pulse, current, voltage or encoded) is measured by a suitable instrument.

For the calculator (including indicating device), the characteristics of simulated input signals (pulse, current, voltage or encoded) should replicate those of the measurement transducer (including flow or volume sensor).

The error of indication of the EUT is calculated according to what is considered to be the true value of the actual volume added during a test, compared with the equivalent volume of either the simulated input signal to the calculator (including indicating device), or the actual output signal from the measurement transducer (including flow or volume sensor), measured during the same test period.

Unless exempted by the metrological authority, a measurement transducer (including flow or volume sensor) and a compatible calculator (including indicating device) have separate pattern approvals, and must be tested together as a combined meter during initial and subsequent verification (see 9). Therefore, the calculation for the error of indication is the same as for a complete meter.

A.3 Relative Error of Indication of a Complete Meter

$$E_{m(i)} = [\ (V_i - V_a) / V_a\ ] \times 100\ (\%)$$

$E_{m(i)}$ relative error of indication of a complete meter at a flowrate, i (where i = 1, 2, ... n)

V_a actual (or simulated) volume passed, during the test period, D_t (m^3 or kL)

V_i volume added to (or subtracted from) the indicating device, during the test period, D_t (m^3 or kL)

A.4 Relative Error of Indication of a Combined Meter

Treat as a complete meter (see A.3).

A.5 Relative Error of Indication of a Calculator (Including Indicating Device) ($E_{c(i)}$)

$$E_{c(i)} = [\ (V_i - V_a) / V_a\ ] \times 100\ (\%)$$

$E_{c(i)}$ relative error of indication of a calculator (including indicating device) at a flowrate, i (where i = 1, 2, ... n)

(a) When tested with a simulated pulse input signal

V_a $= C_p \times T_p$, the water volume equivalent to the total number of volume pulses injected into the indicating device during the test period, D_t (m^3 or kL)

C_p constant equating a nominal volume of water to each pulse (m^3/pulse or kL/pulse)

T_p total number of volume pulses injected during the test period, D_t (pulses)

V_i volume registered by the indicating device, added during the test period, D_t (m^3 or kL)

(b) When tested with a simulated current input signal

V_a = $C_i \times i_t \times D_t$, the water volume equivalent to the average signal current injected into the calculator during the test period, D_t (m^3 or kL)

C_i constant relating the current signal to the flowrate (m^3/h.mA or kL/h.mA)

i_t average current input signal during the test period, D_t (mA)

D_t duration of the test period (h)

V_i volume registered by the indicating device, added during the test period, D_t (m^3 or kL)

(c) When tested with a simulated voltage input signal

V_a = $C_v \times U_c \times D_t$, the water volume equivalent to the average signal voltage injected into the calculator during the test period, D_t (m^3 or kL)

C_v constant relating the voltage input signal to the flowrate (m^3/h.V or kL/h.V)

U_c average value of the voltage input signal during the test period, D_t (V)

V_i volume registered by the indicating device, added during the test period, D_t (m^3 or kL)

(d) When tested with a simulated encoded input signal

V_a water volume equivalent to the numerical value of the encoded input signal, injected into the indicating device during the test period, D_t (m^3 or kL)

V_i volume registered by the indicating device, added during the test period, D_t (m^3 or kL)

A.6 Relative Error of Indication of a Measurement Transducer (Including Flow or Volume Sensor) ($E_{t(i)}$)

$$E_{t(i)} = [(V_i - V_a) / V_a] \times 100 \ (\%)$$

$E_{t(i)}$ relative error of indication of a measurement transducer (including flow or volume sensor) at a flowrate i (where i = 1, 2, ... n)

(a) When tested with a pulse input signal

V_i = $C_p \times T_p$, the water volume equivalent to the total number of volume pulses emitted from the measurement transducer during the test period, D_t (m^3 or kL)

C_p constant equating a nominal volume of water to each output pulse (m^3/pulse or kL/pulse)

T_p total number of volume pulses emitted during the test period, D_t (pulses)

V_a actual volume of water collected during the test period, D_t (m^3 or kL)

(b) When tested with a current output signal

V_i = $C_i \times i_t \times D_t$, the water volume equivalent to the average current output signal emitted from the measurement transducer (including flow or volume sensor) during the test period, D_t (m^3 or kL)

C_i constant relating the output signal current to the flowrate (m^3/h.mA or kL/h.mA)

i_t average current output signal emitted during the test period, D_t (mA)

D_t duration of the test period (h)

V_a actual volume of water collected during the test period, D_t (m^3 or kL)

(c) When tested with a voltage output signal

V_i = $C_v \times D_t \times U_t$, the volume of water equivalent to the average signal voltage emitted by the measurement transducer (including flow or volume sensor) and its duration, measured during the test period, D_t (m^3 or kL)

C_v constant relating the voltage output signal emitted to the flowrate (m^3/h.V or kL/h.V)

D_t duration of the test period (h)

U_t average voltage output signal emitted during the test period, D_t (V)

V_a actual volume of water collected during the test period, D_t (m^3 or kL)

(d) When tested with an encoded output signal

V_i volume of water equivalent to the numerical value of the encoded output signal emitted from the measurement transducer (including flow or volume sensor) during the test period, D_t (m^3 or kL)

V_a actual volume of water collected during the test period, D_t (m^3 or kL)

ANNEX B.
FLOW DISTURBANCE TESTS (MANDATORY)

B.1 General

A meter may be affected by disturbances in the upstream or downstream pipeline or channel (e.g. due to the presence of bends, elbows, valves, pumps or gates).

A meter manufacturer may specify that the meter should be installed with straight lengths of pipe or channel of the same dimensions as the meter, upstream and downstream of the meter.

In such cases the tests specified in this annex shall be conducted with the meter assembled to the specified straight lengths.

B.2 Error Shift

The influence of disturbances is determined by measuring the error of indication in non-disturbed conditions in accordance with 6.3.3, and in disturbed conditions as described in B.4. The difference between the errors of indication in both situations (non-disturbed and disturbed), the so-called error shift, shall be less than one-third of the MPE of section 3.2 (the maximum expanded uncertainty of the test method plus an allowance for the repeatability of the meter under test).

If this requirement is met, the installation will require no additional lengths of upstream pipe/channel. However, if this requirement is not met, the test described in B.3 shall be carried out. The test shall be continued until the above-mentioned requirement for error shift is met.

The piping/channel configuration and/or elements required to meet this requirement shall be noted and specified by the manufacturer. They are part of the 'meter package' to be installed at the required distance downstream of the disturbance.

B.3 Disturbance Generator Installed Further Upstream of the Meter Inlet or Downstream of the Meter Outlet

If the error shift requirement specified in B.2 is not met, the tests have to be continued with the meter by incorporating longer upstream and/or downstream straight pipe/channel and/or flow conditioner.

B.4 Flow Disturbances

Figures B.1 to B.4 provide a representation of the disturbances that are required to conduct the flow disturbance tests given in 6.7.

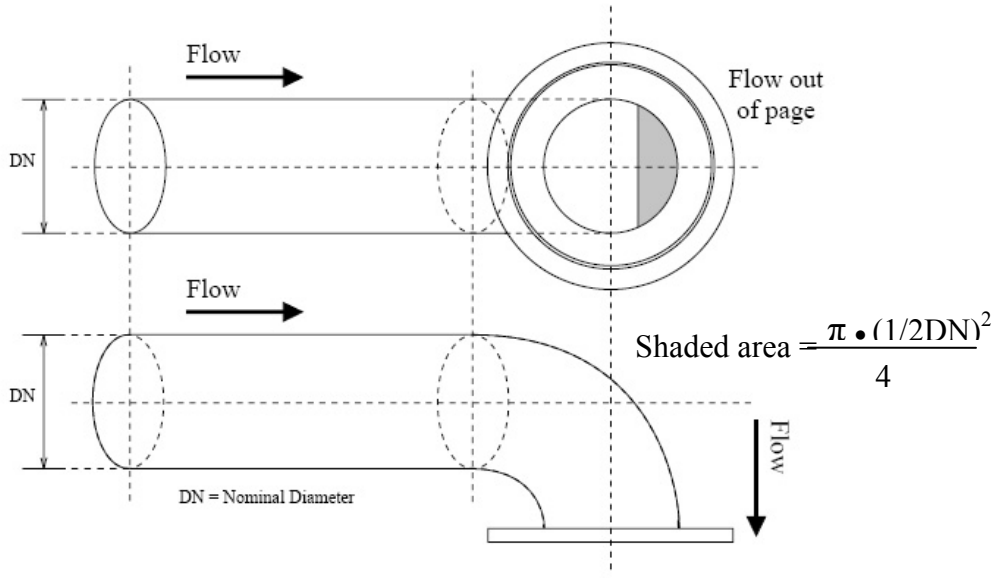

Figure B.1. Flow disturbance for meters intended to operate in partially filled pipes

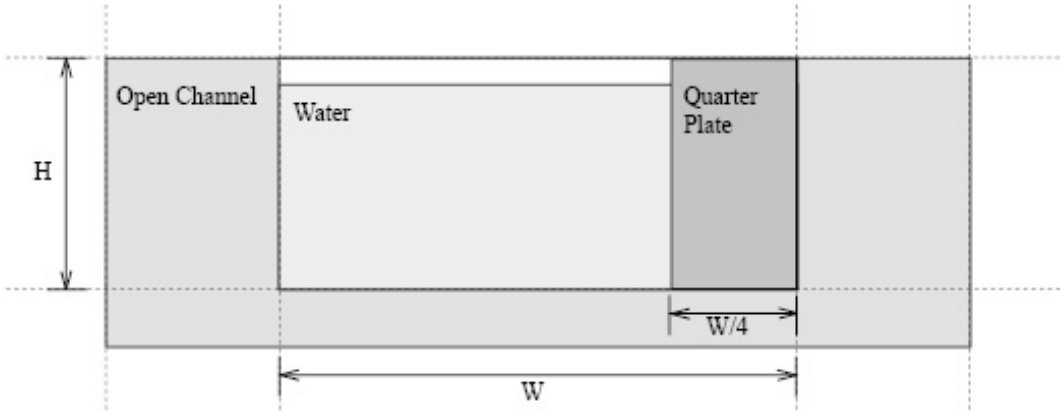

Figure B.2. Flow disturbance for open channel meters – vertical

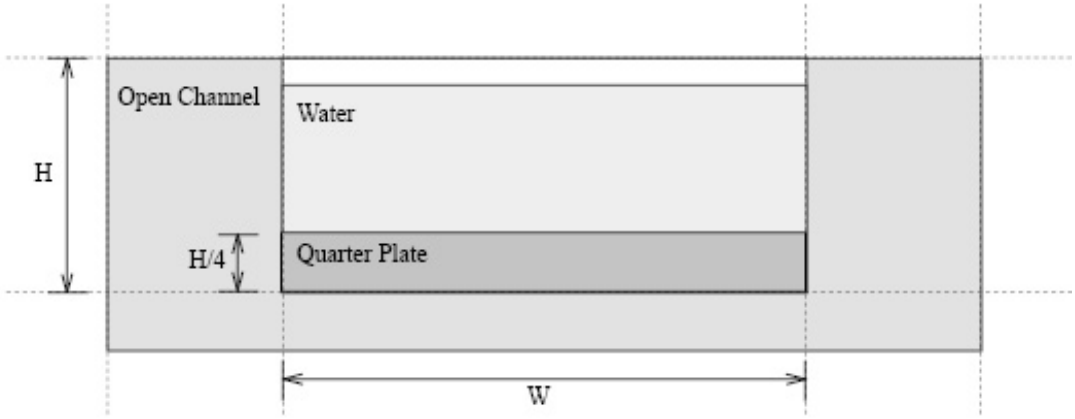

Figure B.3. Flow disturbance for open channel meters – horizontal 1

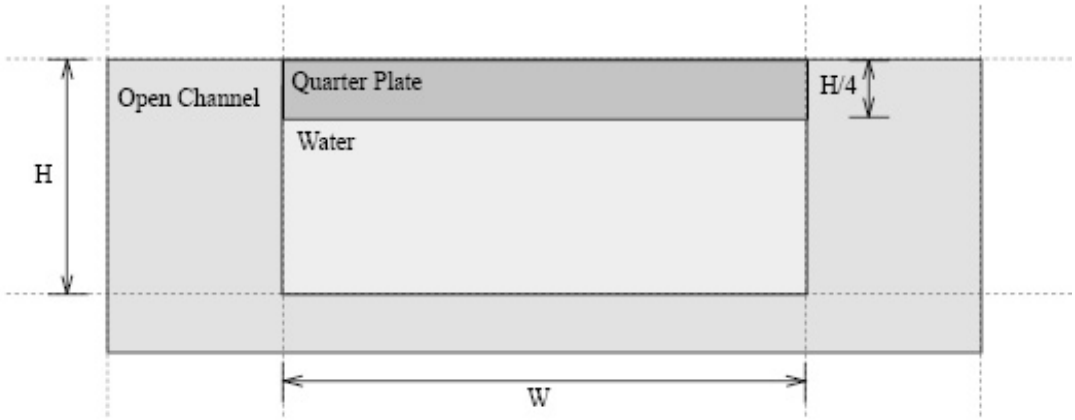

Figure B.4. Flow disturbance for open channel meters – horizontal 2

ANNEX C.
PATTERN EVALUATION OF A FAMILY OF METERS (MANDATORY)

C.1 Families of Meters

This annex describes the criteria to be applied by the approving authority in deciding if a group of meters can be considered to be from the same family for pattern approval purposes, where only selected meter sizes are to be tested.

C.2 Definition

A family of meters is a group of meters of different sizes and/or different flowrates, in which all the meters shall have the following characteristics:

- the same manufacturer;
- geometric similarity of the wetted parts;
- the same metering principle;
- the same ratios Q_3/ Q_1;
- the same electronic device for each meter size;
- a similar standard of design and component assembly;
- the same materials for those components that are critical to the performance of the meter;
- the same installation requirements relative to the meter size, e.g. 10 D (pipe diameter) of straight pipe/channel upstream of the meter and 5 D of straight pipe/channel downstream of the meter.

C.3 Meter Selection

When considering which sizes of a family of meters should be tested, the following rules shall be followed:

- The approving authority shall declare the reasons for including and omitting particular meter sizes from testing.
- The smallest meter in any family of meters shall always be tested.
- Meters which have the most extreme operating parameters within a family, shall be considered for testing, e.g. the largest flowrate range, the highest peripheral (tip) speed of moving parts etc.
- If practical, the largest meter in any family of meters should always be tested. However, if the largest meter is not tested, then any meter having $Q_3 > 2 \times Q_3$ of the largest meter tested, shall not be approved as part of a family.
- Endurance tests shall be applied to meters where the highest wear is expected.
- For meters with no moving parts in the measurement transducer, the smallest size shall be selected for endurance tests.
- All performance tests relating to influence quantities and disturbances shall be carried out on one size from a family of meters.
- The family members underlined in Figure C.1 may be considered as an example for testing.

Note: Each row represents one family, meter 1 being the smallest.

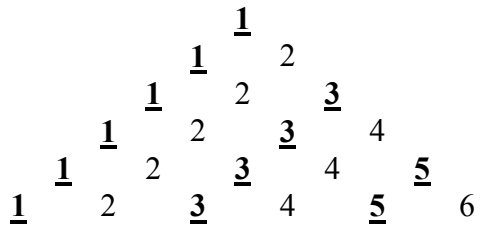

Figure C.1

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