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Part 2: Metrological controls and performance tests

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Dispositifs et systèmes de mesure dynamique de liquides cryogéniques
Partie 1: Exigences métrologiques et techniques,
Partie 2: Contrôles métrologiques et essais de performance

Original version in: English

Explanatory Note

Temporary section to be removed after finalization of the Recommendation

In October 2007 the CIML approved a new Technical Committee 8/Subcommittee 6 (TC8/SC6) project to revise the 1998 edition of this OIML Recommendation. This revision is Project 1~~:~~

- In 2013 a first working draft (1WD), to include the latest: (1) ISO and IEC Standards as recommended in OIML D 11 (2012), (2) developments in hydrogen measurement, (3) density equations, and (4) other relevant standards and national documents is now superseded by this draft.
- This first committee draft (1 CD) to include September 2013 TC8SC6 comments. Please note that Annex B Tables of density for liquid argon, helium, hydrogen, nitrogen and oxygen based on NIST Standard Reference Database 23 *NIST Reference Fluid Thermodynamic and Transport Properties Database (REFPROP): Version 9.0* (2010) will be updated in the 2 CD to reflect enhancements in version 9.1 (2013).

In accordance with Circular BIML 09 No. 273/RG/JFM dated 29 May 2009, the 1WD follow~~s~~ed the draft format version 1.3 encouraged by the Director of BIML for Secretariats drawing up new or making revisions to existing OIML Recommendations. The draft format consists of three parts to include Part 1: Metrological and technical requirements and Part 2: Metrological controls and performance tests in a combined publication. A separate draft publication will be distributed at a later date for Part 3: Report format for type evaluation that revises the 2006 edition of Annex D, the most current Test report format for this OIML Recommendation. The draft format facilitates the OIML Technical Committees and Subcommittees in drafting OIML Recommendations. The draft format also ensures mutual uniformity, to the greatest extent possible, in the application of guidelines, directives, requirements for electronic and software controlled instruments, and other resources that are the basis for the requirements in OIML Recommendations.

In accordance with CIML Resolution No. 2014/16 approving a new project in TC8/SC3; the revision of all parts of R 117 *Dynamic measuring systems for liquids other than water*, to include requirements and test procedures for measuring systems for liquefied natural gas (LNG) in proposed new Annex L.

~~Because of~~ Suggested revisions to the ~~1998~~2013 ~~edition~~ draft are shown by striking out text to be deleted and underlining text to be added.

Contents

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:

a) **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; OIML Member States shall implement these Recommendations to the greatest possible extent;

b) **International Documents (OIML D),** which are informative in nature and which are intended to harmonize and improve work in the field of legal metrology;

c) **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; and

d) **International Basic Publications (OIML B),** which define the operating rules of the various OIML structures and systems.

OIML Draft Recommendations, Documents and Guides are developed by Technical Committees or Subcommittees which comprise representatives from the 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 viewpoint of their author, without the involvement of a Technical Committee or Subcommittee, nor that of the CIML. Thus, they do not necessarily represent the views of the OIML.

This publication - reference OIML R 81-1 & -2, Edition 2013 - was developed by the OIML Subcommittee TC8/SC6 *Measurement of cryogenic liquids*. It was approved for final publication by the International Committee of Legal Metrology in 201# and will be submitted to the International Conference of Legal Metrology in 20## for formal sanction. It supersedes the previous edition of R 81 dated 1998.

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Dynamic measuring devices and systems for cryogenic liquids

Part 1 Metrological and technical requirements

1 Introduction

This Recommendation prescribes the metrological and technical requirements and test procedures for measuring devices and systems used for the dynamic measurement of cryogenic liquids. However, this draft contains significant editorial and technical changes from the previous edition, to include the latest: (1) ISO and IEC Standards as recommended in OIML D 11 (2013), (2) developments in hydrogen measurement, (3) density equations, (4) requirements for software controlled instruments, and (5) other relevant standards and national documents. The changes to this Recommendation also include a rework of the contents of the previous edition and a change in the order of subjects to be consistent with the format in the template for OIML Recommendations.

This OIML Recommendation consists of three parts:

Part 1: Metrological and technical requirements;
Part 2: Metrological controls and performance tests; and
Part 3: Report format for type evaluation.

Parts 1 and 2 are a combined publication and Part 3 is a separate document to be developed at a later date.

This Recommendation establishes the most current conditions that measuring devices and systems shall meet to comply with the requirements of legal metrology services.

2 Scope

This Recommendation prescribes the metrological and technical requirements and test procedures for measuring devices and systems used for the dynamic measurement of cryogenic liquids.

This Recommendation establishes the conditions that measuring devices and systems shall meet to comply with the requirements of legal metrology services.

2.1 Applicable Devices and Systems

Part 1 of the OIML Recommendation specifies the metrological and technical requirements that apply to dynamic devices and systems used in the measurement of cryogenic liquids. Part 2 provides guidelines and other criteria that apply during the initial and subsequent verification of these devices and systems in type evaluation.

In general, this Recommendation applies to all devices used for the continuous measurement of cryogenic liquids such as, but not limited to argon, ethylene, hydrogen, nitrogen and oxygen. In principle this Recommendation applies specifically for the quantitative flow measurements of cryogenic liquids, whatever the measuring methodology, whether installed in a permanent location, or mounted for use in transport and/or other containment vessels or tanks.

2.2 Nonapplicable Devices and Systems

This recommendation does not apply to the following:

- devices used for dispensing liquefied petroleum gases (see OIML R 117 (2007) *Dynamic measuring systems for liquids other than water*); or
- measuring systems used for the measurement of liquefied natural gas (also see OIML R 117 Annex L (200X) *Dynamic measuring systems for liquids other than water*).

This recommendation is not intended to prevent the development of new technologies.

3 Terminology

The vocabulary provided below has been selected so that frequently used terms relating to cryogenic liquid measuring systems will be clearly defined.

The terminology used in this Recommendation conforms to OIML V 2 (2012) *International Vocabulary of Metrology-Basic and General Concepts and Associated Terms (VIM)* [1], *to* OIML V 1 (2013) *International Vocabulary of Terms*

in Legal Metrology (VIML)[2], to OIML D 9 (2011) *Principles of metrological supervision* [3], to OIML D 11 (2013) *General requirements for electronic measuring instruments* [4], to OIML D 31 (2008) *General requirements for software controlled measuring instruments* [5] and to OIML B 3 (2011) *OIML Certificate System for Measuring Instruments* [6] (Terminology in Annex A is not all inclusive of the information in these documents).

In addition, for the purposes of this Recommendation, the following definitions and abbreviations apply:

3.1 General definitions

3.1.1 additional device

A part or a device other than an ancillary device, required to ensure correct measurement or intended to facilitate the measuring operations or which could in any way affect the measure.

Main additional devices are:

- anti-swirl devices;
- by passes;
- gas elimination devices;
- filters;
- pumps;
- devices used for the transfer point;
- valves and hoses.

3.1.2 ancillary device

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

Main ancillary devices are:

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- conversion devices;
- correction devices;
- memory devices;
- printing devices;
- remote indicators;
- repeating indicating devices;
- pre-setting devices;
- price indicating devices;
- self-service devices;
- totalizing indicating devices;
- zero setting devices.

3.1.3 attended service mode

Operating mode of a self-service arrangement in which the supplier is present and controls the authorization for the delivery.

3.1.4 base conditions

Specified values of the conditions to which the measured quantity of liquid is converted. For example, the base temperature and the base pressure of the liquid.

Note: Although the term "reference conditions" is often used instead of "base conditions", metering conditions and base conditions (which refer only to the volume of the liquid to be measured or indicated), should not be confused with the "rated operating conditions" and "reference conditions" which apply to influence quantities.

3.1.5 cryogenic liquid

A fluid with a boiling point of less than 120 K (– 153 °C) under atmospheric pressure conditions, which has been liquefied by refrigeration.

3.1.6 direct selling to the public

A transaction (selling or buying) of quantities of liquids whose settlement is associated with indications provided by a measuring system, any of the parties having access to the place of measurement and one of them being a consumer.

Note 2: The consumer can be any person. Generally, the consumer is the buyer but he can also be the seller.

3.1.7 empty-hose type

A type of system in which the discharge hose is drained after each delivery.

3.1.8 fault *(VIML 5.12)*

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

3.1.9 indicating device

A part of the meter that is capable of displaying continuously the measurement results.

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

3.1.10 master meter

A working standard, traceable to national or international standards, used for the verification of cryogenic liquid measuring devices and systems.

3.1.11 metering conditions

Values of the conditions which characterize the liquid at the point of measurement. For example, temperature and pressure of the liquid.

3.1.12 minimum measured quantity (MMQ) of a measuring system

The smallest quantity of liquid for which the measurement is metrologically acceptable.

Note: In a measuring system intended to deliver, this quantity is called the minimum delivery, and in those used for receiving operations it is called the minimum receipt.

3.1.13 minimum specified quantity deviation (E_{min})

Absolute value of the maximum permissible error for the minimum measured quantity.

3.1.14 normal boiling point

That temperature at which a liquid vaporizes or boils at the atmospheric pressure of 101 325 Pa.

3.1.15 primary indication

An indication (displayed, printed or memorized) that is subject to legal metrology control.

Note 1: Indications other than primary indications are commonly referred to as secondary indications.

3.1.16 repeatability error

The difference between the largest and the smallest results of successive measurements of the same quantity carried out under the same conditions.

3.1.17 scale interval

The difference between the scale values corresponding to two successive scale marks.

3.1.18 self service arrangement and self service device

Arrangement that allows the customer to use a measuring system to obtain a cryogenic liquid without a second party intervention. Specific device that is part of a self-service arrangement and which allows one or more measuring systems to perform in this self-service arrangement.

The self-service device includes all the basic components and integral components that are mandatory so that a measuring system performs in a self-service arrangement.

3.1.19 unattended service mode

Operating mode of a self-service arrangement in which the self-service device controls the authorization for the delivery, based on an action of the customer.

3.1.20 uncertainty in the determination of an error

An estimate characterizing the range of values within which the true value of an error lies, including contributors due to the standard and its use, and contributors due to the verified or calibrated instrument itself.

Note: The components due to a meter verified or calibrated are notably linked to the resolution of its indicating device and to the periodic variation.

3.2 Categories of instruments

3.2.1 dynamic flow measuring system

A meter, other measuring devices and instruments assembled and designed to continuously measure quantities of cryogenic liquids throughout the delivery that are subject to legal metrology control.

3.3 Construction of the instruments

3.3.1 adjustment device

A device incorporated in the meter, that only allows shifting of the error curve generally parallel to itself, with a view to bringing errors within the maximum permissible errors.

3.3.5 gas elimination device

A part or device that is required to ensure that no air, gas, or vapor is drawn into the measuring instrument or system that could affect the correct measurement of the cryogenic liquid.

3.3.2 calculator

A part of the meter that receives the output signal from the transducer(s), transforms it and, if appropriate, stores in memory the results until they are used. Additionally, the calculator may be capable of communicating both ways with the peripheral equipment.

3.3.3 conversion device

A device that automatically converts the quantity of cryogenic liquid measured at metering conditions into a quantity at base conditions, by taking account of the characteristics of the measured liquid (temperature, pressure, density, relative density, etc.) using associated measuring instruments, or associated values stored in a memory.

The ratio of the converted quantity to the quantity at metering conditions is referred to as the "conversion factor."

3.3.4 correction device

A device connected to or incorporated in the meter for automatically correcting the measured quantityat the time of measurement, by taking into account the flowrate and/or the characteristics of the liquid to be measured (viscosity, temperature, pressure, etc.) and pre-established calibration curves.

The characteristics of the liquid shall either be measured using associated measuringdevices, or stored in the memory of the instrument.

3.3.6 gas extractor

Gas elimination device used to extract air or gases accumulated in the supply line of the meter in the form of pockets that are no more than slightly mixed with the liquid.

3.3.7 gas separator

Gas elimination device used for continuously separating, and removing, any mixed air or gases contained in the liquid.

3.3.8 meter

An instrument designed to measure continuously, memorize and display the quantity of liquid that passes through the measurement transducer.

Note: A meter includes at least a measurement transducer (3.3.12), a calculator (3.3.2)(including adjustment or correction devices if present), a conversion device (3.3.3)(if necessary), and an indicating device (3.1.9).

3.3.9 pre-setting device

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

Note: The pre-set quantity may be the volume, mass, or the related total price to pay.

3.3.10 sensor

element of a measuring system that is directly affected by a phenomenon, body, or substance carrying a quantity to be measured

3.3.11 significant fault (VIML 5.14)

A fault exceeding 20 % of the maximum permissible error for the measured quantity the applicable fault limit value.

Note: The following faults are not considered to be significant faults even when they exceed 20 % mpe For particular types of measuring instruments some faults exceeding the fault limit may not be considered a significant fault. The applicable Recommendation shall state when such an exception applies. For example, the occurrence of one or some of the following faults may be acceptable:

a) faults arising from simultaneous and mutually independent causes (e.g., EM fields and discharges) originating in a measuring instrument 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;

d) faults giving rise to variations in the measurement result that are serious enough to be noticed by all those interested in the measurement result.

3.3.12 transducer

Part of the measuring device that provides an output signal, representing volume or mass, having a determined relationship to the input signal.

The transducer can either be incorporated with the meter sensor or be external to the meter sensor. In the latter case, it can be approved either with the sensor or with the calculator.

3.3.13 transfer point

The point at which the quantity of liquid measured is defined as being delivered or received.

3.3.14 zero adjustment

adjustment of a measuring system so that it provides a null indication corresponding to a zero value of a quantity to be measured

3.4 Operating conditions

3.4.1 flow rate, Q

Quotient of the actual quantity of liquid passing through the meter and the time taken for this quantity to pass through the meter.

3.4.2 maximum flow rate, Q_{max}

Highest flow rate at which a meter is required to operate within the limits of its maximum permissible error, while operated within its rated operating conditions.

3.4.3 minimum flow rate, Q_{min}

Lowest flow rate at which a meter is required to operate within the limits of its maximum permissible error, while operated within its rated operating conditions.

3.4.4 operating conditions

Conditions of the liquid (temperature, pressure and density) at which the quantity of liquid is measured.

3.5 Abbreviations

AC	Alternating Current	IUPAC	International Union of Pure and Applied Chemistry
AM	Amplitude Modulation	IUPAP	International Union of Pure and Applied Physics
BIPM	International Bureau of Weights and Measures	MMQ	Minimum Measured Quantity
DC	Direct Current	MPE	Maximum Permissible Error
EM	Electromagnetic	NBP	Normal Boiling Point
EMC	Electromagnetic Compatibility	OIML	International Organization of Legal Metrology
e.m.f.	Electromotive force	P_{max}	Maximum pressure of the liquid
E_{min}	Minimum specified quantity deviation	Q_{max}	Maximum flowrate
EST	Electrostatic Discharge	Q_{min}	Minimum flowrate
EUT	Equipment Under Test	RF	Radio frequency
FDIS	Final Draft International Standard	RH	Relative Humidity
f_{nom}	Nominal frequency	SC	Subcommittee
GUM	Guide to the expression of uncertainty in measurement [28]	TC	Technical committee
IC	Integrated circuit	T_{max}	Maximum temperature of the liquid
IEC	International Electrotechnical Committee	T_{min}	Minimum temperature of the liquid
IFCC	International Federation of Clinical Chemistry and Laboratory Medicine	U_{nom}	Marked Nominal Voltage
I/O	Input/output (refers to ports)	VIM	International vocabulary of metrology – basic and general concepts and associated terms [1]
ISO	International Organization for Standardization	VIML	International vocabulary of term in legal metrology [2]

4 Description of the instrument

4.1 Integral components of a measuring system

[Typically, meter, transfer point, pump, control devices (software, valves switches), air/gas/vapor elimination devices, piping and hose (discharge), recording device. Vapor return line on a loading rack system.]

4.1.1 The measuring system shall include at least a:

- meter,
- proper valves, hoses, lines, and
- transfer point.

4.1.2 The measuring system may also be provided with other ancillary and additional devices necessary to: Indicate its performance relative to quantity and or money values;

- prevent the facilitation of fraud;
- maintain accurate measurement;
- properly function in a particular application.

4.2 Integral components of a meter

4.2.1 A meter shall include at least a:

- calculator,
- indicating device,
- measurement transducer, and

4.2.2 A meter may include;

- adjustment device;
- correction device;
- conversion device.

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4.3 Integral components of a vehicle refueling dispenser

4.3.1 A vehicle refueling dispenser shall include at least a:

- meter,
- proper valves, hoses, lines, and
- transfer point.

4.4 Family of cryogenic liquid measuring devices or systems

4.4.1 A group of cryogenic liquid measuring devices or systems of different sizes and/or different flow rates, in which all devices or systems shall have the following characteristics:

- the same manufacturer,
- geometric similarity of the measuring part,
- the same metering principle,
- Qmax,within the range of $0.5 \times Qmax \leq Qmax \leq 2 \times Qmax$ of the family member tested
- the same accuracy class,
- the same electronic device (see A.4.10) for each meter size and using the same metrological software routines (if applicable) for those components that are critical to the performance of the meter,
- a similar standard of design and component assembly, and
- the same materials for those components that are critical to the performance of the meter.

4.5 Cryogenic liquid measuring devices or system modules

4.5.1 A module as defined in A.2.24. may include a:

- software module;
- meter module;
- indicating device.

4.5.2 A typical configuration of a cryogenic liquid measuring system is shown below in Figure 1

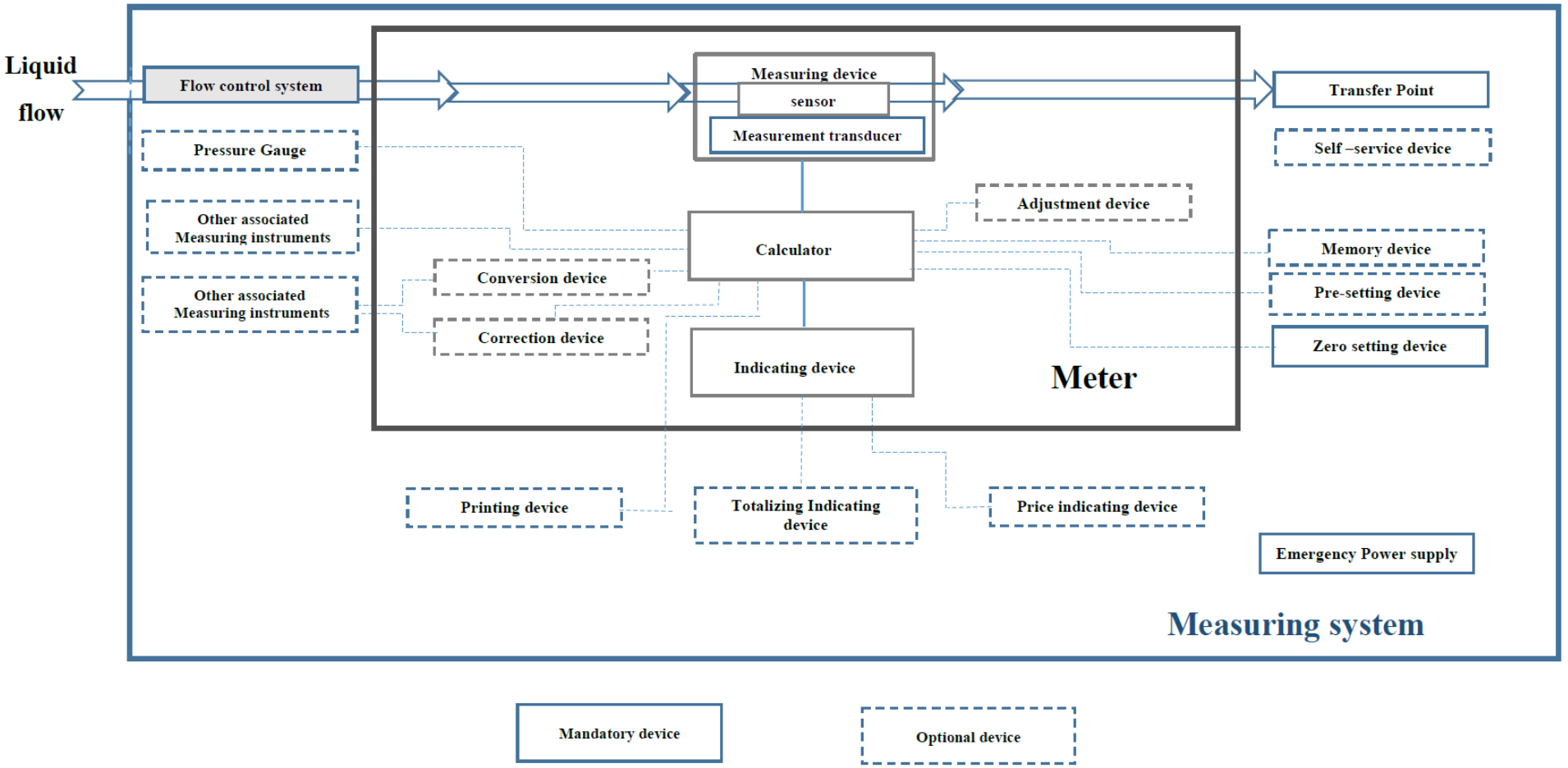

Figure 1 - Constituents of a typical cryogenic liquid measuring system

5 Units of measurement

5.1 Metric system

The measurement results shall be displayed and/or printed in one of the following measurements units according to the International System of Units (SI):

- kilogram (mass),
- litre (liquid volume at the normal boiling point), or
- cubic meter (gas equivalent of a liquid volume at base conditions).

The indicated and recorded units shall be the kilogram, litre or cubic metre, or decimal multiples or sub-multiples thereof.

5.1.1 Temperature shall be indicated in degrees Celsius or in degrees Kelvin,

5.1.2 Density shall be indicated in kilograms per cubic meter, and pressure shall be indicated in bars or Pascals (Pa, kPa, MPa).In countries where other units of mass or volume are legal, the relevant requirements specified in this Recommendation may be converted to these legal units of mass or volume using simple interpolation.

5.2 Density

The density values given in the publications listed in the “Cryogenic liquids density tables” (see Annex B) shall be used for volume-mass computations of liquid argon, helium, hydrogen, nitrogen and oxygen. For other cryogenic liquids, tables applicable under national legal metrology authorities should be used.

5.3 Symbols

Any displayed or printed measurement result shall be clearly provided with the applicable unit symbol or name.

6 Metrological requirements

6.1 Accuracy classes and their symbols

Cryogenic liquid measuring systems are accuracy class: 2.5. The value of the MPE is 2.5%

6.2 Measuring range(s)

6.2.1 Flowrates of a measuring system or a meter

6.2.1.1 The maximum and minimum authorized flowrates for a measuring system are specified by the manufacturer.

6.2.1.2 The ratio between the maximum and minimum flowrates of a measuring system shall be at least equal to 5.

6.2.1.3 The measuring range is limited by the minimum flowrate Q_{min} and the maximum flowrate Q_{max} and shall be specified by the manufacturer of the system. This measuring range shall satisfy the conditions of use of the measuring system; the latter shall be designed so that the flowrate is between the minimum flowrate and the maximum flowrate, except at the beginning and at the end of the measurement or during interruptions.

. The measuring range of a measuring system shall be within the measuring range of each of its components.

6.2.2 Minimum measured quantity

6.2.2.1 The minimum measured quantity of the system shall be specified by the manufacturer.

6.2.2.2 The minimum measured quantity shall not be less than 100 scale intervals.

6.2.2.3 The value of the minimum measured quantity shall be in the form 1×10^n or 2×10^n or 5×10^n authorized units, n being a positive or negative whole number or zero.

6.3 Maximum permissible error (MPE)

The maximum permissible errors apply for all liquids to be metered, all possible ambient conditions of temperatures and pressures, and all flowrates for which the system or the meter is intended to be used.

A measuring system or a meter shall be capable of fulfilling all requirements without adjustment or modification during the relevant evaluation procedure.

The maximum permissible errors applicable to the minimum measured quantity are twice the corresponding values as stated in 6.3.1 and 6.3.2.

Under the rated operating conditions in 6.8, the maximum permissible error (MPE) shall not exceed the following values:

6.3.1 For type approvalof a measuring system and initial verification, and subsequent verification of a measuring system under in-service conditions, the MPE is ± 2.5 % of the measured quantity.

6.3.2 For type approvalof a meter (3.3.8) , before the initial verification, and subsequent verification of the system, the MPE is ± 1.5 % of the measured quantity.

6.3.3 For type approvalof components, the MPE is:

6.3.3.1 Temperature sensor: ± 1 °C

6.3.3.2 Pressure sensor: ± 50 kPa

6.3.3.3 Density sensor: ± 5 kg/m^3

6.3.3.4 Measurement transducer: ± 1 % of measured quantity

6.3.3.5 For a calculator: ± 0.25 % of calculated quantity

6.3.3.6 For a conversion device: ± 1 % of converted quantity

6.3.3.6.1 In the case of a converted quantity indication the MPEs are as in 6.3.1

These MPEs are applicable after increasing as well as decreasing the measurand (hysteresis).

6.3.7 For initial or subsequent verification of a measuring system under in-service conditions, the MPE is ± 2.5 % of the measured quantity.

6.3.4 Correction device

6.3.4.1 Automatic correction

Cryogenic meters may be equipped with a correction device, meant to reduce the errors as close as possible to the zero value. Such correction device shall not be used for the correction of a pre-estimated drift.

1998 although not to be a definition:::::A device connected to or incorporated in the meter for automatically correcting the volume in metering conditions, by taking account of the flowrate and/or the characteristics of the liquid to be measured (viscosity, temperature, pressure, etc.) and pre-established calibration curves.

The characteristics of the liquid may either be measured using associated measuring instruments, or stored in a memory within the instrument.

6.4 Scale intervals

The scale interval of the indication shall be in the form of 1×10^n or 2×10^n or 5×10^n authorized units, n being a positive or negative whole number or zero.

6.5 Repeatability

The difference between the largest and smallest results of successive measurements conducted under similar conditions shall not be greater than 1 % of the measured quantity.

6.6 Multiple indicating devices

Multiple indicating or printing devices are permissible.

. A measuring system may have several devices indicating or printing the same measurement result. Each shall meet the requirements of this Recommendation if subject to control. The scale intervals of the various indications or printings shall be the same. For any measured quantity relating to the same measurement, there shall be no difference between the indications of multiple indicating or printing devices.

6.7 Environmental classes

Measuring systems are divided into three classes according to climatic and mechanical environmental conditions:

- class E for devices installed inlocations where electromagnetic disturbances are likely;
- class H for devices installed for use in locations where local climate is not controlled and as a result heating, cooling, and humidification conditions are either necessary under controlled conditions or apply due to local climate where use is in open air ;
- class Mfor an instrument, especially those mounted in an environment adjacent to or to machinery where there is the transmission of vibration and/or shock to the instrument, .

The following tables include the classes' corresponding test levels and descriptions for all three classifications.

Table 6.7.1 Classification based on expected electromagnetic environment

Class	Description
E1	This class applies to measuring instruments used in locations where electromagnetic disturbances correspond to those likely to be found in a residential, commercial and light industrial environment.
E2	This class applies to instruments used in locations where electromagnetic disturbances correspond to

	those likely to be found in industrial buildings.
E3	This class applies to 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.

Table 6.7.2 Classification based on expected ambient humidity and water exposure

Class	Test level Damp heat (cyclic)	Description
H1		This class applies to instruments or parts of instruments typically used in temperature-controlled enclosed (weather protected) locations. The local humidity is not controlled. Where necessary, heating, cooling or humidification is used to maintain the required environmental conditions. Measuring instruments are not exposed to condensed water, precipitation, or ice formations. These conditions may apply in living locations, continuously staffed offices, certain workshops, and other rooms for special applications.
H2	1	This class applies to instruments or parts of instruments typically used in enclosed (weather protected) locations where the local climate is not controlled. Measuring instruments present may be subject to condensed water, water from sources other than rain and to ice formations. These conditions may apply in some publicly accessible areas in buildings, garages, cellars, certain workshops, factories, industrial plants, ordinary storage rooms for frost-resistant products, farm buildings, etc.
H3	2	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.

Table 6.7.3 Classification based on expected mechanical environment

Class	Test level vibration	Description
M1		This class applies to locations with vibration and shocks of low significance, e.g. for instruments fastened to light supporting structures subject to negligible vibrations and shocks transmitted from local blasting or pile-driving activities, slamming doors, etc.
M2	1	This class applies to locations with significant or high levels of vibration and shock, e.g. transmitted from machines and passing vehicles in the vicinity or adjacent to heavy machines, conveyor belts, etc.
M3	2	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.

However, the manufacturer may specify environmental conditions, based on the intended use of the instrument or devices. The data plate and the operating instructions (see 8 and 9) shall indicate the corresponding limits of use.

6.8 Rated operating conditions

Measuring instruments according to this Recommendation shall be designed and manufactured such that their errors do not exceed the maximum permissible errors (MPEs) for initial verification as defined in 6.3, under the following rated operating conditions:

Rated operating conditions				
a)	Ambient temperature	low	+ 5 °C, - 10 °C, or - 25 ° C [(1)]	Temperature range at least 40 °C
		high	+ 30 °C, + 40 °C, or + 55 °C [(1)]	
b)	Relative humidity	up to 85 % , without condensation [(5)]		
c)	Atmospheric pressure	86 kPa - 106 kPa		
d)	Vibration less than	10 Hz - 150 Hz, 1.6 ms^{-2}, 0.05 m^2s^{-3}, -3dB/octave		
e)	DC mains voltage [(2), (3)]	As specified by the manufacturer		
f)	AC mains voltage [(2), (3)]	U_{nom} - 15 % to U_{nom} + 10 %		
h)	Voltage of internal battery [(2), (4)]	All voltages between a new or freshly charged battery, down to the lowest voltage at which the instrument functions properly within MPE, according to the specifications given by the manufacturer.		
i)	Voltage of a road vehicle battery [(2), (4)]	12 V battery	9 V - 16 V	
		24 V battery	16 V - 32 V	
j)	Temperature of the measurand cryogenic liquid [(2)]			

(1) These values are to be decided by the national authority, as it depends on the climatic conditions and the expected conditions of application (indoors, outdoors, etc.) that are different in different countries.

(2) If applicable

(3) These voltage variations are **not** those meant in 6.10.1, l) and 6.10.2, k)

(4) See also 7.7

(5) 85 % RH is the preferred severity level in OIML D 11, 10.2.

6.8.1 Interruptible and non-interruptible measuring systems

6.8.1.1 Interruptible electronic measuring systems shall be designed and manufactured such that, when they are exposed to the disturbances specified in 13.4, either:

a) significant faults do not occur, or

b) significant faults are detected and acted upon by means of checking facilities. This provision may apply separately to each individual cause of significant fault and/or each part of the measuring system.

6.8.1.2 Non-interruptible electronic measuring systems shall be designed and manufactured in such a way that no significant faults occur when they are exposed to the disturbances specified in 13.4.**6.8.1.3** It is the responsibility of the manufacturer to decide whether a given type of measuring system is interruptible or not, taking account of the applicable rules of security.

6.8.1.4 Measuring systems for direct selling to the public shall be interruptible. When, at the time of type approval, it is not possible to specify the future utilization of the instrument, the requirements in subclause 6.8.1.2 apply.

6.9 Significant fault

6.9.1 A fault exceeding 20 % of the maximum permissible error for the measured quantity is the applicable fault limit value for a significant fault.

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6.9.2 Interchangeable components

For types of cryogenic measuring systems in which some components are meant to be disconnected from each other by the user and interchangeable for operational purposes (e.g. ultrasonic transducers or meter cartridges), the following provisions shall be fulfilled:

a) it shall not be possible to access parameters that contribute to the determination of measurement

results through disconnected points unless the provisions in 10 are fulfilled; and

b) insertion of any device which may influence the accuracy shall be prevented by means of

electronic and data processing securities or, if not possible, by mechanical means.

6.9.3 When a significant fault occurs, measuring systems shall permit the retrieval of the information relating to the measured quantity, that is contained within the measuring system.

6.10 Disturbances

Measuring instruments within the scope of this Recommendation shall be designed and manufactured such that either: a) significant faults do not occur, or b) significant faults are detected and acted upon by means of a checking facilitywhen the system is exposed to disturbances listed in 6.10.1 while in operation and after exposure to the disturbances listed in 6.10.2. .

6.10.1 Test applicable to electronic equipment during disturbances

	Test method	Required severity	Nature of influence quantity	**Fault limit**
a)	Radiated, radio-frequency, electromagnetic fields	up to 3 GHz, 10 V/m	D	**NSFd**
b)	Electrostatic discharge [4]	6 kV contact discharge 8 kV air discharge	D	**NSFa[6], NSFd[4]**
c)	Bursts (transients) on mains lines	Amplitude 1 kV Repetition rate 5 kHz	D	**NSFd**
d)	AC mains voltage dips and short interruptions [2], [5]	0.5 cycles 0 % 1 cycle 0 % 25/30 [3] cycles 70 % 250/300 [3] cycles 0 %	D	**NSFd**
e)	DC mains voltage dips during 0.01 s [2], [4]	40 % & 70 % of the rated voltage	D	**NSFd**
f)	DC mains voltage variations during 0,1 s [1], [2], [4]	85 % & 120 % of the rated voltage	D	**NSFd**
g)	Electrical transient conduction along supply lines of 12 V or 24 V vehicle batteries	Pulses 2a, 3a, 3b, and 4, severity level IV according to ISO 7637-2 [27]	D	**NSFd**

[1] These voltage variations are not those meant in 6.8 e) and f)

[2] If applicable

[3] For 50 Hz/ 60 Hz respectively

[4] *[for non-integrating instruments]*

[5] Although these tests are included in OIML D 11, not all these requirements seem to be reasonable for many categories of measuring instrument.

[6] *[for integrating instruments]*

D Disturbance

I Influence factor

NSFa No significant fault shall occur after the disturbance

NSFd No significant fault shall occur during the disturbance

6.10.2 Test applicable to electronic equipment after exposure to disturbances

	Test method	Required severity	Nature of influence quantity	**Fault limit**
a)	Damp heat, cyclic (condensing)	2 cycles to 40 °C, R.H. > 93 %	D	**NSFa**

e)	Vibration (random)	total frequency range: 10 Hz – 150 Hz total RMS level: 7 m.s-2 ASD level 10 Hz–20 Hz: 1 $m^2 \bullet \cdot s^{-3}$ ASD level 20 Hz–150 Hz: –3dB/octave	I	**MPE**
f)	Electrostatic discharge [(6), (2)]	Contact discharge: 6 kV Air discharge: 8 kV	D	**NSFa[(6)], NSFd[(7)]**
j)	DC mains voltage dips during 0.01 s [(2), (6)]	40 % & 70 % of the rated voltage	D	**NSFa[(6)], NSFd[(7)]**
k)	DC mains voltage variations during 0.1 s [(1), (2), (6)]	85 % & 120 % of the rated voltage	I	MPE
l)	For instruments powered by a road vehicle battery: Transients from DC motors acting as generators after the ignition is switched off [(2), (5)]	Test pulse 2b, severity level IV according to ISO 7637-2 [...]	D	**NSFa**

(1) These voltage variations are **not** those meant in 6.8, e) and f)

(2) If applicable

(4) Although these tests are included in OIML D 11, these requirements seem not reasonable for many categories of measuring instrument.

(5) Only applicable if the measuring instrument may be connected to the battery via the main (ignition) switch of the car, i.e. if the manufacturer of the measuring instrument has **not** specified that the instrument is to be connected directly (or by it's own main switch) to the battery.

(6) *[for integrating instruments]*

(7) *[for non-integrating instruments]*

D Disturbance

I Influence factor

NSFa No significant fault shall occur after the disturbance

NSFd No significant fault shall occur during the disturbance

Note: A fault equal to or smaller than the significant fault according to 6.9 is allowed irrespective of the value of the error of indication.

Maximum allowable variation

6.10.3 Application *(Ref: OIML D 11: 5.2.1 & 5.2.2)*

The provisions in 6.10.a and 6.10.b may be applied separately to:

(a) Each individual cause of significant fault; and/or

(b) Each part of the measuring instrument.

The choice of whether 6.10.a or 6.10.b applies is left to the manufacturer.

6.10.4 Flow disturbance

For types of cryogenic meters in which the accuracy is affected by flow disturbances the shift of the error due to these disturbances shall not exceed the maximum permissible error (in absolute value) as specified in 6.3.

6.11 Durability

Cryogenic meters shall meet the following requirements after being subjected to a flow under rated operating conditions at a rate between 0.8 Q_{max} and Q_{max} comprising a quantity that is equivalent to a flow at Q_{max} during a period of 100 hours: the difference between the initial intrinsic error and the intrinsic error of a measuring instrument after the durability test shall not exceed the maximum permissible errors as specified in 6.3 .

6.11.1 For the purpose of this Recommendation an error greater than the magnitude of the MPE is a significant durability error.

6.11.2 Contrary to 6.11.1, the following errors occurring as the result of the durability test are not regarded as significant, even when they exceed the value defined in 6.11.1:

(a) The indication cannot be interpreted, memorized or transmitted as a measurement result;

(b) The indication implies the impossibility to perform any measurement;

(c) The indication is so obviously wrong that it is bound to be noticed by all those interested in the result of the measurement; or

(d) A durability error cannot be detected and acted upon due to a breakdown of the appropriate durability protection facility.

However, should the test result in either the instrument failing (a) through (d) then the test be deemed invalid and be repeated.

6.11.3 The provisions in 6.8 and 6.10 shall be met durably.

Measuring instruments according to this Recommendation shall be designed and manufactured such that either:

(a) Significant durability errors do not occur, or

(b) Significant durability errors are detected and acted upon by means of a durability protection facility.

Provisions in (a) and (b) may be applied separately to each part of the measuring instrument (for example: analogue and digital parts).

6.12 Presumption of compliance

The type of a measuring instrument according to this Recommendation is presumed to comply with the provisions in 6.1 to 6.10 if it passes the examination and tests specified in Part 2 of this Recommendation.

7 Technical requirements

7.1 Construction

Materials

A cryogenic meter shall be made of such materials and be so constructed to withstand the physical, chemical and thermal conditions to which it is likely to be subjected and to fulfill correctly its intended purposes throughout its life.

7.1.1 Maintenance of liquid state

A measuring system shall be so designed and operated that the product being measured will remain in a liquid state during passage through the meter.

7.1.2 Discharge lines and valves

7.1.2.1 Vapor return lines

A vapor return line between the supplier's tank and the customer's tank shall not be permitted

7.1.2.2 Directional flow valve

A valve(s) or other means intended to prevent flow reversal, that is (are) automatic in operation shall be installed either on the outlet side of the meter or in the inlet line of the receiving tank.

7.1.2.3 Diversion of measured liquid

No means shall be provided by which any measured liquid can be diverted from the measuring element of the meter or the discharge line therefrom. However, a manually controlled outlet that may be opened for purging or draining the measuring system shall be permitted. Effective means shall be provided to prevent the passage of liquid through any such outlet during normal operation of the measuring system.

7.1.2.4 Transfer point

7.1.2.4.1 The measuring systems shall incorporate a transfer point. This transfer point shall be located downstream of the meter in a delivery system and upstream of the meter in a receiving system.

7.1.2.4.2 This transfer point may be in the form of a closing device combined with a system which ensures the evacuation of the discharge hose after each measuring operation.

7.1.2.5 Valves and control mechanisms

Check valves and closing mechanisms not used to define the measuring quantity shall, if necessary, have relief valves in order to dissipate any abnormally high pressures which may arise in the measuring system.

7.1.2.5.1 Zero flow

The cryogenic meter totalization shall not change when the flow rate is zero, while the installation conditions are free from flow pulsations.

Note: This requirement refers to stationary operating conditions. This condition does not refer to the response of the cryogenic meter to changed flow rates or cryogenic meters equipped with a low flow cut-off feature which do not consider quantity below this flow rate value.

7.1.2.6 Discharge hose

The discharge hose of a measuring system shall be of the empty-hose type.

7.1.3 Orientation

If the manufacturer of the meter specifies the meter will only operate correctly while installed in certain orientations and marked as such, the metrological requirements mentioned in 6 shall be fulfilled for these orientations only.

In the absence of such marks the meter shall fulfill these requirements for all orientations.

7.1.4 Flow direction

7.1.4.1 If the meter is marked as able to measure the flow in both directions, the metrological requirements specified in 6 shall be met for each direction separately.

7.1.4.2 Indicating device

A cryogenic meter may be provided with a device to prevent the indicating device from functioning whenever cryogenic liquid is flowing in an unauthorized direction.

7.1.5 Pre-setting device

Measuring systems may be provided with a pre-setting device.

7.1.5.1 The selected quantity is pre-set by operating a digital device which indicates that quantity. The preset quantity shall be indicated before the start of the measurement.

7.1.5.2 Where it is possible to simultaneously view the figures of the display device of the pre-setting device and those of the quantity indicating device, the former shall be clearly distinguishable from the latter.

7.1.5.3 Indication of the selected quantity may, during measurement, either remain unaltered or progressively returns to zero. However, it is acceptable to indicate the preset value on the indicating device for quantity by means of a special operation with the restriction that this value shall be replaced by the zero indication for quantity before the measurement operation can start.

7.1.5.4 The difference found under normal operating conditions, between the pre-set quantity and the quantity shown by the quantity indicating device at the end of the measurement operation, shall not exceed the minimum specified quantity deviation.

7.1.5.5 The pre-set quantities shall be expressed in units of quantity according to 5. This unit or its legal symbol shall be marked on the pre-setting device.

7.1.5.6 The scale interval of the pre-setting device shall be equal to the scale interval of the indicating device.

7.1.5.7 Pre-setting devices may incorporate a device to permit the flow of liquid to be stopped quickly when necessary.

7.1.5.8 Measuring systems with a price indicating device may also be fitted with a price pre-setting device which stops the flow of the liquid when the quantity delivered corresponds to the pre-set price. The requirements in 7.1.5.1 to 7.1.5.7 also apply by analogy.

7.1.6 Calculator

7.1.6.1 All parameters necessary for the elaboration of indications that are subject to legal metrology control, such as unit price, calculation table, correction polynomial, etc. shall be present in the calculator at the beginning of the measurement operation.

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

7.1.7 Adjustment device

Meters may be provided with an adjustment device which permits modification of the ratio between the indicated quantity and the actual quantity of liquid passing through the meter, by a simple command. When this adjustment device modifies this ratio in a discontinuous manner, the consecutive values of the ratio shall not differ by more than 0.001.

This device shall only be used to reduce the measurement error as much as possible.

Adjustment by means of a bypass of the meter is prohibited.

7.1.8 Correction device

Meters may be fitted with correction devices, which are considered to be an integral part of the meter. This implies that the whole set of the requirements which apply to the meter is applicable to the correctedquantity values. In particular the maximum permissible errors like specified in 6.3. The aim of a correction device is to reduce the measurement error as much as possible.

During normal operation, only the corrected quantity values shall be displayed.

The use of this device for improving the errors of a meter to values other than as close as practical to zero is forbidden, even when these values are within the maximum permissible errors

Correction is only allowed on basis of actual (measured) parameters e.g., the correction device shall not allow the correction of a pre-estimated drift in relation to time or quantity.

Measuring instruments or devices associated with the execution of the correction, if any, shall comply with the applicable International Standards or Recommendations. Their accuracy shall be sufficient to permit the requirements on the meter be met, as specified in 6.3.

These associated measuring instruments shall be fitted with checking devices, as specified in 7.5.6.

7.1.9 Gas elimination device

There are several different types of gas elimination devices, including gas separators, gas extractors, and special gas extractors, which are as follows a:

Gas separator a gas elimination device used for continuously separating, and removing, any mixed air or gases contained in the liquid;

Gas extractor a gas elimination device used to extract air or gases accumulated in the supply line of the meter in the form of pockets that are no more than slightly mixed with the liquid; and

Special gas extractor a gas elimination device that, like the gas separator but under less stringent operating conditions, continuously separates any air or gases contained in the liquid, and which automatically stops the flow of liquid if there is a risk of air or gases, accumulated in the form of pockets no more than slightly mixed with the liquid, entering the meter.

7.1.9.1 General requirements

Measuring systems shall incorporate a gas elimination device for the proper elimination of any air or undissolved gases which may be contained in the liquid before it enters the meter. In the case that neither air intake nor gas release will occur in the liquid upstream of the meter, a gas elimination device is not required.

The gas elimination device shall be suitable for the supply conditions and be arranged in such a way that the effect due to the influence of the air or gases on the measurment result does not exceed:

- 0.5 % of the quantity measured for all liquids.

However, it is not necessary for this effect to be less than 1 % of the minimum measured quantity.

The values specified in this section apply to the difference between:

- the meter errors with air intake or with gas, and
- the meter errors without air intake or gas.

Gas elimination devices shall be installed in accordance with the manufacturer's instructions.

7.1.9.2 Gas removal pipe

The gas removal pipe of a gas elimination device shall not include a manually-controlled valve. However, if such a closing device is required for safety reasons, it shall be possible to ensure that the valve remains in the open position during operation by means of a sealing device or by means of a system interlock that would prevent further measurement upon valve closure.

7.1.9.3 Anti-swirl device

If the supply tank of a measuring system is normally to be completely emptied, the outlet of the tank shall be fitted with an anti-swirl device, unless the measuring system incorporates a gas separator. The anti-swirl device is designed to reduce or prevent types of flow and/or drainage (i.e., circular in nature or different to the main liquid flow) so as to limit turbulence and prevent vaporization and minimize their effect on measurement accuracy.

7.1.9.4 General provisions for gas elimination devices

7.1.9.4.1 The gas separated in a gas elimination device shall be evacuated automatically unless a device is provided which automatically either stops or sufficiently reduces the flow of liquid when there is a risk of air or gases entering the meter.

7.1.9.4.2 The operational limits of a gas elimination device are as follows:

- the maximum flowrate(s) for one or more specified liquids,
- the maximum pressure (with no flow running) and minimum pressure (with liquid and without air intake while the pump is running at maximum flowrate) compatible with the correct operation of the gas elimination device, and
- the minimum measured quantity for which it is designed.

7.1.9.5. Gas separator

Within the error limits specified in 7.1.9.1, a gas separator shall ensure the elimination of air or gases mixed with the liquid. A gas separator designed for a maximum flowrate lower than or equal to 20 m3/h shall ensure the elimination of any proportion by volume of air or gases relative to the measured liquid. A gas separator designed for a maximum flowrate higher than 20 m3/h shall ensure the elimination of 30 % air or gases relative to the measured liquid (the volumes of air or gases are measured at atmospheric pressure in determining their percentages). The percentage is considered only when the meter is running at flow rates higher than the minimum flow rate (mean value during one minute).

Furthermore, when provided, the automatic gas elimination device must continue to operate at the maximum pressure fixed for the gas separator.

7.1.9.6 Gas extractors

A gas extractor shall, at the maximum flowrate of the measuring system, ensure the elimination of an air or gas pocket of a volume (measured at atmospheric pressure) at least equal to the minimum measured quantity with no resulting additional effect greater than 1 % of the minimum measured quantity. A special gas extractor (capable of eliminating mixed gas and gas pockets), shall also be capable, at the system's maximum flowrate, of continuously separating a volume of air or gas mixed with the liquid equal to 5 % of the volume of liquid delivered (at the maximum flowrate) without the resulting additional effect exceeding the limits fixed in 7.1.9.1.

7.1.10 Flow Conditioners

For types of cryogenic meters of which the accuracy is affected by flow disturbances such cryogenic meters may be specified to be installed in piping arrangements producing only mild flow disturbances. Those meters shall be marked as such and may only be installed in those piping configurations for which their accuracy has proven to stay within sub-clause 6.10.4 requirements.

7.1.11 Conversion device

7.1.11.1 Measuring systems may be fitted with a conversion device. The provisions of 7.1.11 apply to electronic conversion devices and, by analogy, to mechanical conversion devices.

7.1.11.2 The calculation of the converted quantity shall be made according to the applicable International Recommendations or Standards, or other acceptable methods.

7.1.11.3 The parameters which characterize the measured liquid and which are employed in the conversion formula shall be measured using associated measuring devices subject to control when the parameters vary during the measurement process. However, some of these parameters may be not measured, or associated measuring devices may be not subject to control if these parameters do not vary substantially. In any case, the maximum permissible errors on converted indications due to the conversion device, shall not exceed the values specified in 6.3.3.

7.1.11.4 Associated measuring sensors and suitable provisions for testing shall be installed within a distance of one metre (1 m) of the meter wherever possible. Where this is not possible, it shall be possible to verify that the associated measuring devices are able to determine (within the maximum permissible errors as defined in 6.3) the relevant characteristic quantities of the liquid, as they exist in the measuring device.

The associated measuring devices shall not affect the correct functioning of the meter(s).

7.1.11.5 All the parameters which are not measured and which are necessary for the conversion shall be present in the calculator at the beginning of the measurement operation. It must be possible to print or to indicate them from the calculator. The device(s) used exclusively to print or indicate these nonmeasured parameters are considered to be non-critical and are only subject to tests showing their capability to correctly indicate or print these values.

For a mechanical conversion device that cannot print or indicate these values, a seal must be broken to change any setting.

For direct selling to the public, it is allowed to enter the name or type of the liquid into the calculator at the beginning of the measurement operation; it is not permitted to change any other parameter participating in conversion unless a seal is broken.

In other cases, it is allowed to select or enter the name or type of the liquid or any other data, when this data participates in the conversion of the quantity, subject to the following conditions:

- **A printing device subject to legal metrological control is mandatory;**
- **This data and a note explaining that this data has been entered manually shall be printed at the same time as the measurement results;**
- **The name or type of the liquid shall be known and printed without any ambiguity;**
- **Where the transaction does not involve direct selling to the public, the other allowed data are those which characterize the name or type of the measured liquid without any ambiguity.**

Except in the case of direct selling to the public it is allowed to replace the printing device under the following conditions:

- **in case of conversion by a memory device; or**
- **when both parties have the possibility to be present to conclude the transaction, by any appropriate means to inform the two parties of the conditions of conversion.**

The type approval certificate may indicate how to gain access to the memorized data.

7.1.11.6 In addition to the quantity at metering conditions and the volume at base conditions or the mass, which shall be displayed according to 7.2, the values of other measured quantities (density, pressure, temperature) shall be accessible for testing purposes. When only used for testing or inspection purposes, the device(s) used to access and indicate these values is(are) considered to be non-critical, and is(are) only subject to tests showing its(their) capability to correctly indicate or print these values. Scale intervals for indication of density, pressure and temperature shall be smaller than or equal to one fifth of the maximum permissible errors fixed in 6.3.3 for associated measuring devices.

7.1.11.7 The temperature sensor shall respond rapidly to temperature changes in order to measure the temperature of the liquid passing through the meter in a sufficiently accurate way.

7.2 Presentation of the measured quantity value

Indications shall be in legal units as described in 5.1 and shall be accompanied by the name or symbol of the unit. Indications that are not subjected to metrological control are allowed, provided that they cannot be confused with metrological information. Reading of the indications shall be precise, easy and non-ambiguous when the indicating device comes to rest. If the indicating device comprises several elements, the installation shall be arranged in such a way that the readings of the measurand can be effected by simple juxtaposition of the indications of the different elements.

A measuring system may have several devices indicating or printing the same measurement result. Each shall meet the requirements of this Recommendation if subject to control. The scale intervals of the various indications or printings shall be the same. For any measured quantity relating to the same measurement, there shall be no difference between the indications of multiple indicating or printing devices.

Measuring systems shall be provided with an indicating device giving the quantity of liquid measured at metering conditions.

- When a measuring system is fitted with a conversion device, it shall be possible to indicate the quantity at metering conditions and the converted quantity.

- The use of the same display for the indications of quantities at metering conditions and converted indications is permitted provided that the nature of the displayed quantity is clear and that these indications are available on request.

Provisions applicable to devices which indicate the quantity at metering conditions apply to devices which indicate the converted quantities by analogy.

7.2.1 Indicating devices (indicators)

Reading of the results (on display as well as in print) shall be reliable, easy and unambiguous under conditions of normal use.

The figures forming the results shall be of a size, shape and clarity for reading to be easy.

The continuous display of quantity during the period of measurement is mandatory.

7.2.1.1 The indicated units specified in subclause 5.1 shall be clearly defined.

7.2.1.2 The decimal mark shall appear distinctly.

7.2.1.3 Spacing

The symbol used to separate the integral part of a number from its decimal part is called the decimal marker. The decimal marker “shall be either the point on the line or the comma on the line.” The decimal marker chosen should be that which is customary in the context concerned.

If the number is between +1 and -1, then the decimal marker is always preceded by a zero.

For numbers with many digits the digits may be divided into groups of three by a thin space, in order to facilitate reading. Neither dots nor commas are inserted in the spaces between groups of three. However, when there are only four digits before or after the decimal marker, it is customary not to use a space to isolate a single digit.

For numbers in a table, the format used should not vary within one column.

7.2.1.4 External devices

- If the instruments are connected to an external printing device or data storage, the data transmission from the instruments to the printing device shall be designed so that the results cannot be falsified.

- It shall not be possible to print a document or store the measuring data in an external device for legal purposes if the instrument checking facility(ies) detect(s) a significant fault or a malfunction.

7.2.2 Totalizing indicator

An indicator with a zeroing device may be equipped with a device for totalizing the different quantities shown successively by the indicator.

Note: The totalizing indicator shall be non-resettable.

The presentation of the measuring results shall contain the names or symbols of the units of mass or volume in which they are expressed (see also 5).

The scale interval of each display or print must be in the form 1×10^n, 2×10^n, or 5×10^n units of mass or volume, n being a whole positive or negative number, or zero.

7.2.3 For analogue displays (scales), the following requirements apply:

The scale interval shall be conveniently read. During the transaction: Conveniently readable from a reasonable customer and user position so that each category of either main, intermediate, or subordinate scale intervals/graduations has uniform character, but also have sufficient variation in length width and contrast from the display background so that their value is clearly understood and distinguishable from each other and there is sufficient interval between each so as to avoid any confusion about their meaning and value.

Scale marks shall consist of lines of equal thickness; this thickness shall be constant without being less than 0.2 mm. The length of the shortest scale mark shall be at least equal to the scale spacing.

On one scale, the scale interval of numbering shall be constant.

The height of the numbers (real or apparent) expressed in millimeters shall be not less than 3 times the minimum reading distance expressed in meters, without being less than 2 mm. This height shall be proportional to the length of the scale mark to which it relates.

The width of a number, measured parallel to the base of the scale, shall be less than the distance between two consecutive numbered scale marks.

7.2.4 A digital indication or print shall display at least one figure beginning at the extreme right.

A decimal fraction shall be separated from its integer by a decimal mark (see 7.2.1.2), with the indication showing at least one figure to the left of the sign and all figures to the right.

Zero may be indicated by one zero to the extreme right, without a decimalmark.

The unit shall be chosen so that the displayed or printed values have not more than one non-significant zero to the right.

For values with decimalmark, the non-significant zero is allowed only in the third position after the decimalmark.

7.2.5 Displayed or printed numbers may be divided in groups of three in order to facilitate reading; neither dots nor commas shall be inserted in the space between groups.

The decimal marker on the display or print by the measuring instrument shall be either a comma on the line or a dot on the line. Admissibly of the comma and/or the dot is left to national legislation.

Note: In accordance with OIML policy, the dot is used the English version of this Recommendation and a comma in the French version.

7.3 Adjustment facilities

7.3.1 Adjustments

7.3.1.1 Meters shall be provided with adjusting means that permit adjustments of the ratio between the quantity indicated and the actual quantity of liquid which has passed through the measuring device.

7.3.1.2 If the adjusting means modifies this ratio in a discontinuous manner, the consecutive values of the ratio shall not differ by more than 0.001.

7.3.1.3 Adjustments by means of a by-pass on the measuring device are prohibited.

7.3.2 Zero-setting device

7.3.2.1 An indicating device may be provided with a device which returns the indication to zero either by manual operation or by automatic means.

7.3.2.2 The zero-setting device shall not permit any alteration of the measurement result shown by the indicator (other than by making the result disappear and replacing it by zeros).

7.3.2.3 Once the zeroing operation has begun it shall be impossible for the indicator to show a result different from that of the measurement which has just been made, until the zeroing operation has been completed. Indicating devices shall not be capable of being reset to zero during measurement.

7.4 Protection against fraud

A cryogenic measuring system or meter, including its ancillary devices installed according to the manufacturer's instructions, shall have no characteristics likely to facilitate its fraudulent use; neither by accidental nor by deliberate means when using the instrument in the normal manner; whereas possibilities for unintentional misuse shall be minimal. The general essential requirement dealing with fraudulent use shall be fulfilled in such a way that the interests of all parties involved in the transaction are protected.

As far as applicable, in particular the following aspects shall be taken into account:

7.4.1 Except for a reset of the indication to zero and setting the unit price, it shall be impossible to make any adjustments without breaking a seal(s) (see 10).

7.4.2 The possibility to change software shall comply with the requirements in 7.8.

7.4.3 The risk of calculated (deliberate) influence by digital telephones or static magnets shall be minimized. (For disturbances by radiated, radio frequency electromagnetic fields see also 6.10.1, a).

7.4.4 Data transmission shall comply with 7.10

7.4.5 Measuring systems may be equipped with more than one meter; however, each meter's indicated, non-resettable totalized values, and security for metrological parameters shall be unique for each meter.

7.5 Checking facilities

Electronic measuring systems shall be provided with the checking facilities specified in subclause 7.5

The action of checking facilities depends on the type of facility. The types are: 1) checking facility of type P a permanent automatic checking facility that operates at each measurement cycle [OIML D 11:2013, 3.19.1.1]; 2) checking facility of type I an intermittent automatic checking facility that operates at certain time intervals or per fixed number of measurement cycles [OIML D 11:2013, 3.19.1.2]; and 3) checking facility of type N a non-automatic checking facility requiring the intervention of an operator [OIML D 11:2013, 3.19.2].

7.5.1 Action of checking facilities

The detection by the checking facilities of significant faults shall result in the following actions~~, according to the type~~ for each function of an electronic measuring instrument, according to the:

- type of checking facility (P, I or N), as defined in A.4.18, A.4.14. and A.4.17;
- checking frequency, if appropriate; and
- method of acting upon a significant fault.

7.5.1.1 Checking facilities of types I or P

a) for non-interruptible measuring systems (such as pipelines):

• automatic correction of the fault, or

• stopping only the faulty device when the measuring system without that device continues to comply with the regulations, or

- a visible or audible alarm for the operator; this alarm shall continue until such time as the cause of the alarm is suppressed. In addition, when the measuring system transmits data to peripheral equipment, the transmission shall be accompanied by a message indicating the presence of a fault.

Note: The third bullet point above is not applicable for the disturbances specified in 13.4. In addition, the instrument may be provided with devices to estimate the amount of liquid having passed through the installation during the occurrence of the fault. The result of this estimate shall not be capable of being mistaken for a valid indication.

b) for interruptible measuring systems:

- automatic correction of the fault, or
- stopping only the faulty device, when the measuring system without that device continues to comply with the regulations, or
- stopping the flow.

7.5.2 Checking facilities for the measurement transducer

The object of these checking facilities after the presence of the transducer has been confirmed to verify its correct operation and the correctness of data transmission.

For all technologies, checking facilities shall provide a level of security equivalent to ISO 6551, part 3 Levels of security, 3.1.4 Level B, except for equipment with a cable length of 3 meters or less, for which 3.1.3 Level C applies.

Note: This requirement can be fulfilled without generating two pulses.

It shall be possible to determine the presence and correct functioning of these facilities. *(D 11: 5.3.2)*

7.5.3 Checking facilities for the calculator (Type P or I)

The object of these checking facilities is to check if the calculator system functions correctly and to ensure the validity of the calculations made.

There are no special means required for indicating that these checking facilities function correctly.

The correct value of all data relating to the measurement shall be checked by the instrument whenever these data are transmitted to an ancillary device through an interface.

In addition, the calculation system shall be provided with a means for controlling the continuity of the calculation program.

Requirements in 7.5.1 and 7.5.2 do not apply to measuring instruments or parts of measuring instruments for which the manufacturer claims compliance with the provisions in 6.8.1.1(a) and which are nevertheless equipped with checking facilities. *(D 11: 5.3.3)*

7.5.4. Checking facility for the indicating device (Type N)

The object of this checking facility is to verify that the primary indications are displayed and correspond to the data provided by the calculator.

In addition, it aims at verifying the presence of the indicating devices, when they are removable.

The checking facility for the indicating device shall include at least a visual checking of the display as follows:

- displaying all the digit segments (“eights” test);
- blanking all the digit segments (“blank” test);
- displaying “zeros”.

Each step of the sequence shall last at least 0.75 second.

Note: The produced signal shall originate from the calculator.

7.5.5 Checking facilities for an ancillary device

Any ancillary device with primary indications shall include a checking facility of type I or P. The object of this checking facility is to verify the presence of the ancillary device, when it is a necessary device, and to validate the data transmitted by the calculator.

The object of the checking of a printing device is to ensure that the printing controls function properly so that output corresponds to the data transmitted by the calculator. The presence of paper shall be checked.

Where the action of the checking facility is a warning, this shall be given on or by the ancillary device which is at its origin.

7.5.6 Checking facilities for the associated measuring instruments

Associated measuring instruments shall include a checking facility of type P. The aim of this checking facility is to ensure that the signal given by these associated instruments is within a pre-determined measuring range.

7.6 Durability protection

7.6.1 Cryogenic liquid measuring devices or systems may incorporate a facility to detect and act upon intrinsic error values considered significant after a period of use.

7.6.2 The device or system shall be provided with a means to determine the presence and correct operation of these facilities.

7.6.3 The requirements in 7.6.1 and 7.6.2 do not apply to measuring instruments or parts of measuring instruments for which the manufacturer claims are designed and manufactured such that significant durability errors do not occur and which are nevertheless equipped with durability protection facilities. *(D 11: 5.4.3)*

7.7 Battery-powered instruments

In addition to 6.10,h) and i), the following requirements apply for instruments powered by batteries:

The properties and parameters of the device or system shall not be affected during replacement of the power source.

The power source shall be able to be replaced without breaking the metrological seal.

7.7.1 Non-rechargeable batteries

Instruments powered by non-rechargeable batteries or by rechargeable batteries that cannot be (re)charged during the operation of the measuring device or system, shall comply with the following requirements:

a) the device or system provided with new or fully charged batteries of the specified type shall comply with the metrological requirements;

b) as soon as the battery voltage has dropped to a value specified by the manufacturer as the minimum value of voltage at which the device or system complies with metrological requirements, this shall be detected and acted upon by the instrument.

7.7.2 Rechargeable auxiliary batteries

Devices or systems powered by rechargeable auxiliary batteries that are intended to be (re)charged during the operation of the measuring instrument shall both:

a) comply with the requirements of 7.7.1 with the mains power switched off; and

b) comply with the requirements for AC mains powered instruments with the mains power switched on.

7.7.3 Back-up batteries

Instruments powered by the mains power and provided with a back-up battery for data-storage only, shall comply with the requirements for AC mains powered instruments.

The provisions of 7.7.1(b) and 7.7.2 do not apply for back-up batteries.

7.7.4 Road vehicle battery

Instruments powered by a road vehicle battery shall comply with the relevant requirements of 6.8 and 6.10.

7.7.5 Capacity of batteries

All functions of the device or system shall function correctly without renewing or recharging the batteries and (in particular for continuous totalizing measuring equipment) that prevent the loss of stored data.

7.8 Software

The software that is critical for metrological characteristics shall contain a routine generating an identification code that is automatically changed in case of any modification in the software. This software shall be designed such that changes in software are not possible without breaking a seal.

A fixed version number shall be assigned by the manufacturer to all software which, together with the identification code generated by the software itself, forms the full identification of the software. This version number shall be updated by the manufacturer in the case of a software change.

The instrument shall be provided with a facility to display the actual version of the identification code.

The specific software terminology is defined in Annex A section A.5 of this Recommendation which conforms to OIML D 31.

7.8.1 General requirements

7.8.1.1 Software identification

The legally relevant parts of the software of a cryogenic liquid measuring device or system and/or its components shall be clearly identified with the software version or any other token. The identification may apply to more than one part but at least one part shall be dedicated to the legal purpose.

The identification shall be inextricably linked to the software and shall be:

- presented or printed on command, or
- displayed during operation, or
- displayed at switch-on for those cryogenic meters that can be switched on and off.

If a component of the cryogenic liquid measuring device or system has no display, the identification shall be sent to some other device via a communication interface in order to be displayed on this device.

As an exception, an imprint of the software identification on the cryogenic liquid measuring device or system shall be an acceptable solution if it satisfies the three following conditions:

a) The user interface does not have any control capability to activate the indication of the software identification on the display, or the display does not technically allow the identification of the software to be shown (analogue indicating device or electromechanical counter),

b) The cryogenic liquid measuring device or system does not have an interface to communicate the software identification, and

c) After production of the cryogenic liquid measuring device or system a change of the software is not possible, or only possible if the hardware or a hardware component is also changed.

The software identification and the means of identification shall be stated in the type approval certificate.

7.8.1.2 Correctness of algorithms and functions

The measuring algorithms and functions of the cryogenic liquid measuring device or system and/or its components shall be appropriate and functionally correct.

It shall be possible to examine algorithms and functions either by metrological tests, software tests or software examination.

7.8.1.3 Software protection (against fraud)

The legally relevant software part shall be secured against unauthorized modification, loading, or changes by swapping the memory device. In addition to mechanical sealing, technical means may be necessary to protect cryogenic liquid measuring device or system equipped with an operating system or an option to load software.

Only clearly documented functions are allowed to be activated by the user interface, which shall be realized in such a way that it does not facilitate fraudulent use.

Parameters that fix the legally relevant characteristics of the cryogenic liquid measuring device or system shall be secured against unauthorized modification. For the purpose of verification, displaying of the current parameter settings shall be possible.

Note: Device-specific parameters may be adjustable or selectable only in a special operational mode of the instrument. They may be classified as those that should be secured (unalterable) and those that may be accessed (alterable parameters) by an authorized person, e.g. the instrument owner or product vendor.

Software protection comprises appropriate sealing by mechanical, electronic and/or cryptographic means, making an unauthorized intervention impossible or evident.

7.8.1.3.1 Support of fault detection

The detection by the checking facilities of significant faults may be achieved by software. In such a case, this detecting software is considered legally relevant.

The documentation to be submitted for type evaluation shall contain a list of the anomalies that might result in a significant fault but that will be detected by the software. The documentation shall include information on the expected reaction and in case needed for understanding its operation, a description of the detecting algorithm.

7.8.2 Requirements for specific configurations

7.8.2.1 Specifying and separating relevant parts and specifying interfaces of parts

Metrological relevant parts of a cryogenic liquid measuring device or system – whether software or hardware parts – shall not be influenced by other parts of the cryogenic meter outside of what is legally permissible.

This requirement applies if the cryogenic liquid measuring device or system and/or its components have interfaces for communicating with other electronic devices, with the user, or with other software parts next to the metrological critical parts.

7.8.2.1.1 Separation of components of a cryogenic meter

7.8.2.1.1.1 Components of a cryogenic liquid measuring device or system that perform functions which are relevant to legal metrology shall be identified, clearly defined, and documented. These form the legally relevant part of the cryogenic liquid measuring device or system.

7.8.2.1.1.2 It shall be demonstrated that those relevant functions and data of components cannot be influenced by commands received via an interface outside of what is legally permissible.

This implies that there is an unambiguous assignment of each command to all initiated functions or data changes in the component.

7.8.2.1.2 Separation of software parts

7.8.2.1.2.1 All software modules (programs, subroutines, objects, etc.) that perform functions which are relevant to legal metrology or that contain legal metrology relevant data domains are considered the legal metrology relevant software part of a cryogenic liquid measuring device or system. This part shall be made identifiable as described in OIML D 31 5.1.1.

If the separation of the software is not possible, all software is considered legally relevant.

7.8.2.1.2.2. If the legal metrology relevant software part communicates with other software parts, a software interface shall be defined. All communication shall be performed exclusively via this interface. The legal metrology relevant software part and the interface shall be clearly documented. All legally relevant functions and data domains of the software shall be described to enable a type evaluating authority to decide on whether this software is sufficiently separated.

The interface comprises program code and dedicated data domains. Defined coded commands or data are to be exchanged between the software parts through storing to the dedicated data domain by one software part and reading from it by the other. Writing and reading program code is considered part of the software interface.

The data domain forming the software interface shall be clearly defined and documented and include the code that exports from the legally relevant part to the interface and the code that imports from the interface to this legally relevant part. The declared software interface shall not be circumvented.

The manufacturer is responsible for respecting these constraints. Technical means (such as sealing) of preventing a program from circumventing the interface or programming hidden commands shall not be possible. The programmer of the legal metrology relevant software part as well as the programmer of the legally non-relevant part shall be provided with instructions concerning these requirements by the manufacturer.

7.8.2.1.2.3 There shall be an unambiguous assignment of each command to all initiated functions or data changes in the legally relevant part of the software. Commands that communicate through the software interface shall be declared and documented. Only documented commands are allowed to be activated through the software interface. The manufacturer shall state the completeness of the documentation of commands.

7.8.2.1.2.4 Where legal metrology relevant software has been separated from non-relevant software, the legal metrology relevant software shall have priority using the resources over non-relevant software. The measurement task (realized by the legal metrology relevant software part) must not be delayed or blocked by other tasks.

The manufacturer is responsible for respecting these constraints. Technical means for preventing a legally non-relevant program from disturbing legally relevant functions shall be provided. The programmer of the legally relevant software part as well as the programmer of the legal metrology non-relevant part shall be provided with instructions concerning these requirements by the manufacturer.

7.8.3 Shared indications

A display may be employed for presenting both information from the legal metrology relevant part of software and other information.

Software that realizes the indication of measurement values and other legally relevant information belongs to the legally relevant part.

7.8.4 Storage of data, transmission via communication systems

If measurement values will be used at a location different from the place of measurement or at a stage later than the time of measurement possibly they need to leave the cryogenic liquid measuring device or system (electronic device, sub-assembly) and be stored or transmitted in an insecure environment before they are used for legal purposes. In that case the following requirements apply:

7.8.4.1 The measurement value stored or transmitted shall be accompanied by all relevant information necessary for the future legally relevant use.

7.8.4.2 The data shall be protected by software means as to guarantee the authenticity, integrity and, if necessary the correctness of the information concerning the time of measurement. The software that displays or further processes the measurement values and the accompanying data shall check the time of measurement, authenticity, and integrity of the data after having read them from the insecure storage or after having received them from an insecure transmission channel.

The memory device shall be fitted with a checking facility to ensure that if an irregularity is detected, the data shall be discarded or marked unusable.

Software modules that prepare data for storing or sending, or that check data after reading or receiving are considered part of the legally relevant software.

7.8.4.3 When transferring measurement values through an open network, it is necessary to apply cryptographic methods. Confidentiality key-codes employed for this purpose shall be kept secret and secured in the measuring instruments, electronic devices, or sub-assemblies involved. Security means shall be provided whereby these keys can only be input or read if a seal is broken.

7.8.5 Transmission delay

The measurement shall not be influenced by a transmission delay outside of what is legally permissible.

7.8.6 Transmission interruption

If network services become unavailable, no measurement data shall be lost. The measurement process should be stopped to avoid the loss of measurement data.

7.8.7 Automatic storage

When, considering the application, data storage is required, measurement data must be stored automatically, i.e. when the final value used for the legal purpose has been generated.

The storage device must have sufficient permanency to ensure that the data are not corrupted under normal storage conditions. There shall be sufficient memory storage for any particular application.

When the final value used for the legal purpose results from a calculation, all data that are necessary for the calculation must be automatically stored with the final value.

7.8.8 Deleting of data

Stored data may be deleted when the transaction is settled;

Only after this condition is met and insufficient memory capacity is available for storage of successive data, it is permitted to delete memorized data when both the following conditions are met:

- the sequence of deletion of data will be in the same order as the recording order while the rules established for the particular application are respected, and
- the required deletion will start either automatically or after a specific manual operation.

7.8.9 Maintenance and re-configuration

Updating the legally relevant software of a cryogenic liquid measuring device or system in service shall be considered as:

- a modification of the cryogenic meter, when exchanging the software with another approved version;
- a repair of the cryogenic liquid measuring device or system, when re-installing the same version.

A cryogenic liquid measuring device or system which has been modified or repaired while in service may require initial or subsequent verification, dependent on national regulations.

This clause does not concern software sufficiently separated which has or will have no influence on metrological relevant functions or functioning of the cryogenic meter.

7.8.10 Influences from ancillary devices

A cryogenic liquid measuring device or system provided with ancillary devices shall be designed such that all functions of the ancillary devices (e.g. provisions for communication purposes) do not affect the metrological behavior.

7.9 Durable recording of the measured quantity value

7.9.1 In particular if the measurement is non-repeatable and when the typical application of the instrument is for trade in the absence of at least one of the trading parties, the measuring results shall be recorded by a durable means, accompanied by information to identify the particular measurement. This can be by means of a print (hard copy) and/or by storage in a nonvolatile memory.

7.9.2 If the instruments are connected to an external data printer or data storage, the data transmission from the instruments to the printer shall be designed so that the results cannot be falsified.

It shall not be possible to print a document or store the measuring data in an external device for legal purposes if the instrument checking facility(ies) detect(s) a significant fault or a malfunction.

7.9.3 Printing devices (printers)

For a printer, the following requirements apply in addition to the requirements for the indication of the measuring result given in 7.2:

Printing shall be clear and permanent for the intended use. If relevant, the manufacturer shall specify the type of paper to be used in order to fulfill this requirement.

Note: In particular in case of a thermal printer, it shall be ensured that the print does not fade within a reasonable time, depending on the specific application.

a) for systems equipped with the capability to issue an electronic receipt, the customer may be given the option to receive the receipt electronically (e.g., via cell phone, computer, etc.);

b) the resolution of the printed data shall be the same as the resolution of the indicating device;

c) printed figures shall be at least 2 mm high;

d) on the print-out/hard copy, the name or the symbol of the unit of measurement shall be either to the right of the value or above a column of values;

e) in the case where the printer fails (for instance being switched off, out of paper or ink, or in case of disturbed communication), a warning shall be given or the measurement shall be prohibited;

f) in case of an external printing device, the data transmission shall comply with 7.10;

g) in case of an external printing device, connected to more than one measuring instrument, the printed measuring result shall be accompanied by an identification of the measuring instrument;

h) the printed measuring result shall be accompanied by an identification of the measurement (sequence number, date and time, license plate, etc.); and

i) it shall not be possible to print out a measuring result if the instrument checking facility(ies) detect(s) a significant fault or a malfunction.

7.9.3.1 A printing device may be connected to an indicator.

7.9.3.2 The printed scale interval shall be the same as the scale interval of the indicator.

7.9.3.3 The quantity printed shall be expressed in one of the units authorized for the indicator. The unit used or its symbols, and the decimal mark if any, shall be indicated on the ticket. The printed quantities shall be adequately and clearly defined.

7.9.3.4 The printer may print other information identifying the measurement such as serial number, date, place of measurement, type of liquid, etc.

7.9.3.5 If a printer allows repetition of the printing before a new measurement has started, copies shall be clearly marked as such, for example by printing “duplicate”.

7.9.3.6 For any quantity, the printed values shall be the same as those indicated.

7.9.3.7 Printed ticket. In the case of a volume indication, the ticket shall have printed on it the base conditions in terms of the liquid.

7.9.3.8 If the measuring system is fitted with a printing device, any printing operation shall not be possible during the course of a measurement. The printing operation itself shall not initiate any change in the quantity indicated on the indicating device.

7.9.3.9 In the case of a vehicle mounted cryogenic liquid measuring device or system a ticket or invoice cannot remain in the printer without printing once the vehicle is in motion.

7.9.4 Storage of measured quantity value

For storage of the measuring results, the following requirements apply:

Measuring systems may be fitted with a memory device to store measurement results until their use or to keep a trace of commercial transactions, providing proof in case of a dispute.

Devices used to read stored information are considered as included in the memory devices. Devices used to display or print the stored measuring results shall comply with the requirements 7.2 or 7.9.3 respectively.

If external devices are needed to display and/or print stored data, these devices are considered being part of the cryogenic liquid measuring device or system, so they shall be readily available at the location of the device or system during the whole life-cycle of the device or system.

The storage of the data shall have sufficient permanency to ensure that the data are not corrupted under normal storage conditions. There shall be sufficient memory storage for any particular application. It shall be assured that means are available for future recovery of the stored data.

Memorization shall be such that it is impossible in normal use to modify stored values.

Memory devices shall be fitted with checking facilities according to 7.5.

The aim of the checking facility is to ensure that stored data correspond to the data provided by the calculator and that restored data correspond to stored data.

It shall not be possible to store the measuring data in an external device if the instrument checking facility(ies) detect(s) a significant fault or a malfunction.

7.9.4.1 The medium on which the data are stored shall have sufficient permanency to ensure that the data are not corrupted under normal storage conditions.

7.9.4.2 When the storage is full, it is permitted to delete memorized data provided that:

- data are deleted in the same order as the recording order and the rules established for the application are respected, and
- deletion can be carried out only after a special manual operation.

7.9.4.3 Memorization shall be such that it is impossible in normal use to modify stored values.

7.10 Data transmission

The instrument may be equipped with an interface permitting coupling to any peripheral devices or other instruments.

An interface shall not allow the metrological functions of the instruments or their measurement data to be influenced by the peripheral devices, by other interconnected instruments, or by disturbances acting on the interface outside of what is legally permissible.

Functions that are performed or initiated via an interface shall meet the relevant requirements and conditions of clause 7.8 and 10.1. If the instrument is connected to a data printer or an external data storage, the design of the data transmission shall ensure that the measuring results cannot be falsified.

7.11 Power supply device

When the flow is interrupted during a failure of the principal power supply device:

• the measuring system (to include vehicle fueling dispensers) shall be provided with an emergency power supply device to safeguard all the measuring functions during that failure, such that

a) continuously and automatically at least 15 minutes immediately following the failure of the

principal electrical supply, or

b) a total of at least 5 minutes in one or several periods controlled manually during one hour

immediately following the failure.

or

• data contained at the moment of the failure shall be saved and displayed on the resumption of power on an indicating device subject to legal metrology control for sufficient time to permit the conclusion of the current transaction.

8 Inscriptions

8.1 Instrument

The instrument shall have a permanent, non-transferable, and easily readable identification plate or label providing the following information:

a) manufacturer’s trade mark/corporate name;

b) year of manufacture;

c) class designation in accordance with this Recommendation;

d) type designation/model number;

e) type approval mark according to national regulations;

f) serial number of the instrument and of the measuring transducer;

g) measuring range;

h) details of the electrical power:

- in case of mains power: nominal mains voltage, frequency and power required;
- in case of power by a road vehicle battery: the nominal battery voltage and power required;
- in case of internal removable battery: the type and nominal voltage of the battery;
- if applicable: details of other power sources like portable generator, fuel cells, or solar cells.

i) specific conditions for use (for instance specific properties of the material to be measured), if applicable;

j) details about ancillary devices, if applicable;

k) if the temperature range exceeds the range prescribed in 6.8, a): this wider range;

l) identification of the software, if applicable (see 7.8).

Note: Instead of being on an identification plate, the information in may be displayed on demand through the indicating device.

8.2 External printers

External printing devices connected to the measuring instrument shall have a permanent, non-transferable, and easily readable identification plate or label giving the following information:

a) manufacturer's trade mark/corporate name;
b) type designation/model number;
c) type approval mark according to national legislation;
d) serial number;
e) identification of the measuring instrument(s) of which the measurement results can be printed;
f) details of the electrical power:
    - in case of mains power: nominal mains voltage, frequency and power required;
    - in case of power by a road vehicle battery: the nominal battery voltage and power required;
    - in case of internal removable battery: the type and nominal voltage of the battery;
    - in short form: details of other power sources like portable generator, fuel cells, or solar cell, if applicable.
g) specific conditions for use (for instance specific ambient conditions), if applicable;
h) identification of the software, if applicable (see 7.8).

8.3 Modules

Modules that perform a specific function(s) for which type approval has been granted shall be identifiable by a permanent, non-transferable and easily readable identification plate or label providing the following information:

a) manufacturer's trade mark/corporate name;
b) type designation / model number;
c) type approval mark according to national legislation;
d) serial number;
e) identification of the measuring instrument(s) of which the measurement results can be printed;
f) details of the electrical power:
    - in case of mains power: nominal mains voltage, frequency and power required;
    - in case of power by a road vehicle battery: the nominal battery voltage and power required;
    - in case of internal removable battery: the type and nominal voltage of the battery;
    - in short form: details of other power sources like portable generator, fuel cells, or solar cells, if applicable.
g) specific conditions for use (for instance specific ambient conditions), if applicable;
h) identification of the software, if applicable (see 7.8).

9 Instruction manual

9.1 Exceptions

Unless the simplicity of the measuring instrument makes this unnecessary, each individual instrument shall be accompanied by an instruction manual for the user.

9.2 Publication language

The instruction manual shall be in the official language(s) of the country (or another generally accepted language according to national legislation) and easily understandable.

It shall include:

a) operating instructions;
b) maximum and minimum storage temperatures;
c) rated operating conditions;
d) warm-up time after switching on the electrical power;
e) all other relevant mechanical and electromagnetic environmental conditions;
f) a specification of the voltage and frequency required of a portable generator, taking into account

varying load conditions typical of those encountered at the location of use, if applicable;

g) details of other power sources like fuel cells, or solar cells, if applicable;

h) for instruments, powered by an external power converter: specifications of this power converter;

i) details about compatibility with ancillary equipment, if applicable;

j) if the temperature range exceeds the range prescribed in 6.8, a), this wider range shall be included;

k) any specific installation conditions like for instance a limitation of the length of signal, data, and control lines;

l) the specifications of the battery, if applicable (see 7.7);

m) instructions for installation, maintenance, repairs, permissible adjustments (this can be in a separate document, not meant for the user/owner);

n) conditions for compatibility with interfaces, sub-assemblies (modules) or other measuring instruments.

10 Sealing and stamping

10.1 Sealing

Effective sealing devices shall be provided on all parts of the instruments that are not materially protected in another way against operations liable to affect the accuracy or the integrity of the instruments.

This applies in particular but is not limited to:

- adjustment means;
- replacement of specific parts if this replacement is expected to change the metrological characteristics;
- software integrity (see 7.8);
- correction devices;
- conversion devices.

General provision

Protection of the metrological properties of the meter is accomplished via hardware (mechanical) sealing or via electronic sealing.

In any case, memorized quantities of liquid measured (volume or mass) shall be sealed to prevent unauthorized access.

Where applicable the design of verification marks and seals is subject to national or regional legislation.

10.1.1 Mechanical sealing

Mechanical sealing shall be carried out by means of lead and wire seals or other equally effective means.

10.1.1.1 Hardware sealing (if applicable)

In case of hardware sealing the location of the marks shall be chosen in such a way that the access to the part sealed by one of these marks results in permanently visible damage to this seal.

Locations to be sealed with verification or protection marks shall be provided on the instrument:

a) On all plates which bear information prescribed by this Recommendation;

b) On all parts of the case which cannot be otherwise protected against interference likely to affect the accuracy of the measurement;

c) Seals shall be able to withstand outdoor conditions.

10.1.2 Electronic sealing

10.1.2.1 When access to parameters that affect the determination of the results of a measurement is not protected by mechanical sealing means, the protection shall fulfill the following:

- access shall only be possible by such means as an alpha or numeric code, or “hard key”;
- an event counter (000–999) shall be provided to indicate that interventions have been made.

Note: The electronic sealing device should have a means of identifying if an intervention occurs and by whom. The responsible national body may require such means as the use of labels or an event logger that includes an event counter, date and time of intervention, and the identity and value of the parameter changed.

Unrestricted access is allowed but, after changing the parameters, the instrument shall be put back into use "in sealed condition" only by authorized persons, e.g., by using a "password".

a) The code (password) shall be alterable.

b) The device shall either clearly indicate when it is in the configuration mode (not under legal metrological control), or it shall not operate while in this mode. This status shall remain until the instrument has been put into use "in sealed condition" in accordance with clause (a).

c) Identification data concerning the most recent intervention shall be recorded in an event logger. The record shall include at least:

- an identification of the authorized person that implemented the intervention; and
- an event counter or date and time of the intervention as generated by the internal clock.

In addition to the above-mentioned data the following data is to be stored:

- the old value of the changed parameter; and
- the registers´ totals.

The traceability of the most recent intervention shall be assured. If it is possible to store the records of more than one intervention, and if deletion of a previous intervention must occur to permit a new record, the oldest record shall be deleted.

10.1.2.2 For cryogenic liquid measuring devices or systems of which parts may be disconnected the following provisions shall be fulfilled:

a) Access to the parameters that contribute in the determination of results of measurements shall not be possible via a disconnected port unless the provisions in clause 10.1 are fulfilled;

b) Interposing any device which may influence the accuracy shall be prevented by means of electronic and data processing securities or, if not possible, by mechanical means; and

c) Moreover, these devices or systems shall be equipped with provisions which do not allow the meter to operate if the various parts are not configured according to the manufacturer's specifications.

Note: An unauthorized disconnection (like made by the user) may be prevented, for example, by means of a device that blocks the execution of any measurement after disconnecting and reconnecting.

10.2 Provisions for stamping

The instrument shall be provided with a stamping plate or other suitable facility to affix the relevant type approval mark(s) and verification mark(s) according to national or regional legislation.

11 Suitability for testing

The design of the instrument shall be such that initial and subsequent verification and metrological supervision can be carried out on site according to 13, 14, and 15, without unreasonable effort.

Part 2 Metrological controls and performance tests

12 Metrological controls

12.1 General

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

This chapter gives general guidelines for each of these steps.

All tests shall be carried out under the installation conditions (straight sections of piping upstream and downstream of the meter, flow conditioners, etc.) stipulated by the supplier of the type of meter to be tested.

All equipment used and incorporated as part of the execution of the test procedure shall be suitable for the testing of the meter(s) under test. The working range of all equipment and reference standards shall equal or exceed that of the meter(s) under test. All reference standards used shall be traceable to national and/or international standards of measurement.

Verification of the measuring system may be conducted by the gravimetric or volumetric method, or with a master meter. The gravimetric test method is recommended; other suitable methods may be used provided the requirements of 12.3 are met.

12.1.1 If cryogenic liquid measuring meters are to be tested in series, there should be no significant interaction between the meters. This condition may be verified by testing every meter of the series once at each position in the line.

During the tests corrections shall be made for temperature and pressure differences between the meter(s) under test and the reference standard; otherwise these differences have to be taken into account in the uncertainty calculations

The temperature and pressure measurements have to be performed at a representative position on the meter(s) under test and on the reference standard.

12.2 Responsibility for compliance with the requirements

Notwithstanding the kind of legal metrology control in a country, the manufacturer (or his formal representative) has the full responsibility that the instruments comply with the requirements in Part 1 at the moment they are delivered to the user.

After installment, the owner of the instrument has the responsibility that the instrument is well maintained and complies with the requirements in Part 1 as long as the instrument is in use. The operational presence of the instrument in his premises is considered as “in use”.

12.3 Uncertainty of test results

Every test is subject to uncertainty. The uncertainty of a measurement is defined as: non-negative parameter, characterizing the dispersion of the quantity values being attributed to a measurand based on the information used [VIM 2.26].

The uncertainty of the test method shall be taken into account in the decision on the applicability of the test method.”

The expanded uncertainty, U (for coverage factor k = 2), for the reference standard (including its indicating device), shall be less than 1/5 of the applicable maximum permissible errors of the measuring system under test for type approval and shall be less than 1/3 of the applicable maximum permissible errors of the measuring system under test for other verifications. (See Guide to the Expression of Uncertainty in Measurement, 2008).

The reference standards and their use may be the subject of other International Recommendations.

13 Type evaluation

A type of a measuring system is presumed to comply with the requirements in subclauses 6.10 and 6.10.2 if it passes the inspection and tests specified in subclause13.9.6.

Measuring systems subject to legal metrology control shall be subject to type approval. In addition, the components of a measuring system, mainly, but not limited to, those listed below, and sub-systems that may include more than one of these components, may be subject to separate type approval:

- transducer;
- meter;
- electronic calculator (including the indicating device);
- conversion device;
- devices providing or memorizing measurements results;
- printer;
- temperature sensor;
- pressure sensor;
- density sensor.

13.1 Units submitted to type test

13.1.1 The applicant shall provide the body responsible for the evaluation with an instrument representative of the final type (15.1.2.3.). Type evaluation shall be carried out on at least one unit in the family (i.e., the unit's Qmax is within the range of $0.5 \times Qmax \leq Qmax \leq 2 \times Qmax$), which represents the definitive type. The evaluation shall consist of the examination and tests specified in 13.3 and 13.4.The applicant for the type test shall supply at least one module, as defined in A.2.24, device, or measuring system for type testing. Tests are carried out on the complete measuring device or system where size and configuration permit. Otherwise, electronic devices shall be submitted separately to tests, in the form of equipment comprising at least the following devices:

- measuring transducer;
- calculator;
- indicating device;
- power supply device;
- correction device, if appropriate.

This equipment shall be included in a simulation setup representative of the normal operation of the measuring system. For example, the movement of the liquid may be simulated by an appropriate device. The calculator shall be in its final housing. In all cases, peripheral equipment may be tested separately.

In case the applicant wants to have approved several versions or measuring ranges, the testing laboratory decides which version(s) and range(s) shall be supplied.

13.1.2 As a rule, tests will be carried out on the complete measuring instrument which represents the same type. Simulation of any part of the instrument tested should be avoided. If this is not possible, all parts of the instrument that can be affected by the test must play an active role in the tests.

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

Note: As a general rule, the dismantling of the measuring instruments or devices for the tests is not intended.

In order to accelerate the test procedure, the testing laboratory may carry out different tests simultaneously on different units. In this case, the testing laboratory decides which version or measuring range will be subjected to a specific test.

All accuracy and influence tests (13.4.2) shall be performed on the same unit, but disturbance tests (13.4.3) may be carried out on not more than 2 additional instruments. See table 13.1.2.

Table 13.1.2	
Tests that shall be carried out on one and the same specimen	Tests that may be divided amongst no more than 2 additional instruments
· Repeatability · Durability	· Ambient temperature test · Vibration test · Power supply voltage variation tests · Verification of checking facilities · Damp heat test · Radiated and conducted RF EM · Dips and interruptions · Bursts on mains and control lines · DC ripple · Surges on mains and control lines · Electrostatic discharge

If a specimen does not pass a specific test and as a result and it has to be modified or repaired, the applicant shall carry out this modification to all the instruments supplied for test. After this modification, at least 2 different specimens shall be subjected to this particular test. If the testing laboratory has sound reasons to fear that the modification has negative influence on tests that already had a positive result, these tests shall be repeated.

13.2 Documentation

The application for type evaluation of a measuring system or of a component of a measuring system shall include the following documents:

- description giving the technical characteristics and the principle of operation;
- photograph;
- a list of the components with a description of their type of materials. When this has a metrological influence, an assembly drawing with identification of different components, for measuring systems, the references of the approval certificates of the components, if any, for measuring systems and for meters fitted with integral parts that change the measurement result (e.g., describe how the correction devicedetermines the correction parameters), a description of the way the intergral part operatesto determine the measurement;
- drawing showing the location of seals and verification marks;
- drawing of regulatory markings.

In addition, the application for type approval of an electronic measuring system shall include:

- a functional description of the various electronic devices;
- a flow diagram of the logic, showing the functions of the electronic devices;
- any document or evidence which shows that the design and construction of the electronic measuring system complies with the requirements of this Recommendation;
- lists of the essential sub-assemblies, components (in particular electronics and other essential ones) with their essential characteristics;
- mechanical drawings;
- electric/electronic diagrams;
- installation requirements;
- security sealing plan;
- panel layout;
- general information on the software required for a micro-processor equipped measuring instrument;
- In particular the requirement that the conformity of the device or system and their checking facilities comply with the provisions of 7.5 shall be covered;
- test outputs, their use, and their relationships to the parameters being measured;
- operating instructions that shall be provided to the user,

If the testing laboratory deems this necessary, it can require more detailed documentation; either to be able to study the quality of the instrument, or to be able to lay down the approved type, or both.

13.3 Examinations

Examinations and testing of instruments are intended to verify compliance with the requirements of Part 1 of this Recommendation.

Design inspection

This examination of documents aims at verifying that the design of electronic devices and their checking

facilities comply with the provisions of this Recommendation. It includes:

- an examination of the mode of construction and of the electronic sub-systems and its components used, to verify their appropriateness for the intended use;
- considering faults likely to occur, to verify that in all considered cases these devices comply with the provisions of subclause 7.5;
- verification of the presence and effectiveness of the test device(s) for the checking facilities.

13.3.1 The instrument and the documentation shall be given a visual inspection to obtain a general appraisal of its design and construction and the documentation shall be studied.

In particular, the following aspects shall be examined:

units *(5)*;

accuracy classes and their symbols *(6.1)*;

measuring ranges *(6.2)*;

scale intervals *(6.4)*;

construction *(7.1)*;

presentation of the measured quantity value *(7.2)*;

adjustment facilities *(7.3)*;

protection against fraud *(7.4)*;

checking facilities *(7.5)*;

durability protection *(7.6)*;

software *(7.8)*;

durable recording of measuring results *(7.9)*;

printing device *(7.9.3)*;

storage of measured quantity value *(7.9.4)*;

data transmission *(7.10)*;

inscriptions *(8)*;

instruction manual *(9)*;

sealing and stamping *(10);*

suitability for testing *(11)*.

13.3.2 The instrument shall be submitted to performance tests specified in 13.4 to determine its correct functioning under various conditions.

13.4 Performance tests

General

These tests intended to ensure that measuring systems perform and function as prescribed in a specified environment and under specified conditions. Where appropriate, each test indicates the reference conditions under which the intrinsic error is determined.

When the effect of one influence quantity is being evaluated, all other influence quantities are to be held relatively constant, at values close to reference conditions. When the effect of a disturbance is being evaluated, no other disturbance shall be present and all influence quantities shall be held relatively constant, at values close to reference conditions. Every test is subject to uncertainty. The uncertainty of a measurement is defined as: parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand. [VIM 3.9].

Relatively stable test conditions for each of the parameters

of the liquid are as follows:

- temperature: ± 5 °C;
- pressure: ± 20 % not to exceed 200 kPa (2 bar);
- flowrate: ± 5 %.

The instrument should be tested with the liquid to be commercially measured or with a liquid of the same general physical characteristics.

• class E for devices installed inlocations where electromagnetic disturbances are likely;

• class H for devices installed for use in locations where local climate is not controlled and as a result heating, cooling, and humidification conditions are either necessary under controlled conditions or apply due to local climate where use is in open air;

• class M for an instrument, especially those mounted in an environment adjacent to or to machinery where there is the transmission of vibration and/or shock to the instrument.

Severity levels (see OIML D 11)

For each performance test, typical test conditions are indicated that correspond to the climatic and mechanical environment conditions to which measuring systems are usually exposed. Measuring systems are divided into three classes according to the climatic and mechanical environment conditions:

• class Efor a fixed instrument installed inlocations where electromagnetic disturbances are likely;

• class Hfor a fixed instrument installedfor use in locations where local climate is not controlled and as a result heating, cooling, and humidification conditions are either necessary under controlled conditions or apply due to local climate where use is in open air;

• class M for an instrument, especially those mounted in an environment adjacent to or to machninery where there is the transmission of virbration and/or shock to the instrument .

The applicant for type approval may define specific environmental conditions for the future use of the equipment in the documentation supplied to the metrology service. In this case, the metrology service carries out the tests at severity levels corresponding to these specific environmental conditions. If type approval is granted, the data plate shall indicate the corresponding limits of use. Conditions of use for which the instrument is approved shall be provided by the manufacturers. The metrology service shall verify that the conditions of use are met.

Test		*Nature of the influence quantity*	*Severity class/level (reference OIML D11)*		
			E	H	M
13.4.2.2.1	Dry Heat	Influence factor	2	3	3
13.4.2.2.2	Cold	Influence factor	2	3	3
13.4.2.2.3	Damp heat, cyclic	Disturbance	1	2	2
13.4.2.3	Vibration (random)	Influence factor	~~-~~1	-	~~3~~
13.4.2.4.1	DC power supply voltage variation	Influence factor	1	1	1

Test		*Nature of the influence quantity*	*Severity class/level (reference OIML D11)*		
			E	H	M
13.4.2.4.2	AC power supply voltage variations	Influence factor	1	1	1
?????????					
13.4.3.1	Electromagnetic susceptibility	Disturbance	2	2	2
13.4.3.2	Electrostatic discharge	Disturbance	1	1	1
13.4.3.3	Bursts	Disturbance	2	2	2
13.4.3.4	AC mains voltage dips, short interruptions and voltage reduction	Disturbance	1a & 1b	1a & 1b	1a & 1b
13.4.3.5	Perturbations on DC voltage powered instruments	Disturbance	2	2	2

13.4.a) Tests for maximum errors

13.4, a)i Flow rates for tests of the maximum errors of the meter

The errors of the meter shall be determined for at least the minimum number of flowrates (N_f) (for example, at Qmax, 80 % Qmax, 70 % Qmax, 50 % Qmax, 40 % Qmax and at Qmin), distributed over the measuring range at regular intervals; where, N_f is the number of flowrates as specified in the following table. At each flowrate the errors shall be determined at least three times under identical test conditions, independently. Each error shall not be greater than the maximum permissible error (in absolute value), as specified in 6.3. The repeatability shall meet the requirements of 6.5.

Qmax/Qmin	N_f
< 5	3
5 - 9	5
10 -12	6
13 - 21	7
22 - 35	8
> 35	9

13.4 a)ii Flow rates for tests of maximum errors

The measuring system shall be tested at the maximum flowrate achievable under the conditions of installation, the minimum flowrate marked on the instrument, and at least one intermediate flowrate. At least one test shall be conducted at each flowrate (see 13.4.a)i).

Note: For subsequent verification, see subclause 15.1.2.c).

13.4.b) Other tests

The following tests shall also be carried out:

- test for maximum errors (13.4, a)i) at minimum measured quantity, if practical;
- tests with flow disturbances, if appropriate.

13.4.b), i Performance tests – Influence factors and disturbances on measuring systems

These tests aim at verifying that the measuring system complies with the provisions of subclause 13.4.2 as regards influence quantitiesand for disturbances are specified in 13.4.3, respectively.

a) Performance under the effect of influence factors

When subjected to the effect of influence factors as provided for in the 13.4.2, the equipment shall continue to operate correctly and the errors shall not exceed the applicable maximum permissible errors.

b) Performance under the effect of disturbances

When subjected to external disturbances as provided for in the 13.4.3, the equipment shall either continue to operate correctly or detect and indicate the presence of any significant fault. Significant faults shall not occur on non-interruptible measuring systems.

13.4.c) Test conditions

13.4.c)i Vaporization

Care shall be exercised to reduce vaporization and volume changes to a minimum. When testing gravimetrically, the weigh tank and transfer systems shall be pre-cooled to the temperature of the liquid prior to the start of the test to avoid the venting of vapor from the vessel being weighed.

13.4.c)ii Test liquid

The system shall be tested with the liquid to be measured, except that another cryogenic liquid of the same physical characteristics may be used if evidence can be provided indicating that the alternate test liquid to be used will provide equivalent performance under the required test conditions.

The EUT should be tested with sufficient liquid or liquids with similar characteristics over the range of liquids for which the manufacturer has requested approval (see 13.4.c)iii). When the meter is intended to measure different liquids, the test should be carried out with the liquid that provides the most severe conditions of use.

13.4.c)iii Test quantities

Any test quantity shall be equal to or greater than the minimum measured quantity.

The minimum test quantity shall normally not be less than 300 scale intervals of the meter under test and 1000 scale intervals of the master meter, whichever is the smallest. However, the test quantity for determining the error near the minimum measured quantity shall be equal to the minimum measured quantity.

Note 1: For a flying start-stop test (that is, a test to determine the time interval required to collect a preselected weight of liquid), when the uncertainty in the standard can be maintained as specified in clause12.3, smaller test quantities may be used. However, in no case shall the test quantity be less than 140 kg for devices having a maximum flowrate of at least 50 l/min, as specified by the manufacturer.

Note 2: When testing with a master meter, the test quantity shall be equal to at least the amount delivered in 3 minutes at its maximum discharge rate. When testing uncompensated meters in a continuous recycle flow, appropriate corrections shall be applied if product conditions are abnormally affected by this test mode.

13.4.d) Repeatability tests conducted to determine compliance with 6.5

Repeatability tests shall be conducted with quantities equal to or greater than five times the minimum measured quantity.

13.4.e) Simulated tests

Except for 13.4.2.3, the tests may be conducted by simulating the flow without any actual product passing through the measuring system, if it can be shown that the flow sensor is not affected by the test conditions.

Note 1: Simulated flow must produce an output or outputs from the measuring system corresponding to an actual flowrate between the minimum and maximum flowrates for the system.

Note 2: While flow is being simulated, it must be possible to ascertain that the flow measurement capabilities of the system are fully operational.

13.4.f) Pre-set test

For those systems consisting of a console and dispensers and equipped with pre-set quantity, the dispenser must deliver at least the pre-set quantity; it cannot deliver less. For example, if the console sends only the money equivalent of the pre-set quantity to the dispenser, the dispenser shall deliver at least the pre-set quantity. It may not stop at the first quantity amount that results in mathematical agreement with the money value equivalent of the pre-set quantity if the quantity indication is less than the pre-set quantity. Similarly, if a money value is pre-set, the dispenser is not properly designed if it always stops at the lowest quantity value that provides mathematical agreement with the pre-set money value.

Tests for agreement of digital values shall be performed in the postpay, prepay money, and pre-set quantity modes. Agreement should be checked at several unit prices including the maximum unit price and with the dispenser operating at its maximum flow rate.

13.4.1 Reference conditions

Except for the parameter being tested, the following reference conditions shall be kept by the testing laboratory during the tests:

Table 13.4.1

	Influence	**Value**
a)	Temperature	20 °C ± 2 °C[3]
b)	Humidity	65 % RH ± 5 %
c)	Atmospheric pressure	Ambient pressure, stable within 10 hPa[3]
d)	Vibration	Negligible [2]
e)	DC mains voltage [1]	Less than 10 % of the variation specified by the manufacturer of the EUT
f)	AC mains voltage [1]	U_{nom} ± 1 %
g)	Voltage of a road vehicle battery [1]	Stable (except for the voltmeter and the EUT, no other equipment connected. [2]
h)	Radiated, radio-frequency, electromagnetic fields	< 0,2 V/m [2]
i)	Conducted radio-frequency fields [1]	< 0,2 V e.m.f. [2]
j)	Electrostatic discharge	none
k)	Power frequency magnetic field	< 1 A/m [2]
l)	Bursts (transients) on signal, data and control lines [1]	negligible [2]
m)	Surges on signal, data and control lines [1]	negligible [2]
n)	AC mains voltage dips, short interruptions and voltage variations [1]	negligible [2]
o)	Bursts (transients) on AC and DC mains [1]	negligible [2]
p)	Ripple on DC mains power [1]	negligible [2]
q)	Surges on AC and DC mains power [1]	None [2]

(1)	If applicable
(2)	As in a normal laboratory condition these conditions can be expected to be fulfilled without specific measures, it is usually not deemed necessary to measure/monitor these values.
(3)	The temperature and pressure of the measured liquid shall be recorded during the test for the determination of density or volume correction factors, when applicable (see Annex B).

13.4.2 Error under rated operating conditions

The type of measuring instrument is presumed to comply with the provisions specified in 6.3 to 6.10 of this Recommendation, if it passes the tests (13.4.2.2 - 13.4.2.4.2), confirming that the error of the measuring instrument does not exceed the maximum permissible error specified in 6.3 under the reference conditions in 13.4.1.

13.4.2.1 Maximum permissible error under reference conditions

This test is applied to verify compliance with the requirements 6.3, and 6.5 to 6.7 under reference conditions.

The error curve shall be established for at least 5 values of the measurand, evenly spaced over the measuring range, with both increasing and decreasing measurand.

In case of multiple indicating/printing devices, the indication of all these devices shall be recorded for every value of the measurand.

Precondition:	Normal electrical power supplied and “on” for a time period equal to or greater than the warm-up time specified by the manufacturer. Adjust the EUT as close to zero indication as practicable prior to the test.
Condition of the EUT:	Power is to be “on” for the duration of the test. The EUT shall not be readjusted at any time during the test.
Test	After stabilization at the relevant temperature, apply at least 5 different test measurands (increasing and decreasing, and slowly add or subtract a value equal to the MPE) and record: a) date and time; b) temperature; c) relative humidity; d) measurands; e) indications; f) errors; g) functional performance.
Maximum allowable variations:	All functions shall operate as designed. All errors shall be within the maximum permissible errors specified in 6.3.

13.4.2.2 Static temperatures

13.4.2.2.1 Dry heat *[OIML D 11: 10.1])*

In addition to the information to the IEC test procedures, the following test procedure in brief shall be applied:

Applicable standards	Applicable standards IEC 60068-2-2 [9], IEC 60068-3-1 [14]
Test method	Exposure to dry heat (non condensing)
Applicability	General
Object of the test	Verification of compliance with the provisions in 6.8 and 6.10 under conditions of high temperature.
Test procedure in brief	The test comprises exposure to the specified high temperature under “free air” conditions during the period of time specified (the period specified is the period succeeding the moment at which 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 tests are performed at temperatures below 35 °C, the relative humidity shall not exceed 50 %.					
	One of the following test levels may be specified:					
Test level index	**1**	**2**	**3**			unit
Temperature	**30**	**40**	**55**			°C
Duration	**2**	**2**	**2**			h
Information to be presented	a) date and time b) preconditioning c) details of mounting or supports d) state of the EUT including cooling system during conditioning e) test level to be applied: temperature and duration of exposure f) measurements and/or loading during conditioning g) recovery (if non-standard)					

13.4.2.2.2 Cold ***[OIML D11: 10.1]***

In addition to the information to the IEC test procedures, the following test procedure in brief shall be applied:

Applicable standards:	IEC 60068-2-1 [8] and IEC 60068-3-1 [14]				
Test method:	Exposure to low temperature.				
Applicability	General				
Object of the test:	Verification of compliance with the provisions in subclause 6.8 and 6.10 under conditions of low temperature.				
Test procedure in brief:	The test comprises exposure to the specified low temperature under “free air” conditions during the period of time specified (the period specified is the period succeeding the moment at which the EUT has reached temperature stability). The change in temperature shall not exceed 1 °C/min during heating up and cooling down. IEC specifies that the power to the EUT shall be switched off before the temperature is raised.				
Test level index	**1**	**2**	**3**		unit
Temperature	**+ 5**	**–10**	**–25**		°C
Duration	**2**	**2**	**2**		h
Information to be presented	a) date and time b) preconditioning c) details of mounting or supports d) state of the EUT including cooling system during conditioning e) extend: temperature and duration of exposure f) measurements and/or loading during conditioning g) recovery (if non-standard)				

13.4.2.2.3 Damp heat, cyclic (condensing) *[OIML D 11:10.2]*

This test is applied to verify compliance with the provisions in 6.8.1.1,a) after conditions of damp heat, cyclic (condensing).

In addition to the information to the IEC test procedures, the following test procedures in brief shall be applied:

Applicable standards:	IEC 60068-2-30 [11], IEC 60068-3-4 [15]		
Test method:	Exposure to damp heat with cyclic temperature variation.		
Object of the test:	Verification of compliance of the electronic measuring instrument with the provisions in subclause 6.9.1 under conditions of high humidity when combined with cyclic temperature changes.		
Applicability	Cyclic tests shall be applied in all the cases where condensation is concerned and can potentially be of influence or when the penetration of vapor will be accelerated by the breathing effect.		
Test procedure in brief:	The test comprises exposure to cyclic temperature variation between 25 °C and the appropriate upper temperature, maintaining the relative humidity 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: 1) temperature rise during 3 h 2) temperature maintained at upper value until 12 hours from the start of the cycle 3) temperature lowered to lower temperature level within a period of 3 h to 6 h, the rate of fall during the first hour and a half being such that the lower level would be reached in a 3 hour period. 4) temperature maintained at lower level 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 its final value. Special electrical conditions and recovery conditions may need to be specified.		
Level index	**1**	**2**	unit
Upper temperature	**40**	**55**	°C
Duration	**2**	**2**	24 –hour cycles
Information to be presented	a) extend: temperature and number of cycles b) state of the EUT during conditioning c) details of mounting or support d) need for intermediate measurements e) instrument recovery conditions f) special precautions to be taken regarding surface moisture elimination g) measurements to be made at the end of the test, sequence of parameters to be measured, and the maximum time period allowed for and between the measurement of these parameters		

13.4.2.3 Vibration (random) *[OIML D 11: 11.1]*

In addition to the information to the IEC test procedures, the following test procedure in brief shall be applied:

Applicable standards:	, IEC 60068-2-47 [12], IEC 60068-2-64 [13], IEC 60068-3-8 [16].			
Test method:	Exposure to random vibration.			
Applicability	General.			
Object of the test:	Verification of compliance of the electronic measuring instrument to the provisions in subclause 6.8 and 6.10 under conditions of random-vibration.			
Test procedure in brief:	The test comprises exposure to the vibration for a time sufficient for testing the various functions of the EUT during the exposure The EUT shall, in turn, be tested in three, mutually perpendicular axes mounted on a rigid fixture by its normal mounting means. The EUT shall normally be mounted in such a way that the gravity vector points in the same direction as it would in normal use If the measurement principle is such that the effect of the direction of the gravity vector can be considered neglibible, the EUT may be mounted in any position.			
	One of the following test levels may be specified:			
Test level index	**1**	**2**		unit
Total frequency range	**10-150**	**10-150**		Hz
Total RMS level	**1.6**	7		ms^{-2}
ASD level 10-20 Hz	**0.05**	**1**		$m^2 s^{-3}$
ASD level 20-150 Hz	**–3**	**–3**		dB/octave
Duration per axis	For each of the orthogonal directions the vibration exposure time shall be 2 minutes in each functional mode			
Information to be presented	a) date and time 1) total RMS level, 2) ASD (acceleration spectral density) level, 3) number of axes, 4) duration per axis.			

13.4.2.4 **Mains voltage variations** ***[OIML D 11: 12.1]***

Perturbations on DC voltage powered instruments

Electronic measuring systems with DC voltage power supply shall not be subjected to the tests 13.4.2.4.2 AC power supply, and 13.4.3.3 Bursts. They shall meet the following:

When the power supplied is less than –15 % Unom, or greater than +10 % Unom, during a measurement the EUT shall either indicate within mpe or not provide an indication that could be construed as measurement value.

13.4.2.4.1 DC mains voltage variation *[OIML D 11: 12.1]*

In addition to the information to the IEC test procedures, the following test procedure in brief shall be applied:

Applicable standards:	IEC 60654-2 [17]
Test method:	Applying low and high level DC mains power voltage.

Applicability	Applicable for measuring instruments which are temporarily or permanently connected to a DC mains power network while in operation and generally only applicable in industrial environment. No requirements for class E1 and E3 have been suggested because this test only applies to DC mains power networks, which are almost exclusively applied in industrial environments.
Object of the test:	Verification of compliance with the provisions subclause 6.8, e) under conditions of varying DC mains power voltage changes between upper and lower limit.
Test procedure in brief	The test comprises exposure to the specified power supply condition for a period sufficient for achieving temperature stability and subsequently performing the required measurements.
Test level index	**1**
Test level	The upper voltage limit is the DC level at which the EUT is has been manufactured to automatically detect high-level conditions. The lower limit will be the DC level at which the EUT has been manufactured to automatically detect low-level conditions. The EUT shall comply with the specified maximum permissible errors at voltage levels between the two levels. Testing may be restricted to subsequent exposure to the upper and lower voltage level.

13.4.2.4.2 AC mains voltage variation *[OIML D 11: 12.2]*

In addition to the information to the IEC test procedures, the following test procedure in brief shall be applied:

Applicable standards:	IEC/TR3 61000-2-1 [18], IEC 61000-4-1 [19]	
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.	
Object of the test:	Verification of compliance with the provisions in subclause 6.8, f) under conditions of AC mains network voltage changes between upper and lower limit.	
Test procedure in brief	The test comprises exposure of the EUT to the specified power supply condition for a period sufficient for achieving temperature stability and subsequently performing the required measurement	
	The following test levels are preferred:	
Test level index		**1**
Mains voltage[(1)(2)]	Upper limit	**U_{nom1} + 10 %**
	Lower limit	**U_{nom2} - 15 %;**
Notes	[(1)] For three phase mains power supplies, the voltage variation is applicable for each of the phases successively. [(2)] The values of U_{nom} are those as marked on the measuring instrument. U_{nom1} concerns the highest and U_{nom2} concerns the lowest value in the case a range is specified. If only one nominal mains voltage value (U_{nom}) is presented then $U_{nom1} = U_{nom2} = U_{nom}$.	

13.4.3 Disturbances

The type of measuring instrument is presumed to comply with the provisions specified in 6.10 if it passes the following tests:

13.4.3.1 Radiated radio frequency immunity *[OIML D 11: 13.2]*

For instruments containing electronics, this test is applied to verify compliance with the provisions in 6.10.1, a) under conditions of radiated electromagnetic fields.

Instruments that do not contain any active electronic circuits (transistors, IC's, radio tubes), are presumed to comply with the provisions in 6.10.1, a), without being subjected to this test. This justification shall be mentioned in the test report.

In addition to the information to the IEC test procedures, the following test procedures in brief shall be applied:

Applicable standards:	IEC 61000-4-3 [21]; 61000-4-20 [24]						
Test method:	Exposure to radiated radio frequency electromagnetic fields.						
Applicability	Applicable for electronic measuring instruments containing active electronic circuits.						
Object of the test:	Verification of compliance with the provisions in subclause 6.10 under conditions of exposure to electromagnetic fields.						
Test procedure in brief:	The EUT is exposed to electromagnetic fields with the required field strength and the field uniformity. 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 type and set-up, 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.(1)						
Test levels							
Test level index			2	**3**			unit
Frequency range (general origin)	80-1000 MHz(1), (2), (5)			**10**			V/m
Modulation	80 % AM, 1 kHz, sine wave						
EMF specifically caused by wireless communication networds							
Test level index				**3(1)**	**4(1)**	i(2)	unit
Frequency range (wireless communications networks)	446 MHz			**10**	**30**	E_i	V/m
	3 GHz(3)			**10**	**30**		
	(3 − 6) GHz(4)			10	30		
Modulation	80 % AM, 1 kHz, sine wave						
Information to be presented	a) date and time b) climatic conditions c) wiring to and from EUT d) duration of the test e) value of the measurand f) indications and errors						

13.4.3.2 Electrostatic discharge *[OIML D 11: 13.2]*

For instruments containing electronics, this test is applied to verify compliance with the provisions in 6.10.1, c) under conditions of electrostatic discharges.

Instruments that do not contain any active electronic circuits (transistors, IC's, radio tubes), are presumed to comply with the provisions in 6.10.1, c) without being subjected to this test. This justification shall be mentioned in the test report.

In addition to the information to the IEC test procedures, the following test procedures in brief shall be applied:

Applicable standards:		IEC 61000-4-2 [20]					
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 subclause 6.10 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 shall be used and the test set-up shall comply 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. The time interval between successive discharges shall be at least 1 second. For EUT not equipped with a ground terminal, the EUT shall be fully discharged between discharges. If the EUT is an integrating instrument, the test pulses shall be applied continuously during the measurement time. 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 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. Indirect application: The discharges are applied in the contact mode only on coupling planes mounted in the vicinity of the EUT.					
Test level index(1)				**3**			Unit
Test voltage	Contact discharge			**6**			kV
	Air discharge			**8**			kV
Notes		(1) In this case "level" means: "up and including" the specified level (i.e., the test shall also be performed at the specified lower levels in the standard). (2) The level assumed most applicable and preferred to implement is presented in bold face print type. Contact discharges shall be applied on conductive surfaces. Air discharges shall be applied on non-conductive surfaces.					
Information to be		a) date and time					

presented	b) test level to be applied c) climatic conditions d) for non-earthed EUTs procedure for discharging the EUT between two successive electrostatic discharges e) the number of discharges at each point f) value of the measurand g) indications and errors h) functional performance

13.4.3.3 Bursts (transients) on AC and DC mains *[OIML D 11: 12.3]*

For instruments containing electronics, this test is applied to verify compliance with the provisions in 6.10.1, e) and f) under conditions of bursts (transients) on mains, signal and control lines.

[If applicable:] For this test, supply lines for power by an external battery shall be considered as "signal, data, and control lines".

Instruments that do not contain any active electronic circuits (transistors, IC's, radio tubes), are presumed to comply with the provisions in 6.10.1, e) and f), without being subjected to this test. This justification shall be mentioned in the test report.

In addition to the information to the IEC test procedures, the following test procedures in brief shall be applied:

Applicable standards:	IEC 61000-4-4 [22]					
Test method:	Introducing transients on the mains power lines.					
Applicability	kApplicable for measuring instruments which are temporarily or permanently connected to a mains power network while in operation.					
Object of the test:	Verification of compliance with the provisions in subclause 6.10 under 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 to bursts of voltage spikes for which the output voltage on 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. The injection network on the mains shall contain blocking filters to prevent the burst energy being dissipated in the mains. If the EUT is an integrating instrument, the test pulses shall be continuously applied during the measurement time.					
Test level index		**2**	**3**			Unit
Amplitude (peak value)		**1**	**2**			kV
Repetition rate	**5**					kHz
Notes	(.					
Information to be presented	a) date and time b) test level to be applied c) climatic conditions d) value of the measurand e) field strength f) indications and errors g) functional performance					

13.4.3.4 AC mains voltage dips and short interruptions and reductions *[OIML D 11: 12.3]*

For instruments containing electronics, this test is applied to verify compliance with the provisions in 6.10.1, i) under conditions of AC mains voltage dips, short interruptions and voltage variations.

Instruments that do not contain any active electronic circuits (transistors, IC's, radio tubes), and/or not powered by AC mains power, are presumed to comply with the provisions in 6.10.1, i), without being subjected to this test. This justification shall be mentioned in the test report.

In addition to the information to the IEC test procedures, the following test procedures in brief shall be applied:

Applicable standards:		61000-4-11 [23], IEC 61000-6-1 [25], IEC 61000-6-2 [26]				
Test method:		Introduction short-time reductions of mains voltage using the test set-up defined in the applicable standard.				
Applicability		Applicable for measuring instruments with rated input current of less than 16 A per phase which are temporarily or permanently connected to an AC mains power network while in operation.				
Object of the test:		Verification of compliance with the provisions in 6.10 under conditions of short time mains voltage reductions.				
Test procedure in brief		A test generator is to 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. If the EUT is an integrating instrument, the tests shall be applied continuously during the measurement time.				
Test level index			**1**	**2**		unit
Voltage dips[(2)]	Test a	Reduction to	**0**	**0**		%
		Duration	**0.5**	**0.5**		cycles
	Test b	Reduction to	**0**	**0**		%
		Duration	**1**	**1**		cycles
	Test c	Reduction to	**70**	**40**		%
		Duration	**25/30[(4)]**	**10/12[(4)]**		cycles
	Test d	Reduction to	n/a	**70**		%
		Duration	n/a	**25/30[(4)]**		cycles
	Test e	Reduction to	n/a	**80**		%
		Duration	n/a	**250/300[(4)]**		cycles
Short interruptions	Reduction to		**0**			%
	Duration		**250/300[(4)]**			cycles
Notes		[(2)] For the voltage dips, all tests within the test level may be applicable [(4)] Values applicable for 50 Hz / 60 Hz respectively				
Information to be presented:		a) date and time; b) amplitude and duration of simulated disturbances c) performance of the instrument d) climatic conditions e) if the EUT is an integrating instrument: an exact description of the sequence of the test pulses, f) value of the measurand; g) field strength; h) indications and errors;				

13.4.3.5 Electrical transient conduction along supply lines

gIn addition to the information to the IEC test procedures, the following test procedures in brief shall be applied:

<table>
<tr><td>Applicable standards:</td><td colspan="2">ISO 7637-2 [27]</td><td colspan="3">§ 5.6.2: Test pulse 2a + 2b
§ 5.6.3: Test pulse 3a + 3b</td></tr>
<tr><td>Test method:</td><td colspan="5">Electrical transient conduction along supply lines.</td></tr>
<tr><td>Applicability</td><td colspan="5">Applicable to all measuring instruments supplied by the internal battery of a vehicle and charged by use of a combustion engine driven generator.</td></tr>
<tr><td>Object of the test:</td><td colspan="5">Verification of compliance with the provisions in 6.8 and 6.9 under the following conditions:
• transients due to a sudden interruption of currents 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)(5);
• 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="5">The test comprises exposure to disturbances on the power voltage by direct coupling into the supply lines.</td></tr>
<tr><td>Test level index</td><td colspan="3"></td><td colspan="2">IV</td><td rowspan="3">unit</td></tr>
<tr><td rowspan="2">Test pulse</td><td colspan="3"></td><td colspan="2">Pulse voltage U_s</td></tr>
<tr><td></td><td></td><td>U_{nom} = 12 V</td><td>U_{nom} = 24 V</td></tr>
<tr><td>2a</td><td></td><td></td><td>+ 50</td><td>+ 50</td><td>V</td></tr>
<tr><td>2b(1)</td><td></td><td></td><td>+ 10</td><td>+ 20</td><td>V</td></tr>
<tr><td>3a</td><td></td><td></td><td>– 150</td><td>– 200</td><td>V</td></tr>
<tr><td>3b</td><td></td><td></td><td>+ 100</td><td>+ 200</td><td>V</td></tr>
<tr><td>Notes</td><td colspan="5">(1) Test pulse 2b is only applicable in case the measuring instrument may be connected to the battery via the main switch of the car, so if the manufacturer of the measuring instrument has not specified that the instrument is to be connected directly to the battery.</td></tr>
<tr><td>Information to be presented:</td><td colspan="5">a) test pulses to be applied
b) test level to be applied
c) minimum number of pulses or test time
d) performance of the EUT during and after the test pulses</td></tr>
</table>

13.4.4 Durability

A durability test should be carried out at the maximum flowrate of the meter, with the liquid the meter is intended to measure or with a liquid of similar characteristics.

When the meter is intended to measure different liquids, the test should be carried out with the liquid that provides the most severe conditions.

An accuracy test shall precede the durability tests. After the durability test, the meter is again subject to a new accuracy test.

13.4..4.a) Durability test

A durability test shall be conducted as follows:

• an accuracy test shall be conducted prior to the durability test;

• as far as possible, the meter is subjected to a durability test on a test bench. However, it is accepted that the meter be temporarily mounted in a measuring system in normal operation. It is then necessary that the nominal operating flowrate of the measuring system be more than 0.8 Qmax;

• The durability test shall preferably be conducted for 100 hours in one or several periods at a flowrate from 80 % Qmax to Qmax. The selection and approval of an appropriate test site/facility and associated equipment shall avoid locations and other circumstances that limit the scope of the evaluation. If technical difficulties make these combined conditions unachievable at minimum the equivalent quantity (100 hours at 80 % Qmax) of liquid that represents 30-60 days operation shall have been passed through the meter.

• After the 100 hour test, an accuracy test shall be conducted with the same quantity asthe accuracy test prior to the durability test. The test results shall not vary from the first test by more than 1.5 % of the measured quantity, without any adjustment or correction.

13.5 Type evaluation report

TO BE COMPLETED IN PART 3: AFTER COMPLETION OF PART 1 AND PART 2 THE REMAINING TASKS FOR PROJECT 1 WILL COMMENCE. WORK WILL BEGIN TO UPDATE THE REPORT FORMAT FOR TYPE EVALUATION. THIS PROJECT REVISES THE 2006 EDITION OF ANNEX D

13.6 Type approval certificate

The following information shall appear on the type approval certificate:

• name and address of the recipient of the approval certificate;

• name and address of the manufacturer, if it is not the recipient;

• type of the cryogenic meter or system and/or commercial designation;

• metrological and technical characteristics, such as Accuracy Class, unit(s) of measurement, values of Q_{max}, and Q_{min};

• type approval mark;

• period of validity of the type approval (if applicable);

• environmental classification, if applicable (see Table13.4);

• information on the location of marks for type approval, initial verification and sealing (for example, picture or drawing);

• list of documents which accompany the type approval certificate; and

• specific remarks.

When applicable, the version of the metrological part of the evaluated software shall be indicated in the type approval certificate or in its annexes (technical file) for the:

- location of the imprint of the software identification on the instrument/electronic device;
- means for presenting or displaying on command or during the operation or at start up and for turning on and off ; or
- means for sending via a communication interface to be displayed/printed on another sub-assembly/electronic device.

The following information shall appear on the type approval certificate:

• name and address of the recipient of the approval certificate;

• name and address of the manufacturer, if it is not the recipient;

• type and/or commercial designation;

• metrological and technical characteristics;

• type approval mark;

• period of validity;

• environmental classification, if applicable (see Table 13.4);

• information on the location of marks for type approval, initial verification and sealing (for example, picture or drawing);

• list of documents which accompany the type approval certificate;

• specific remarks.

When applicable, the version of the metrological part of the evaluated software shall be indicated in the type approval certificate or in its annexes (technical file).

13.7 Modification of an approved type

13.7.1 The recipient of the type approval shall inform the body responsible for the approval of any modification or addition which concerns an approved type.

13.7.2 Modifications and additions shall be subject to a supplementary type approval when they influence, or are likely to influence, the results of measurement or the regulatory conditions of use of the instrument.

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

13.7.3 When the body having approved the initial type judges that the modifications or additions are not such as to influence the results of measurement, this body allows the modified instruments to be presented for initial verification without granting a supplementary type approval certificate. A new type approval has to be issued when the modified type no longer fulfills the provisions of the previous type approval.

13.8 Type approval

13.8.1. Type approval of a meter or of a measurement transducer

A type approval may be given for a meter (3.3.5). It may also be given for the measurement transducer (as defined in A.1.10) separately when it is intended to be connected to different types of calculators. Examinations and tests shall be carried out on the meter alone or on the measurement transducer when it is the subject of a separate application for type approval. They also may be carried out on the whole measuring system.

Normally, tests are carried out on the complete meter, fitted with an indicating device, with all the ancillary devices and with the correction device, if any.

However, the meter subject to testing need not be fitted with its ancillary devices when the latter are not such as to influence the accuracy of the meter and when they have been verified separately (for example: electronic printing device). The measurement transducer may also be tested alone provided the computing and indicating devices have been subject to separate type approvals. If this measurement transducer is intended to be connected to a calculator fitted with a correction device, the correction algorithm as described by the manufacturer shall be applied to the output signal of the transducer to determine its errors.

Tests shall be carried out to ensure that the errors of indication on the meter will not exceed the maximum permissible errors at the limits of each of the rated operating conditions. The type approval body is required to determine and document the operating conditions at which the type approval testing will be conducted. Required testing is specified in and 6.11.

13.8.2. Type approval of an electronic calculator

13.8.2.1 When an electronic calculator is submitted for a separate type approval, tests are conducted on the calculator on its own, simulating different inputs with appropriate standards. For this purpose, the error obtained on the indication of the result is calculated by considering that the true value is computed with standard methods of calculation using the simulated quantities applied to inputs of the calculator.

13.8.2.2 When the calculator carries out calculations for a conversion device, tests specified in 13.8.2.1 are performed for the calculation of volume at base conditions or mass. The maximum permissible errors are those fixed in 6.3.3.5.

13.8.2.3 Accuracy tests also include an accuracy test on the measurement of each characteristic quantity of the liquid. For this purpose, the error obtained on the indication of each of these characteristic quantities (these indications are mandatory considering 7.2) is calculated by considering the true value as that provided by the standard connected to the inputs of the calculator and which simulates the corresponding associated measuring device. For the indication of each of these quantities, the maximum permissible errors fixed in 6.3.3 shall be applied depending on the type of input with which the calculator is fitted.

13.8.2.4 It is then necessary to perform a test to check the presence and operation of checking facilities relevant to associated measuring devices mentioned in 7.5.6.

13.8.3 Type approval of a conversion device

When a conversion device is submitted for a separate type approval, either of the procedures specified in 13.8.3.1 or 13.8.3.2 may be used. The approach to be applied shall be specified by the applicant for type approval.

13.8.3.1 General case

It is necessary to verify that the conversion device connected to all its associated measuring instruments complies with the provisions of 6.3.3.6. For that purpose, the quantity to be converted is considered to be without error when at metering conditions. In the case of an electronic conversion device, it is necessary to perform the examination and tests described in6.5 and 13.8.3. The maximum permissible errors are those fixed in 6.3.3.6. The “true” values for the characteristic quantities shall be derived from appropriate standards (thermostatically controlled bath, liquids with standard density, pressure balance, etc.). The quantity at metering conditions may be simulated.

13.8.3.2 Electronic conversion device separately

Instead of the procedure in 13.8.3.1, it is also possible:

- to verify separately the accuracy of associated measuring instruments (see 6.3.3.1, 6.3.3.2, and 6.3.3.3);
- to verify that the provisions of 13.8.2 are fulfilled; and
- to perform the examinations and tests described in 13.8.3.2.

The "true" values for the characteristic quantities shall be derived from appropriate standards (thermostatically controlled bath, liquids with standard density, pressure balance, etc.).

The necessary conditions for compatibility shall be stated in the type approval certificate.

13.8.4 Type approval of an ancillary device

13.8.4.1 When an ancillary device that provides primary indications is intended to be approved separately, its indications shall be compared with indications provided by an indicating device already approved having the same scale interval or a smaller one. For any measured quantity relating to the same measurement, the indications provided by the various devices shall not deviate one from another. As far as possible, the necessary conditions for compatibility with other devices of a measuring system are stated in the type approval certificate.

13.8.4.2 Electronic devices may be approved separately when they are used for the transmission of primary indications or other information necessary to the determination of primary indications. For example, a device which concentrates information from two or more calculators and transmits to a single printing device. When at least one of the signals of the primary indication information is analogue, the device shall be tested associated with another device for which this Recommendation provides maximum permissible errors. When all the signals of the primary indication are digital, the above provision may be applied. However, when the inputs and outputs of the device are available, it can be tested separately; in this case, only errors due to the testing method are allowed and the device shall present no other error. In both cases and as far as possible, the necessary conditions for compatibility with other devices of a measuring system are stated in the type approval certificate.

13.8.5 Type approval of a gas elimination device

As a rule, tests shall be carried out to prove that the air or gas eliminating devices satisfy the requirements in 7.1.9.5 or 7.1.9.6.

It is acceptable, however, that tests are not carried out at flowrates greater than 100 m^3/h and that the air separating devices are approved by analogy with devices of the same design with smaller dimensions.

13.8.6 Type approval of a measuring system

The type approval of a measuring system consists of verifying that the measuring system, the meter, and the components meet the corresponding requirements, and that these components are compatible with each other.

For the meter it is possible to verify that its own components meet the corresponding requirements and that they are compatible with each other.

The tests to carry out for the type approval of a measuring system may be determined on the basis of the type approvals already granted for the various components of the system.

Note: Components may be subject to separate type approval when they are intended to be part of several types of measuring systems. This is advantageous when the various measuring systems are manufactured by different manufacturers and when the bodies responsible for the various type approvals are different.

13.8.7 Type approval of an electronic device

In addition to the examinations or tests which result from the preceding paragraphs, an electronic measuring system or an electronic component of this system shall be subject to the following tests and examinations.

13.8.7.1 Design inspection

This examination of documents aims at verifying that the design of electronic devices and their checking facilities comply with the provisions of this Recommendation.

It includes:

a) an examination of the mode of construction and of the electronic sub-systems and components used, to verify their appropriateness for their intended use;

b) consideration of malfunctions likely to occur, to verify that in all considered cases these devices comply with the requirements in 7.5; and

c) verification of the presence and effectiveness of the test device(s) for the checking facilities.

13.8.7.2 Performance tests

These tests aim at verifying that the measuring system complies with the requirements in 6.8.1 with regard to influence quantities. These tests are specified in 13.4.

a) Performance under the effect of influence factors:

When subjected to the effect of influence factors as provided for in 13.4, the equipment shall continue to operate correctly and the errors shall not exceed the applicable maximum permissible errors.

b) Performance under the effect of disturbances:

When subjected to external disturbances as provided for in 13.4, the equipment shall either continue to operate correctly or detect and indicate the presence of any significant faults. Significant faults shall not occur on non-interruptible measuring systems.

13.8.7.3 Equipment under test (EUT)

Tests are carried out either on the complete measuring system or on the constituent elements.

The EUT shall be included in a set-up representative of the normal operation of the measuring system. In particular, the calculator with indication device shall be installed in its final housing; or, in the case of a fuel dispenser, shall be installed in a housing representative of the final housing. The type approval body may decide that a type approval certificate covering a given type of calculator with indicating device will cover any other housing for the same type.

In all cases, ancillary devices may be tested separately.

14 Initial verification

14.1 General considerations

A new instrument shall undergo initial verification only after type approval. The verification shall be carried out using suitable standards of adequate accuracy. These standards shall be subjected to a suitable calibration program, assuring their metrological traceability.

Before being taken into service, the initial verification of each individual instrument is intended to verify compliance with the requirements of clauses 5 - 11.

14.1.1 Stages of initial verification

Initial verification of a measuring system:

- is carried out in a single stage when the system can be transported without dismantling and when it is verified under the intended conditions of use;
- is carried out in two stages in all other cases.

First stage: pertains to the flow sensor, on its own or fitted with its associated ancillary devices, or possibly included in a sub-system. The first stage tests may be carried out on a test bench, possibly in the factory of the manufacturer, or on the installed measuring system. At this stage, the metrological examinations may be carried out with different liquids to those that the system is intended to measure.

The first stage also concerns the calculator and the density sensor notably. If necessary, the measurement transducer and the calculator may be verified separately.

Second stage: pertains to the measuring system under actual working conditions. It is carried out at the place of installation under operating conditions and with the intended liquid of use. However, the second stage may be carried out in a place chosen by the body in charge of verification when the measuring system can be transported without dismantling and when the tests can be performed under the operating conditions intended for the measuring system.

NOTE: It is not intended that the instrument or its components should be dismantled for a test.

14.2 Legal status of the instrument submitted for verification

Production measuring instruments shall be in conformance with the approved type.

Initial verification of a measuring instrument includes a procedure to ensure that the individual measuring instruments conform to the approved type. But, notwithstanding this initial verification carried out by the appropriate Legal Authority or under its responsibility, the manufacturer has the full responsibility that the instrument complies with all the applicable requirements according to this Recommendation and other relevant requirements.

14.3 Examination and tests at initial verification

14.3.1 Inspection

Before starting the tests, the following examinations shall be performed:

a) a visual inspection to determine conformance with the approved type and to obtain a general appraisal of its design and construction;

b) completeness and the correctness of the inscriptions;

c) presence, the completeness, and the language of the documentation meant for the user;

d) compliance of the power supply voltage and frequency at the location of use to with the specifications on the measuring instrument’s label;

e) units (5);

f) measuring range (6.2);

g) scale interval (6.4);

h) construction (7.1);

i) presentation of the measured quantity value (7.2);

j) adjustment facilities (7.3);

k) durable storage / printer (7.9);

l) compliance of the software with the approved type (7.8);

m) sealing devices (10.1)

n) provisions for stamping (10.2)

14.3.2 Tests

14.3.2a) When initial verification takes place in two stages, the first stage shall include:

- an examination for conformity of the meter, including the associated ancillary devices (conformity with the respective type);
- a metrological examination of the meter, including the associated ancillary devices.

The second stage shall include:

- an examination for conformity of the measuring system, including the meter and the ancillary and additional devices;
- a metrological examination of the measuring system; if possible, this examination is carried out within the limits of operating conditions for the system.

14.3.2 b) When initial verification takes place in one stage, all the tests mentioned in subclause 14.3.2 a) shall be performed.

14.3.2 c) The maximum permissible errors on initial verification shall meet the requirements of 6.3.

14.3.3 Tests under rated operating conditions

The tests to determine the errors of the instrument shall be carried out under rated operating conditions.

14.4 Error

After the instrument has warmed up, determine the error curve according to test 13.4.2.1.

The errors observed shall be within the limits of the maximum permissible errors according to 6.3 for each measurement. A meter shall be tested with the liquid to be commercially measured except that, in a type evaluation nitrogen may be used.

14.5 Verification marks, seals and document

After successful initial verification, the verification marks and the sealings shall be attached and/or an accompanying document shall be made up according to national regulations.

15 Metrological supervision

15.1 Mandatory subsequent verification

The obligation of subsequent verification and, if applicable: the interval, is subjected to national legislation. This Recommendation however, suggests an interval not exceeding 5 years.

The subsequent verification shall be carried out using suitable standards, of adequate accuracy. These standards shall be subjected to a suitable calibration program, assuring their metrological traceability.

As a rule, the tests shall be carried out on the complete instrument.

15.1.1 Examination

Subsequent verification shall only be performed if it can be proved that:

a. earlier initial verification has been successfully performed and the appropriate verification marks are undamaged;

b. the period elapsed since the previous verification does not exceed the prescribed period by more than 10 %;

c. the seals are not broken.

15.1.2 Tests

Before starting the tests, a visual inspection shall be performed to determine the validity of the previous verification and the presence of all required stamps, seals and documents.

Subsequent verification shall be carried out as specified in 14. A meter shall be tested with the liquid to be commercially measured except that, in a type evaluation nitrogen may be used.

The tests to determine the errors of the instrument shall be carried out under rated operating conditions.

a) After the instrument has warmed up, determine the error curve according 13.4.2.1. The errors observed shall be within the limits of the maximum permissible errors of 6.3 on initial verification for each measurement.

b) The maximum permissible errors on subsequent verification shall meet the requirements of 6.3.

c) If the protective seals of the meter and/or the ancillary devices are intact, a complete examination of the measuring system may not be necessary. To determine the error curve, tests should be conducted at least with a quantity of liquid equal to the minimum measured quantity, and at least at 60 % of the maximum flowrate of the meter.

d) The procedures and requirements for subsequent verification of a measuring system may be identical to the initial verification.

15.2 For countries not having a system of mandatory subsequent verification

Metrological supervision of measuring instrument in use, consists of randomly checking the presence of the right and valid and undamaged verification marks and seals, and the evidence of regular maintenance according to the manufacturers' instructions.

15.3 Conditions of use

Self service authorization

Accidental or intentional fraud causes great concern when customers use card-activated systems in service stations, bank-card-activated systems directly access bank accounts. The following criteria and test procedures apply to card-activated retail motor-fuel dispensers.

A card-activated system shall authorize the dispensing of product for not more than three minutes for the time between authorization and "handle on" at the dispenser. It shall properly record transactions on the appropriate card account.

When a card-activated system is subjected to power loss of greater than 10 seconds, the dispenser shall de-authorize. Because systems may be installed with separate power lines to the console, card reader, and dispenser, tests should be run with power failures to different parts of the system to evaluate the potential for accidental or intentional errors. The appropriate device response depends when the power loss occurs during the delivery sequence.

15.4 Visibility by the public

15.4.1. Vehicle mounted cryogenic liquid measuring device or system indications

Primary indicating device shall be visible from a reasonable customer position. Electronic vehicle-mounted metering/controlling systems on which transaction information is displayed shall provide a remote customer display as a standard feature that is located in a reasonable customer position (e.g., at the meter on the rear of the vehicle).

15.5 Environmental conditions

These conditions depend on the specific environment where the instrument is expected to be installed (residential, general public, commercial, industrial etc.), the concept of the measurement system, and the use of the measurement system. Typically, the manufacturer declares the environmental conditions; however, the approved type is based on the tests results.

Annexes

Annex A Definitions from other applicable international publications

(Mandatory)

A.1 Definitions from VIM [1]

A.1.1 Accuracy class *[VIM 4.25]*

Class of measuring instruments or measuring systems that meet stated metrological requirements that are intended to keep measurement errors or instrumental uncertainties within specified limits under specified operating conditions.

(For notes, please refer to VIM)

A.1.2 Error (of measurement) *[VIM 2.16)]*

Measured quantity value minus a reference quantity value.

(For notes, please refer to VIM)

A.1.3 Influence quantity *[VIM 2.52]*

A quantity that, in a direct measurement, does not affect the quantity that is actually measured, but affects the relation between the indication and the measurement result.

(For examples and notes, please refer to VIM)

A.1.4 Maximum permissible (measurement) error *[VIM 4.26]*

Extreme value of measurement error, with respect to a known reference quantity value, permitted by specifications or regulations for a given measurement, measuring instrument, or measuring system.

Note 1 Usually the term “maximum permissible errors” or “limits of error” are used, where there are two extreme values.

Note 2 The term “tolerance” should not be used to designate ‘maximum permissible error’.

A.1.5 Measurand *[VIM 2.3]*

The quantity intended to be measured.

A.1.6 Measured (quantity) value *[VIM 2.10)]*

Quantity value representing a measurement result.

(For notes, please refer to VIM)

A.1.7 Measurement repeatability *[VIM 2.21]*

The measurement precision under set of repeatability conditions of measurement.

A.1.8 Measurement uncertainty *[VIM 2.26]*

Non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used.

(For notes, please refer to VIM)

A.1.9 Measuring system *[VIM 3.2]*

A set of one or more measuring instruments and often other devices, including any reagent and supply, assembled and adapted to give information used to generate measured quantity values within specified intervals for quantities of specified kinds.

Note: A measuring system may consist of only one measuring instrument.

A.1.10 Measuring transducer *[VIM 3.7]*

A device, used in measurement that provides an output quantity having a specified relation to the input quantity.

EXAMPLES

Thermocouple, electric current transformer, strain gauge, pH electrode, Bourdon tube, bimetallic strip.

Note: For the purpose of this Recommendation, the measurement transducer includes the flow or quantity sensor.

A.1.11 Metrological traceability *[VIM 2.41]*

Property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty.

(For notes, please refer to VIM)

A.1.12 Rated operating conditions *[VIM 4.9]*

Operating conditions that must be fulfilled during measurement in order that a measuring instrument or measuring system perform as designed.

A.1.13 Reference (operating) conditions *[VIM 4.11]*

Operating condition prescribed for evaluating the performance of a measuring instrument or measuring system or for comparison of measurement results.

(For notes, please refer to VIM)

A.1.14 Resolution *[VIM 4.14]*

Smallest change in a quantity being measured that causes a perceptible change in the corresponding indication.

A.1.15 Resolution of a displaying (indicating) device *[VIM 4.15]*

Smallest difference between displayed indications that can be meaningfully distinguished.

A.1.16 Sensor *[VIM 3.8]*

Element of a measuring system that is directly affected by a phenomenon, body, or substance carrying a quantity to be measured.

A.1.17 Working measurement standard *[VIM 5.7]*

Measurement standard that is used routinely to calibrate or verify measuring instruments or measuring systems,

A.2 Definitions from the VIML [2]

A.2.1 Audit trail *[VIML 6.05]*

Continuous data file containing a time stamped information record of events, e.g. changes in the values of the parameters of a device or software updates, or other activities that are legally relevant and which may influence the metrological characteristics.

A.2.2 Category of instruments *[VIML 4.01]*

Identification or classification of instruments according to unique metrological and technical characteristics that may include the measured quantity, the measuring range, and the principle or method of measurement.

A.2.3 Device-specific parameter *[VIML 4.12]*

Legally relevant parameter with a value that depends on the individual instrument. Device-specific parameters comprise adjustment parameters (e.g. span adjustment or other adjustments or corrections) and configuration parameters (e.g. maximum value, minimum value, units of measurement, etc.).

A.2.4 Durability *[VIML 5.15]*

Ability of a measuring instrument to maintain its performance characteristics over a period of use.

A.2.5 Durability error *[VIML 5.16]*

Difference between the intrinsic error after a period of use and the initial intrinsic error of a measuring instrument.

A.2.6 Durability test *[VIML 5.22]*

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

A.2.7 Evaluation (type) *[VIML 2.04]*

Systematic examination and testing of the performance of one or more specimens of an identified type (pattern) of measuring instruments against documented requirements, the results of which are contained in the evaluation report, in order to determine whether the type may be approved.

A.2.8 Event *[VIML 6.06]*

Action in which a modification of a measuring instrument parameter, adjustment factor or update of software module is made.

A.2.9 Family of measuring instruments *[VIML 2, 4.02]*

Identifiable group of measuring instruments belonging to the same manufactured type within the same category that have the same design features and metrological principles for measurement but which may differ in some metrological and technical performance characteristics, as defined in the relevant Recommendation.

A.2.10 Family of modules *[VIML 2, 4.05]*

Identifiable group of modules belonging to the same manufactured type that have similar design features but may differ in some metrological and technical performance requirements as defined in the relevant Recommendation.

A.2.11 Fault *[VIML 5.12]*

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

Notes: (1) Principally, a fault is the result of an undesired change of data contained in or flowing through an electronic measuring instrument.

(2) From the definition it follows that in this Document, a "fault" is a numerical value which is expressed either in a unit of measurement or as a relative value, for instance as a percentage.

A.2.12 Influence factor *[VIML 5.18]*

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

A.2.13 Initial intrinsic error *[VIML 5.11]*

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

A.2.14 Initial verification *[VIML 2.12]*

Verification of a measuring instrument which has not been verified previously.

A.2.16 Intrinsic error *[VIML 0.06]*

The error of a measuring instrument determined under reference conditions.**A.2.15 International System of Units, SI** *[VIML 0.02]*

The system of units, based on the International System of Quantities, their names and symbols, including a series of prefixes and their names and symbols, together with rules for their use, adopted by the General Conference on Weights and Measures (CGPM)

A.2.17 Legally controlled measuring instrument *[VIML 4.07]*

Measuring instrument which conforms to prescribed requirements, in particular legal metrological requirement.

A.2.18 Legal metrology *[VIML 1.01]*

The practice and process of applying statutory and regulatory structure and enforcement to metrology.*(For notes, please refer to VIML)*

A.2.19 Legally relevant *[VIML 4.08]*

Software/hardware/data or part of the software/hardware/data of a measuring instrument which interferes with properties regulated by legal metrology, e.g. the accuracy of the measurement or the correct functioning of the measuring instrument.

A.2.20 Legally relevant parameter *[VIML 4.10]*

Parameter of a measuring instrument, electronic device, or a sub-assembly subject to legal control.

The following types of legally relevant parameters can be distinguished: type-specific parameters and device-specific parameters.

A.2.21 Marking *[VIML 2.19]*

Affixing of one or more of the marks.

(For notes, please refer to VIML)

A.2.22 Metrological authority *[VIML 1.05]*

legal entity designated by law or by the government to be responsible for specified legal metrology activities

Note 1: The legal entity may be a central or local government body, or a non–governmental body empowered by the government.

Note 2: The responsibility may include e.g. type approval.

A.2.23 Metrological supervision *[VIML 2.03]*

The activity of legal metrological control to check the observance of metrology laws and regulations

(For notes, please refer to VIML)

A.2.24 Module *[VIML 4.01]*

Identifiable part of a measuring instrument or of a family of measuring instruments that performs a specific function or functions and that can be separately evaluated according to prescribed metrological and technical performance requirements in the relevant Recommendation.

A.2.25 Performance test *[VIML 5.21]*

Test intended to verify whether the EUT is able to accomplish its intended functions.

A.2.26 Preliminary examination *[VIML 2.10]*

Examination of a measuring instrument either to partial requirements or before certain elements of the measuring instrument are installed as part of the verification procedure

A.2.27 Rejection mark *[VIML 3.05]*

Mark applied to a measuring instrument in a conspicuous manner to indicate that the measuring instrument does not comply with the statutory requirements and obliterating the previously applied verification mark.

A.2.28 Sealing *[VIML 2.20]*

Means intended to protect the measuring instrument against any unauthorized modification, readjustment, removal of parts, software, etc. It can be achieved by hardware, software or a combination of both.

A.2.29 Sealing mark *[VIML 3.06]*

Mark intended to protect the measuring instrument against any unauthorized modification, readjustment, removal of parts, etc.

A.2.30 Securing *[VIML 2.21]*

To prevent unauthorized access to the device’s hardware or software part.

A.2.31 Significant durability error *[VIML 5.17]*

Durability error exceeding the value specified in the applicable Recommendation.

A.2.32 Significant fault *[VIML 5.14]*

A fault exceeding the applicable fault limit value.

Note: For particular types of measuring instruments some faults exceeding the fault limit may not be considered a significant fault. The applicable Recommendation shall state when such an exception applies. For example, the occurrence of one or some of the following faults may be acceptable:

a) faults arising from simultaneous and mutually independent causes (e.g., EM fields and discharges) originating in a measuring instrument 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;

d) faults giving rise to variations in the measurement result that are serious enough to be noticed by all those interested in the measurement result.

A.2.33Subsequent verification *[VIML 2.13]*

Verification of a measuring instrument after a previous verification.

(For notes, please refer to VIML)

A.2.34 Test program *[VIML 5.20]*

Description of a series of tests for certain types of equipment.

A.2.35 Type approval *[VIML 2.05]*

Decision of legal relevance, based on the type evaluation report that the type of a measuring instrument complies with the relevant statutory requirements and results in the issuance of the type approval certificate.

A.2.36 Type approval mark *[VIML 3.07]*

Mark applied to a measuring instrument certifying its conformity to the approved type.

A.2.37 Type (pattern) evaluation *[VIML 2.04]*

Conformity assessment procedure on one or more specimens of an identified type (pattern) of measuring instruments which results in an evaluation report and / or an evaluation certificate.

A.2.38 Type-specific parameter *[VIML 4.11]*

Legally relevant parameter with a value that depends on the type of instrument only. Type-specific parameters are part of the legally relevant software.

Example: Considering a measuring system of liquids other than water, the range of cinematic viscosity of a turbine is a type-specific parameter fixed by the type approval of the turbine. All the manufactured turbines of the same type have the same range of viscosity.

A.2.39 Verification mark *[VIML 3.04]*

Mark applied to a measuring instrument in a conspicuous manner certifying that the verification of the measuring instrument was carried out and compliance with statutory requirements was confirmed.

(For notes, please refer to VIML)

A.2.40 Verification of a measuring instrument *[VIML 2.09]*

Conformity assessment procedure (other than type evaluation) which results in the affixing of a verification mark and/or issuing of a verification certificate.

A.3 Definitions from OIML D 9 [3]

(For definitions in OIML D 9 that are copied from the VIML see Annex A.2)

A.4 Definitions from OIML D 11 [4]

(For definitions in OIML D 11 that are copied from the VIML see Annex A.2)

A.4.1 Automatic checking facility *(OIML D 11, 3.19.1)*

Checking facility that operates without the intervention of an operator.

A.4.2 Auxiliary battery *(OIML D 11, 3.25)*

Battery that is:

a) Mounted in, or connected to, an instrument that can be powered by the mains power as well; and
b) Capable of supplying power for the complete instrument for a reasonable period of time.

A.4.3 Back-up battery *(OIML D 11, 3.26)*

Battery that is intended to maintain power supply for specific functions of an instrument in the absence of the primary power supply.

(For example: to preserve stored data)

A.4.4 Durability protection facility *(OIML D 11, 3.20)*

Facility incorporated in a measuring instrument and that enables significant durability errors to be detected and acted upon.

A.4.5 Electronic measuring instrument *(OIML D 11, 3.1)*

An instrument intended to measure an electrical or non-electrical quantity using electronic means and/or equipped with electronic devices.

Note: For the purpose of this Recommendation, auxiliary equipment, provided that it is subject to metrological control, is considered to be a part of the measuring instrument.

A.4.6 Intermittent automatic checking facility (type I) *(OIML D 11, 3.19.1.2)*

Automatic checking facility that operates at certain time intervals or per fixed number of measurement cycles.

A.4.7 Mains power *(OIML D 11, 3.22)* (New)

Primary external source of electrical power for an instrument, including all sub-assemblies. (Examples: public power (AC or DC), generator, external battery or other DC supply systems).

A.4.8 Non-automatic checking facility (type N) *OIML D 11, 3.19.2)*

A checking facility that requires the intervention of an operator.

A.4.9 Permanent automatic checking facility (type P) *(OIML D 11, 3.19.1.1)*

An automatic checking facility that operates at each measurement cycle.

A.4. 10 Power converter (power supply device) *(OIML D 11, 3.23)*

Sub-assembly converting the voltage from the mains power to a voltage suitable for other sub-assemblies.

A.4.11 Test *(OIML D 11, 3.21)*

Series of operations intended to verify the compliance of the equipment under test (EUT) with specified requirements.

A.4.12 Test procedure *(OIML D 11, 3.21.1)*

Detailed description of the test operations.

A.5 Definitions from OIML D 31 [5]

(For definitions in OIML D 31 that are copied from the VIML see Annex A.2)

A.5.1 Communication *[OIML D 31, 3.1.8]*

Exchange of information between two or more units (e.g. software modules, electronic devices, subassemblies, etc.) according to specific rules.

A.5.2 Communication interface *[OIML D 31, 3.1.9]*

Electronic, optical, radio or other technical interface that enables information to be passed between components of a measuring instrument (e.g. electronic devices) or sub-assemblies.

A.5.3 Data domain *[OIML D 31, 3.1.12]*

Location in memory that each program needs for processing data. Depending on the kind of programming language used, this location is defined by hardware addresses or by symbolic names (variable names). The size of the smallest addressable domain is typically one byte, but the size is nearly not limited: it ranges from 1 bit (e.g. a flag of a register) to arbitrary data structures which may be as large as the needs of the programmer are.

Data domains may belong to one software module only, or to several. For high level languages (such as JAVA, C/C++, etc.) it is easy to separate the data domain of one software module from access by any other software modules by means of the language.

A.5.4 Error log *[OIML D 31, 3.1.18]*

Continuous data file containing an information record of failures/faults that have an influence on the metrological characteristics. This especially applies to volatile failures that are not recognizable afterwards when the measurement values are used.

A.5.5 Event counter *[OIML D 31, 3.1.21]*

Non resettable counter that increments each time an event occurs.

A.5.6 Interface *[OIML D 31, 3.1.27] [ISO 2382-9:1995]*

Shared boundary between two functional units, defined by various characteristics pertaining to the functions, physical interconnections, signal exchanges, and other characteristics of the units, as appropriate.

A.5.7 Legally relevant software part *[OIML D 31, 3.1.31]*

Part of all software modules of a measuring instrument, electronic device, or sub-assembly that is legally relevant.

A.5.8 Non-interruptible/interruptible measurement *[OIML D 31, 3.1.34]*

A non-interruptible measurement is a cumulative continuous measuring process with no definite end. The measuring process cannot be stopped and continued again by a user or operator without inadmissibly disturbing the measurement or the supply with goods or energy. If the cumulative measurement of a quantity of a substance can be stopped easily and rapidly during normal operation – not only in case of emergency – without falsifying the measurement result, it is called interruptible.

A.5.9 Software *[OIML D 31, 3.1.40]*

Generic term comprising program code, data, and parameters.

A.5.10 Software examination *[OIML D 31, 3.1.41]*

Technical operation that consists of determining one or more characteristics of the software according to the specific procedure (e.g. analysis of technical documentation or running the program under controlled conditions).

A.6 Definitions from OIML B 3[6]

(For definitions in OIML B 3 that are copied from the VIML see Annex A.2)

Annex B Tables of density for liquid argon, helium, hydrogen, nitrogen and oxygen

(Mandatory)

Please note that Annex B Tables of density for liquid argon, helium, hydrogen, nitrogen and oxygen that follows is based on NIST Standard Reference Database 23 *NIST Reference Fluid Thermodynamic and Transport Properties Database (REFPROP): Version 9.0* (2010) and will be updated in the 2 CD to reflect enhancements in version 9.1 (2013)

Temperature and pressure of the metered test liquid shall be measured during the test for the determination of density or volume correction factors when applicable. For Liquid Density and Volume Correction Factors (with respect to temperature and pressure) the reference publications for the tables of cryogenic liquids argon [1], helium [2], hydrogen [3], nitrogen [4], and oxygen [5] are shown below. NIST Standard Reference Database 23 [6][7], a complete database program containing all of the most recent equations for calculating density for various cryogenic liquids, is also available online at: http://www.nist.gov/srd/nist23.cfm.

Ref.	Reference document(s)	Abstract
[1]	Tegeler, Ch., Span, R., Wagner, W. "A New Equation of State for Argon Covering the Fluid Region for Temperatures from the Melting Line to 700 K at Pressures up to 1000 MPa." J. Phys. Chem. Ref. Data, 28(3):779-850, 1999.	This work reviews the available data on thermodynamic properties of argon and presents a new equation of state in the form of a fundamental equation explicit in the Helmholtz energy. The functional form of the residual part of the Helmholtz energy was developed by using state-of-the-art linear optimization strategies and a new nonlinear regression analysis. The new equation of state

		contains 41 coefficients, which were fitted to selected data of the following properties: (a) thermal properties of the single phase ($p\rho T$) and (b) of the liquid–vapor saturation curve (p_s, ρ', ρ'') including the Maxwell criterion, (c) speed of sound w, isochoric heat capacity c_v, second and third thermal virial coefficients B and C and second acoustic virial coefficient β_a. For the density, the estimated uncertainty of the new equation of state is less than ±0.02% for pressures up to 12 MPa and temperatures up to 340 K with the exception of the critical region and less than ±0.03% for pressures up to 30 MPa and temperatures between 235 and 520 K. In the region with densities up to half the critical density and for temperatures between 90 and 450 K the estimated uncertainty of calculated speeds of sound is in general less than ±0.02%. The new formulation shows reasonable extrapolation behavior up to very high pressures and temperatures. Independent equations for the vapor pressure, for the pressure on the sublimation and melting curve and for the saturated liquid and saturated vapor densities are also included. Tables for the thermodynamic properties of argon from 84 to 700 K for pressures up to 1000 MPa are given. © 1999 American Institute of Physics.
[2]	Ortiz-Vega, D.O., Hall, K.R., Arp, V.D., and Lemmon, E.W. “Interim Equation” International Journal of Thermophysics	(To be developed)
[3]	Leachman, J.W., Jacobsen, R.T, Lemmon, E.W., and Penoncello, S.G. “Fundamental Equations of State for Parahydrogen, Normal Hydrogen, and Orthohydrogen" J. Phys. Chem. Ref. Data, Volume 38, Number 3, pp. 565, 2009.	If the potential for a boom in the global hydrogen economy is realized, there will be an increase in the need for accurate hydrogen thermodynamic property standards. Based on current and anticipated needs, new fundamental equations of state for parahydrogen, normal hydrogen, and orthohydrogen were developed to replace the existing property models. To accurately predict thermophysical properties near the critical region and in liquid states, the quantum law of corresponding states was applied to improve the normal hydrogen and orthohydrogen formulations in the absence of available experimental data. All three equations of state have the same maximum pressure of 2000 MPa and upper temperature limit of 1000 K. Uncertainty estimates in this paper can be considered to be estimates of a combined expanded uncertainty with a coverage factor of 2 for primary data sets. The uncertainty in density is 0.04% in the region between 250 and 450 K and at pressures up to 300 MPa. The uncertainties of vapor pressures and saturated liquid densities vary from 0.1% to 0.2%. Heat capacities are generally estimated to be accurate to within 1%, while speed-of-sound values are accurate to within 0.5% below 100 MPa.
[4]	Span, R., Lemmon, E.W., Jacobsen, R.T, Wagner, W., and Yokozeki, A. “A Reference Thermodynamic Property Formulation for Nitrogen.” J. Phys. Chem. Ref. Data, Volume 29, Number 6, pp. 1361-1433, 2000.	A new formulation for the thermodynamic properties of nitrogen has been developed. Many new data sets have become available, including high accuracy data from single and dual-sinker apparatuses which improve the accuracy of the representation of the $p\rho T$ surface of gaseous, liquid, and supercritical nitrogen,

		including the saturation states. New measurements of the speed of sound from spherical resonators yield accurate information on caloric properties in gaseous and supercritical nitrogen. Isochoric heat capacity and enthalpy data have also been published. Sophisticated procedures for the optimization of the mathematical structure of equations of state and special functional forms for an improved representation of data in the critical region were used. Constraints regarding the structure of the equation ensure reasonable results up to extreme conditions of temperature and pressure. For calibration applications, the new reference equation is supplemented by a simple but also accurate formulation, valid only for supercritical nitrogen between 250 and 350 K at pressures up to 30 MPa. The uncertainty in density of the new reference equation of state ranges from 0.02% at pressures less than 30 MPa up to 0.6% at very high pressures, except in the range from 270 to 350 K at pressures less than 12 MPa where the uncertainty in density is 0.01%. The equation is valid from the triple point temperature to temperatures of 1000 K and up to pressures of 2200 MPa. From 1000 to 1800 K, the equation was validated with data of limited accuracy. The extrapolation behavior beyond 1800 K is reasonable up to the limits of chemical stability of nitrogen, as indicated by comparison to experimental shock tube data. © 2001 by the U.S. Secretary of Commerce on behalf of the United States. All rights reserved.
[5]	Schmidt, R., Wagner, W. “A New Form of the Equation of State for Pure Substances and its Application to Oxygen.” Fluid Phase Equilibria, 19:175 200, 1985.	A new wide range equation of state is presented and expressed analytically in the form of the free energy as a function of density and temperature. This fundamental equation contains, in addition to pure polynomial and "BWR"-terms, new exponential functions especially convenient for the critical region. To guarantee an effective structure, the combination of the terms of the equation was found by using an optimization method recently developed. As a result, the optimized function for the free energy is capable of representing the thermodynamic surface of oxygen in the range 54 <= T <= 300 K, 0 < p <= 818 bar and 0 < rho <= 41 mol dm-3 within the experimental uncertainty of the data available. With the exception of very few items of data, this statement is also valid for the whole coexistence curve and the critical region. Extrapolations of this new equation beyond the range of data yield physically meaningful results.
[6]	Lemmon, E.W., Huber, M.L., McLinden, M.O. NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties-REFPROP, Version 9.0, National Institute of Standards and Technology, Standard Reference Data Program, Gaithersburg, 2010.	
[7]	Leachman, J.W., Jacobsen, R.T, Lemmon, E.W., and Penoncello, S.G. “Fundamental Equations of State for Parahydrogen, Normal Hydrogen, and Orthohydrogen" J. Phys. Chem. Ref. Data,	If the potential for a boom in the global hydrogen economy is realized, there will be an increase in the need for accurate hydrogen thermodynamic property standards. Based on current and anticipated needs,

	Volume 38, Number 3, pp. 565, 2009.	new fundamental equations of state for parahydrogen, normal hydrogen, and orthohydrogen were developed to replace the existing property models. To accurately predict thermophysical properties near the critical region and in liquid states, the quantum law of corresponding states was applied to improve the normal hydrogen and orthohydrogen formulations in the absence of available experimental data. All three equations of state have the same maximum pressure of 2000 MPa and upper temperature limit of 1000 K. Uncertainty estimates in this paper can be considered to be estimates of a combined expanded uncertainty with a coverage factor of 2 for primary data sets. The uncertainty in density is 0.04% in the region between 250 and 450 K and at pressures up to 300 MPa. The uncertainties of vapor pressures and saturated liquid densities vary from 0.1% to 0.2%. Heat capacities are generally estimated to be accurate to within 1%, while speed-of-sound values are accurate to within 0.5% below 100 MPa.

The tables on the following pages give the values in SI units of the density as a function of temperature and pressure for liquid argon, helium, hydrogen, nitrogen and oxygen. Two tables are given for each fluid:

• the "-a" tables give the values of ~~vapor~~ pressure, density and volume per mass unit as a function of temperature for the so-called saturated liquid (liquid under its vapor pressure);

• the "-b" tables give the values of density as a function of temperature for the so-called subcooled liquid (liquid under pressure).

Ranges of the tables:

Table 1 – Argon Temperature from 85 K to 150 K and pressure up to 4.73 MPa;

Table 2 – Helium Temperature from 4 K to 5.14 K and pressure up to 0.21 MPa;

Table 3 – Hydrogen Temperature from 20.0K to 30.0 K and pressure up to 0.82 MPa;

Table 4 – Nitrogen Temperature from 75 K to 126 K and pressure up to 3.36 MPa;

Table 5 – Oxygen Temperature from 88 K to 154 K and pressure up to 4.93 MPa.

The tables were drawn up from the computer program NIST Standard Reference Database 23.The data provided with these tables were prepared by the Thermophysical Properties Division of the National Institute of Standards and Technology (former National Bureau of Standards) and are consistent with the data reported in [1] [2], [3], [4] and [5]. The computer programs which were used to prepare these tables are available from the NIST Material Measurement Laboratory, Measurement Services Division.

Note: The National Institute of Standards and Technology (NIST) has prepared these tables at the request of the Organisation Internationale de Métrologie Légale (OIML). Since they were prepared under the auspices of the United States Government, they are not subject to copyright.

Table 1-a: Argon			
Temperature (K)	Pressure (MPa)	Density (kg/m^3)	Volume/mass unit (dm^3/kg)
85.000	0.078897	1409.5	0.70947
86.000	0.088110	1403.4	0.71256
87.000	0.098131	1397.3	0.71569
88.000	0.10901	1391.1	0.71886

Table 1-a: Argon			
Temperature (K)	Pressure (MPa)	Density (kg/m^3)	Volume/mass unit (dm^3/kg)
89.000	0.12078	1384.9	0.72209
90.000	0.13351	1378.6	0.72536
91.000	0.14723	1372.3	0.72868
92.000	0.16199	1366.0	0.73206
93.000	0.17785	1359.6	0.73549
94.000	0.19485	1353.2	0.73897
95.000	0.21305	1346.8	0.74252
96.000	0.23249	1340.3	0.74612
97.000	0.25323	1333.7	0.74979
98.000	0.27532	1327.1	0.75353
99.000	0.29882	1320.4	0.75733
100.00	0.32377	1313.7	0.76121
101.00	0.35023	1306.9	0.76516
102.00	0.37825	1300.1	0.76919
103.00	0.40789	1293.2	0.77330
104.00	0.43920	1286.2	0.77749
105.00	0.47224	1279.1	0.78178
106.00	0.50706	1272.0	0.78615
107.00	0.54371	1264.8	0.79062
108.00	0.58226	1257.6	0.79519
109.00	0.62276	1250.2	0.79987
110.00	0.66526	1242.8	0.80465
111.00	0.70982	1235.2	0.80956
112.00	0.75650	1227.6	0.81458
113.00	0.80535	1219.9	0.81973
114.00	0.85644	1212.1	0.82501
115.00	0.90981	1204.2	0.83044
116.00	0.96553	1196.2	0.83601
117.00	1.0237	1188.0	0.84175
118.00	1.0842	1179.7	0.84764
119.00	1.1473	1171.3	0.85372
120.00	1.2130	1162.8	0.85998
121.00	1.2814	1154.1	0.86644
122.00	1.3524	1145.3	0.87311
123.00	1.4262	1136.3	0.88001
124.00	1.5028	1127.2	0.88715
125.00	1.5823	1117.9	0.89455
126.00	1.6648	1108.4	0.90223
127.00	1.7503	1098.7	0.91021
128.00	1.8388	1088.7	0.91851
129.00	1.9305	1078.6	0.92717
130.00	2.0255	1068.1	0.93621
131.00	2.1237	1057.4	0.94568
132.00	2.2252	1046.5	0.95560
133.00	2.3303	1035.2	0.96603

Table 1-a: Argon			
Temperature (K)	Pressure (MPa)	Density (kg/m^3)	Volume/mass unit (dm^3/kg)
134.00	2.4388	1023.5	0.97703
135.00	2.5509	1011.5	0.98867
136.00	2.6666	999.00	1.0010
137.00	2.7862	986.05	1.0141
138.00	2.9096	972.57	1.0282
139.00	3.0369	958.49	1.0433
140.00	3.1682	943.71	1.0597
141.00	3.3037	928.13	1.0774
142.00	3.4435	911.61	1.0970
143.00	3.5876	893.98	1.1186
144.00	3.7363	874.98	1.1429
145.00	3.8896	854.28	1.1706
146.00	4.0479	831.38	1.2028
147.00	4.2111	805.45	1.2415
148.00	4.3797	775.03	1.2903
149.00	4.5541	736.88	1.3571
150.00	4.7346	680.43	1.4697

Table 2-a: Helium			
Temperature (K)	Pressure (MPa)	Density (kg/m^3)	Volume/mass unit (dm^3/kg)
4.0000	0.081603	128.96	7.7544
4.0200	0.083261	128.62	7.7746
4.0400	0.084943	128.29	7.7951
4.0600	0.086647	127.94	7.8161
4.0800	0.088375	127.59	7.8375
4.1000	0.090125	127.24	7.8593
4.1200	0.091899	126.88	7.8816
4.1400	0.093697	126.51	7.9043
4.1600	0.095518	126.14	7.9275
4.1800	0.097363	125.77	7.9512
4.2000	0.099233	125.39	7.9754
4.2200	0.10113	125.00	8.0001
4.2400	0.10304	124.60	8.0254
4.2600	0.10499	124.20	8.0513
4.2800	0.10696	123.80	8.0777
4.3000	0.10895	123.38	8.1048
4.3200	0.11097	122.96	8.1325
4.3400	0.11301	122.54	8.1608
4.3600	0.11508	122.10	8.1899
4.3800	0.11717	121.66	8.2196
4.4000	0.11929	121.21	8.2502
4.4200	0.12144	120.75	8.2815
4.4400	0.12361	120.28	8.3136
4.4600	0.12581	119.81	8.3466
4.4800	0.12804	119.32	8.3805
4.5000	0.13029	118.83	8.4154
4.5200	0.13257	118.33	8.4513
4.5400	0.13488	117.81	8.4882
4.5600	0.13722	117.28	8.5262
4.5800	0.13958	116.75	8.5655
4.6000	0.14197	116.20	8.6059
4.6200	0.14439	115.64	8.6477
4.6400	0.14684	115.06	8.6909
4.6600	0.14932	114.47	8.7355
4.6800	0.15182	113.87	8.7818
4.7000	0.15436	113.25	8.8298
4.7200	0.15692	112.62	8.8796
4.7400	0.15952	111.96	8.9314
4.7600	0.16214	111.29	8.9853
4.7800	0.16480	110.60	9.0415
4.8000	0.16749	109.89	9.1002
4.8200	0.17020	109.15	9.1616
4.8400	0.17295	108.39	9.2261

Table 2-a: Helium			
Temperature (K)	Pressure (MPa)	Density (kg/m^3)	Volume/mass unit (dm^3/kg)
4.8600	0.17573	107.60	9.2938
4.8800	0.17854	106.78	9.3652
4.9000	0.18139	105.92	9.4407
4.9200	0.18426	105.03	9.5208
4.9400	0.18717	104.10	9.6061
4.9600	0.19012	103.12	9.6973
4.9800	0.19310	102.09	9.7953
5.0000	0.19611	101.00	9.9014
5.0200	0.19916	99.831	10.017
5.0400	0.20224	98.581	10.144
5.0600	0.20536	97.228	10.285
5.0800	0.20851	95.746	10.444
5.1000	0.21171	94.097	10.627
5.1200	0.21495	92.220	10.844
5.1400	0.21822	90.005	11.111

Table 3-a: Hydrogen			
Temperature (K)	Pressure (MPa)	Density (kg/m^3)	Volume/mass unit (dm^3/kg)
20.000	0.093414	71.135	14.058
20.200	0.099202	70.909	14.103
20.400	0.10524	70.680	14.148
20.600	0.11155	70.449	14.195
20.800	0.11812	70.214	14.242
21.000	0.12496	69.977	14.290
21.200	0.13208	69.736	14.340
21.400	0.13949	69.493	14.390
21.600	0.14719	69.246	14.441
21.800	0.15519	68.996	14.494
22.000	0.16350	68.743	14.547
22.200	0.17211	68.486	14.601
22.400	0.18105	68.226	14.657
22.600	0.19031	67.963	14.714
22.800	0.19990	67.695	14.772
23.000	0.20983	67.425	14.831
23.200	0.22011	67.150	14.892
23.400	0.23073	66.871	14.954
23.600	0.24172	66.588	15.018
23.800	0.25306	66.302	15.083
24.000	0.26478	66.010	15.149
24.200	0.27688	65.715	15.217
24.400	0.28936	65.415	15.287

Table 3-a: Hydrogen			
Temperature (K)	Pressure (MPa)	Density (kg/m^3)	Volume/mass unit (dm^3/kg)
24.600	0.30223	65.110	15.359
24.800	0.31550	64.800	15.432
25.000	0.32917	64.485	15.508
25.200	0.34325	64.165	15.585
25.400	0.35776	63.839	15.664
25.600	0.37268	63.507	15.746
25.800	0.38804	63.170	15.830
26.000	0.40384	62.827	15.917
26.200	0.42008	62.477	16.006
26.400	0.43678	62.120	16.098
26.600	0.45393	61.756	16.193
26.800	0.47155	61.385	16.291
27.000	0.48965	61.006	16.392
27.200	0.50823	60.619	16.496
27.400	0.52729	60.223	16.605
27.600	0.54685	59.819	16.717
27.800	0.56692	59.404	16.834
28.000	0.58750	58.980	16.955
28.200	0.60859	58.544	17.081
28.400	0.63022	58.097	17.213
28.600	0.65237	57.637	17.350
28.800	0.67508	57.164	17.493
29.000	0.69833	56.677	17.644
29.200	0.72214	56.174	17.802
29.400	0.74653	55.654	17.968
29.600	0.77149	55.116	18.144
29.800	0.79704	54.557	18.329
30.000	0.82319	53.976	18.527

Table 4-a: Nitrogen			
Temperature (K)	Pressure (MPa)	Density (kg/m^3)	Volume/mass unit (dm^3/kg)
75.000	0.076043	816.67	1.2245
76.000	0.086102	812.20	1.2312
77.000	0.097152	807.69	1.2381
78.000	0.10926	803.15	1.2451
79.000	0.12247	798.56	1.2522
80.000	0.13687	793.94	1.2595
81.000	0.15251	789.27	1.2670
82.000	0.16947	784.56	1.2746
83.000	0.18780	779.80	1.2824
84.000	0.20757	774.99	1.2903

Table 4-a: Nitrogen			
Temperature (K)	Pressure (MPa)	Density (kg/m^3)	Volume/mass unit (dm^3/kg)
85.000	0.22886	770.13	1.2985
86.000	0.25174	765.23	1.3068
87.000	0.27626	760.26	1.3153
88.000	0.30251	755.24	1.3241
89.000	0.33055	750.16	1.3330
90.000	0.36046	745.02	1.3422
91.000	0.39230	739.82	1.3517
92.000	0.42616	734.54	1.3614
93.000	0.46210	729.19	1.3714
94.000	0.50020	723.77	1.3817
95.000	0.54052	718.26	1.3922
96.000	0.58316	712.67	1.4032
97.000	0.62817	706.99	1.4144
98.000	0.67565	701.22	1.4261
99.000	0.72566	695.34	1.4381
100.00	0.77827	689.35	1.4506
101.00	0.83358	683.25	1.4636
102.00	0.89166	677.03	1.4770
103.00	0.95259	670.67	1.4910
104.00	1.0164	664.17	1.5056
105.00	1.0833	657.52	1.5209
106.00	1.1533	650.70	1.5368
107.00	1.2264	643.70	1.5535
108.00	1.3028	636.50	1.5711
109.00	1.3826	629.10	1.5896
110.00	1.4658	621.45	1.6091
111.00	1.5526	613.55	1.6299
112.00	1.6430	605.36	1.6519
113.00	1.7371	596.85	1.6755
114.00	1.8351	587.98	1.7007
115.00	1.9370	578.70	1.7280
116.00	2.0431	568.96	1.7576
117.00	2.1533	558.66	1.7900
118.00	2.2678	547.73	1.8257
119.00	2.3869	536.02	1.8656
120.00	2.5106	523.36	1.9107
121.00	2.6391	509.48	1.9628
122.00	2.7727	493.97	2.0244
123.00	2.9116	476.14	2.1002
124.00	3.0562	454.65	2.1995
125.00	3.2069	426.08	2.3470
126.00	3.3645	372.04	2.6879

Table 5-a: Oxygen			
Temperature (K)	Pressure (MPa)	Density (kg/m^3)	Volume/mass unit (dm^3/kg)
88.000	0.080114	1152.0	0.86808
89.000	0.089331	1147.0	0.87180
90.000	0.099350	1142.1	0.87558
91.000	0.11022	1137.1	0.87941
92.000	0.12197	1132.1	0.88329
93.000	0.13467	1127.1	0.88724
94.000	0.14836	1122.0	0.89124
95.000	0.16308	1116.9	0.89531
96.000	0.17889	1111.8	0.89945
97.000	0.19584	1106.6	0.90365
98.000	0.21397	1101.4	0.90792
99.000	0.23334	1096.2	0.91226
100.00	0.25400	1090.9	0.91668
101.00	0.27601	1085.6	0.92118
102.00	0.29941	1080.2	0.92576
103.00	0.32426	1074.8	0.93042
104.00	0.35062	1069.3	0.93518
105.00	0.37853	1063.8	0.94002
106.00	0.40806	1058.2	0.94496
107.00	0.43925	1052.6	0.94999
108.00	0.47217	1047.0	0.95513
109.00	0.50687	1041.3	0.96038
110.00	0.54340	1035.5	0.96574
111.00	0.58183	1029.6	0.97122
112.00	0.62220	1023.7	0.97682
113.00	0.66458	1017.8	0.98255
114.00	0.70902	1011.7	0.98842
115.00	0.75559	1005.6	0.99442
116.00	0.80433	999.42	1.0006
117.00	0.85532	993.16	1.0069
118.00	0.90859	986.81	1.0134
119.00	0.96423	980.38	1.0200
120.00	1.0223	973.85	1.0268
121.00	1.0828	967.24	1.0339
122.00	1.1459	960.52	1.0411
123.00	1.2115	953.70	1.0485
124.00	1.2798	946.77	1.0562
125.00	1.3509	939.72	1.0641
126.00	1.4247	932.55	1.0723
127.00	1.5014	925.25	1.0808
128.00	1.5809	917.81	1.0896
129.00	1.6635	910.22	1.0986
130.00	1.7491	902.48	1.1081
131.00	1.8378	894.57	1.1179
132.00	1.9296	886.48	1.1281

Table 5-a: Oxygen			
Temperature (K)	Pressure (MPa)	Density (kg/m^3)	Volume/mass unit (dm^3/kg)
133.00	2.0248	878.19	1.1387
134.00	2.1232	869.70	1.1498
135.00	2.2250	860.98	1.1615
136.00	2.3303	852.02	1.1737
137.00	2.4392	842.80	1.1865
138.00	2.5516	833.28	1.2001
139.00	2.6678	823.43	1.2144
140.00	2.7878	813.24	1.2297
141.00	2.9116	802.64	1.2459
142.00	3.0394	791.60	1.2633
143.00	3.1713	780.05	1.2820
144.00	3.3074	767.92	1.3022
145.00	3.4477	755.13	1.3243
146.00	3.5925	741.55	1.3485
147.00	3.7418	727.05	1.3754
148.00	3.8958	711.42	1.4056
149.00	4.0547	694.37	1.4402
150.00	4.2186	675.48	1.4804
151.00	4.3878	654.06	1.5289
152.00	4.5626	628.82	1.5903
153.00	4.7434	596.79	1.6756
154.00	4.9307	547.04	1.8280

Annex C BIBLIOGRAPHY

(Informative)

Ref.	Standards and reference documents	Abstract
[1]	**ISO/IEC Guide 9** (2007) **OIML V 2-200** (2012) International Vocabulary of Metrology – Basic and General Concepts and Associated Terms (VIM), (Edition 2010 with minor corrections)	An international agreement on terminology, prepared as a collaborative work of experts appointed by BIPM, IEC, IFCC, ISO, IUPAC, IUPAP and OIML. This vocabulary covers subjects relating to measurement and includes information on the determination of physical constants and other fundamental properties of materials and substances. (In practice, these publications are usually referred to as the "VIM".)
[2]	**OIML V1** (2013) International Vocabulary of Terms in Legal Metrology (**VIML**)	No abstract available International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM). 3rd Edition (Bilingual E/F). (Edition 2010 with minor corrections)
[3]	**OIML D 9** (2004) Principles of metrological supervision	The purpose of this International Document is to provide elements to be considered for developing a model of metrological supervision in Member States which can be used as a basis for the harmonization of metrological supervision at an international level.
[4]	**OIML D 11** (2013) General requirements for measuring instruments - Environmental conditions	The primary aim of this International Document is to provide OIML Technical Committees and Subcommittees with guidance for establishing appropriate metrological performance testing requirements for influence quantities that may affect the measuring instruments covered by International Recommendations.
[5]	**OIML D 31** (2008) General requirements for software controlled measuring instruments	Specifies the general requirements applicable to software related functionality in measuring instruments and gives guidance for verifying the compliance of an instrument with these requirements.
[6]	**OIML B 3 (2011)**OIML Basic Certificate System for OIML Type Evaluation of Measuring Instruments	No abstract available
[7]	**IEC 60068-1** ((2013-10-07) Environmental testing. Part 1: General and guidance **IEC 60068**-1:2013 | IEC Webstore	Enumerates a series of environmental tests and appropriate severities, and prescribes various atmospheric conditions for measurements for the ability of specimens to perform under normal conditions of transportation, storage and operational use.
[8]	**IEC 60068-2-1** (2007-03) Environmental testing, Part 2: Tests, Test A: Cold **IEC 60068**-2-1:2007 | IEC Webstore	
[9]	**IEC 60068-2-2** (2007-07)	Deals with dry heat tests applicable both to heat-dissipating and non heat-dissipating specimens. The object of the dry heat test is

	Environmental testing - Part 2-2: Tests - Test B: Dry heat **IEC 60068**-2-2:2007 | IEC Webstore	limited to the determination of the ability of components, equipment or other articles to be used, transported or stored at high temperature.
[10]	**IEC 60068-2-6 (2007-12)** **Environmental testing - Part 2-6: Tests - Test Fc: Vibration (sinusoidal)** **IEC 60068**-2-6:2007 | IEC Webstore	Gives a method of test which provides a standard procedure to determine the ability of components, equipment and other articles, hereinafter referred to as specimens, to withstand specified severities of sinusoidal vibration. The purpose of this test is to determine any mechanical weakness and/or degradation in the specified performance of specimens and to use this information, in conjunction with the relevant specification, to decide upon the acceptability of the specimens. In some cases, the test method may also be used to demonstrate the mechanical robustness of specimens and/or to study their dynamic behaviour.
[11]	**IEC 60068-2-30** (2005-08) Environmental testing - Part 2-30: Tests - Test Db: Damp heat, cyclic (12 h + 12 h cycle) **IEC 60068**-2-30:2005 | IEC Webstore	Determines the suitability of components, equipment or other articles for use, transportation and storage under conditions of high humidity - combined with cyclic temperature changes and, in general, producing condensation on the surface of the specimen.
[12]	**IEC 60068-2-47** (2005) Environmental testing - Part 2-47: Test - Mounting of specimens for vibration, impact and similar dynamic tests **IEC 60068**-2-47:2005 | IEC Webstore	Provides methods for mounting products, whether packaged or unpackaged, as well as mounting requirements for equipment and other articles, for the series of dynamic tests in IEC 60068-2, that is impact (Test E), vibration (Test F) and acceleration, steady-state (Test G).
[13]	**IEC 60068-2-64 (2008)** **Environmental testing - Part 2-64: Tests - Test Fh: Vibration, broadband random and guidance** **IEC 60068-2-64**:2008 | IEC Webstore	IEC 60068-2-64:2008 demonstrates the adequacy of specimens to resist dynamic loads without unacceptable degradation of its functional and/or structural integrity when subjected to the specified random vibration test requirements. Broadband random vibration may be used to identify accumulated stress effects and the resulting mechanical weakness and degradation in the specified performance. This standard is applicable to specimens which may be subjected to vibration of a stochastic nature resulting from transportation or operational environments, for example in aircraft, space vehicles and land vehicles. It is primarily intended for unpackaged specimens, and for items in their transportation container when the latter may be considered as part of the specimen itself. If the specimens are subjected to vibration of a combination of random and deterministic nature resulting from transportation or real life environments, for example in aircraft, space vehicles and for items in their transportation container, testing with pure random may not be sufficient.
[14]	**IEC 60068-3-1** (2011-08)	Provides guidance regarding the performance of cold and dry heat tests. This second edition

	Environmental testing- Part 3-1: Supporting documentation and guidance Cold and dry heat tests **IEC 60068**-3-1:2011 | IEC Webstore	cancels and replaces the first edition, published in 1974, and constitutes a technical revision. The main changes with regard to the previous edition are as follows: - removal of guidance regarding thermal characteristics of chamber walls; - revision of sections that address environmental chambers that do not use movement of air for temperature control.
[15]	**IEC 60068-3-4** (2001-08) Environmental testing Part 3-4: Supporting documentation and guidance - Damp heat tests **IEC 60068-3-4**:2001 | IEC Webstore	Provides the necessary information to assist in preparing relevant specifications, such as standards for components or equipment, in order to select appropriate tests and test severities for specific products and, in some cases, specific types of application. The object of damp heat tests is to determine the ability of products to withstand the stresses occurring in a high relative humidity environment, with or without condensation, and with special regard to variations of electrical and mechanical characteristics. Damp heat tests may also be utilized to check the resistance of a specimen to some forms of corrosion attack.
[16]	**IEC 60068-3-8** (2003-08) Environmental testing - Part 3-8: Supporting documentation and guidance - Selecting amongst vibration tests **IEC 60068**-3-8:2003 | IEC Webstore	Provides guidance for selecting amongst the IEC 60068-2 stationary vibration test methods Fc sinusoidal, Fh random and F(x) Mixed mode vibration. The different steady-state test methods and their aims are briefly described in Clause 4. Transient test methods are not included. For vibration testing, the environmental conditions, especially the dynamic conditions for the specimen, should be known. This standard helps to collect information about the environmental conditions (Clause 5), to estimate or measure the dynamic conditions (Clause 6) and gives examples to enable decisions to be made on the most applicable environmental vibration test method. Starting from the condition, the method of selecting the appropriate test is given. Since real life vibration conditions are dominated by vibration of a random nature, random testing should be the commonly used method, see Table 1, Clause 7. The methods included hereafter may be used to examine the vibration response of a specimen under test before, during and after vibration testing. The selection for the appropriate excitation method is described in Clause 8 and tabulated in Table 2. In this standard specification, writers will find information concerning vibration test methods and guidance for their selection.
[17]	**IEC 60654-2** (1979-01) Operating conditions for industrial-process measurement and control equipment. Part 2: Power **IEC 60654-2**:1979 | IEC Webstore	Gives the limiting values for power received by land-based and offshore industrial-process measurement and control systems or parts of systems during operation. Maintenance and repair conditions are not considered.
[18]	**IEC/TR3 61000-2-1** (1990-05) Electromagnetic compatibility (EMC) - Part 2: Environment - Section 1: Description of the environment - Electromagnetic	Has the status of a technical report, and gives information on the various types of disturbances that can be expected on public

	environment for low-frequency conducted disturbances and signalling in public power supply systems **IEC** TR **61000-2-1**:1990 | **IEC** Webstore	power supply systems. The following disturbance phenomena are considered: - harmonics - inter-harmonics - voltage fluctuations - voltage dips and short supply interruptions - voltage unbalance - mains signalling - power frequency variation - d.c. components.
[19]	**IEC 61000-4-1** (2006-10) Electromagnetic compatibility (EMC) - Part 4-1: Testing and measurement techniques - Overview of IEC 61000-4 series **IEC 61000-4-1**:2006 | IEC Webstore	The object of this part of IEC 61000 is to give applicability assistance to the technical committees of IEC or other bodies, users and manufacturers of electrical and electronic equipment on EMC standards within the IEC 61000-4 series on testing and measurement techniques and to provide general recommendations concerning the choice of relevant tests.
[20]	**IEC 61000-4-2** (2008-12) Electromagnetic compatibility (EMC) - Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test **IEC 61000-4-2**:2008 | IEC Webstore	IEC 61000-4-2:2008 relates to the immunity requirements and test methods for electrical and electronic equipment subjected to static electricity discharges, from operators directly, and from personnel to adjacent objects. It additionally defines ranges of test levels which relate to different environmental and installation conditions and establishes test procedures.
[21]	**IEC 61000-4-3** (2010-04) Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques Radiated, radio-frequency, electromagnetic field immunity test **IEC 61000-4-3**:2006+AMD1:2007+AMD2:**2010** CSV | **IEC** Webstore	IEC 61000-4-3:2006+A1:2007+A2:2010 is applicable to the immunity requirements of electrical and electronic equipment to radiated electromagnetic energy. It establishes test levels and the required test procedures. The object of this standard is to establish a common reference for evaluating the immunity of electrical and electronic equipment when subjected to radiated, radio-frequency electromagnetic fields. Particular considerations are devoted to the protection against radio-frequency emissions from digital radiotelephones and other RF emitting devices.
[22]	**IEC 61000-4-4** (2012-04) Electromagnetic compatibility (EMC) – Part 4-4:Testing and measurement techniques – Electrical fast transient/burst immunity test **IEC 61000-4-4**:2012 | IEC Webstore	~~This Final Draft International Standard is an up-to-3-months' pre-release of the official publication. It is available for sale during its voting period: 2012-01-27 to 2012-03-30. By purchasing this FDIS now, you will automatically receive, in addition, the final publication.~~ IEC 61000-4-4:2012 relates to the immunity of electrical and electronic equipment to repetitive electrical fast transients. It has the status of a basic EMC publication in accordance with IEC Guide 107. It gives immunity requirements and test procedures related to electrical fast transients/bursts. It additionally defines ranges of test levels and establishes test procedures. The object of this standard is to establish a common and reproducible reference in order to evaluate the immunity of electrical and electronic

		equipment when subjected to electrical fast transient/bursts on supply, signal, control and earth ports. The test method documented in this standard describes a consistent method to assess the immunity of an equipment or system against a defined phenomenon.
[23]	**IEC 61000-4-11** (2004-03) Electromagnetic compatibility (EMC) - Part 4-11: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests **IEC 61000-4-11**:2004 | IEC Webstore	This part of IEC 61000 defines the immunity test methods and range of preferred test levels for electrical and electronic equipment connected to low-voltage power supply networks for voltage dips, short interruptions, and voltage variations. This standard applies to electrical and electronic equipment having a rated input current not exceeding 16 A per phase, for connection to 50 Hz or 60 Hz a.c. networks. It does not apply to electrical and electronic equipment for connection to 400 Hz a.c. networks. Tests for these networks will be covered by future IEC standards. The object of this standard is to establish a common reference for evaluating the immunity of electrical and electronic equipment when subjected to voltage dips, short interruptions and voltage variations.
[24]	**IEC 61000-4-20** (2010-08) Electromagnetic compatibility (EMC) - Part 4-20: Testing and measurement techniques - Emission and immunity testing in transverse electromagnetic (TEM) waveguides **IEC 61000-4-20**:2010 | IEC Webstore	IEC 61000-4-20:2010 relates to emission and immunity test methods for electrical and electronic equipment using various types of transverse electromagnetic (TEM) waveguides. These types include open structures (for example, striplines and electromagnetic pulse simulators) and closed structures (for example, TEM cells).
[25]	**IEC 61000-6-1** (2005-03) Electromagnetic compatibility (EMC) - Part 6-1: Generic standards - Immunity for residential, commercial and light-industrial environments **IEC 61000-6-1**:2005 | IEC Webstore	Applies to electrical and electronic apparatus intended for use in residential, commercial and light-industrial environments. Immunity requirements in the frequency range 0 Hz to 400 GHz are covered. No tests need to be performed at frequencies where no requirements are specified. This generic EMC immunity standard is applicable if no relevant dedicated product or product-family EMC immunity standard exists. This standard applies to apparatus intended to be directly connected to a low-voltage public mains network or connected to a dedicated DC source which is intended to interface between the apparatus and the low-voltage public mains network. This standard applies also to apparatus which is battery operated or is powered by a non-public, but non-industrial, low-voltage power distribution system if this apparatus is intended to be used in the locations described below. The environments encompassed by this standard are residential,

		commercial and light-industrial locations, both indoor and outdoor.
[26]	**IEC 61000-6-2** (2005-01) Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity for industrial environments **IEC 61000-6-2**:2005 | IEC Webstore	Applies to electrical and electronic apparatus intended for use in industrial environments, as described below. Immunity requirements in the frequency range 0 Hz to 400 GHz are covered. No tests need to be performed at frequencies where no requirements are specified. This generic EMC immunity standard is applicable if no relevant dedicated product or product-family EMC immunity standard exists. This standard applies to apparatus intended to be connected to a power network supplied from a high or medium voltage transformer dedicated to the supply of an installation feeding manufacturing or similar plant, and intended to operate in or in proximity to industrial locations, as described below. This standard applies also to apparatus which is battery operated and intended to be used in industrial locations. The environments encompassed by this standard are industrial, both indoor and outdoor. The immunity requirements have been selected to ensure an adequate level of immunity for apparatus at industrial locations.
[27]	**ISO 7637-2:2011** Road vehicles. Electrical disturbances -from conduction and coupling-- Part 2 : Electrical transient conduction along supply lines only ISO 7637-2:2011	Specifies test methods and procedures to ensure the compatibility to conducted electrical transients of equipment installed on passenger cars and commercial vehicles fitted with 12 V or 24 V electrical systems. It describes bench tests for both the injection and measurement of transients. It is applicable to all types of road vehicles independent of the propulsion system (e.g. spark ignition or diesel engine, electric motor).Function performance status classification for immunity to transients is also provided.
[28]	**G 1-100** (2008) Evaluation of measurement data - Guide to the expression of uncertainty in measurement (GUM)	This Guide establishes general rules for evaluating and expressing uncertainty in measurement that are intended to be applicable to a broad spectrum of measurements. The basis of the Guide is Recommendation 1 (CI-1981) of the Comité International des Poids et Mesures (CIPM) and Recommendation INC-1 (1980) of the Working Group on the Statement of Uncertainties.