Australian Government
National Measurement Institute

NMI R 125

Measuring Systems for the Mass of Liquids in Tanks

(OIML R 125:1998(E), IDT)

The English version of international standard OIML R 125:1998 *Measuring Systems for the Mass of Liquids in Tanks* (1998) is adopted as the identical national standard with the reference number NMI R 125

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1. SCOPE

NMI R 125 provides the metrological and technical requirements for the pattern approval of instruments used to determine the mass of liquid in tanks used for trade in Australia. NMI R 125 also specifies the tests required for verification/certification and reverification.

2. CONTENTS

NMI R 125 is comprised of, and therefore identical with, OIML R 125: 1998 *Measuring Systems for the Mass of Liquids in Tanks* published by the International Organisation of Legal Metrology (OIML).

3. VARIATIONS AND INTERPRETATIONS

The following variations and interpretations apply:

(a) The metrological authority for pattern approval is the National Measurement Institute.

(b) The metrological authorities for verification are the State/Territory verifying/certifying authorities.

(c) For references to ‘initial verification’ substitute ‘verification/certification’ and for ‘in-service’ substitute ‘reverification’.

(d) OIML R 33 is equivalent to NMI R 33, OIML R 76-1 is equivalent to NMI R 76-1 and OIML R 60 is equivalent to NMI R 60.

(e) Refer to the following bibliography for the most recent edition of each International Electrotechnical Commission (IEC) publication. Corresponding Australian standards are also given.

IEC 60068-2-1 (1990) Basic Environmental Testing Procedures. Part 2: Tests. Test A: Cold. Section 3 — Test Ad: Cold for Heat-dissipating Specimen with Gradual Change of Temperature. Also refer to amendments IEC 60068-2-1-am1 (1993) and IEC 60068-2-1-am2 (1994).

IEC 60068-2-2 (1974) Basic Environmental Testing Procedures. Part 2: Tests. Test B: Dry Heat. Section 4 — Test Bd: Dry Heat for Heat-dissipating Specimen with Gradual Change of Temperature. Also refer to amendments IEC 60068-2-2-am1 (1993) and IEC 60068-2-2-am2 (1994).

IEC 60068-2-3 (1969) Basic Environmental Testing Procedures. Part 2: Tests. Test Ca: Damp Heat, Steady State. The equivalent Australian standard is AS 1099.2.3–1990.

IEC 60068-2-28 replaced by IEC 60068-3-4 (2001) Environmental Testing — Part 3–4: Supporting Documentation and Guidance — Damp Heat Tests.

IEC 60068-2-30 (1980) Basic Environmental Testing Procedures. Part 2: Tests. Guidance for Damp Heat Tests. Test Dd and Guidance: Damp Heat, Cyclic (12 + 12-hour Cycle). Also refer to amendment IEC 60068-2-30-am1 (1985).

IEC 60068-2-56 (1988) Basic Environmental Testing Procedures. Part 2: Tests. Test Cb: Damp Heat, Steady State, Primarily for Equipment.

IEC 60068-3-1 (1974) Basic Environmental Testing Procedures. Part 3: Background Information. Section 1 — Cold and Dry Heat Tests. Also refer to first supplement IEC 60068-3-1A (1978).

IEC 61000-4-2 (2001) Electromagnetic Compatibility (EMC). Part 4: Testing and Measurement Techniques. Section 2: Electrostatic Discharge Immunity Test.

IEC 61000-4-3 (2002) Electromagnetic Compatibility (EMC). Part 4: Testing and Measurement Techniques. Section 3: Radiated, Radio-frequency, Electromagnetic Field Immunity Test.

IEC 61000-4-4 (1995) Electromagnetic Compatibility (EMC). Part 4: Testing and Measurement Techniques. Section 4: Electrical Fast Transient/Burst Immunity Test. Also refer to amendments IEC 61000-4-4-am1 (2000) and IEC 61000-4-4-am2 (2001).

IEC 61000-4-11 (2001) Electromagnetic Compatibility (EMC). Part 4: Testing and Measurement Techniques. Section 11: Voltage Dips, Short Interruptions and Voltage Variations Immunity Tests.

INTERNATIONAL RECOMMENDATION

OIML R 125

Edition 1998 (E)

Measuring systems for the mass of liquids in tanks

Systèmes de mesure de la masse des liquides dans les réservoirs

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OIML R 125 Edition 1998 (E)

ORGANISATION INTERNATIONALE DE MÉTROLOGIE LÉGALE

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 two 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 improve the work of the metrological services.

OIML Draft Recommendations and Documents are developed by technical committees or subcommittees which are formed by the Member States. Certain international and regional institutions also participate on a consultation basis.

Cooperative agreements are established between OIML and certain institutions, such as ISO and IEC, with the objective of avoiding contradictory requirements; consequently, manufacturers and users of measuring instruments, test laboratories, etc. may apply simultaneously OIML publications and those of other institutions.

International Recommendations and International Documents are published in French (F) and English (E) and are subject to periodic revision.

This publication - reference OIML R 125, edition 1998 (E) - was developed by the OIML subcommittee TC 8/SC 2 *Static mass measurement*. It was approved for final publication by the International Committee of Legal Metrology in 1997, and will be submitted to the International Conference of Legal Metrology in 2000 for formal sanction.

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Terminology

The following terminology includes terms applicable to those instruments covered by this Recommendation and some general terms included in the *International Vocabulary of Basic and General Terms in Metrology* (VIM, Second edition, 1993). For an alphabetical cross-reference to these terms, see Annex F.

GENERAL TERMS

T.1 Mass measuring instrument

A measuring instrument which determines and indicates the mass of liquid contained in a calibrated tank. The instrument includes devices such as a measurement transducer (or transducers) which measures a quantity related to the mass of the liquid, a processor and an indicator.

T.2 Mass measuring system

A system which comprises the measuring instrument, the calibrated tank and any ancillary and/or additional devices.

T.3 Calibrated tank

A container which is calibrated and for which the results are given in a tank calibration table. This table is used in conjunction with the mass measurement transducer to determine the mass contained in the tank.

T.4 Mass measurement transducer

A device which measures a quantity related to the mass of the liquid and which provides a signal to the processor from which the mass is determined.

T.5 Tank calibration table

A table which shows the relation between the height of the liquid level and the volume contained in the tank at that level under specified conditions.

T.6 Datum point

The datum point constitutes the origin for the measurement of liquid levels (zero reference). It is the intersection of the vertical measurement axis with the upper surface of the datum plate, or with the bottom, inside surface of the tank if a datum plate is not provided.

T.7 Processor

A device which contains all the necessary information and receives all the necessary signals from the transducers thus enabling it to calculate the mass contained in the tank as well as other quantities. It may also store information, provide checking facilities for the information and communicate with ancillary devices.

T.8 Indicator

A device which displays the mass calculated by the processor and other quantities. It may or may not be part of the processor.

T.9 Device

A part of an instrument that performs a specific function. It is usually manufactured as a separate unit and is capable of being independently tested.

T.9.1 Ancillary device

A device associated with the instrument which is intended to perform a specific function, e.g. a repeat indication device, ticket printer, card reader, data input terminal, etc.

T.9.2 Additional device

A device other than an ancillary device, required to ensure the correct metrological performance of the system, e.g. valves allowing verification of pressure transducers, atmospheric pressure balancing pipes between pressure transducers, etc.

T.10 Vertical cylindrical tank

A tank whose horizontal cross-section is a circle and whose walls are vertical.

T.11 External floating roof

A tank roof which forms part of the external surfaces of the tank but which floats freely on the surface of the liquid, except at low levels when the weight of the roof is taken on its supports on the tank bottom.

T.12 Internal floating roof

A tank roof which floats freely on the surface of the liquid in a tank fitted with a fixed external roof. At low levels the weight of the roof is taken on its supports on the tank bottom.

MEASUREMENT TERMS

T.13 Measured mass

The mass of liquid determined from the signals obtained from the measurement transducer(s).

T.14 Gross mass

The gross mass is the mass of the liquid determined by the measuring instrument (measured mass) as well as the mass of the liquid below the transducer and includes water and sediment entrained in the liquid. It does not include the mass of vapor above the liquid, the mass of the floating roof (if fitted), nor the mass of the free bottom sediment and water.

T.15 Minimum measured quantity (inventory and transfer)

The quantity of indicated mass below which the maximum permissible error may be exceeded. This quantity applies to liquid contained in the tank (inventory) or transferred into or out of the tank (transfer).

T.16 Maximum measured quantity

The maximum measurable quantity as specified by the manufacturer of the measurement transducer (for testing of devices) or of the calibrated tank for installed instruments.

T.17 Zero quantity

The quantity of liquid equivalent to a zero signal from the measurement transducer.

ELECTRONIC TERMS

T.18 Electronic mass measuring instrument

A mass measuring instrument equipped with electronic devices.

T.19 Electronic device

A device employing electronic sub-assemblies and performing a specific function. An electronic device is usually manufactured as a separate unit and is capable of being independently tested.

Note: An electronic device, as defined above, may be a complete measuring instrument or part of a measuring instrument.

T.20 Electronic sub-assembly

Part of an electronic device employing electronic components and having a recognizable function of its own.

T.21 Electronic component

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

PERFORMANCE TERMS

T.22 Error of measurement

T.22.1 Absolute error

The result of a measurement minus the (conventional) true value of the measurand (VIM 3.10).

T.22.2 Relative error

The absolute error of measurement divided by the conventional true value of the measurand (VIM 3.12).

T.23 Intrinsic error

The error of a measuring instrument used under reference conditions (VIM 5.24).

T.24 Initial intrinsic error

The intrinsic error of a measuring instrument as determined prior to performance tests.

T.25 Maximum permissible error (of a measuring instrument)

The extreme values of an error permitted by specifications, regulations, etc. for a given measuring instrument (VIM 5.21).

T.26 Repeatability

The closeness of the agreement between the results of successive measurements of the same measurand carried out under the same conditions of measurement (VIM 3.6).

T.27 Fault

The difference between the error indication and the intrinsic error of a measuring instrument.

Note: Principally a fault is the result of an undesired change of data contained in, or flowing through, an electronic measuring instrument.

T.28 Significant fault

A fault greater than the absolute value of the maximum permissible error for the minimum quantity.

The following faults are not considered to be significant, even when they exceed the value defined above:

(a) faults arising from simultaneous and mutually independent causes in the measuring instrument itself or in its checking facilities;

(b) faults implying the impossibility to perform any measurement;

(c) transitory faults being momentary variations in the indication, which cannot be interpreted, memorized or transmitted as a measurement result; and

(d) faults giving rise to variations in the measurement result which are so serious that they are bound to be noticed by all those interested in the measurement result.

T.29 Influence quantity

A quantity which is not the subject of the measurement but which influences the value of the measurand or the indication of the measuring instrument (VIM 2.7).

T.29.1 Influence factor

An influence quantity having a value within the rated operating conditions of the measuring instrument specified in this Recommendation.

T.29.2 Disturbance

An influence quantity having a value within the limits specified in this Recommendation, but outside the specified rated operating conditions of the measuring instrument.

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

T.30 Rated operating conditions

Conditions of use giving the range of values of influence quantities for which the metrological characteristics are intended to lie within the specified maximum permissible errors (adapted from VIM 5.5).

T.31 Reference conditions

A set of specified values of influence factors fixed to ensure valid intercomparisons of results of measurements (adapted from VIM 5.7).

T.32 Base conditions

The specified conditions to which a measured quantity is converted, e.g. base temperature and base pressure.

Note: The values chosen as base conditions should preferably be 15 °C or 20 °C and 101 325 Pa.

T.33 Performance

The ability of the measuring instrument to accomplish its intended functions.

CHECKING TERMS

T.34 Checking facility

A facility that is incorporated in a measuring instrument which enables significant faults to be detected and acted upon.

Note: "Acted upon" refers to any adequate response by the measuring instrument (luminous or acoustic signal, prevention of the measurement process, etc.).

T.34.1 Automatic checking facility

A checking facility operating without the intervention of an operator.

T.34.1.1 Permanent automatic checking facility (Type P)

An automatic checking facility operating at each measurement cycle.

T.34.1.2 Intermittent automatic checking facility (Type I)

An automatic checking facility operating at certain time intervals or over a fixed number of measurement cycles.

T.34.2 Nonautomatic checking facility (Type N)

A checking facility which requires the intervention of an operator.

TESTING TERMS

T.35 Test

A series of operations intended to verify the compliance of the equipment under test with certain requirements.

T.35.1 Test procedure

A detailed description of the tests.

T.35.2 Test program

A description of a series of tests for certain types of equipment.

T.35.3 Performance test

A test intended to verify whether the equipment under test is able to accomplish its intended functions.

Measuring systems for the mass of liquids in tanks

Section I

General

1 Scope

This Recommendation specifies the metrological and technical requirements for the pattern approval and verification of instruments used to determine the mass of liquid contained in a tank using methods which measure mass-related properties of the liquid while it is in a static state, e.g. the hydrostatic pressure of the liquid and gases in the tank.

It does not include instruments which determine the mass of the liquid by methods covered by other OIML Recommendations, e.g. by weighing, by measuring the volume and density and converting to mass or by mass flow measurement.

This Recommendation also includes pattern approval and verification procedures and test methods. References to other documents are made for construction, installation, operating requirements and calibration procedures, in particular ISO 11223-1 (1995) *Petroleum and liquid petroleum products - Direct static measurements - Contents of vertical storage tanks. Part 1: Mass measurement by hydrostatic tank gauging* and ISO 7507 (1993) *Petroleum and liquid petroleum products - Calibration of vertical cylindrical tanks.*

2 Application

Instruments covered by this Recommendation are used to determine the mass of liquids in calibrated tanks using such properties as hydrostatic pressure or buoyancy effect on a partly submerged body. Other properties may be measured. The instrument may be used to determine either the quantity of liquid in the tank (inventory), of the quantity of liquid transferred into or out of the tank (transfer).

As the determination of the mass also requires other information relating to the dimensions and construction of the tank, the application of these instruments is limited to vertical cylindrical tanks with or without internal or external floating roofs.

These requirements apply only to the determination of the gross mass of liquid. Other quantities of the liquid in the tank may be determined.

3 General provisions

3.1 Constituents of a measuring system

A measuring system includes at least:

(a) a measuring instrument; and
(b) a calibrated tank.

The measuring system may be provided with ancillary and additional devices - see Annex E.

If several instruments intended for separate measuring operations have common devices, each instrument is considered as forming, with the common devices, a measuring system.

3.2 Constituents of a measuring instrument

A measuring instrument includes at least:

(a) a measurement transducer;
(b) a processor; and
(c) an indicator.

See Annex E.

3.3 Ancillary devices

Ancillary devices may be fitted to the instrument. Generally these devices are optional but if they are included in the measurement up to the settlement of the transaction or are made mandatory by national regulation, they shall comply with these requirements. The transaction is settled when the interested parties have made their agreement known as regards the measured quantity of the transaction.

If settlement is not carried out at the time of the measurement, e.g. both parties are not present or there is deferred payment, then a printing or memorizing device accessible to both parties shall be provided up to the settlement of the transaction.

When ancillary devices are not included in the transaction they shall not affect the correct metrological functions of the measuring instrument when connected.

3.4 Field of operation

The field of operation of a system is determined by the following characteristics:

(a) minimum measured quantity (inventory and transfer);
(b) maximum measured quantity applicable to the instrument;
(c) rated operating conditions (see subclause 5.1); and
(d) limits of liquid properties.

The field of operation of a system shall be within the field of operation of each of its constituent devices.

Section II

METROLOGICAL REQUIREMENTS

4 Classification and maximum permissible errors

4.1 Classification

4.1.1 Accuracy class

The accuracy class specified in this Recommendation is 0.5.

4.2 Maximum permissible errors

Maximum permissible errors are applicable to all quantities equal to, or greater than, the minimum measured quantity.

4.2.1 Value of maximum permissible error for the measuring system

The maximum permissible error for pattern approval, initial verification and subsequent verification of the measuring system is ± 0.5 % of the measured mass.

4.2.2 Value of maximum permissible error for the measuring instrument

The maximum permissible error for pattern approval and initial verification of the measuring instrument is ± 0.4 % of the measured mass.

4.2.3 Application of maximum permissible errors

The maximum permissible errors are applicable to the mass of liquid contained in the tank or transferred into or out of the tank.

They apply for all liquids, all liquid temperatures and all liquid pressures for which the system is used or intended to be used. Any limitations found during the pattern approval evaluation will be specified in the certificate of approval. The limitations should take into account any provisions for manual adjustments, automatic corrections or checking facilities.

4.2.4 Repeatability

The difference between the results of several determinations of the same mass under the same operating conditions shall not be greater than two-fifths of the absolute value of the maximum permissible error for that mass.

4.2.5 Maximum permissible variation between indicators

The difference between the indications of the same quantity on different indicators shall not exceed one scale interval. If the value of the scale interval differs on the indicating devices, the greatest of the scale intervals is applicable.

4.2.6 Rules for the determination of errors

The rules for the determination of errors are as follows:

(a) The reference standards used for the determination of the maximum permissible errors shall have an expanded uncertainty (coverage factor $k = 2$) of not greater than one-third of the maximum permissible error specified.

(b) The maximum permissible errors apply to all instruments irrespective of their principles of operation.

(c) The maximum permissible errors are applicable for increasing and decreasing quantities.

(d) For instrument tests the instrument shall be tested in as complete a form as possible; however devices may also be tested separately. The devices which make up an instrument generally comprise the following:
   (i) one or more transducers which measure a quantity from which the mass is derived, e.g. hydrostatic pressure or buoyancy force; and
   (ii) a processor which may apply correction for ambient temperature and pressure changes and which also provides and indicates the mass output in conjunction with the necessary tank calibration table and other factors.

(e) For instrument tests the output may include information from a tank calibration table in which case this is assumed to have zero error.

(f) The initial intrinsic error is found at reference conditions of 20 ± 5 °C, atmospheric pressure, nominal supply voltage and 60 ± 15 % relative humidity.

(g) The initial intrinsic error is referenced to a straight line which passes through zero and maximum output if the output at these values can be adjusted. If the output cannot be adjusted the error as found is the initial intrinsic error.

(h) The maximum permissible errors and significant fault for the measuring instrument are applicable for the influence factors, disturbances, and humidity effect given in clause 5.

(i) The maximum permissible error and significant fault shall be rounded to the nearest scale interval.

(j) If load cells or a weighing instrument are used to measure the buoyancy of a partly submerged body, they shall comply with the metrological requirements of OIML R 60 *Metrological regulations for load cells* or OIML R 76 *Nonautomatic weighing instruments* with an appropriate class and number of verification scale intervals to achieve the required instrument maximum permissible errors.

(k) If devices are tested separately, then reduced maximum permissible errors may be applied to each device such that $p_1^2 + p_2^2 + p_3^2 + ... \leq 1$ where p_1, etc. are fractions of the maximum permissible error for the instrument. The fractions are subject to agreement between the manufacturer and the metrological authority.

4.3 Maximum value of the minimum measured quantity

The value of the minimum measured quantity shall be determined by pattern evaluation tests (see Annex D) but shall not exceed a quantity equivalent to 2 m of liquid of density 800 kg/m^3.

5 Influence factors, disturbances and humidity

5.1 Rated operating conditions for influence factors

Instruments shall be designed and manufactured so that they do not exceed the maximum permissible errors when tested over the following ranges of influence factors:

(a) mains power voltage variations:
   – 15 % to + 10 % of nominal voltage; and

(b) air temperature variations:
   – 10 °C to + 40 °C for indoor application;
   – 25 °C to + 55 °C for outdoor application.

However, other air temperature ranges may be specified depending on the use of the instrument. The instrument shall be tested for the range specified and the limits shall be marked on the instrument accordingly.

5.2 Disturbances

Electronic instruments shall be designed and manufactured so that when subjected to disturbances either a significant fault does not occur or the fault is detected and a visible or audible indication is provided in conjunction with the indication of the measurement. Such disturbances include:

(a) short time power reduction;
(b) electrical bursts;
(c) electrostatic discharge; and
(d) electromagnetic susceptibility.

The fault indication shall continue until the user takes action or the fault is corrected. This requirement may apply separately to each individual cause of significant fault and/or each part of the instrument.

The severity levels of the disturbances are given in Annex A.3.

Note: The choice of which of the above alternatives is used is left to the manufacturer.

5.3 Humidity

Electronic measuring instruments which consist of main devices with hollow, sealed spaces and normally used in outdoor applications shall have these devices subjected to the damp heat cyclic test described in Annex A.2.3.

The difference in indication at reference conditions (see subclause 4.2.6(f)) for the same input before and after the test shall not differ by more than the absolute value of the maximum permissible error for the minimum quantity.

In addition, all electronic measuring instruments, whether for indoor or outdoor application, shall be subjected to the damp heat steady state test described in Annex A.2.2.

The indication for the same input shall remain within the maximum permissible errors when applied at reference conditions before and after the test (see subclause 4.2.6(f)) and when applied at the test conditions specified in Annex A.2.2 after 48 h at these conditions.

5.4 Tests

A pattern of an instrument is presumed to comply with the requirements of subclauses 5.1 to 5.3 if it has passed the examination and tests specified in Annex A.

Section III

Technical Requirements

The following technical requirements cover the design and construction of instruments.

6 Operational requirements

6.1 Fraudulent use

Instruments shall not facilitate fraudulent use.

6.2 Suitability of construction

Instruments shall be constructed so that all controls, indicators, etc. are suitable for service under normal conditions of use.

6.3 Suitability for verification

Instruments shall be constructed so that the performance requirements of this Recommendation can be verified. In particular, provision shall be made for checking the measurement transducers on site by applying an input from a reference standard.

Provision shall be made for checking data entered into, or measured by, the instrument which is included in the measurement result.

6.4 Zero adjustment

Instruments may be provided with facilities to set the instrument to be correct when the mass measurement transducer is at zero quantity. This condition may be when the tank is empty or may be simulated by isolating the measurement transducer from the tank.

7 Indicators and printing devices

An instrument shall be provided with at least one indicator showing the gross mass. Other indicators and printers may be fitted and all shall comply with 7.1–7.6.

7.1 Clarity of indications

Indications and printing shall be clear and unambiguous and printing shall be indelible.

Digital indications shall be stable at the changeover point. All digits shall be oriented in the normal viewing position and shall permit reading by simple juxtaposition.

7.2 Units of measurement

All indications shall include the name or symbol of the unit of measurement. On tickets, the name or symbol may be printed by the printer or preprinted on the ticket.

All mass indications shall be in one of the following units of measurement:

Unit	*Symbol*
gram	g
kilogram	kg
tonne	t

Additional indications of volume, height, temperature and density shall be in the following units of measurement:

Unit	*Symbol*
cubic metre	m^3
litre	L
millimetre	mm
metre	m
kilogram/cubic metre	kg/m^3
degrees Celsius	°C

7.3 Value of the scale interval

The value of all scale intervals shall be in the form 1, 2 or 5×10^n where n is a positive or negative whole number or zero.

The value of the mass scale interval shall not be greater than the absolute value of the maximum permissible error of the minimum quantity. All indicators and printers showing the mass transferred or stored shall comply with this requirement. However, the scale interval of the various indicators may be different.

Other indicators including mass totalizers may have any value of the scale interval.

7.4 Decimal numbers

If the indication is expressed in a decimal form, there shall be at least one zero preceding the decimal mark for values less than one.

The decimal mark on tickets shall be printed with the measured value by the printer.

One or more fixed zeros may be used to the right of the variable numbers for values greater than one.

7.5 Printed information

Any printed ticket shall include sufficient information to identify the transaction, for example:

- vendor's identification;
- product identification;
- quantity;
- date of transaction;
- transaction serial number;
- tank identification; and
- user-entered parameters related to the quantity.

If the quantity measured is the difference between two measurements, both measurements shall be printed with the same transaction serial number.

7.6 Identification of measurement indication

7.6.1 General

General features of indicators include:

(a) the indicator may be located remotely from the tank being measured;

(b) more than one indicator may be used for the measuring instrument fitted to each tank;

(c) the indications from the measuring instruments of a number of tanks may be indicated on the one indicator;

(d) an indicator may indicate more than one quantity, e.g. mass, volume, density, temperature, preset quantities, totals, etc.;

(e) other measurement data may be indicated, e.g. correction factors, tank calibration data, liquid parameters, etc.;

(f) alarm and error signals may be indicated;

(g) some measurement indications may not be used for trade transactions; and

(h) the indications may be repeated on a printed ticket.

7.6.2 Requirements

The following requirements shall apply for the identification of measurement indication:

(a) the gross mass indication shall either be permanently indicated or shall be readily available by a simple action by the operator;

(b) the gross mass indication shall always be readily identifiable with a permanently affixed designation for the tank being measured;

(c) if any other mass can be indicated, e.g. preset or total, these indications shall be clearly identified;

(d) other quantities indicated shall be identified by their unit;

(e) all alarm or error signals shall be identified;

(f) non-trade indications shall be identified as such;

(g) all other measurement data shall be identified, in particular parameters which are manually entered and any resulting, calculated parameters;

(h) the above identifications shall be in the form of appropriate words or symbols; if the meaning of the symbols is not obvious (symbols for the units of measurement *are* obvious), then an explanation of the symbols shall be included either on a nameplate attached to the instrument or in an accompanying operating manual; and

(i) the requirements in (a) to (h) apply to printed tickets as well as to indicators.

8 Measurement data

8.1 General

In addition to the variable input from the measurement transducers, additional stored and manually entered data are included in order to obtain the final measurement result.

As an example, for instruments which measure hydrostatic pressure, the gross mass of the liquid consists of the calculated mass of the liquid below the pressure transducer and the measured mass of the liquid above the transducer minus the mass of vapor in the vapor space, the mass of a floating roof (when applicable) and the mass of free bottom sediment and water.

Calculation of the gross mass of the liquid involves the tank calibration table which specifies the volume of the tank at various heights.

If density is measured by means of two transducers, the distance between the transducers is required and also a temperature transducer is required to measure the average temperature between the two pressure transducers so that the density of the liquid at base temperature can be obtained.

For systems which measure the buoyancy of a partly submerged body, the ratio between the diameter of the floating body and the diameter of the tank for the full height of the body has to be obtained from the tank calibration table.

8.2 Requirements for measurement data

It is the responsibility of the manufacturer to determine the measurement data needed, the calculations required and the accuracy to which the measurements and calculations should be made. This Recommendation only specifies mandatory requirements applicable to the results of the measurement. Other documents such as ISO 11223-1 make recommendations for how the results can be achieved.

8.2.1 Maintenance of measurement information

The fixed information required for the determination of the mass shall be stored in a memory device such that the information can be verified and cannot be lost accidentally. Any variable information obtained from the measuring instruments and the fixed information at the time of a power failure shall be available for indication at least 24 h after the failure.

8.2.2 Display of data

Provision shall be made for displaying the fixed data contained in the instrument and used for obtaining the gross mass. This may be a permanent or temporary display. The display of this information shall comply with subclause 7.6.

8.2.3 Security

Fixed data used for obtaining the mass shall not be capable of being altered under normal conditions of use. Access to the information shall be protected by a suitable security means. This does not apply to information to be entered manually for a measurement, e.g. a preset quantity. In this case, the requirements of subclause 7.6 shall apply.

9 Markings

Instruments shall be clearly and permanently marked on a permanently attached nameplate in the vicinity of the indicating device with the following information:

- manufacturer's name or mark;
- instrument designation (model identification);
- serial numbers of devices and year of manufacture;
- pattern approval mark;
- class mark;
- maximum measured quantity (max....g, kg or t);
- minimum measured quantity
  transfer (min.....g, kg or t);
  inventory (min.....g, kg or t);
- scale interval (d ..... g, kg or t);
- temperature range;

- density range;
- tank identification and calibration table reference number;
- position of mass measurement transducers relative to tank datum point; and
- any other special notice relating to the instrument or its indicators.

Note: If the indicator displays measurement from more than one tank and therefore some of the above information may be different for different tanks, then this information shall be specified for each tank together with the appropriate tank reference.

10 Verification mark and sealing

10.1 Verification mark

Provision shall be made for the application of a verification mark either on a stamping plug or on an adhesive label. The following requirements apply:

(a) the mark shall be easily affixed without affecting the metrological properties of the instrument;
(b) the mark shall be visible without moving or dismantling the instrument when in use;
(c) the part on which the mark is located shall not be removable from the instrument without damaging the mark; and
(d) the size of the space shall be sufficient to contain the marks applied by the national metrology service.

10.2 Sealing

Provision shall be made for sealing those devices with parameters that determine the measurement result.

11 Construction requirements for electronic measuring instruments

11.1 General

Electronic measuring instruments shall be constructed so that they comply with the following metrological and technical requirements:

11.1.1 Influence factors

Influence factors specified in subclause 5.1 and corresponding test procedures specified in Annex A.

11.1.2 Disturbances

Disturbances specified in subclause 5.2 and corresponding test procedures specified in Annex A.

11.2 Checking facilities

The following general requirements apply to checking facilities included in the instrument to detect disturbances as specified in subclause 5.2. The methods used for checking are the responsibility of the manufacturer. Facilities other than those referred to in this section may be required to maintain the metrological performance.

11.2.1 Type

The checking facility may be either permanent automatic (type P), intermittent automatic (type I) or nonautomatic (type N) as appropriate.

11.2.2 Evaluation of checking facilities

It shall be possible during the pattern approval examination to determine the presence and correct functioning of these facilities.

11.2.3 Detection indication

If a significant fault is detected, either the instrument is made inoperative or a visual or audible indication shall automatically occur and shall continue until the user takes action or the fault or error is corrected.

11.2.4 Transducer check

During each measurement operation, e.g. during a transfer operation, check that the transducer is working correctly within expected ranges and that data transmission is correct.

11.2.5 Processor check

At the beginning and at the end of the measurement operation, all data storage devices shall be checked automatically to verify that the values of all permanently memorized instructions and data are correct.

All relevant measurement data shall be checked for correct values whenever transferred, stored internally or transmitted to peripheral equipment via the interface.

11.2.6 Indication check

If the failure of an indicator display element can cause a false indication, then the instrument shall have a display test facility which on demand shows all relevant elements of the indicator display, in both active and non-active states, for sufficient time to allow the operator to check them.

11.2.7 Ancillary check

The presence of the ancillary device and the correctness of the data transmission shall be checked. In the case of the printer, the presence of paper and the electronic control circuits (excluding the printing mechanism drive circuits) shall be checked. If a visual or audible indication of a fault is provided, it may be located on the ancillary device.

Section IV

PRACTICAL INSTALLATION REQUIREMENTS

12 Installation requirements

For instruments using hydrostatic pressure transducers, ISO 11223-1 specifies installation requirements to achieve the best accuracy of measurement. The following general requirements for installation list those requirements considered necessary to achieve the required accuracy for the measurement of mass.

12.1 Hydrostatic pressure transducers

The requirements for installing hydrostatic pressure measurement transducers are:

(a) The transducer measuring the hydrostatic pressure of the liquid shall be located at a known vertical distance from the datum point of the tank calibration table. It shall be possible to measure this distance and any uncertainty associated with the measurements can be included in the calculation of minimum quantity using the method given in Annex D.

(b) If the tank is not freely vented to the atmosphere, a transducer which measures the vapor pressure shall be mounted above the maximum liquid level. It shall be possible to measure the vertical distance from the transducer to the datum point and any uncertainty associated with the measurement can be included in the calculation of minimum quantity using the method given in Annex D.

(c) All transducers shall be mounted in positions on the tank which are subject to minimal deflections due to the effect of temperature and liquid pressure or alternatively corrections may be applied for these effects. They shall be mounted above the normal level of sediment and water in the tank and shall be protected from interference by other devices.

(d) All transducers shall be located on, or near, the tank so that the effect of the sun and wind are minimized. Alternatively, provision shall be made to protect the transducers from differences in temperature and atmospheric pressure or to equalize or minimize these effects.

(e) All transducers shall be mounted on, or near, the tank so that they can be isolated by any means from the hydrostatic pressure in the tank and a known range of pressures including atmospheric pressure, using pressure standards, can be applied to the transducer for verification purposes.

(f) Instruments which measure the hydrostatic pressure by means of a transducer located remotely from the tank shall comply with the above requirements in principle, e.g. for (a) the requirement applies to the sensing element located on the tank rather than the transducer.

12.2 Buoyancy force transducer

A buoyancy force measurement transducer includes a load cell or weighing instrument which measures the buoyancy force on a partly submerged displacer.

The requirements for installation of a buoyancy force measurement transducer are:

(a) The displacer shall be located at a known distance from the datum point of the tank calibration table. It shall be possible to measure this distance and the dimensions of the displacer and any uncertainty associated with the measurements can be included in the calculation of minimum quantity similar to the method given in Annex D.

(b) The transducer shall be mounted in a position on the tank with minimal deflections due to the effects of temperature, liquid pressure and eddies and currents in the liquid.

(c) The transducer shall be protected from excessive influence of prevailing winds and the sun which could cause variations in the measurement.

(d) The displacer shall be protected from the effects of eddies, currents or turbulence in the liquid which could cause variations in the measurement.

(e) The displacer shall be located above the normal level of sediment and water in the tank.

(f) The transducer and displacer shall be protected from interference by other devices.

(g) The transducer shall be mounted so that standard masses can be applied on site for verification purposes.

Section V

METROLOGICAL CONTROLS

13 General

The metrological control of measuring instruments consists of pattern approval, initial verification and subsequent verification.

13.1 Pattern approval

13.1.1 Documentation

Submission of an instrument to a national metrology service for pattern approval shall be accompanied by sufficient technical information (including drawings, specifications, photographs and descriptions) to ensure complete understanding of the construction and method of operation of the instrument.

Details of the measurement data contained in the memory, calculation methods and details of checking facilities shall also be provided.

For electronic measuring instruments the documentation shall include a list of electronic sub-assemblies with their essential characteristics, and a description of their electronic devices with drawings, diagrams and general software information explaining their construction and operation.

13.1.2 Sample instruments

Examination shall be carried out on at least one sample instrument submitted for laboratory tests and, if required by the national metrology service, one instrument installed on site for tests under working conditions.

The laboratory tests may be carried out on the devices of the instrument instead of the instrument.

13.1.3 Laboratory examination

The instrument shall be examined in conjunction with the submitted documentation to ensure that it complies with the technical requirements of Section III.

13.1.4 Laboratory tests

Instruments or devices of instruments tested under laboratory conditions shall comply with the maximum permissible errors for measuring instruments (subclause 4.2), the requirements for influence factors, disturbances and humidity effects (clause 5) and performance tests (Annex A).

The tests may be carried out using an appropriate reference standard which applies a simulated quantity to the instrument representing the total quantity range likely to be met in practice.

13.1.5 Field tests

Instruments tested under field conditions shall comply with the maximum permissible errors for initial and subsequent verification for measuring systems (subclause 4.2), the technical requirements of Section III, the practical requirements of Section IV and the performance tests of Annex B. Tests detailed in Annex B.1 and B.2 are optional if the tests in Annex B.3 and/or laboratory tests ensure compliance.

For the purpose of carrying out field tests, the national metrology service may require from the applicant any liquid, reference standard, transfer standard, liquid conveying equipment or any other necessary device as well as appropriate qualified personnel.

The site for carrying out field tests should be agreed upon by the metrology service and the applicant.

13.2 Initial verification

Instruments tested for initial verification shall comply with the certificate of approval, maximum permissible errors for initial and subsequent verification (subclause 4.2), the practical requirements of Section IV and the performance tests of Annex B. Tests detailed in Annex B.1 and B.2 are optional if the tests in Annex B.3 and/or laboratory tests ensure compliance.

Other conditions are the same as for subclause 13.1.5. If appropriate, field tests for pattern approval and initial verification may be combined.

13.3 Subsequent verification

Subsequent verification shall be carried out to the same conditions as for initial verification.

ANNEX A

PERFORMANCE TESTS AND EXAMINATIONS UNDER LABORATORY SIMULATED CONDITIONS

(Mandatory)

A.1 General

Performance tests carried out under the influence factors, disturbances and humidity effects specified in subclauses 5.1, 5.2 and 5.3 respectively, ensure that electronic measuring instruments perform over a range of environmental conditions likely to be met in normal use.

The instrument shall be switched on for a period of time equal to, or greater than, the warm-up time specified by the manufacturer. Power is to be "on" for the duration of each test.

Any compensating device used for temperature or pressure variations shall be set up to simulate how it would be used in practice.

The reference standard providing the input during the tests shall be kept at reference conditions as specified in subclause 4.2.6(f).

A.1.1 Tests for influence factors

At least three tests at five equally spaced, increasing and decreasing simulated quantities shall be carried out between minimum and maximum measured quantities, inclusive. The tests should first be carried out under reference conditions (subclause 4.2.6(f)) and then at each of the extreme conditions of the influence factors specified in subclause 5.1.

When the effect of one influence factor is being evaluated, all other factors shall be held relatively constant at a value close to the reference conditions specified in subclause 4.2.6(f). If applicable, the indication shall be adjusted to zero at zero quantity at reference conditions and shall not be adjusted again during the tests. If zero can be adjusted, any deviation of zero indication due to the test condition shall be recorded and indications at any test quantity shall be corrected accordingly to obtain the measurement result. If zero cannot be adjusted, no corrections shall be made.

The errors for the three tests at each quantity and each condition shall be calculated and compared with the maximum permissible errors (see subclause 4.2.2). If different electronic devices are subject to different applications, i.e. indoor or outdoor, then each shall be tested separately to the required conditions (see subclause 5.1). The errors for the three tests at each quantity shall be compared with the permissible difference for repeatability (see subclause 4.2.4). If applicable the variation between indicators shall also be checked against the permissible difference (see subclause 4.2.5).

A.1.2 Tests for disturbances

Tests for disturbances shall be carried out on all instruments, whether or not they are fitted with checking facilities.

Tests at one simulated quantity shall be carried out, firstly at reference conditions (see subclause 4.2.6(f)) and no disturbances, and then with the application of each disturbance specified in subclause 5.2. Only one disturbance at a time shall be applied. The difference between the results of tests with and without the disturbance shall be calculated and compared with the significant fault (see T.28). All indicators shall be checked.

A.1.3 Tests for humidity effects

For the damp heat, steady state test, at least three tests at five equally spaced, increasing and decreasing simulated quantities shall be carried out at the reference conditions (subclause 4.2.6(f)) before and after the application of the damp heat and at the specified damp heat.

If applicable the indication shall be adjusted to zero at zero quantity at reference conditions and shall not be adjusted again during the tests. If zero can be adjusted, any deviation of zero indication due to the test condition shall be recorded and indications at any test quantity shall be corrected accordingly to obtain the measurement result. If zero cannot be adjusted, no corrections shall be made.

The errors for the three tests at each quantity and at each condition shall be calculated and compared with the maximum permissible errors (see subclause 4.2.2). The repeatability of the three test results shall be compared with the permissible difference (see subclause 4.2.4).

For the damp heat, cyclic tests at least three tests at one simulated quantity shall be carried out at reference conditions (see subclause 4.2.6(f)) before and after the application of the damp heat. The difference between the test results obtained before and after the application of the damp heat shall be calculated and compared with the permissible change (see subclause 5.3). Any deviation in zero indication shall be treated in the same way as for damp heat, steady state tests.

A.2 Test procedures for influence factors

Additional information for carrying out the test procedures for influence factors is given below. The instrument being tested is referred to as the equipment under test (EUT).

A.2.1 Static temperature test

Test procedure in brief

The EUT shall be exposed to constant temperatures within the range specified in subclause 5.1, under "free air" conditions for 2 h after the temperature of the EUT has stabilized. The EUT shall be tested as specified in Annex A.1.1 in the following order:

(a) at 20 °C following conditioning;
(b) at the specified high temperature, e.g. 40 °C, 55 °C or other;
(c) at the specified low temperature, e.g. – 10 °C, – 25 °C or other; and
(d) again at 20 °C following conditioning.

The rate of change of temperature during the transition period between test temperatures shall not exceed 1 °C/min and the humidity of the test environment shall not exceed 20 g/m^3.

Maximum allowable variations

All functions shall operate as designed. The test results shall comply with the maximum permissible errors.

References

IEC 60068-2-1 (1990), IEC 60068-2-2 (1974) and IEC 60068-3-1 (1974).

A.2.2 Damp heat, steady state test

Test procedure in brief

The EUT shall be exposed to the applicable upper temperature specified in subclause 5.1(b) and a relative humidity of 85 % for 48 h. The handling of the EUT shall be such that no condensation of water occurs on the EUT.

The EUT shall be tested as specified in Annex A.1.3.

Maximum allowable variations

All functions shall operate as designed. The test results shall comply with the maximum permissible errors.

References

IEC 60068-2-3 (1969), IEC 60068-2-28 (1990) and IEC 60068-2-56 (1988).

A.2.3 Damp heat, cyclic (condensing) test

Test procedure in brief

The EUT shall be exposed to cyclic temperature variation between 25 °C and the applicable upper temperature specified in subclause 5.1 (b). The relative humidity shall be maintained above 95 % during the temperature change and low temperature phases, and at 93 % at the upper temperature phases. Condensation should occur on the EUT during the temperature rise.

The 24 h cycle consists of:

(a) temperature rise during 3 h;
(b) temperature maintained at upper value until 12 h after the start of the cycle;
(c) temperature lowered to lower value within 3 to 6 h, the rate of fall during the first 90 min being such that the lower value would be reached in 3 h; and
(d) temperature maintained at lower value until the 24 h cycle is completed.

The stabilizing period before, and recovery after, the cyclic exposure shall be such that all parts of the EUT are within 3 °C of their final temperature. Two cycles shall be carried out.

The EUT shall be tested as specified in Annex A.1.3.

Maximum allowable variations

All functions shall operate as designed. The test results shall comply with the maximum permissible errors.

References

IEC 60068-2-30 (1980) and IEC 60068-2-28 (1990).

A.2.4 AC power variation test

Test procedure in brief

The EUT shall be subjected to AC mains power variations specified in subclause 5.1 under constant environmental conditions. The EUT shall be tested as specified in Annex A.1.1 in the following order:

(a) at nominal voltage;
(b) at an upper limit of 110 % of nominal voltage; and
(c) at a lower limit of 85 % of nominal voltage.

The nominal voltage is that marked on the instrument.

Maximum allowable variations

All functions shall operate as designed. The test results shall comply with the maximum permissible errors.

Reference

IEC 61000-4-11 (1994).

A.3 Test procedures for disturbances

A.3.1 Short time power reduction test

Test procedure in brief

The EUT shall be subjected to short time power reductions by reducing the AC mains voltage. The test shall be conducted under constant environmental conditions.

A test generator suitable for reducing the amplitude of the AC mains voltage shall be used. The test generator shall be adjusted before connecting the EUT.

Each test shall be repeated ten times with an interval between tests of at least 10 s. The EUT shall be tested as specified in Annex A.1.2 with the following reductions:

(a) 100 % reduction in 8 ms to 10 ms; and
(b) 50 % reduction in 16 ms to 20 ms.

Maximum allowable variations

If the instrument does not detect and react to a significant fault occurring as a consequence of the short time power reduction, then the fault shall not exceed the absolute value of the maximum permissible error for the minimum quantity.

Reference

IEC 61000-4-11 (1994).

A.3.2 Electrical bursts test

Test procedure in brief

The EUT shall be subjected to electrical bursts of voltage spikes. The test shall be conducted under constant environmental conditions.

The transient generator shall have an output impedance of 50 Ω and shall be adjusted before connecting the EUT. At least ten positive and ten negative randomly phased bursts of voltage spikes with a double exponential waveform shall be applied. Each spike shall have a rise time of 5 ns and a half amplitude duration of 50 ns. The burst length shall be 15 ms, the burst period (repetition time interval) shall be 300 ms.

The EUT shall be tested as specified in Annex A.1.2 at the following amplitudes (peak values):

(a) 1 kV for power supply lines; and
(b) 0.5 kV for input/output control circuits and communication lines;

with a repetition frequency of the impulses of 5 kHz ± 20 %.

Maximum allowable variations

If the instrument does not detect and react to a significant fault occurring as a consequence of the electrical bursts, then the fault shall not exceed the absolute value of the maximum permissible error for the minimum quantity.

Reference

IEC 61000-4-4 (1995).

A.3.3 Electrostatic discharge test

Test procedure in brief

The EUT shall be subjected to electrostatic discharges under constant environmental conditions.

A capacitor of 150 pF shall be charged using a suitable DC voltage source. The capacitor shall then be discharged through the EUT by connecting one terminal to the ground (chassis) and the other via 330 Ω to surfaces which are normally accessible to the operator. At least ten discharges shall be applied. The time interval between successive discharges shall be at least 10 s. An EUT not equipped with a ground terminal shall be placed on a grounded plate which projects beyond the EUT by at least 0.1 m on all sides. The ground connection to the capacitor shall be as short as possible.

In the contact discharge mode, to be carried out on conductive surfaces, the electrode shall be in contact with the EUT and the discharge shall be actuated by the discharge switch of the generator.

In the air discharge mode, on insulating surfaces, the electrode shall be brought up to the EUT and the discharge occurs by spark.

The EUT shall be tested as specified in Annex A.1.2 at a test voltage of 6 kV for the contact mode and 8 kV for the air mode.

Maximum allowable variations

If the instrument does not detect and react to a significant fault occurring as a consequence of the electrostatic discharge, then the fault shall not exceed the absolute value of the maximum permissible error for the minimum quantity.

Reference

IEC 61000-4-2 (1995).

A.3.4 Electromagnetic susceptibility test

Test procedure in brief

The EUT shall be exposed to electromagnetic radiation under constant environmental conditions. The field strength can be generated using the following methods:

(a) the strip line is used at low frequencies (below 30 MHz or in some cases below 150 MHz) for small EUTs;

(b) the long wire is used at low frequencies (below 30 MHz) for larger EUTs; or

(c) dipole antenna or antenna with circular polarization placed 1 m from the EUT for high frequencies.

The specified field strength shall be established prior to the actual testing without the EUT in the field. The field shall be generated in two orthogonal polarizations and the frequency range shall be scanned slowly. If an antenna with circular polarization, i.e. logspiral or helical, is used to generate the electromagnetic field, a change in the position of the antenna is not required.

When the test is carried out in a shielded enclosure to comply with international laws prohibiting interference to radio communications, the effect of reflected radiation from the shield shall be negated by such means as anechoic shielding.

The EUT shall be tested as specified in Annex A.1.2 at a field strength of 3 V/m, 80 % AM, 1 kHz sine wave over a frequency range of 26 MHz–1 000 MHz.

Maximum allowable variations

If the instrument does not detect and react to a significant fault occurring as a consequence of the electromagnetic susceptibility of the instrument, then the fault shall not exceed the absolute value of the maximum permissible error for the minimum quantity.

Reference

IEC 61000-4-3 (1995).

ANNEX B

PERFORMANCE TESTS UNDER FIELD CONDITIONS

(Mandatory)

B.1 Transfer quantities

At least three tests shall be carried out by transferring a quantity at least equal to the minimum quantity to or from the tank, the quantity being measured by a reference standard or standards of the required accuracy (see subclause 4.2.6(a)). For example the liquid may be transferred into vehicle tanks for weighing on a verified weighbridge or the liquid may be transferred through a mass flowmeter which has previously been calibrated against a verified weighing instrument. Air buoyancy corrections as described in Annex C shall be considered where necessary.

The tests shall be carried out under reasonably constant conditions and over as short a period of time as possible to minimize the effects of influence factors. All results shall be within the maximum permissible errors specified in subclause 4.2 for initial and subsequent verification for measuring systems.

B.2 Tank contained quantities

At least three tests shall be carried out by comparing the indication of a quantity of liquid contained in the tank of at least the minimum quantity against the quantity measured by a reference standard or standards.

These tests can be carried out in conjunction with the transfer tests by measuring different quantities contained in the tank as the liquid is transferred. All results shall be within the maximum permissible errors specified in subclause 4.2 for initial and subsequent verifications of the measuring systems.

B.3 Indirect performance tests

The various devices may be tested separately, in which case reduced maximum permissible errors apply to each device.

B.3.1 Tank calibration table

The tank calibration information used by the instrument shall be displayed and random checks shall be made against the official calibration table for that tank. The quantities indicated shall be within ± 0.1 % of the quantity recorded on the official calibration table.

B.3.2 Measurement transducers

The position of the transducers shall be checked to ensure that they are located at the distances set in the instrument. The transducers are isolated from the tank and known inputs shall be applied from standard masses or standard pressure testers. The mass indicated by the instrument shall be compared with the mass calculated using the known transducer input, and the known factors such as gravity, density and tank tables stored in the instrument.

The error of the mass indicated shall not exceed the maximum permissible errors specified in subclause 4.2 for tests of the instrument or devices.

ANNEX C

AIR BUOYANCY CORRECTION

(Informative)

During calibration of a mass measuring instrument, there may be a need to convert the weight of liquid indicated on a weighing instrument to mass in which case air buoyancy corrections shall be made according to the equation, m = fw, where m is the mass, f is the correction factor and w is the weight indicated by a weighing instrument.

The factor, f, is given by the equation:

$f = (1 - \rho_a / \rho_p) / (1 - \rho_v / \rho)$,

where:

ρ_a is the density of air when calibrating the scale;

ρ_p is the density of the standard weights;

ρ_v is the density of gas or vapor displaced when the tank is filled;

ρ is the density of the liquid.

Note: In a closed tank (e.g. LPG) $\rho_v = 0$ as no vapor is displaced.

In accordance with OIML R 33 *Conventional value of the result of weighing in air*, the conventionally chosen values of the physical constants for air and standard weights are:

ρ_a = 1.2 kg/m^3 at 20 °C;

ρ_p = 8 000 kg/m^3 at 20 °C.

For weighing open tanks the gas displaced will be air and ρ_v will equal ρ_a. Table 1 provides values of correction factors at standard conditions for weighing open tanks.

Table 1 Air buoyancy correction

Product density (kg/m^3)	*Factor*
501.1 – 522.8	1.002 2
522.9 – 546.5	1.002 1
546.6 – 572.5	1.002 0
572.6 – 601.1	1.001 9
601.2 – 632.6	1.001 8
632.7 – 667.7	1.001 7
667.8 – 706.9	1.001 6
707.0 – 751.0	1.001 5
751.1 – 801.0	1.001 4
801.1 – 858.2	1.001 3
858.3 – 924.1	1.001 2
924.2 – 1 001.0	1.001 1
1 001.1 – 1 091.9	1.001 0
1 092.0 – 1 201.0	1.000 9
1 201.1 – 1 334.3	1.000 8
1 334.4 – 1 500.9	1.000 7
1 501.0 – 1 715.2	1.000 6
1 715.3 – 2 000.9	1.000 5

ANNEX D

CALCULATION OF THE MINIMUM QUANTITY

(Informative)

The minimum quantity is defined as "the quantity of liquid measured, below which the maximum permissible error may be exceeded" and shall be determined by pattern evaluation tests.

Figure 1 shows a typical mass measuring system fitted with hydrostatic pressure transducers. The tank is fitted with a datum plate located at the base of the tank and provides a point from which liquid level measurements are made.

The minimum quantity of liquid that can be measured within the maximum permissible error is limited by the uncertainty associated with the various parts of the measurement system. The following analysis shows how to calculate the minimum quantity that can be measured within the maximum permissible error in terms of a typical system as shown in Figure 1. The calculations include the total quantity of liquid in the tank, i.e. the quantities above and below the measurement transducer. Other calculations would be applicable for other arrangements of tanks and other measurement transducers.

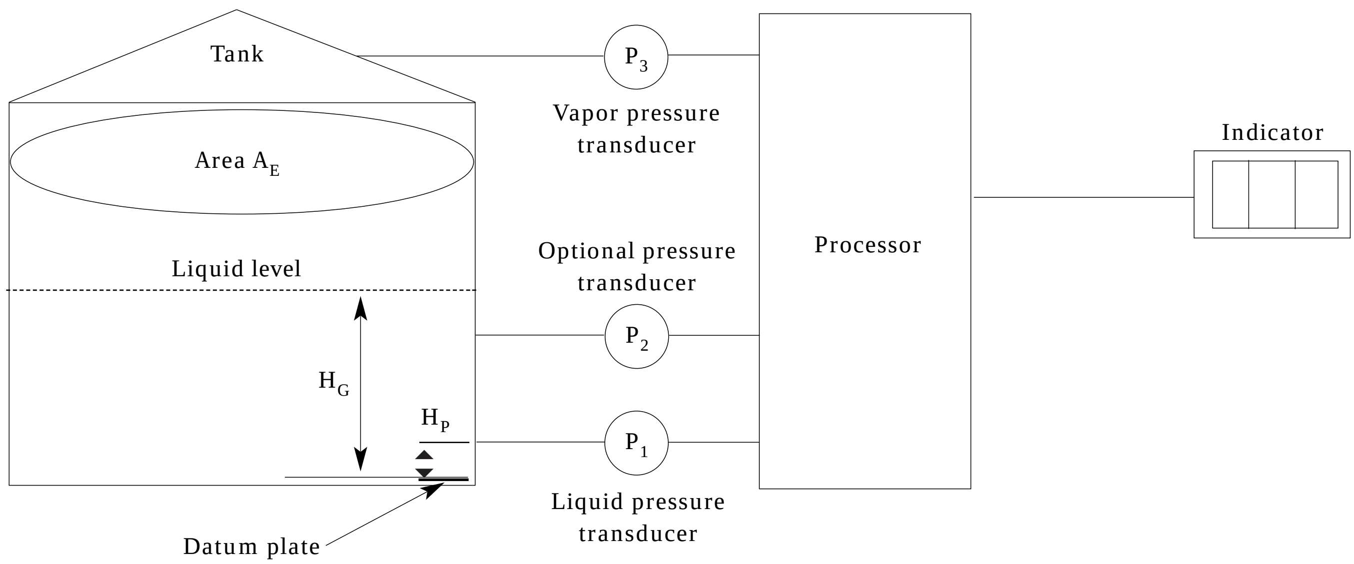


Figure 1 - A typical liquid mass measuring system

M_G = gross mass
H_P = height of pressure sensor P_1 above datum plate
H_G = height of liquid above datum plate
A_{EP} = cross-sectional area of vertical cylindrical tank at H_P
A_{EG} = cross-sectional area of vertical cylindrical tank at H_G
ρ_{H_P} = density of liquid below P_1
P_1, P_2, P_3 = pressure at sensors P_1, P_2, P_3
M_{heel} = mass of product below P_1
M_{head} = mass of product above P_1
$\Delta M_G, \Delta H_P, \Delta A_{EP}$, etc. = uncertainty of measurement of M_G, etc.

The gross mass is defined as the sum of the head mass and the heel mass, i.e. the mass of liquid above and below sensor P_1. Thus:

$$M_G = M_{heel} + M_{head} \tag{1}$$

The relative uncertainty of the gross mass is given in terms of the uncertainties in the head and heel masses and are added as the uncertainty in the head mass is random whilst the uncertainty in the heel mass is systematic. Thus:

$$\frac{\Delta M_G}{M_G} = \frac{\Delta M_{heel}}{M_G} + \frac{\Delta M_{head}}{M_G} \tag{2}$$

Other relative uncertainties are found from pattern approval tests, namely:

$$\frac{\Delta A_{EG}}{A_{EG}}, \quad \frac{\Delta P_1}{P_1}, \quad \frac{\Delta \rho_{H_P}}{\rho_{H_P}} \quad \text{... etc.}$$

The head and heel masses can be expressed in terms of the heights of the pressure sensor P_1 (H_p) and the product level (H_G) relative to the datum plate and the gross mass (M_G) as follows:

$$M_{heel} = \frac{H_P}{H_G} \times M_G \tag{3}$$

$$M_{head} = \left(1 - \frac{H_P}{H_G}\right) \times M_G \tag{4}$$

Using these expressions the gross mass can also be expressed in terms of H_P and H_G and either the head and heel mass thus:

$$M_G = \frac{H_G}{H_P} \times M_{heel} \tag{5}$$

$$M_G = \frac{1}{\left(1 - \frac{H_P}{H_G}\right)} \times M_{head} \tag{6}$$

Using the expressions given in (5) and (6), equation (2) can be rewritten for the relative uncertainty of the gross mass in terms of the heights H_P and H_G thus:

$$\frac{\Delta M_G}{M_G} = \frac{H_P}{H_G} \times \frac{\Delta M_{heel}}{M_{heel}} + \left(1 - \frac{H_P}{H_G}\right) \times \frac{\Delta M_{head}}{M_{head}} \tag{7}$$

The heel mass can be calculated from:

$$M_{heel} = H_P \times A_{EP} \times \rho_{H_P} \tag{8}$$

The relative uncertainty of the heel mass is given by:

$$\left|\frac{\Delta M_{heel}}{M_{heel}}\right| = \left|\frac{\Delta H_P}{H_P} + \frac{\Delta A_{EP}}{A_{EP}} + \frac{\Delta \rho_{H_P}}{\rho_{H_P}}\right| \tag{9}$$

or

$$\left|\frac{\Delta\ M_{heel}}{M_{heel}}\right| = \sqrt{\left(\frac{\Delta H_P}{H_P}\right)^2 + \left(\frac{\Delta A_{EP}}{A_{EP}}\right)^2 + \left(\frac{\Delta \rho_{H_P}}{\rho_{H_P}}\right)^2}$$

The head mass can be calculated from:

$$M_{head} = (P_1 - P_3) \times A_{EG} \tag{10}$$

The relative uncertainty of the head mass is given by:

$$\left|\frac{\Delta M_{head}}{M_{head}}\right| = \left|\frac{\Delta P_1 + \Delta P_3}{P_1 - P_3} + \frac{\Delta A_{EG}}{A_{EG}}\right| \tag{11}$$

or

$$\left|\frac{\Delta M_{head}}{M_{head}}\right| = \sqrt{\left(\frac{\Delta P_1 + \Delta P_3}{P_1 - P_3}\right)^2 + \left(\frac{\Delta A_{EG}}{A_{EG}}\right)^2}$$

By combining the results from equations (7), (9) and (11), an expression is obtained for the magnitude of the relative uncertainty of the gross mass in terms of H_G and H_P. Thus:

$$\left|\frac{\Delta M_G}{M_G}\right| = \frac{H_P}{H_G} \times \left|\frac{\Delta H_P}{H_P} + \frac{\Delta A_{EP}}{A_{EP}} + \frac{\Delta \rho_{H_P}}{\rho_{H_P}}\right| + \left(1 - \frac{H_P}{H_G}\right) \times \left|\frac{\Delta P_1 + \Delta P_3}{P_1 - P_3} + \frac{\Delta A_{EG}}{A_{EG}}\right| \tag{12}$$

or

$$\left|\frac{\Delta M_G}{M_G}\right| = \left|\frac{H_P}{H_G}\right| + \frac{H_P}{H_G} \times \left|\frac{\Delta A_{EP}}{A_{EP}} + \frac{\Delta \rho_{H_P}}{\rho_{H_P}}\right| + \frac{H_G - H_P}{H_G} \times \left|\frac{\Delta P_1 + \Delta P_3}{P_1 - P_3} + \frac{\Delta A_{EG}}{A_{EG}}\right| \tag{13}$$

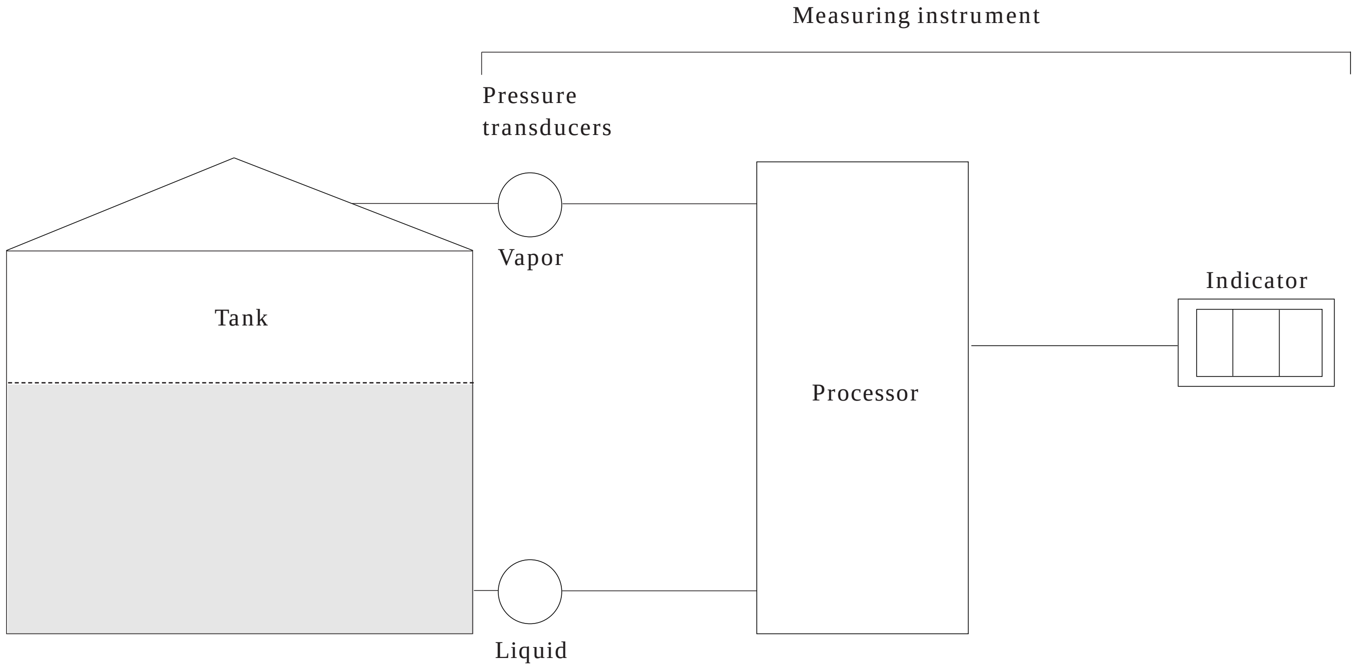
From equation (13), the value of H_G equivalent to the minimum quantity can be calculated so that the relative uncertainty of the gross mass of the minimum quantity equals the maximum permissible error, namely

$\Delta M_G / M_G = 0.5$ %.

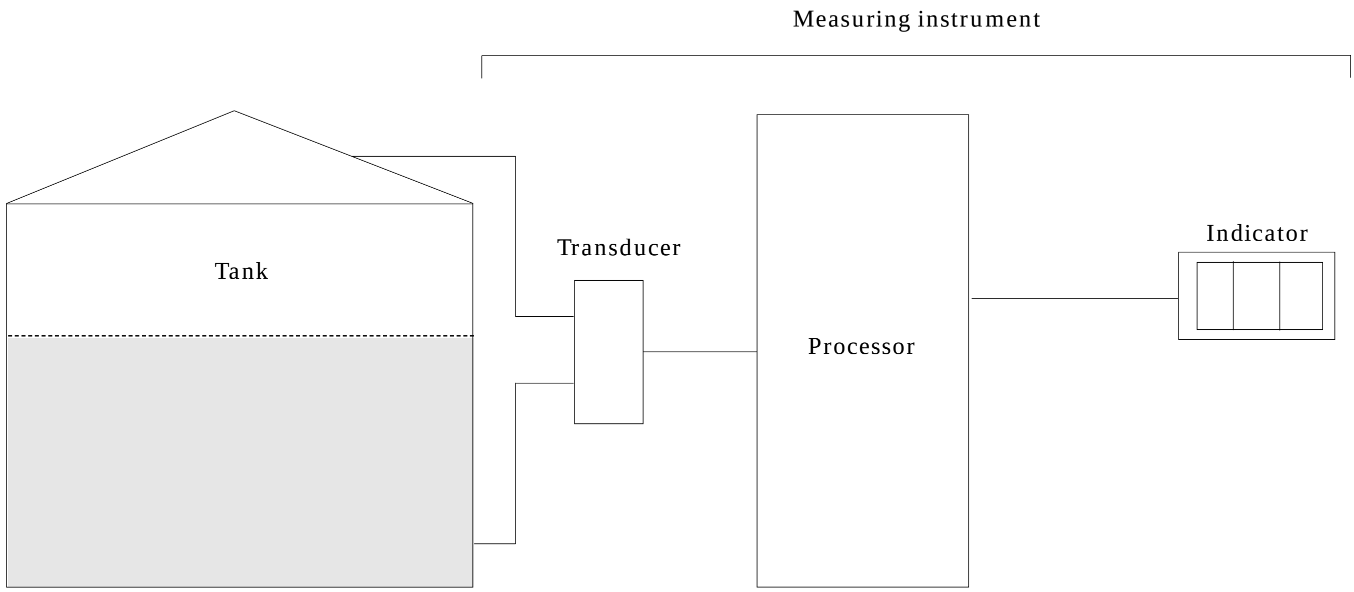
ANNEX E
DIAGRAMS SHOWING COMMON MEASURING PRINCIPLES USED
(Informative)

E.1 Hydrostatic pressure measurement

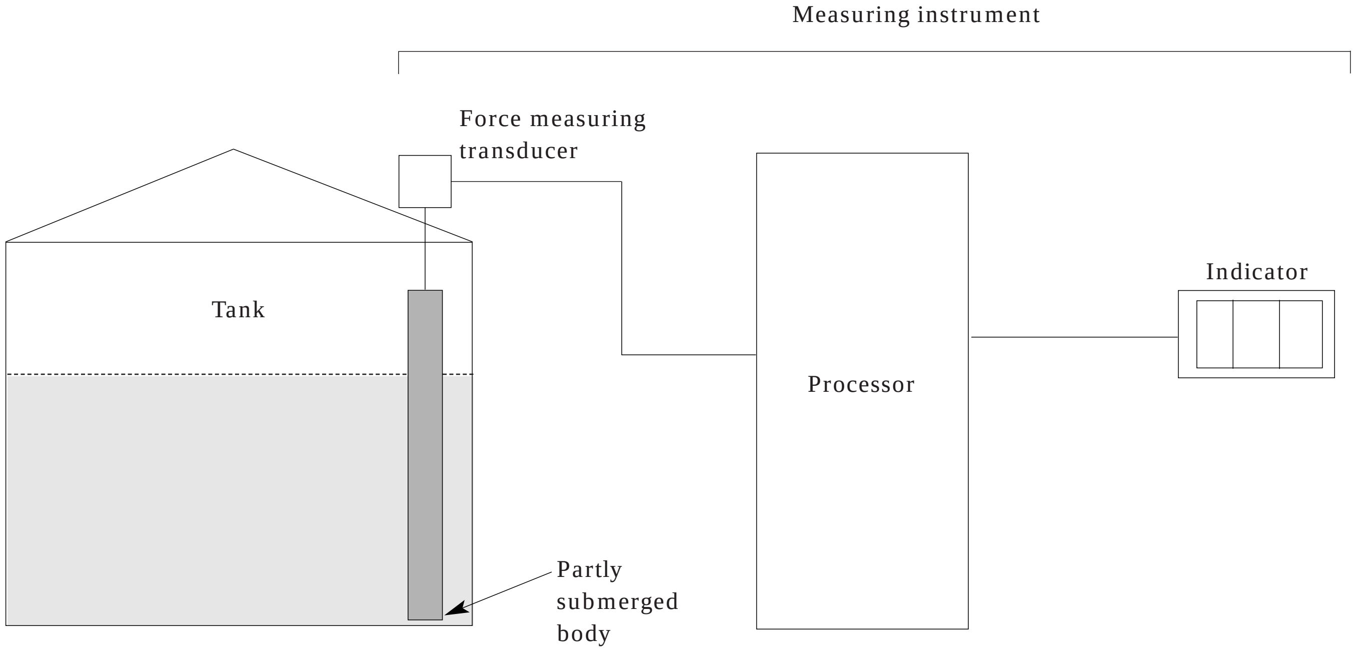
E.1.1 Transducer located on tank



E.1.2 Transducer located remote from tank



E.2 Buoyancy force measurement



ANNEX F
ALPHABETICAL LIST OF TERMINOLOGY
(Informative)

Absolute error T.22.1
Additional device T.9.2
Ancillary device T.9.1
Automatic checking facility T.34.1
Base conditions T.32
Calibrated tank T.3
Checking facility T.34
Datum point T.6
Device T.9
Disturbance T.29.2
Electronic component T.21
Electronic device T.19
Electronic mass measuring instrument T.18
Electronic sub-assembly T.20
Error of measurement T.22
External floating roof T.11
Fault T.27
Gross mass T.14
Indicator T.8
Influence factor T.29.1
Influence quantity T.29
Initial intrinsic error T.24
Intermittent automatic checking facility (Type I) T.34.1.2
Internal floating roof T.12
Intrinsic error T.23
Mass measurement transducer T.4
Mass measuring instrument T.1
Mass measuring system T.2
Maximum permissible error T.25
Maximum measured quantity T.16
Measured mass T.13
Minimum measured quantity T.15
Nonautomatic checking facility (Type N) T.34.2
Performance T.33
Performance test T.35.3
Permanent automatic checking facility (Type P) T.34.1.1
Processor T.7
Rated operating conditions T.30
Reference conditions T.31
Relative error T.22.2
Repeatability T.26
Significant fault T.28
Tank calibration table T.5
Test T.35
Test procedure T.35.1
Test program T.35.2
Vertical cylindrical tank T.10
Zero quantity T.17