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National Measurement Institute

NMI R 80-2 Road and rail tankers with level gauging

Part 2: Metrological controls and tests

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1. Scope

NMI R 80-2 specifies the test procedures for the pattern approval of road and rail tankers with level gauging.

2. Contents

NMI R 80-2:2021 is considered to be a **modified** adoption of OIML R 80-2:2017 *Road and rail tankers with level gauging. Part 2: Metrological controls and tests* published by the International Organisation of Legal Metrology (OIML).

OIML's international recommendation is published in three parts and the first and third parts have been adopted as the national standards NMI R 80-1 *Road and rail tankers with level gauging. Part 1: Metrological and technical requirements* and NMI R 80-3 *Road and rail tankers with level gauging. Part 3: Report Format for type evaluation* respectively.

3. Amendments and Interpretations

Amendments and interpretations have been made to the 2009 version of OIML R 80-2. These are described in the table below. Substantive amendments to OIML R 80-2 have been made in blue text.

Clause	Details
General	All references in this document to 'this Recommendation' shall be taken to refer to NMI R 80-2.
General	In Australia 'type' approval (or examination) is referred to as 'pattern' approval (or examination. The two terms refer to the same concept. This has not been marked as a change throughout the document.
General	All references in this document to the 'issuing authority', 'the approval body', 'the pattern evaluation body' or 'the body responsible for pattern evaluation' shall be taken to refer to the Chief Metrologist.
General	All references in this document to the 'verification authority' shall be taken to be NMI, Trade Measurement Inspectors, Servicing Licensees and/or their employees.
General	Date references have been changed throughout the document as relevant. This has not been marked as a change throughout the document.
1	The metrological and technical requirements specified in the NMI General Certificates of Approval for vehicle tanks may be applied as part of the pattern evaluation of systems approved in accordance with this Recommendation.
4.2.2	For the purposes of pattern evaluation and approval in accordance with NMI R 80-2, the presence and use of temperature sensors and volume conversions are not considered mandatory requirements for the level gauging system. Pattern approval applications **may** include temperature sensors and volume conversion functions within the scope of the pattern evaluation process. In this case, the requirements and tests specified below shall be applied. Certificates of Approval shall indicate whether or not volume conversion forms part of the approved pattern of the level gauging system, and consequently, the applicability of these tests for the purposes of verification.
4.2.3	The pattern evaluation of the level gauging system shall include an assessment of the sensitivity of measurement performance with respect to inclination. The application of these tests will be subject to the outcome of that assessment.

4.3.2 (a)	Certificates of Approval shall indicate whether or not volume conversion forms part of the approved pattern of the level gauging system, and consequently, the applicability of the above tests for the purposes of verification.
4.3.2 (b)	Certificates of Approval shall indicate whether or not inclination forms part of the approved pattern of the level gauging system, and consequently, the applicability of the above tests for the purposes of verification.
4.3.4.2.4	The pattern evaluation of the level gauging system shall include an assessment of the sensitivity of measurement performance with respect to inclination. The requirement for these tests during verification will be assessed as part of the pattern evaluation of the level gauging system, and specified on the Certificate of Approval.

INTERNATIONAL RECOMMENDATION

OIML R 80-2

Edition 2017 (E)

Road and rail tankers with level gauging

Part 2: Metrological controls and tests

Camions et wagons citernes avec mesurage de niveau

Partie 2 : Contrôles métrologiques et essais

OIML R 80-2 Edition 2017 (E)

ORGANISATION INTERNATIONALE DE METROLOGIE LEGALE

INTERNATIONAL ORGANIZATION OF LEGAL METROLOGY

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Foreword

The International Organization of Legal Metrology (OIML) is a worldwide, intergovernmental organization whose primary aim is to harmonize the regulations and metrological controls applied by the national metrological services, or related organizations, of its Member States. The main categories of OIML publications are:

- **International Recommendations (OIML R)**, which are model regulations that establish the metrological characteristics required of certain measuring instruments and which specify methods and equipment for checking their conformity; the OIML Member States shall implement these Recommendations to the greatest possible extent;
- **International Documents (OIML D)**, which are informative in nature and intended to harmonize and improve work in the field of the metrology;
- **International Guides (OIML G)**, which are also informative in nature and which are intended to give guidelines for the application of certain requirements to legal metrology;
- **International Basic Publications (OIML B)**, which define the operating rules of various OIML structures and systems.

OIML Draft Recommendations, Documents and Guides are developed by Project Groups linked to Technical Committees or Subcommittees which comprise representatives from OIML Member States. Certain international and regional institutions also participate on a consultation basis. Cooperative agreements have been established between the OIML and certain institutions, such as ISO and the IEC, with the objective of avoiding contradictory requirements. Consequently, manufacturers and users of measuring instruments, test laboratories, etc. may simultaneously apply OIML publications and those of other institutions.

International Recommendations, Documents, Guides and Basic Publications are published in English (E) and translated into French (F) and are subject to periodic revision.

Additionally, the OIML publishes or participates in the publication of **Vocabularies (OIML V)** and periodically commissions legal metrology experts to write **Expert Reports (OIML E)**. Expert Reports are intended to provide information and advice, and are written solely from the view of the CIML. Thus, they do not necessarily represent the views of OIML.

This publication – reference OIML R 80-2, edition 2017 – was developed by Project Group 6 in OIML TC 8/SC 1 *Static volume and mass measurement*. It was approved for final publication by the CIML in 2017 and will be submitted to the International Conference on Legal Metrology in 2020 for formal sanction.

OIML publications may be downloaded from the OIML website in the form of PDF files. Additional information on OIML Publications may be obtained from the Organization's headquarters:

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1 Scope

OIML R 80-2 is applicable to the pattern evaluation of complete road and rail tankers with level gauging and also for pattern evaluation of the following separate components:

- the measuring tank;
- the level gauging device; and
- the indicating device.

Initial and subsequent verifications in accordance with OIML R 80-2 are applicable to complete road and rail tankers with level gauging, as defined in OIML R 80-1.

OIML R 80-2 sets out details of the test program, principles, equipment and procedures to be used for pattern evaluation, initial and subsequent verification testing.

National regulations may require some of the provisions in this Recommendation to apply to ancillary devices as well.

The metrological and technical requirements specified in the NMI General Certificates of Approval for vehicle tanks may be applied as part of the pattern evaluation of systems approved in accordance with this Recommendation.

2 Terms and definitions

The terms defined in OIML R 80-1 apply. In addition, the definitions below apply to the terms used.

cut-off point

level at which the level gauge sensor is able to measure the minimum filling height at the maximum inclination of the tank

Note: Below this level a measurement of the filling height cannot be guaranteed.

residual volume

liquid content of the compartment including pipework at the cut-off point level

3 Metrological control

3.1 General

3.1.1 In general (depending on national or regional legislation), legal metrological control can consist of pattern approval, initial and subsequent verification, and metrological supervision.

3.1.2 The essential elements of a measuring system in the scope of this Recommendation mainly concern those listed below and may be subject to separate pattern evaluation:

- measuring tank;
- level gauging device;
- indicating device.

3.1.3 The results of metrological control may be used for purposes of safety control.

4 Pattern evaluation

4.1 Examination for pattern evaluation

4.1.1 Documentation

The application for pattern evaluation of a road or rail tanker shall include the following documentation:

- the documentation as prescribed in OIML R 80-1, 6.2;
- a description giving the technical characteristics and the principle of operation;
- a description of the electronic devices with drawings, diagrams and general software information explaining their characteristics and operation;
- operating instructions;
- documentation or other evidence that supports the assumption that the design and characteristics of the measuring instrument comply with the requirements of this Recommendation; and
- drawings representing
    - a general assembly of the road or rail tanker,
    - a general assembly of the measuring tank, including its compartments,
    - a general assembly and function of the level gauging system,
    - auxiliary and ancillary installations, as appropriate,
    - details of the dome, reinforcing elements and discharge device(s),
    - identification plate,
    - location of seals and verification marks,
    - if available, pattern evaluation certificate for the measuring compartment/tank, and
    - if available, pattern evaluation certificate gauge measuring device.

4.1.2 Selection of specimens

The body responsible for pattern evaluation decides the number of specimens necessary for the pattern evaluation tests.

If the applicant is seeking approval for several versions or measuring ranges, the body responsible for pattern evaluation decides which version(s) and range(s) shall be supplied.

Several tests may be carried out in parallel on different specimens. In this case, the body responsible for pattern evaluation decides which version or measuring range will be subjected to a specific test.

If a specimen does not pass a specific test and, as a result, has to be modified or repaired, the applicant shall carry out this modification to all the instruments supplied for test. If the testing laboratory has sound reasons to fear that the modification has a negative influence on tests that already had a positive result, these tests shall be repeated.

4.1.3 Evaluation of the measuring tanks

The (pattern) evaluation of tanks for road or rail tankers includes the following operations:

- external inspection;
- leak test;
- pressure test, if required;
- calibration;
- check on temperature dilatation of the tank;
- check on shape invariability;
- check on invariability of capacity in service;
- check on correct filling;

- check on complete discharge;
- check on sensitivity and expansion volume;
- check of ancillary devices and of the inclination correction (if any); and
- check on rest volumes.

Note 1: Each tank/compartment is unique and therefore shall be calibrated individually. Typically, the calibration and – depending on the actual case – some of the other tests listed will need to be carried out during the initial verification as well.

Note 2: Where tests have been performed for safety issues, the results of any of these tests may be taken into account in this evaluation.

If a pressure test is required, its execution shall precede the volumetric calibration.

4.1.4 Evaluation of level gauges

The pattern evaluation of the level gauge measuring system includes the following examinations, if applicable:

- applied units of measurement;
- accuracy classes and their symbols;
- measuring ranges;
- scale intervals or resolution;
- performance tests;
- presentation of the measured value;
- adjustment facilities;
- protection against fraud;
- checking facilities;
- durability provisions;
- software aspects;
- durable recording of measuring results;
- printing device;
- storage of measurement results;
- inscriptions;
- instruction manual; and
- sealing and stamping.

Note: A separate pattern evaluation certificate for the level gauge measuring system may be issued.

4.1.5 Pattern approval certificate

The following information shall appear on the pattern approval certificate:

- name and address of the issuing authority and name of the responsible person;
- name and address of the applicant of the pattern approval certificate;
- name and address of the manufacturer, if not the same as the applicant;
- metrological principle and technical characteristics;
- pattern approval mark;
- date of issue and period of validity;
- information on the location of markings concerning pattern approval, initial verification and sealing (e.g. a picture or drawing);
- list of documents accompanying the pattern approval certificate;
- specific remarks;

- version and signature of the metrological part of the evaluated software, if applicable, and
- sufficient information to perform the tests during initial and subsequent verification.

4.1.6 Modification of an approved pattern

The applicant requesting approval of the pattern shall inform the body responsible for the evaluation about any modification or addition which concerns the metrological part of an approved pattern.

Modifications and additions shall be subject to a supplementary pattern evaluation and approval when they will, or are likely to, influence the measurement results or the measuring system's regulatory conditions of use.

The body having approved the initial pattern shall decide to which extent the examinations and tests described below shall be carried out on the modified pattern in relation to the nature of the modification.

Note: The manufacturer shall present written evidence (of this fact) issued by the approval body, when introducing the product on the market.

If the body having approved the initial pattern judges that the modifications or additions are not likely to influence the measurement results, this body shall allow in writing the modified measuring systems to be presented for initial verification without requesting a supplementary pattern approval.

4.2 Testing during pattern evaluation

4.2.1 General test considerations

As a rule, tests are carried out on the complete measuring system. Simulation of any part of the system tested is to be avoided. If this is not possible, for instance for components which cannot be tested either partially or with the whole system, all parts of the measuring system that can be affected by the influence quantity shall play an active role in the measurements.

If the size or configuration of the measuring system does not lend itself to testing as a whole unit, or if only a separate device of the measuring instrument is concerned, the tests, or certain tests, shall be carried out on the devices (modules) separately, provided that, in the case of tests with the devices in operation, these devices are included in a simulated setup, sufficiently representative of its normal operation.

For components of the measuring system that cannot be fully tested within the whole system (e.g. temperature sensors), it is recommended to test them separately and to document the test results in a suitable way and in accordance with the applicable national regulations.

4.2.2 Testing of volume-conversion and temperature-measuring devices

For the purposes of pattern evaluation and approval in accordance with NMI R 80-2, the presence and use of temperature sensors and volume conversions are not considered mandatory requirements for the level gauging system.

Pattern approval applications **may** include temperature sensors and volume conversion functions within the scope of the pattern evaluation process. In this case, the requirements and tests specified below shall be applied.

Certificates of Approval shall indicate whether or not volume conversion forms part of the approved pattern of the level gauging system, and consequently, the applicability of these tests for the purposes of verification.

Analogue temperature sensors and conversion devices may be tested independently from each other. A conversion device may be tested by simulation of the sensor. In this case, the requirements of R 80-1, 5.1.5 are met if the error of the temperature sensor does not exceed 3/5 of the MPE specified in this subclause and the error of the conversion device does not exceed 2/5 of this MPE.

The functioning of the volume conversion software shall be checked at least at three temperatures for each product or product group by using simulated temperatures and liquid levels. Recommended test

points are: at the minimum temperature (or a value near 0 °C), at the reference temperature and at the maximum temperature of the product. The test volume shall be at least 10 000 litres.

For this test the MPE requirement as defined for static measuring systems (referred to as A in Table 2 of OIML R 80-1) will be met if maximum errors and faults on the indications of quantities of liquid applicable to calculators, positive or negative, each are less than or equal to one-tenth of the requirements in line A of Table 2.

During the pattern evaluation, the correct functioning of the checking facilities shall be checked.

4.2.3 Testing of inclination sensors

The pattern evaluation of the level gauging system shall include an assessment of the sensitivity of measurement performance with respect to inclination. The application of these tests will be subject to the outcome of that assessment.

The inclination sensors shall be examined for a matrix-like type of inclination within the range the measuring system is intended to be used for, in both longitudinal and transverse directions, as well as in all possible (i.e. four) simultaneous inclinations in both directions. The result of these examinations shall be such that the requirements of OIML R 80-1, 5.5.4 are met.

Note: Experience has shown that for the common tank shapes these requirements will be met if the deviation of the inclination indication is not greater than 0.1° in any of the directions to be tested.

The recommended number of test points is 9. The maximum deviation at all of these points shall be recorded in the test report.

4.2.4 Testing of floats

4.2.4.1 General

For pattern evaluation, at least one float of each type shall be tested at reference conditions. All floats shall be tested at least with a liquid having a density close to the minimum, as well as a liquid close to the maximum. These are to be selected within the density range of the liquids for which the float is intended and permitted to be used.

These liquids shall include the liquid generally used for tank calibration (typically water) if the density of this liquid is not the same or close to the maximum density.

The respective immersion depth shall be in the intended height range of the float (cylindrical area).

For measuring systems fitted with corresponding corrections, the change of the immersion depth within the permissible density range of each intended liquid is determined by calculation against the dimensions and weight of the float.

The immersion depth of the float shall be calculated at the maximum and minimum permissible density of each liquid. The deviation between the immersion depth at the maximum and minimum permissible density of each liquid shall not exceed the value given in Table 8 of OIML R 80-1.

For measuring systems not fitted with corresponding corrections, the immersion depth is determined at least with two liquids, one having a density close to the minimum and one having a density close to the maximum density. The selected liquids' densities shall lie within the permissible density range for which the float is intended and permitted to be used, and shall include the liquid generally used for tank calibration, typically water.

If the liquid is different from the liquid close to the maximum density, the immersion depth shall be calculated against the dimensions and weight of the float. This deviation between the immersion depth at the maximum and minimum permissible densities of the intended liquids shall be included in the uncertainty evaluation of the level measurement.

The expanded uncertainty shall not exceed values given in Table 6 of OIML R 80-1.

At pattern evaluation, one float should be defined as the reference float for further use in initial verification and in the event that it is necessary to replace a float during use.

To avoid influences on the metrological properties, the floats need no additional marking after testing when fulfilling the requirements.

4.2.4.2 Testing of the float construction at pattern evaluation

4.2.4.2.1 Chemical resistance

The manufacturer shall submit documentation proving the adequate chemical resistance of the float material. This documentation shall include the evaluation of the typical fluids and conditions for its later use. These fluids and conditions shall not have any influence on the specified physical characteristics of the float.

4.2.4.2.2 Pressure resistance

If the float is specified to be used for tanks having a working pressure not exceeding 0.05 MPa, the float shall be exposed for a time period of 10 minutes to a pressure of 0.075 MPa. In all other cases the float shall be exposed for a time period of 10 minutes to 1.5 times the intended working pressure of the tank. The float shall withstand this pressure test without deformation, cracks or change of the physical characteristics.

4.2.4.2.3 Adaption of the float to the rod

It shall be verified that during later use, the float is free to move up to its maximum inclination and will not become stuck on the level gauge rod.

4.2.4.2.4 Temperature influence on immersion depth

The influence of the liquid temperature on establishing the immersion depth of the float shall be tested where it cannot be proven by numerical calculation that the liquid temperature has no significant influence on the accuracy of the whole system.

The immersion depth of the float shall not change by more than the value given in Table 8 of OIML R 80-1.

An example of a test stand for the determination of the immersion depth of a float using the reference float method is given in the informative Annex A.

4.2.5 Testing of the dipstick pipes for ultrasonic systems

The accuracy of the mechanical dimensions of the reference marks of the dipstick pipe(s) shall be verified, for example by clamping each of the pipes into a gauge and comparing the distance of the reference marks at the reference edges of the gauge with the values marked on the gauge. The deviations shall not exceed the values given in Table 4 of OIML R 80-1.

4.2.6 Testing of computer or controller

The evaluation of the conversion device shall be part of the pattern evaluation procedure. Its accuracy, the correct functioning of the checking facilities, etc. shall be verified.

4.2.7 Testing of an indicating device

The proper operation of the checking facilities of the indicating devices shall be verified, for instance by connecting/disconnecting the indicating device.

4.3 Testing in the scope of initial verification

4.3.1 General

It is recommended that, before its first use, an initial verification takes place on the instrument to show that it is in conformity with the pattern evaluation certificate.

Initial verification can only be performed on a calibrated tank. Prior to initial verification, the calibration of the tank, leak tests and pressure tests shall have been performed and documented.

Note: The tank calibration procedure is described in informative Annex B.

Concerning the leakage and pressure compliance tests, documented evidence on compliancy with the regulations for safe transport of portable tanks by road or rail may be considered sufficient.

All test equipment used shall have the required accuracy and must, to the extent possible, be traceable to the SI.

The use of simulators or computer-aided measuring facilities is permitted.

It shall be ensured that all components (e.g. valve control) operate as designed.

4.3.2 Pre-verification of components

Components of the measuring system which can only be tested on specific locations (e.g. at the manufacturer's site) or which require a large effort to test on site may be pre-verified. For pre-verified components no additional tests on site are necessary.

Each of the following components shall fulfil the specified and/or described construction details and properties applicable to any components which have been verified during pattern evaluation and laid down in the pattern approval certificate.

Unless otherwise stated, components subjected to a pre-verification test shall be marked and, if necessary, sealed.

For the following components, if applicable and decided to be tested at the manufacturer's premises the following examinations and tests shall be performed:

a) Temperature sensor:

- *Property to be tested*: accuracy at three different temperatures;
- *Aspect to be registered/documented*:
    - statement concerning the fulfilling of the required accuracy by the liquid temperature range of the measuring system; or
    - statement on whether the test results show that the required accuracy specifications for the temperature sensor as laid down in the pattern approval certificate of the measuring system are met.

Certificates of Approval shall indicate whether or not volume conversion forms part of the approved pattern of the level gauging system, and consequently, the applicability of the above tests for the purposes of verification.

b) Inclination sensor:

- *Aspect to be examined*: correct mounting orientation stated on the housing;
- *Property to be tested*: accuracy in longitudinal and transversal directions and in all possible simultaneous inclinations in both directions;
- *Aspects to be registered/documented*:
    - results of the accuracy measurements;
    - zero-degree deviation, if any;
    - statement on whether the test results show that the required accuracy specifications for the inclination sensor as laid down in the pattern approval certificate of the measuring system are met.

Certificates of Approval shall indicate whether or not inclination forms part of the approved pattern of the level gauging system, and consequently, the applicability of the above tests for the purposes of verification.

c) Float:

- *Aspect to be examined*: the dimensions and weight of the float shall be checked to be within the permissible tolerances specified in the pattern approval certificate;
- *Property to be tested*: the immersion depth offset of the individual float shall be determined in relation to the reference float of the same or equivalent pattern;
- *Aspects at least to be recorded in an accompanying document:*
    - serial number;
    - test fluid;
    - immersion depth offset;
    - method of determination of the immersion depth offset; and
    - other individual characteristics;
- *Further aspects to be recorded in the test report:*
    - all test results;
    - statement on whether the test results show that the required specifications for the float as laid down in the pattern approval certificate of the measuring system are met.

Note 1: Knowledge of the immersion depth offset of the float is necessary only to prevent a complete new calibration of the tank or compartment after replacing the float. This offset ΔD_{float} can be determined by comparing the indications of the reference float (Index m) and of the float to be tested (Index float): $\Delta D_{float} = D_{float} - D_m$ (see Annex A).

Note 2: To avoid influences on the metrological properties, the floats need not be marked.

d) Dipsticks for float systems for full compartment delivery:

- *Property to be tested:* accuracy at 10 points regularly distributed on its measuring range in both directions using a filling height simulator;
- *Required accuracy:* the maximum permissible error on height measurement (MPE_h) is given by the following formula:

  $MPE_h = 5 \cdot S \cdot (A - B)$

  where A and B are the MPE values as specified in Table 2 of OIML R 80-1 presented in the applicable row referred to as A or B respectively presented in the applicable accuracy class column, and where S concerns the sensitivity given in Table 5 of OIML R 80-1;
- *Aspects to be recorded in the test report:* statement on whether the test results show that the required specifications for the dipstick are met.

e) Dipsticks for float systems for partial compartment delivery:

- *Property to be tested:* accuracy at three different heights using a filling height simulator;
- *Required accuracy:* the expanded uncertainty associated with the measurement result shall be less than the values given in Table 6 of OIML R 80-1;
- *Aspects to be recorded in the test report:* statement on whether the test results show that the required specifications for the dipstick are met.

f) Ultrasonic level sensor:

- *Property to be tested:* accuracy of the level measurement;
- *Test method:* a shortened reference pipe is used which contains a well-defined reference echo mark in the level measuring tube at a distance of 350–500 mm from the sensor. The reference tube shall be attached to the sensor subjected to the testing. The arrangement

shall be immersed in de-ionized, gas-free water, while taking care to remove any gas bubbles which may have been trapped in the tubes. The sensor is connected to a reference controller;

- *Required accuracy:* the deviation between the level reading obtained from the controller and the distance of the echo mark shall be less than the required accuracy value specified in the pattern approval certificate of the measuring system;
- *Aspects to be recorded in the test report:* statement on whether the test results show that the required accuracy for the ultrasonic level sensor is met.

g) Ultrasonic dipstick pipe:

- *Aspect to be examined:* mechanical dimensions of the reference marks of the dipstick pipe;
- *Aspects to be recorded in the test report:* statement on whether the examination results show that the required specifications for the dipstick pipe as laid down in the pattern approval certificate of the measuring system are met.

4.3.3 Testing of non-pre-verified components

If components of the measuring system have not been pre-verified, the corresponding tests shall be performed during its initial verification.

4.3.4 Testing of the complete measuring system

4.3.4.1 Visual inspection

Prior to the testing the following details shall be checked:

- external and internal appearance of the tank or damage to the compartment;
- completeness of markings, etc. on the identification plate;
- compliance with the specifications of the pattern examination certificate including the version of the software (modules) and signatures used, if appropriate;
- stored values of the metrologically relevant parameters as defined in the pattern examination certificate;
- all sealing points according the sealing plan; and
- presence and completeness of the measuring system documentation.

4.3.4.2 Accuracy tests

The following tests provide the basis for testing the accuracy of a dipstick measuring system.

Where additional tests are required to show compliance with R 80-1, these shall be defined in the pattern approval certificate.

4.3.4.2.1 Test of the volume in normal position

Test the volume in normal position (inclination between 0° ± 0.2°).

A test volume value is chosen which shall be no larger than twice the minimum measured quantity (MMQ) of the measuring system. The tank compartment shall be filled up to at least 90 % of its nominal volume. The compartment shall be emptied step by step, each step comprising the amount of the test volume. The last step shall comprise a complete emptying of the tank. If the volume of this last step is smaller than the test volume, the tank shall be further filled up using standard capacity measure(s) to deliver the test volume. If such a standard capacity is not available, the operation may also be performed by volume stacking.

Taking into account the requirement in OIML R 80-1, 5.1.3.3, the permissible deviation is:

- twice the percentage as given for the applicable accuracy class of the measuring system for a test volume equal to the MMQ;
- plus or minus the percentage as applicable for the accuracy class of the measuring system for a test volume equal to or larger than twice the MMQ.

Note 1: This test can also be performed by using an appropriate volumetric liquid meter.

Note 2: This test can also be performed by using a vessel on an appropriate weighing instrument and by using water as the test liquid.

4.3.4.2.2 Establishing the residual volume

The residual volume shall be established, if not already done during the accuracy test.

To test the correct setup of the residual volume, a completely empty compartment and its associated pipework is filled with the nominal volume of the standard capacity measure (see OIML R 120 [1]). The compartment shall be discharged completely and the indicated delivered volume shall be within the accuracy as stated in Table 1 of OIML R 80-1 for the applicable accuracy class. This volume consists of a metered part by the level gauge sensor and the fixed part of the residual volume.

Note: This test can also be carried out by using an appropriate volumetric liquid meter.

4.3.4.2.3 Leak test of the tank

The tank shall be leak-tested according to R 80-1, 5.2.2.2.

4.3.4.2.4 Testing of the inclination dependency of the volume

The pattern evaluation of the level gauging system shall include an assessment of the sensitivity of measurement performance with respect to inclination. The requirement for these tests during verification will be assessed as part of the pattern evaluation of the level gauging system, and specified on the Certificate of Approval.

Each tank compartment shall be filled to a liquid level within 15 % to 30 % and within 70 % to 90 % of its nominal compartment volume.

Their volumes shall be determined in each of the following orientations:

Positioned with an inclination compared to the horizontal plane:

- in the longitudinal direction between +2° and +3° (front side up);
- in the longitudinal direction between –2° and –3° (back side up);
- in the transversal direction between +2.5° and +5° (right side up); and
- in the transversal direction between –2.5° and –5° (left side up),

while maintaining the inclination in the respectively perpendicular angle within ± 0.5°.

The error of the volume during these tests shall not exceed 3/5 of the MPE of the volume in the normal position (see OIML R 80-1, 5.1.7.2).

4.3.4.2.5 Test of the influence of adjacent compartments

To test the influence of adjacent compartments, a compartment is filled to 30 % of the nominal capacity and subsequently the adjacent compartment is filled to 90 % of its nominal capacity. The indication of the volume of liquid in the first compartment shall not change by more than 1/3 of the MPE when the adjacent compartment is filled or emptied (see OIML R 80-1, 5.2.2.4).

4.3.4.3 Determining the error of the level height measurement

This test is applicable to the level gauging device which displays only height (or ullage).

- Property to be tested and method: Each level gauging system is checked at 3 points regularly distributed on its measuring range in both directions by comparison with a mechanical dipstick.

- Required accuracy: The MPE on height measurement (MPE_h) after installation is given by the following formula:

  $MPE_h = 10 \cdot S \cdot (A - B)$

where *A* and *B* are the MPE values as specified in Table 2 of OIML R 80-1 presented in the applicable row referred to as A or B respectively presented in the applicable accuracy class column, and where *S* concerns the sensitivity given in Table 5 of OIML R 80-1.

If the dipstick already satisfies the pre-verification test (see 4.3.2) the level gauging device may be verified, after installation, at one point (level) situated close to the nominal capacity by comparison with a mechanical dipstick.

4.3.4.4 Tests on the computer or controller

During initial verification, the software (modules) used as well as their signature shall be checked for compliance with the versions stated in the pattern approval certificate.

If present, the protection function (e.g. electronic sealing) for the data of legal relevance shall be checked.

4.4 Subsequent verification

4.4.1 General

Subsequent verification is subject to national regulations. The following actions are recommended:

4.4.1.1 Visual inspection

The visual inspection comprises the inspection of the following items:

For the measuring tank:

- external damage;
- any damage to a measuring compartment inside the tank, if suspected, only after the compartment has been sufficiently cleaned to allow for a safe inspection; and
- compliance with the pattern approval certificate.

For the level gauging system:

- compliance of the parameters or signature(s) relevant to verification with those at the time of initial verification;
- compliance of the version of the software (modules) used as well as of their signature with the pattern approval certificate or supplements;
- availability of the measuring system documentation;
- identification of the incorporated components;
- mechanical damage of the level sensors;
- presence of the measuring system type plate;
- availability of operating instructions.

4.4.1.2 Volumetric test using a volume standard

In Annex D an example of the principle of testing is described.

It will be sufficient, however, to prove that the results of three measurements of the same amount, taken at filling states of approximately 90 % and 50 %, after completely emptying the compartment, are within ± 0.5 % of the measured quantity.

If during one or several of these tests the above mentioned margin is exceeded, further deliveries of the same amount may be performed until 80 % of the minimum delivered quantity of the compartment under

test is reached or exceeded. The deviation between the sum of these successive measurements and the sum of the volume standard readings shall be within ± 0.5 %.

Checking of the temperature sensor according to Annex D.3 shall be carried out simultaneously with these tests.

4.4.1.3 Volumetric test using a reference meter

The test is carried out as described in Annex D.4. The testing quantities shall be equal to the minimum measured quantity.

4.4.1.4 Check of pipework volumes for measuring systems with collector

The pipework system, including the collector, is subjected to a simplified test which consists of the second test step described in Annex C, preceded by an initial flushing as described.

4.4.1.5 Check of the inclination correction

The test shall be carried out as described in Annex D.5 but only at one level near 30 % or 70 % of the nominal volume of each compartment.

4.4.1.6 Sealing

Missing or damaged seals shall be renewed only by authorized personnel, possibly based on the user's application.

All seals which have been broken during repair shall be documented and renewed.

4.4.2 Recommended actions after replacement of components for measuring systems for full compartment delivery/receipt

When any components of a measuring system under legal control are replaced, the actions below are recommended.

4.4.2.1 Actions on replacement of the controller or computer

- separate test of the new device according to 4.2.6;
- entry of the new data into the measuring system document.

4.4.2.2 Actions on replacement of a simple indicating device

- separate test of the indicating device according to 4.2.7

4.4.2.3 Actions on replacement of dipsticks for float systems

- comparison with a mechanical dipstick at a level close to nominal capacity;
- entry of the new data into the measuring system document.

4.4.2.4 Actions on replacement of a sensor/float

- comparison with a mechanical dipstick at a level close to nominal capacity;
- entry of the new data into the measuring system document.

4.4.3 Recommended actions after replacement of components for measuring systems for partial compartment delivery/receipt

When any components of a measuring system under legal control are replaced, the actions below are recommended.

4.4.3.1 Actions on replacement of the controller or computer

- separate test of the new device according to 4.2.6;
- entry of the new data into the measuring system document;
- single volume measurement by the verification authority with the quantity of the MMQ delivered from the random compartment, check of the indicated and corrected volume;
- comparison and evaluation of parameters.

4.4.3.2 Actions on replacement of a simple indicating device

- Separate test of the indicating device according to 4.2.7.

4.4.3.3 Actions on replacement of dipsticks for float systems

- separate test of the new dipstick for the float system according to 4.3.2;
- entry of the new dipstick correction values into the level gauging system;
- entry of the new data into the measuring system documentation;
- single volume measurement by the verification authority, quantity of about 1 to 2 times the MMQ delivered from the compartment fitted with the new dipstick, check of the volume at working conditions, unless otherwise specified in the pattern approval certificate;
- comparison and evaluation of parameters.

4.4.3.4 Actions on replacement of a sensor/float

- separate test of the new float according to 4.3.2;
- entry of the new float correction values into the level gauging system;
- entry of the new data into the measuring system documentation;
- single volume measurement by the verification authority, quantity of about 1 to 2 times the MMQ delivered from the compartment fitted with the new float, check of the volume at working conditions, unless otherwise specified in the pattern approval certificate;
- comparison and evaluation of parameters.

4.4.3.5 Actions on replacement of dipsticks for ultrasound systems

- separate test of the new dipstick for ultrasound systems according to 4.3.2;
- entry of the new correction values into the level gauging system;
- entry of the new data into the measuring system documentation, if applicable;
- single volume measurement by the verification authority, quantity of about 1 to 2 times the MMQ delivered from the compartment fitted with the new dipstick, check of the volume at working conditions, unless otherwise specified in the pattern approval certificate;
- comparison and evaluation of parameters.

4.4.3.6 Actions on replacement of a temperature sensor

- separate test of the new temperature sensor according to 4.3.2;
- entry of the new sensor parameters into the parameter list;
- entry of the new data into the measuring system documentation;
- temperature measurement by the verification authority during delivery of a random quantity from the relevant compartment;
- recording and comparison of the delivery temperature with a certified thermometer, comparison and evaluation of parameters.

4.4.4 Recommended actions after repair of or corrections to the measuring system

After a new calibration table has been compiled for one or several tank compartments (recalibration of a tank or compartment, e.g. after repair of the tank or a deformation after an accident), the verification of the measuring system is no longer valid.

During the next verification, all re-calibrated measuring compartments shall be tested as for initial verification. The re-examination of the pipework volumes may be dispensed with if these have not changed. Prior to the due date the compartments for which no new calibration tables have been compiled[1] need not be subsequently verified due to the repair. After the repaired compartments have

[1] Which therefore refers to compartments which have not been part of the repair.

been checked, the measuring system may need to be provided with a seal stating the original period of validity of the verification if applicable and depending on national legislation.

If the repair was carried out within the scope of a subsequent verification, the repaired compartments will be treated as in initial verification and the other compartments as in subsequent verification.

5 Performance tests for pattern evaluation of measuring systems

5.1 General

This subclause defines the program of performance tests intended to verify that measuring systems perform and function as intended in a specified environment and under specified conditions. Each test indicates, where appropriate, the reference conditions for determining the intrinsic error.

These tests supplement any other prescribed test.

When the effect of one influence quantity is being evaluated, all other influence quantities shall be held relatively constant, at values close to reference conditions.

5.2 Reference conditions

Ambient temperature:	15 ºC to 35 ºC
Relative humidity:	25 % to 75 %
Atmospheric pressure:	84 kPa to 106 kPa
Mains (power supply) voltage:	Nominal voltage (U_{nom})
Mains (power supply) frequency:	Nominal frequency (f_{nom})

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

The test laboratory shall have the ability to authorize different reference conditions as long as these conditions are fully documented with an explanation of why the alternate reference conditions were used, the implications of the alternate reference conditions, and the effects on the testing results.

5.3 Environmental classification

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

The following environmental conditions according to OIML D 11 [2] *General requirements for measuring instruments - environmental classification* are considered applicable:

Climatic environment: Class H3

This class applies to instruments or parts of instruments used in open air locations, excluding those in extreme climate zones such as polar and desert environments.

Mechanical environment: Class M3

This class applies to locations where the level of vibration and shock is high or very high, e.g. where measuring instruments are directly mounted on machines, conveyor belts, etc.

Electromagnetic environment: Class E3

This class applies to electronic measuring instruments powered by the battery of a vehicle and exposed to electromagnetic disturbances which correspond to those likely to be found in any environment not considered hazardous for the general public.

Note: In the exception that a system may be powered by AC mains, the OIML D 11 class E2 applies as well.

According to these classifications, the test levels as presented in Table 1 shall be applied.

Table 1 Summary of performance tests

Kind of performance tests	Test description	R 80-2 subclause	Evaluation [1]	
Climatic	Dry heat	5.4.1	I	MPE
	Cold	5.4.2	I	MPE
	Damp heat, cyclic (condensing)	5.4.3	D	NSFa
Mechanical	Vibration (random)	5.4.4	I	MPE
Electrical, general	Radiated electromagnetic fields	5.4.5	D	NSFd
	Conducted currents generated by RF EM fields	5.4.6	D	NSFd
	Electrostatic discharge	5.4.7	D	NSFd
	Power frequency magnetic field	5.4.8	D	NSFd
	Bursts (transients) on signal, data and control lines	5.4.9	D	NSFd
Electrical, AC mains voltage[3]	AC mains voltage variations	5.4.10	I	MPE
	Surges on AC lines	5.4.11	D	NSFd
	AC mains voltage dips, short interruption and voltage variations	5.4.12	D	NSFd
	Bursts (transients) on AC mains	5.4.13	D	NSFd
Electrical, internal battery [4]	Low voltage of internal battery	5.4.14	I	MPE
Electrical, power from external 12 V and 24 V road vehicle batteries [5]	Voltage variations	5.4.15.1	I	MPE
	Electrical transient conduction along supply lines	5.4.15.2	D	NSFd
	Electrical transient conduction via lines other than supply lines	5.4.15.3	D	NSFd

[1] I - Influence factor
D - Disturbance
MPE - Maximum permissible error
NSFa - No significant fault shall occur after the disturbance
NSFd - No significant fault shall occur during the disturbance

[2] Test levels are in accordance with OIML D 11 and IEC standards mentioned in the subclauses of 5.4.

[3] only applicable for systems powered by AC mains.

[4] only applicable for systems powered by internal battery.

[5] only applicable for systems powered by road vehicle battery.

The thermal conditions in which measuring systems and ancillary devices are used vary considerably. These are highly dependent on the place on earth, ranging from arctic to tropical regions. Therefore, no classes combining low and high temperature limits have been described in this Recommendation.

Note: National (or regional) legislation will generally set the lower and upper temperature limits (taking into account the test levels in 5.4.1and 5.4.2). The manufacturer is required to indicate the rated operating conditions (in this case the temperature range) of the equipment under test (EUT). The pattern evaluation body will choose the testing levels by taking into account the manufacturer's specifications as well as the higher and lower temperature test levels options presented above.

5.4 Performance tests

The following tests need only be carried out where, as a result of the physical principle of the measuring system or a part of it, a significant influence may be expected.

If a test is not carried out the reason shall be noted in the test report.

Note: The test procedures have been given in condensed form, for information only, and are adapted from the referenced IEC publications. Before conducting the test, the applicable publication should be consulted.

5.4.1 Dry heat

Table 2

Applicable standards	IEC 60068-2-1 [5], IEC 60068-3-1 [4]				
Test method	Exposure to low temperature				
Applicability	General.				
Object of the test	Verification of compliance with the provisions 5.7.1.1 of R 80-1 under conditions of low ambient air temperature.				
Test procedure in brief	The test comprises exposure of the EUT to the specified low temperature under “free air” conditions for a 2-hour period after the EUT has reached temperature stability. The change in temperature shall not exceed 1 °C/min during heating up and cooling down. The absolute humidity of the test atmosphere shall not exceed 20 g/m^3. When testing is performed at temperatures below 35 °C, the relative humidity shall not exceed 50 %. The EUT shall be tested: - at the reference temperature of 20 °C after 1 hour conditioning, - at the specified low temperature, 2 hours after temperature stabilization, - after 1 hour recovery of the EUT at the reference temperature of 20 °C. During the tests, the EUT shall be in operation. Simulated inputs are permitted. Tests shall be performed at a fixed level				
	One of the following test levels may be specified:				
Test level index	1	2	3	4	5
Temperature	30 °C	40 °C	55 °C	70 °C	85 °C
Number of cycles	One cycle				
Permitted maximum deviation	All functions shall operate as designed. All errors measured during the application of the influence shall be within the maximum permissible errors.				

5.4.2 Cold

Table 3

Applicable standards	IEC 60068-2-1 [5], IEC 60068-3-1 [4]			
Test method	Exposure to low temperature			
Object of the test	Verification of compliance with the provisions 5.7.1.1 of R 80-1 under conditions of low ambient air temperature.			
Test procedure in brief	The test comprises exposure of the EUT to the specified low temperature under “free air” conditions for a 2-hour period after the EUT has reached temperature stability. The change of temperature shall not exceed 1 °C/min during heating up and cooling down. The EUT shall be tested: - at the reference temperature of 20 °C after 1 hour conditioning, - at the specified low temperature, 2 hours after temperature stabilization, - after 1 hour recovery of the EUT at the reference temperature of 20 °C. During the tests, the EUT shall be in operation. Simulated inputs are permitted. Tests shall be performed at a fixed level			
	One of the following test levels may be specified:			
Test level index	1	2	3	4
Temperature	+5 °C	–10 °C	–25 °C	–40 °C
Number of cycles	One cycle			
Permitted maximum deviation	All functions shall operate as designed. All errors measured during the application of the influence shall be within the maximum permissible errors.			

5.4.3 Damp heat, cyclic (condensing)

Table 4

Applicable standards	IEC 60068-2-30 [6], IEC 60068-3-4 [7]
Test method	Exposure to damp heat with cyclic temperature variation
Applicability	Applicable only for instruments used outdoors.
Object of the test	Verification of compliance with the provisions in 5.7.1.2 of R 80-1 under conditions of high humidity combined with cyclic temperature changes.
Test procedure in brief	The test comprises exposure of the EUT to cyclic temperature variation between 25 °C and the appropriate upper temperature of 55 °C, maintaining the relative humidity above 95 % during the temperature changes and during the phases at the low temperature, and at or above 93 % at the upper temperature phases. Condensation is expected to occur on the EUT during the temperature rise. The 24-hour cycle comprises: - temperature rise during 3 hours, - temperature maintained at upper value until 12 hours from the start of the cycle, - temperature lowered to lower temperature level within a period of 3 to 6 hours, the declination (rate of fall) during the first hour and a half being such that the lower temperature level would be reached in a 3 hour period, - temperature maintained at the lower level until the 24 h period is completed. The stabilizing period before and recovery period after the cyclic exposure shall be such that the temperature of all parts of the EUT is within 3 °C of its final value. During the tests, the EUT shall be in operation. Simulated inputs are permitted. After the application of the disturbance and recovery the EUT shall be tested at a fixed level.
Duration	Two cycles
Restrictions	During the application of the disturbance, the power supply of the EUT is in switch-off mode.
Permitted maximum deviation	After the application of the disturbance and recovery, all functions shall operate as designed. All errors shall be within the maximum permissible errors.

5.4.4 Vibration (random)

Table 5

Applicable standards	IEC 60068-2-47 [8], IEC 60068-2-64 [9], (IEC 60068-3-8 [10])	
Test method	Exposure to random vibration	
Applicability	General.	
Object of the test	Verification of compliance with the provisions in 5.7.1.1 of R 80-1 under conditions of random vibration.	
Test procedure in brief	The test comprises exposure of the EUT to vibration. The EUT shall be tested in three, mutually perpendicular axes mounted on a rigid fixture by its normal mounting means. After the application of the disturbance and recovery the EUT shall be tested at a fixed level.	
Total frequency range	10 – 150	Hz
Total RMS level	7	$m \cdot s^{-2}$
ASD level 10–20 Hz	1	$m^2 \cdot s^{-3}$
ASD level 20–150 Hz	–3	dB/octave
Number of axis	3	
Duration per axis	For each of the orthogonal directions, the vibration exposure time shall be 2 minutes.	
Restrictions	During the application of the influence quantity the power supply of the EUT is in switch-off mode.	
Permitted maximum deviation	After the application of the disturbance, all functions shall operate as designed. All errors shall be within the maximum permissible errors after the influence factor is removed.	

5.4.5 Radiated radio frequency electromagnetic fields

Table 6

<table>
<tr><td>Applicable standards</td><td colspan="2">IEC 61000-4-3 [11]; IEC 61000-4-20 [12]</td></tr>
<tr><td>Test method</td><td colspan="2">Exposure to radiated radio frequency electromagnetic fields</td></tr>
<tr><td>Applicability</td><td colspan="2">Only applicable for electronic measuring instruments containing active electronic circuits.</td></tr>
<tr><td>Object of the test</td><td colspan="2">Verification of compliance with the provisions in 5.7.1.2 of R 80-1 under conditions of exposure to electromagnetic fields.</td></tr>
<tr><td>Test procedure in brief</td><td colspan="2">The EUT is exposed to electromagnetic fields with the required field strength and the field uniformity as defined in the referred standard.

The level of field strength specified refers to the field generated by the unmodulated carrier wave.

The EUT shall be exposed to the modulated wave field. The frequency sweep shall be made only pausing to adjust the RF signal level or to switch RF-generators, amplifiers and antennas if necessary. Where the frequency range is swept incrementally, the step size shall not exceed 1 % of the preceding frequency value.

The dwell time of the amplitude modulated carrier at each frequency shall not be less than the time necessary for the EUT to be exercised and to respond, but shall in no case be less than 0.5 s.

Adequate EM fields can be generated in facilities of different types and setups, the use of which is limited by the dimensions of the EUT and the frequency range of the facility.

The expected most critical frequencies (e.g. clock frequencies) shall be analyzed separately.

During the tests, the EUT shall be in operation. Simulated inputs are permitted. Tests shall be performed at a fixed level.</td></tr>
<tr><td rowspan="3">Test parameter levels</td><td>Frequency range</td><td>(26) 80 – 3000 MHz</td></tr>
<tr><td>Amplitude</td><td>10 V/m</td></tr>
<tr><td>Modulation</td><td>80 % AM, 1 kHz, sine wave</td></tr>
<tr><td>Permitted maximum deviation</td><td colspan="2">During the disturbance, either significant faults do not occur or checking facilities detect a malfunction and act upon it in accordance with 5.7.3 of R 80-1 when significant faults occur.</td></tr>
<tr><td>Notes</td><td colspan="2">- IEC 61000-4-3 only specifies test levels above 80 MHz. For frequencies in the lower range the test method for conducted radio frequency disturbances is generally applicable (test 3.4.6).
- For EUT having no mains or other cabling available to allow for the execution of the conducted radio frequency test, the lower limit of radiation test shall be 26 MHz
- In all other cases, both 3.4.5 and 3.4.6 shall apply.</td></tr>
</table>

5.4.6 Conducted (common mode) currents generated by RF EM fields

Table 7

Applicable standard	IEC 61000-4-6 [13]	
Test method	Injection of RF currents representing exposure to RF electromagnetic fields	
Applicability	Only applicable for electronic measuring instruments containing active electronic circuits and equipped with external electrical wiring (mains power, signal, data and control lines).	
Object of the test	Verification of compliance with the provisions in 5.7.1.2 of R 80-1 while exposed to electromagnetic fields.	
Test procedure in brief	An RF EM current, simulating the influence of EM fields shall be coupled or injected into the power ports and I/O ports of the EUT using coupling/decoupling devices as defined in the referred standard. The characteristics of the test equipment consisting of an RF generator, (de-)coupling devices, attenuators, etc. shall be verified before connecting the EUT. During the tests, the EUT shall be in operation. Simulated inputs are permitted. Tests shall be performed at a fixed level	
Test parameter levels	Frequency range	0.15 – 80 MHz
	RF amplitude	10 V (e.m.f.)
	Modulation	80 % AM, 1 kHz, sine wave
Permitted maximum deviation	During the disturbance, either significant faults do not occur or checking facilities detect a malfunctioning and act upon it in accordance with 5.7.3 of R 80-1 when significant faults occur.	
Notes	- If the EUT is composed of several elements, the tests shall be performed at each extremity of the cable if both of the elements are part of the EUT. - For the frequency range 26 – 80 MHz, the testing laboratory can either carry out tests according to 3.4.5 or according to 3.4.6. But in case of dispute, the results according to 3.4.6 shall prevail.	

5.4.7 Electrostatic discharge

Table 8

Applicable standard	IEC 61000-4-2[14]	
Test method	Exposure to electrostatic discharge (ESD)	
Applicability	Applicable to all electronic measuring instruments.	
Object of the test	Verification of compliance with the provisions in 5.7.1.2 of R 80-1 in case of direct exposure to electrostatic discharges or such discharges in the neighborhood of the EUT.	
Test procedure in brief	The test comprises exposure of the EUT to electrical discharges. An ESD generator as defined in the referred standard shall be used and the test setup shall comply with the dimensions, materials used and conditions as specified in the referred standard. Before starting the tests, the performance of the generator shall be verified. At least 10 discharges per preselected discharge location shall be applied. For EUTs not equipped with a ground terminal, the EUT shall be fully discharged between discharges. The time interval between successive discharges shall be at least 1 second. Contact discharge is the preferred test method. Air discharge is far less defined and reproducible and therefore shall be used only where contact discharge cannot be applied. Direct application: In the contact discharge mode to be carried out on conductive surfaces, the electrode shall be in contact with the EUT before activation of the discharge. In such a case the discharge spark occurs in the vacuum relays of the contact discharge tip. On insulated surfaces only the air discharge mode can be applied. The EUT is approached by the charged electrode until a spark discharge occurs. During the tests, the EUT shall be in operation. Simulated inputs are permitted. Tests shall be performed at a fixed level.	
Test parameter levels	Air discharges	8 kV
	Contact discharges	6 kV
Number of test cycles	At each test point, at least ten direct discharges shall be applied at intervals of at least ten seconds between discharges, during the same measurement or simulated measurement. For indirect discharges, a total of ten discharges shall be applied on the horizontal coupling plane and a total of ten discharges on the vertical coupling plane.	
Permitted maximum deviation	During the disturbance, either significant faults do not occur or checking facilities detect a malfunctioning and act upon it in accordance with 5.7.3 of R 80-1 when significant faults occur.	

5.4.8 Power frequency magnetic field

Table 9

Applicable standard	IEC 61000-4-8[15]	
Test method	Exposure to power frequency electromagnetic fields (50 Hz or 60 Hz)	
Applicability	General.	
Object of the test	Verification of compliance with the provisions in 5.7.1.2 of R 80-1 under conditions of power frequency magnetic field (50 Hz or 60 Hz).	
Test procedure in brief	The test comprises exposure of the EUT in each of the 3 orthogonal directions to a power frequency magnetic field (50 Hz or 60 Hz).	
Test parameter levels	Continuous field	30 A/m
	Short duration (1 s up to 3 s)	300 A/m
Note	The duration of the exposure to the continuous field will need to be dependent on the response time of the EUT. An interval needs to be chosen that is sufficiently long for the measuring instrument to respond.	
Permitted maximum deviation	During the disturbance, either significant faults do not occur or checking facilities detect a malfunctioning and act upon it in accordance with 5.7.3 of R 80-1 when significant faults occur.	

5.4.9 Burst (transients) on signal, data and control lines

Table 10

Applicable standard	IEC 61000-4-4 [16]	
Test method	Introducing transients on signal, data and control lines	
Applicability	Only applicable for electronic measuring instruments containing active electronic circuits which during operation are permanently or temporarily connected to external electrical signal, data and/or control lines. This test is not applicable to equipment powered by a road vehicle battery.	
Object of the test	Verification of compliance with the provisions in 5.7.1.2 of R 80-1 during conditions where electrical bursts are superimposed on I/O and communication ports.	
Test procedure in brief	A burst generator as defined in the referred standard shall be used. The characteristics of the generator shall be verified before connecting the EUT. The test comprises exposure of the EUT to bursts of voltage spikes for which the output voltage on a 50 Ω and 1000 Ω load are defined in the referred standard. Both positive and negative polarity of the bursts shall be applied. The duration of the test shall not be less than 1 min for each amplitude and polarity. A capacitive coupling clamp as defined in the standard shall be used for coupling the bursts into the I/O and communication lines. The bursts are applied during all the time necessary to perform the test; for that purpose more bursts than indicated above may be necessary. During the tests, the EUT shall be in operation. Simulated inputs are permitted. Tests shall be performed at a fixed level.	
Test parameter level	Amplitude peak value	1 kV
	Repetition rate	5 kHz
Restrictions	Tests on signal lines are applicable only for I/O signal, data and control ports, with a cable length exceeding 3 m (as specified by the manufacturer).	
Permitted maximum deviation	During the disturbance, either significant faults do not occur or checking facilities detect a malfunctioning and act upon it in accordance with 5.7.3 of R 80-1 when significant faults occur.	

5.4.10 AC mains voltage variation

Table 11

Applicable standards	IEC/TR3 61000-2-1 [17], IEC 61000-4-1 [18]	
Test method	Applying low and high level AC mains power voltage (single phase)	
Applicability	Applicable for measuring instruments which are temporarily or permanently connected to an AC mains power network while in operation. This test is not applicable to equipment powered by a road vehicle battery	
Object of the test	Verification of the compliance with the provisions in 5.7.1.1 of R 80-1 under conditions of varying AC mains power voltage.	
Test procedure in brief	The test comprises exposure of the EUT to the specified power supply condition for a time period sufficient for achieving temperature stability and subsequently performing the required measurements.	
Mains voltage	Upper limit	U_{nom1} + 10 %
	Lower limit	U_{nom2} – 15 %
Permitted maximum deviation	All functions shall operate as designed and all the errors measured during the application of the influence factor shall be within the maximum permissible errors.	
Notes	For three-phase mains power supplies, the voltage variation is applicable for each of the phases successively. The values of U_{nom} are those marked on the measuring instrument. If a range is specified, U_{nom1} concerns the highest and U_{nom2} the lowest value in the range. If only one nominal mains voltage value (U_{nom}) is specified then $U_{nom1} = U_{nom2} = U_{nom}$	

5.4.11 Surges on AC lines

Table 12

<table>
<tr><td>Applicable standard</td><td colspan="2">IEC 61000-4-5 [19]</td></tr>
<tr><td>Test method</td><td colspan="2">Introducing electrical surges on the mains power lines</td></tr>
<tr><td>Applicability</td><td colspan="2">Applicable for measuring instruments which are temporarily or permanently connected to an AC mains power network while in operation.
This test is not applicable to equipment powered by a road vehicle battery</td></tr>
<tr><td>Object of the test</td><td colspan="2">Verification of compliance with the provisions in 5.7.1.2 of R 80-1 during conditions where electrical surges are superimposed on the mains voltage.</td></tr>
<tr><td>Test procedure in brief</td><td colspan="2">A surge generator as defined in the referred standard shall be used. The characteristics of the generator shall be verified before connecting the EUT.
The test comprises exposure of the EUT to surges for which the rise time, pulse width, peak values of the output voltage/current on high/low impedance load and minimum time interval between two successive pulses are defined in the referred standard.
At least 3 positive and 3 negative surges shall be applied.
On AC mains supply lines the surges shall be synchronized with the AC supply frequency and shall be repeated such that the injection of surges on all 4 phase shifts: 0°, 90°, 180° and 270° with the mains frequency is covered.
The injection network circuit depends on the applicable conductor and is defined in the referred standard.</td></tr>
<tr><td rowspan="2">Test parameter levels</td><td rowspan="2">Amplitude (peak value)</td><td>2.0 kV line to line</td></tr>
<tr><td>1.0 kV line to ground</td></tr>
<tr><td>Permitted maximum deviation</td><td colspan="2">After the disturbance, either significant faults do not occur or checking facilities detect a malfunctioning and act upon it in accordance with 5.7.3 of R 80-1 when significant faults occur.</td></tr>
</table>

5.4.12 AC mains voltage dips, short interruptions and variations

Table 13

<table>
<tr><td>Applicable standards</td><td colspan="5">IEC 61000-4-11 [20], IEC 61000-6-1 [21], IEC 61000-6-2 [22]</td></tr>
<tr><td>Test method</td><td colspan="5">Introduction of short-time reductions in mains voltage using the test setup defined in the applicable standard</td></tr>
<tr><td>Applicability</td><td colspan="5">Applicable for measuring instruments with rated input current less than 16 A per phase which are temporarily or permanently connected to an AC mains power network while in operation.
This test is not applicable to equipment powered by a road vehicle battery</td></tr>
<tr><td>Object of the test</td><td colspan="5">Verification of compliance with the provisions in 5.7.1.2 of R 80-1 under conditions of short time mains voltage reductions.</td></tr>
<tr><td>Test procedure in brief</td><td colspan="5">A test generator shall be used which is suitable to reduce the amplitude of the AC mains voltage for the required period of time.
The performance of the test generator shall be verified before connecting the EUT.
The mains voltage reduction tests shall be repeated 10 times with intervals of at least 10 s between the tests.</td></tr>
<tr><td rowspan="13">Test parameter levels</td><td colspan="5"></td></tr>
<tr><td rowspan="10">Voltage dips</td><td rowspan="2">Test a</td><td>Reduction to</td><td>0</td><td>%</td></tr>
<tr><td>Duration</td><td>0.5</td><td>cycles</td></tr>
<tr><td rowspan="2">Test b</td><td>Reduction to</td><td>0</td><td>%</td></tr>
<tr><td>Duration</td><td>1</td><td>cycles</td></tr>
<tr><td rowspan="2">Test c</td><td>Reduction to</td><td>40</td><td>%</td></tr>
<tr><td>Duration</td><td>10/12 (1)</td><td>cycles</td></tr>
<tr><td rowspan="2">Test d</td><td>Reduction to</td><td>70</td><td>%</td></tr>
<tr><td>Duration</td><td>25/30 (1)</td><td>cycles</td></tr>
<tr><td rowspan="2">Test e</td><td>Reduction to</td><td>80</td><td>%</td></tr>
<tr><td>Duration</td><td>250/300 (1)</td><td>cycles</td></tr>
<tr><td colspan="2" rowspan="2">Short interruptions</td><td>Reduction to</td><td>0</td><td>%</td></tr>
<tr><td>Duration</td><td>250/300 (1)</td><td>cycles</td></tr>
<tr><td>Notes</td><td colspan="5">(1) Values applicable for 50 Hz / 60 Hz respectively</td></tr>
<tr><td>Permitted maximum deviation</td><td colspan="5">During the disturbance either significant faults do not occur or checking facilities detect a malfunctioning and act upon it in accordance with 5.7.3 of R 80-1 when significant faults occur.</td></tr>
</table>

5.4.13 Bursts (transients) on AC mains

Table 14

Applicable standard	IEC 61000-4-4 [16]	
Test method	Introducing transients on mains power lines	
Applicability	Applicable for measuring instruments which are temporarily or permanently connected to mains power network while in operation. This test is not applicable to equipment powered by a road vehicle battery	
Object of the test	Verification of compliance with the provisions in 5.7.1.2 during conditions where electrical bursts are superimposed on the mains voltage.	
Test procedure in brief	A burst generator as defined in the referred standard shall be used. The characteristics of the generator shall be verified before connecting the EUT. The test comprises exposure of the EUT to bursts of voltage spikes for which the output voltage on 50 Ω and 1 000 Ω load are defined in the referred standard. Both positive and negative polarity of the bursts shall be applied. The duration of the test shall not be less than 1 min for each amplitude and polarity. The injection network on the mains shall contain blocking filters to prevent the burst energy being dissipated in the mains.	
Test parameter levels	Amplitude (peak value)	2 kV
	Repetition rate	5 kHz
Permitted maximum deviation	During the disturbance either significant faults do not occur or checking facilities detect a malfunctioning and act upon it in accordance with 5.7.3 of R 80-1 when significant faults occur.	

5.4.14 Low voltage of internal battery (not connected to mains power)

Table 15

Applicable standards	No standard is available
Test method	Applying minimum supply voltage
Applicability	Applicable to all measuring instruments supplied by internal battery.
Object of the test	Verification of compliance with the provisions in 5.7.1.1 of R 80-1 during low battery voltage.
Test procedure	The test comprises exposure of the EUT to the specific low battery level condition during a period sufficient for achieving temperature stability and for performing the required measurements. The maximum internal impedance of the battery and the minimum battery supply voltage level (U_{min}) shall be specified by the manufacturer of the instrument. If an alternative power supply source is used instead of the internal battery, for instance in bench testing, the internal impedance of the specified type of battery shall also be simulated. The alternative power supply shall be capable of delivering sufficient current at the applicable supply voltage. The test sequence is as follows: Let the power supply stabilize at a voltage as defined within the rated operating conditions and apply the measurement and/or loading condition. Record: 1) The data defining the actual measurement conditions including date, time and environmental conditions; 2) the actual power supply voltage. Perform measurements and record the error(s) and other relevant performance parameters. Verify compliance with 5.7.1.1 of R 80-1. Repeat the above procedure with actual supply voltage at U_{min} and again at 0.9 U_{min}. Verify compliance with the requirements.
Lower limit of the voltage	The lowest voltage at which the EUT functions properly according to the specifications.
Number of cycles	At least one test cycle for each functional mode.
Permitted maximum deviation	All functions shall operate as designed and all the errors measured during the application of the influence factor shall be within the maximum permissible errors.

5.4.15 Tests for power from road vehicle batteries

5.4.15.1 Voltage variations

Table 16

Applicable standard	ISO 16750-2 [23]		
Test method	Variation in supply voltage		
Applicability	Applicable to all measuring instruments supplied by the internal battery of a vehicle and charged by use of a combustion engine driven generator.		
Object of the test	Verification of compliance with the provisions in 5.7.1.1 of R 80-1 under conditions of high voltage (for example while charging) and low battery voltage.		
Test procedure in brief	The test comprises exposure of the EUT to the specified maximum and minimum power supply voltage conditions for a period of time sufficient for achieving temperature stability and performing the required measurements at these conditions.		
Test parameter levels	Nominal battery voltage (U_{nom})	U_{nom} = 12 V	U_{nom} = 24 V
	Lower limit	9 V	16 V
	Upper limit	16 V	32 V
Permitted maximum deviation	At both the upper supply voltage level and the lower supply voltage level: - all functions shall operate as designed; - all errors shall be within the maximum permissible errors.		

5.4.15.2 Electrical transient conduction along supply lines

Table 17

<table>
<tr><td>Applicable standard</td><td colspan="3">ISO 7637–2 [24]
5.6.2: Test pulse 2a + 2b
5.6.3: Test pulse 3a + 3b</td></tr>
<tr><td>Test method</td><td colspan="3">Electrical transient conduction along supply lines</td></tr>
<tr><td>Applicability</td><td colspan="3">Applicable to all measuring instruments which while in operation are supplied by the internal battery of a vehicle which may at the same time be charged by use of a combustion engine driven generator.</td></tr>
<tr><td>Object of the test</td><td colspan="3">Verification of compliance with the provisions in 5.7.1.2 of R 80-1 under the following conditions:
- transients due to a sudden interruption of current in a device connected in parallel with the device under test due to the inductance of the wiring harness (pulse 2a);
- transients from DC motors acting as generators after the ignition is switched off (pulse 2b);
- transients on the supply lines which occur as a result of the switching processes (pulses 3a and 3b).</td></tr>
<tr><td>Test procedure in brief</td><td colspan="3">The test comprises exposure of the EUT to disturbances on the power voltage by direct coupling into the supply lines.
During the tests, the EUT shall be in operation.
Simulated inputs are permitted. Tests shall be performed at a fixed level.</td></tr>
<tr><td rowspan="6">Test parameter levels</td><td rowspan="2">Test pulse</td><td colspan="2">Pulse voltage level U_s</td></tr>
<tr><td>U_{nom} = 12 V</td><td>U_{nom} = 24 V</td></tr>
<tr><td>2a</td><td>+50 V</td><td>+50 V</td></tr>
<tr><td>2b</td><td>+10 V</td><td>+20 V</td></tr>
<tr><td>3a</td><td>–150 V</td><td>–200 V</td></tr>
<tr><td>3b</td><td>+100 V</td><td>+200 V</td></tr>
<tr><td>Notes</td><td colspan="3">Test pulse 2b is only applicable when the electrical power circuitry of the measuring instrument can be interrupted by the master switch of the car and as a consequence is not permanently connected to the battery of the car. This test will therefore be applicable in all situations where the manufacturer of the measuring instrument has not specified that the instrument is to be connected directly to the battery.</td></tr>
<tr><td>Permitted maximum deviation</td><td colspan="3">During the disturbances 2a, 3a and 3b and after the disturbance 2b, either significant faults do not occur or checking facilities detect a malfunctioning and act upon it in accordance with 5.7.3 of R 80-1 when significant faults occur.</td></tr>
</table>

5.4.15.3 Electrical transient conduction via lines other than supply lines

Table 18

<table>
<tr><td>Applicable standard</td><td colspan="3">ISO 7637–3 [25]
4.5: CCC method for the fast transient test pulses 3a and 3b</td></tr>
<tr><td>Test method</td><td colspan="3">Electrical transient conduction along lines other than supply lines</td></tr>
<tr><td>Applicability</td><td colspan="3">Only applicable to analogue I/O cabling of modular measuring instruments installed in vehicles.</td></tr>
<tr><td>Object of the test</td><td colspan="3">Verification of compliance with the provisions in 5.7.1.2 of R 80-1 under conditions of transients which occur on other lines than supply lines as a result of the switching processes (pulses a and b).</td></tr>
<tr><td>Test procedure in brief</td><td colspan="3">The test comprises exposure of the EUT to bursts of voltage spikes by capacitive and inductive coupling via lines other than supply lines.
During the tests, the EUT shall be in operation.
Simulated inputs are permitted.</td></tr>
<tr><td rowspan="4">Test parameter levels</td><td rowspan="2">Test pulse</td><td colspan="2">Pulse voltage U_s</td></tr>
<tr><td>U_{nom} = 12 V</td><td>U_{nom} = 24 V</td></tr>
<tr><td>3a</td><td>–60 V</td><td>–80 V</td></tr>
<tr><td>3b</td><td>+40 V</td><td>+80 V</td></tr>
<tr><td>Permitted maximum deviation</td><td colspan="3">During the disturbance, either significant faults do not occur or checking facilities detect a malfunctioning and act upon it in accordance with 5.7.3 of R 80-1 when significant faults occur.</td></tr>
</table>

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Annex A
Example of a test stand for the determination of the immersion depth of a float by the reference float method

(Informative)

A.1 Description of the test stand

A test setup for measuring the float immersion depth is shown in Figure A1. Two level gauges of the same type of later use are affixed in a liquid-tight container with a support for each level float fixed at the bottom of the container. Spacers are used and necessary for a good reference surface for the floats. The level gauge is used to measure the level of the float under the same conditions as in later use.

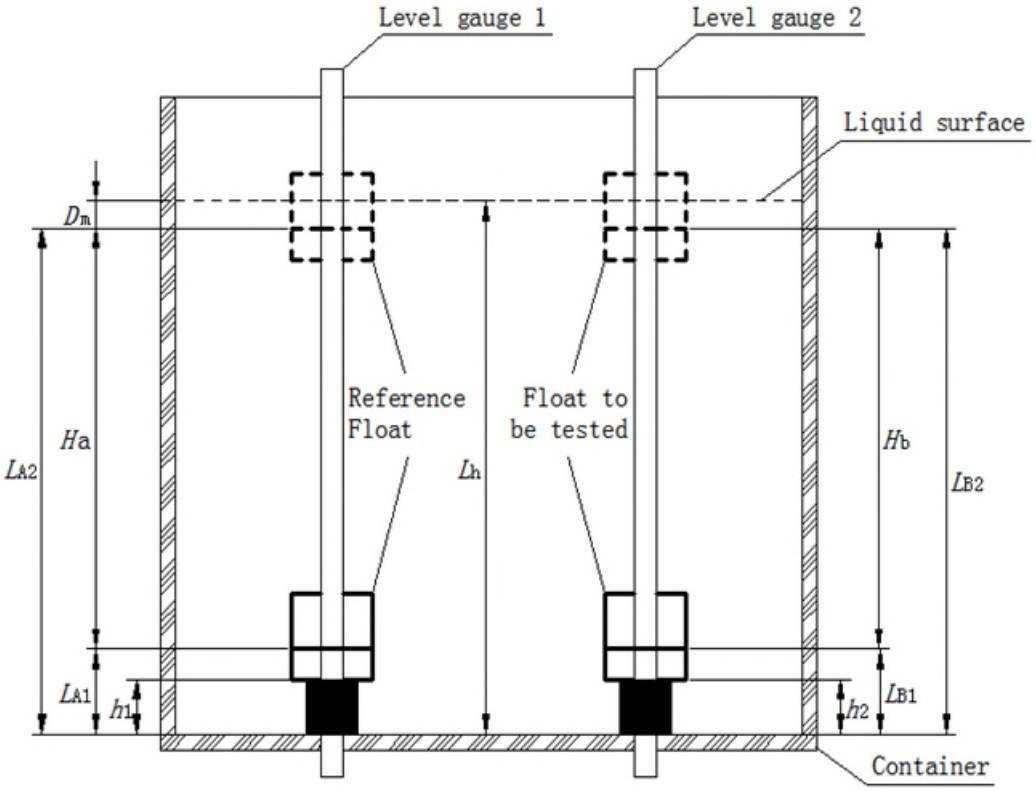


Figure A1: Test setup for measuring the float immersion depth

A.2 Calibrating the test setup with a reference float

The value L_{A_1} has to be determined while the float is resting on the support, by reading the level value indicated by the level gauge. Subsequently the container is filled with the test fluid. After the fluid level is stabilized the value L_{A_2} can be taken from the level gauge. The immersion depth can now be calculated using the equation:

$$D_m = L_h - L_{A2}$$

The level gauge 2 has to be checked in the same way and should give the same results for the immersion depth D_m. The immersion depth of the reference float is calibrated and is used as a master float.

A.3 Determination of the immersion depth of the float

The level gauge 1 together with the reference float now serves as the master for determining the immersion depth of the floats used in the measuring system. The level gauge 2 is now used for the float that has to be calibrated. The values L_{A1} and L_{B1} are taken when the container is empty. The values L_{A2} and L_{B2} are taken after filling the container with test fluid. The immersion depth of the float D_{float} can be calculated by:

$$D_{float} = D_m + L_{B2} - L_{A2}$$

A.4 Immersion depth offset

The immersion depth offset of the float to be tested is determined as follows:

$$\Delta D_{float} = D_{float} - D_m$$

Annex B
Tank calibration

(Informative)

B.1 General

B.1.1 Each tank/compartment is unique and has to be calibrated. If the tank consists of several compartments every compartment has to be calibrated. An empty compartment can be used to store the liquid of the compartment for calibration.

B.1.2 Each tank/compartment has to be calibrated together with the corresponding level sensor system according to R 80-1, 5.5. The expanded uncertainty of the determination of the volume of liquid in the tank for initial verification shall not exceed one-third of the MPE according to R 80-1, Table 2. The expanded uncertainty shall be estimated according to the *Guide to the expression of uncertainty in measurement* [26] applying a coverage factor k=2.

B.1.3 Using calibration data based on construction documents or tanks/compartments of similar construction is not acceptable.

B.2 External conditions

For the purpose of calibration, the tank has to be fixed with supports on the ground in its normal position. During the calibration any movement or inclination of the tank has to be avoided. The tank has to be filled with liquid up to the nominal volume. During the calibration process, a tank capacity table with pairs of level/volume values for the tank shall be established and stored.

B.3 Minimum measured quantity (MMQ)

The minimum measured quantity (MMQ) shall be specified for each measuring compartment in accordance with 5.1.7 of R 80-1 unless stated otherwise in the pattern approval certificates for the level gauging system or for the measuring tank. The MMQ according to 5.1.7.2 of R 80-1 may be specified within the process of the tank calibration. The thus determined MMQ may still be amended but at the latest during the initial verification (for example if the measurement results appear to exceed the error limits).

B.4 Determination of the pipe volume

During these tests the pipe volume for the tank/each compartment also has to be determined (see Annex C concerning the testing of different constructed systems). All these tests have to be in compliance with the manufacturer's documentation.

The calibration data together with the pipe volume have to be stored in the measuring system. The data for the inclination correction also have to be stored in the system. These data are calculated from the construction documents of the tank shape. No additional calibration is needed to determine the inclination correction data.

Note: Manufacturers of level gauge metering systems generally employ special tailored calibration facilities for their type of level gauge measuring systems. If level gauge metering systems are not calibrated according to manufacturers' recommendations or if wrong inclination correction data are used, the measuring system will fail the initial verification.

Annex C
Determination of the pipe volume

(Informative)

C.1 Test on the pipework volumes for delivery by gravity

The volumes of the pipework between the valve at the bottom of each of the measuring compartments and the applicable transfer points which need to be stored as metrologically relevant values of the measuring system are to be tested as follows.

The measuring compartment and the pipework are filled with the fluid via the loading connection until the valve at the bottom of the compartment is completely flooded. After all the air has been removed from the pipe, the valve shall be closed and the pipework shall be emptied via the transfer point. The requirements in 5.1.5 of R 80-1 can also be met in the case of a complete drainage of the system, if the difference between this quantity and the value stored in the measuring system is (similar to the requirements in 5.2.2.4 of R 80-1) less than one third of the minimum specified volume deviation E_{min} (see 2.45 of R 80-1) of the compartment.

C.2 Test on delivery via collector

For the execution of this test, the compartment of the measuring container having the smallest minimum measured quantity shall be selected. The available delivery paths (full and/or empty hose(s)) shall each be tested separately following the two-step procedure described in C 2.1 and C 2.2, each time delivering a test volume of 1 000 L or the minimum delivery quantity of the selected compartment, whichever is smaller.

Before commencing these tests an initial flushing needs to be performed. For the purpose of this initial flushing, the applicable compartment is filled with at least 200 L and subsequently emptied through the collector and the selected delivery path. The exact quantities used and indicated during flushing are irrelevant to the outcome of this test.

C.2.1 Measuring systems with gas separator or level sensor for the cut-off point

After the flushing, the compartment is filled with a quantity of liquid of twice the test volume. In a first step, the test volume is discharged through the originally empty collector line using the same delivery path as during the initial flushing, using a volume standard or reference meter. In the second step, the remaining product is delivered through the same delivery path until the system stops. The MPE for this deviation is ± 0.5 % of the minimum measured quantity of the compartment used for the test.

C.2.2 Measuring systems with level sensor for the pipework system

After flushing, the test volume plus approximately half the volume of the collector pipework is filled into the compartment. After that, the test volume (not including the added volume for the pipework) shall be delivered into/through the volume standard or reference meter.

In the second step, the test volume minus the pipework volume which had been added before, is filled into the compartment, and subsequently delivered into/through the standard/reference meter, until the system shuts off.

The MPE for these deviations is ± 0.5 % of the minimum measured quantity of the compartment used for the tests.

Annex D
Examples for the tests listed in 4.2–4.4

(Informative for measuring systems for partial delivery and accuracy class 0.5)

D.1 Preparations for the volumetric test of the individual measuring compartments

Each measuring compartment of the measuring tank shall be separately tested by gradual, step by step discharge.

If possible, tests shall be performed with a product for which the measuring system is intended (preferably fuel oil or diesel oil). Initially, the compartment shall be filled with about 90 % of the permissible loading quantity and connected to a volume standard or reference meter via the gravity outlet of the compartment (if present). The filling quantity should be selected such that it is sufficient for all testing steps as well as the initial flushing (if required) so that pumping back of product can be avoided.

Note: The initial flushing ensures that the pipes and hoses are filled completely.

D.2 Testing of a measuring compartment using a volume standard

The volume standards used shall have a volume of less than twice the minimum measured quantity of the smallest compartment to be tested.

The test can be carried out at any flow rate, but needs to be sufficiently small (especially for the last discharge steps) to prevent air from entering the pipe system by way of swirl formation.

Each filling step consists of a delivery during which the volume standard is filled from the respective measuring compartment. After each delivery, the delivery temperature, the operating volume and the converted volume are observed and recorded from both the indication of the level gauging system and the measured standard volume of the volume standard, and documented. Subsequently, the errors are calculated (see example). The compartment shall be completely emptied during the test. If the residual quantity cannot be measured with the volume standard, gravimetric methods may be used. In this case, the verification of the converted volume may be dispensed with. For the assessment, it may be necessary to add the volumes of several steps so that at least 0.8 times the minimum delivery is obtained. The MPE shall be applied to these summation values (see example).

Example: Volumetric test

Nominal loading volume of tank compartment: 15 000 L

Minimum measured quantity of tank compartment = 1/10 of loading volume: 1 500 L

Nominal volume of volume standard used: 1 000 L

Maximum permissible error

Minimum specified volume deviation $E_{min} = 2 \times 0.3\ \% \cdot V \leq 2 \times V_{min}$: ± 9 L

Maximum permissible error for $V > 2 \times V_{min}$: 0.3 %·V

No. of measure-ment	Compart-ment contents before measure-ment	Indica-tion of level gauging system	Indica-tion of standard	Error of actual measurement		Error for volume between 1 × and 2 × MMQ (from sum of two individual measurements)		Error for volume > 2 × MMQ (from sum of three individual measurements)	
				Absolute	Relative	Absolute	Relative	Absolute	Relative
	L	L	L	L	%	L	%	L	%
1	15 015	1 000	1 002.4	–2.4	–0.24				
2	14 015	1 001	1 000.2	+0.8	+0.08	–1.6	–0.08		
3	13 014	1 003	1 000.1	+2.9	+0.29	+3.7	+0.18	+1.3	+0.04
4	12 011	1 004	1 002.5	+1.5	+0.15	+4.4	+0.22	+5.2	+0.17
5	11 007	997	1 002.5	–5.5	–0.55	–4.0	–0.20	–1.1	–0.04
6	10 010	996	998.9	–2.9	–0.29	–8.4	–0.42	–6.9	–0.23
7	9 014	999	1 000.6	–1.6	–0.16	–4.5	–0.23	–10	–0.33
						check: values shall be ≤ 9 L			check: values shall be ≤ 0.3 %

Note: In the example, the error determined for measurement No. 6 is – 0.42 %, but the 8.4 L are smaller than the minimum specified volume deviation.

In measurement No. 7, the MPE for the minimum measured quantity is exceeded. The compartment shall be rejected.

D.3 Test of the temperature sensors

The temperature sensors shall be tested during the delivery by determining the mean temperature of the delivered product for a quantity of at least 1 000 L and comparing it with the mean temperature calculated by the system. As an alternative, the temperature can also be measured and directly compared in a place next to the temperature sensor. The deviation shall not exceed ± 0.5 °C. Testing of the temperature sensors may be done during the volume tests of the respective measuring compartments.

The temperature sensors shall be tested during the delivery by determining the mean temperature of the delivered product for a quantity of at least 1 000 L and comparing it with the mean temperature calculated by the system. As an alternative, the temperature can also be measured and directly compared

in a place next to the temperature sensor. The deviation shall not exceed ± 0.5 °C. Testing of the temperature sensors may be done during the volume tests of the respective measuring compartments.

D.4 Test of the compartment using a reference meter

The standard used may be a reference meter suitable for the product used for testing. Prior to the first measurement, the meter shall be tested using a volume standard. During testing, the flow rates used shall comply with the specification of the reference meter.

The test procedure is the same as in D.2, except that the volume steps may now be equal to the minimum measured quantity of the compartment under test.

D.5 Test of the inclination correction

This test shall be performed for each measuring compartment, once with a filling volume of approx. 15 to 30 % and once with approx. 70 to 90 % of its nominal volume. It is recommended to simultaneously test all compartments in two runs, with an arbitrary combination and sequence of filling states. The center of gravity of the partially loaded truck should be carefully checked for each loading state.

The first measurement for each filling state shall be performed in normal position, i.e. within ± 0.2° in the longitudinal and in the transverse direction. After a settling time of approx. 5 min, the filling volumes of all compartments shall be read. They are the reference values for the subsequent tests in inclined positions.

Then the tank is successively brought into the following positions:

- in the longitudinal direction, inclined by + 2° to + 3° (“front up”);
- in the longitudinal direction, inclined by – 2° to – 3° (“rear up”);
- in the transverse direction, inclined by + 2.5° to + 5° (“right up”);
- in the transverse direction, inclined by – 2.5° to – 5° (“left up”),

whereby the inclination shall not be greater than ± 0.5° in the direction not considered.

After a settling time of approx. 5 min, the filling volumes of all compartments shall be read.

For each of the filling states, and for each of the measuring compartments, the volume indication in each of the four inclined positions shall be equal to the reference values determined in normal position within ± 0.3 % of the minimum measured quantity of the respective compartment (see example below).

Example: Inclined position test

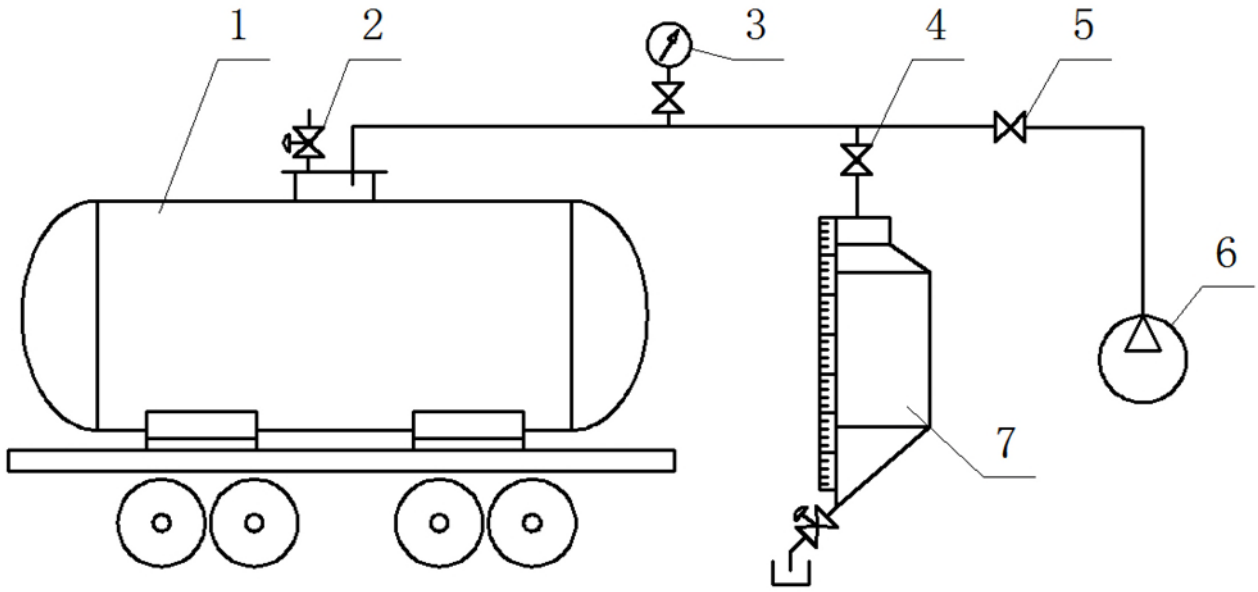
Tanker with three compartments

- compartment volume 10 000 L each
- minimum measured quantity (1/5 of the permissible compartment volume): 2 000 L per compartment
- maximum permissible errors for inclined position test (± 0.3 % of minimum measured quantity): ± 6 L

Procedure:

(1) filling of compartments 1 and 3 with 2 000 L of fuel oil each and compartment 2 with 8 000 L of fuel oil
(2) horizontal alignment of tank and recording of reference measurement values
(3) inclination of tank front upwards, recording of measurement values
(4) inclination of tank rear upwards, recording of measurement values
(5) inclination of tank right upwards and recording of measurement values
(6) inclination of tank left upwards and recording of measurement values
(7) evaluation of the recorded measurement results
(8) filling up of compartments 1 and 3 with 8 000 L of fuel oil each and emptying of compartment 2 to 2 000 L of fuel oil
(9) horizontal realignment of tank and recording of reference measurement values
(10) repetition of measurement at inclinations “front upwards”, “rear upwards”, “right upwards” and “left upwards” and recording of the measurement results
(11) evaluation of the recorded measurement results.

D.6 Influence of internal pressure



(1) tank under test
(2) vent
(3) pressure gauge
(4) ball valve
(5) separation valve
(6) pump
(7) standard capacity measure

While ensuring by means of vent 2 that there are no air pockets, the pressure is increased by means of pump 6 up to p_{max} (indicated on pressure gauge 3). Valve 5 is then closed and, by opening valve 4, water is gradually withdrawn and its volume is measured using the volumetric measure 7. The volume is indicated on the graduated rule of the measure 7, and the corresponding pressure is read from pressure gauge 3.

The calculated volume changes $\triangle Vi$ are recorded in tabular form:

Pressure in tank *p* (bar)	**Increase of tank volume ΔV (L)**
p_1	ΔV_1
p_2	ΔV_2
....	….
p_{max}	ΔV_{max}

or presented in the form of a graph dependency $\Delta V = \Delta V(p)$.