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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:

- **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;
- **International Documents (OIML D),** which are informative in nature and which are intended to harmonize and improve work in the field of legal metrology;
- **International Guides (OIML G),** which are also informative in nature and which are intended to give guidelines for the application of certain requirements to legal metrology;
- **International Basic Publications (OIML B),** which define the operating rules of the various OIML structures and systems; and

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

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

Additionally, the OIML publishes or participates in the publication of **Vocabularies (OIML V)** and periodically commissions legal metrology experts to write **Expert Reports (OIML E)**. Expert Reports are intended to provide information and advice, and are written solely from the 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.

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1 Introduction

1.1 Metrology in general, and legal metrology specifically, is quite a different discipline and function than it was even twenty years ago, both at national and international levels. ~~Metrology in general, including legal metrology, nowadays is already quite different from what it was some twenty – thirty years ago, both at national and international levels.~~ Metrology is facing ~~multiply~~ multiple developments such as globalisation of economics and international trade, geopolitical changes, elimination of technical barriers to trade, liberalisation, privatisation and redefinition of the role of the state in metrology.

Metrology~~–~~ also evolves ~~has changed also due to~~together with implementation of quality management systems in various organisations, accreditation of testing and calibration laboratories, and conformity assessment procedures based on quality system of production. The quality of products and services is increasingly dependent on reliable measurements.

1.2 The measurements are important to conformity assessment and specifically legal metrology, including the requirements for legal control of measuring instruments. The metrological traceability enters into legal metrology as part of conformity assessment. The results of measurements covered by regulations shall be expressed in legal units and shall be traceable to the SI [9].

~~The quality of products and services is increasingly dependent on reliable measurements.~~

~~**1.2**~~ The importance attached to measurements is also reflected in relevant international measurement standards by the requirement that measurements ~~must~~ shall be traceable to the SI through national realisations in National Metrology Institutes (NMI) which can be referred to as national or international measurement standards. So, for example, according to ISO/IEC 17025:~~2005~~ 2017 ~~*General requirements for the competence of testing and calibration laboratories*~~ [1], when the measurement accuracy and measurement uncertainty affect the validity of the reported result, or metrological traceability is a requirement, measuring equipment shall be calibrated before being placed into service.~~all equipment used in testing and/or calibration laboratories having significant effect on the accuracy or validity of the result of the test or calibration shall be calibrated before being put into service.~~ The calibration program~~me~~ for ~~calibration of~~ equipments shall ensure that calibrations and measurements made by the laboratory are metrological traceable ~~-~~to the SI units.

In line with another standard, ISO 9001:~~2008~~ 2015 ~~*Quality management systems. Requirements*~~[8], when measurement traceability is a requirement, or is considered by the organization to be an essential part of providing confidence in the validity of measurement results, measuring equipment shall be calibrated or verified at specified intervals or prior to use, against measurement standards traceable to international or national measurement standards.~~in an organisation where it is necessary to ensure valid results, measuring equipment shall be calibrated or verified prior to use and at specified intervals, against measurement standards traceable to international or national measurement standard.~~

1.3 Metrological traceability ~~Traceability~~ is based on the one hand on calibrations, traceable to national measurement standards, particularly those that are primary measurement standards and international measurement standards, and on the other hand on equivalence between national measurement standards, as stated in joint BIPM, OIML, ILAC and ISO declarations on the relevance of Mutual Recognition Arrangements (MRA´s) [6] and on metrological traceability [7].

1.4 Metrological traceability ~~Traceability~~ of measurements to the SI or, if this is not possible, to other internationally agreed references is essential if the results of these measurements are to be comparable and if uncertainty of measurements is to be meaningfully assigned. National

measurement systems provide the framework, within which all measurements necessary for the proper performance of a calibration, testing or verification are traceable, where the concept is applicable, to national measurement standards or, when using reference materials, to national or international reference materials.

1.5 The quest for a better quality of measurements is the very reason for the existence of hierarchy schemes. This can be achieved in a number of ways, the classical scheme that is based on the direct calibration chain being the most widely used.

2 Scope

2.1 This document deals with the principles of metrological traceability and how the metrological traceability may be achieved. It proposes also general rules for the establishment of hierarchy schemes for measuring instruments as a specification of chains of calibration for measuring instruments (including means and methods of dissemination of units), which serves to evidence their metrological traceability.~~This Document lays down a clear and transparent picture of the principles of traceability and how the traceability may be achieved. It proposes also general rules for the establishment of hierarchy schemes for measuring instruments as a specification of chains of comparison for measuring instruments (including means and methods of unit transfers), which serves to evidence their traceability.~~

~~**2.2** However, it is not the only hierarchy scheme available and, depending on circumstances, other ways of reaching this scope may be preferable. These are not discussed in this Document, but could be described in other International Documents.~~

2.2 This Document gives guidance and assistance to organisations on how to comply with the metrological traceability~~traceability~~ requirements for relevant standards. It is intended for legal metrology laboratories where supervision of measuring and test equipment is an important part of quality assurance. It may be used by organisations involved in industrial production processes (development, manufacture, installation, final inspection) and by calibration and testing laboratories.

2.3 Depending on circumstances, other ways of reaching this scope may be preferable. These are not discussed in this Document, but could be described in other International Documents.

~~**2.3**~~

3 Terminology

Unless otherwise stated in the following sub-clauses, the terminology used in this Document conforms to VIML [3], VIM~~3~~ [2] and GUM [4].

For the purpose of this Document, the definitions and abbreviations given below apply.

3.1 ~~**Calibration**~~ **calibration hierarchy** (~~VIM3~~VIM, 2.40)
sequence of calibrations from a reference to the final measuring system, where the outcome of each calibration depends on the outcome of the previous calibration

For notes see (VIM, 2.40)

3.2 ~~**Metrological**~~ **metrological traceability** (~~VIM3~~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

NOTE 1~~)~~ For this definition, a 'reference' can be a definition of a measurement unit through its practical realization, or a measurement procedure including the measurement unit for a non-ordinal quantity, or a measurement standard.
NOTE 2~~)~~ Metrological traceability requires an established calibration hierarchy.

For other notes see (VIM, 2.41)

~~For the application of legal metrology control, metrological traceability may be obtained either through evaluation of uncertainties or through compliance with stated maximum permissible errors.~~

3.3 ~~**Metrological**~~ **metrological traceability chain**, traceability chain (~~VIM3~~VIM, 2.42)
sequence of measurement standards and calibrations that is used to relate a measurement result to a reference

NOTE 1~~)~~ A metrological traceability chain is defined through a calibration hierarchy.
NOTE 2~~)~~ A metrological traceability chain is used to establish metrological traceability of a measurement result.
NOTE 3~~)~~ A comparison between two measurement standards may be viewed as a calibration if the comparison is used to check and, if necessary, correct the quantity value and measurement uncertainty attributed to one of the measurement standards

3.4 ~~**Metrological**~~ **metrological traceability to a measurement unit**, metrological traceability to a unit (~~VIM3~~VIM, 2.43)
metrological traceability where the reference is the definition of a measurement unit through its practical realization

NOTE~~:~~ The expression "traceability to the SI" means 'metrological traceability to a measurement unit of the International System of Units'.

3.5 **measuring instrument** (VIM, 3.1)
device used for making measurements, alone or in conjunction with one or more supplementary devices

NOTE 1 A measuring instrument that can be used alone is a measuring system.
NOTE 2 A measuring instrument may be an indicating measuring instrument or a material measure.

3.6 **indicating measuring instrument** (VIM, 3.3)
carrying information about the value of the quantity being measured

EXAMPLES Voltmeter, micrometer, thermometer, electronic balance.
NOTE 1 An indicating measuring instrument may pro-vide a record of its indication.
NOTE 2 An output signal may be presented in visual or acoustic form. It may also be transmitted to one or more other devices.

3.7 **material measure** (VIM, 3.6)
measuring instrument reproducing or supplying, in a permanent manner during its use, quantities of one or more given kinds, each with an assigned quantity value

EXAMPLES Standard weight, volume measure (sup-plying one or several quantity values, with or without a quantity-value scale), standard electric resistor, line scale (ruler), gauge block, standard signal generator, certified reference material.

NOTE 1 The indication of a material measure is its assigned quantity value.
NOTE 2 A material measure can be a measurement standard.

~~3.5~~3.8 ~~Legal~~ legal control of measuring instruments (VIML, 2.02)
generic term used to globally designate legal operations to which measuring instruments may be subjected, e.g. type approval, verification, etc.

~~3.6~~3.9 ~~Hierarchy~~ hierarchy scheme
descriptive and graphical specification of metrological traceability~~traceability~~ chain for a given kind of measuring instrument which serves to evidence their metrological traceability~~traceability~~

~~3.7~~3.10 ~~National~~ national hierarchy scheme
hierarchy scheme for a given kind of measuring instruments in the particular country, containing specification of recommended (permissible) kinds of measuring instruments for individual levels of metrological traceability, requirements for their metrological characteristics and recommended (permissible) methods and means of dissemination of units~~unit transfer~~

~~3.8~~3.11 ~~Local~~ local hierarchy scheme

hierarchy scheme for a given kind of measuring instruments at a given location, in a given organisation or in a given laboratory, containing specification of reference and working standards, their metrological characteristics and methods and means of dissemination of units ~~unit transfer~~

~~3.9~~3.12 ~~Means~~ means of units dissemination~~unit transfer~~

technical devices, reference materials or material medium, in which ~~comparison~~ calibration is carried out, necessary for transfer of values from measurement standards to compared measuring instruments and which influence uncertainties of dissemination of units~~unit transfer~~

~~3.10~~3.13 ~~National~~ National Metrology Institute (National Standard Laboratory, Designated Laboratory)

the institute in a country that has a responsibility, sometimes set out legally, for the conservation of one or more national measurement standards. The recommended role of a National Metrology Institute (NMI) is described in detail in section 3.2.2.3 of the OIML D 1:2012 [10]

~~3.11~~3.14 ~~Legal~~ legal metrology laboratory (~~Legal~~ legal metrology services)

authorised laboratory ~~body~~ responsible for a legal control of measuring instruments, e.g. type approval, verification, etc. The recommended role of a legal metrology laboratory is described in detail in section 3.2.2.3 of the OIML D 1:2012 [10]

~~3.12~~3.15 ~~Accredited~~ accredited calibration laboratory

laboratory that performs calibration of measuring instruments and is formally recognised by an accreditation authority and is competent to carry out the calibration (e.g. competence in accordance with ISO/IEC 17025:2017)

4 Metrological traceability ~~Traceability~~ and its elements

4.1 Metrological traceability ~~Traceability~~ of the results obtained through the use of measuring and test equipment by means of traceable calibration or verification is necessary in order:

- a) to meet the requirements of growing national and international trade;
- b) to guarantee the product quality and compatibility of manufactured parts;
- c) to protect the interests of individuals and enterprises, protect national interests;
- d) to protect public health and safety, including environment, medical and related services.

4.2 For the application of legal metrology control, metrological traceability may be obtained either through evaluation of measurement uncertainty or through compliance with stated maximum permissible error.

~~4.2~~4.3 For the application of any laws and regulations prescribing requirements on measurements, on prepackages and on measuring instruments, the metrological traceability~~traceability~~ to SI units is required and may be obtained:

- a) either through the system of national measurement standards and certified reference materials, or
- b) through traceability to recognised national measurement standards or certified reference materials of other countries.

~~4.3~~4.4 The term metrological traceability means that the indication of an indicating measuring instrument (or a material measure) has been compared, in one or more stages, with a national measurement standard for the measurand in question. In each of these stages, a calibration has been performed using a measurement standard which value and uncertainty are already determined by calibration with a higher-level standard. Therefore there is a hierarchy of calibrations as shown in Fig. 1.

~~4.4~~4.5 For practical reasons, especially in the legal metrology verifications or in case of repeated standard or routine calibrations, measurement uncertainty may be expressed in the form of fraction of maximum permissible error (MPE) of measurement standard (or measuring instrument) indications.

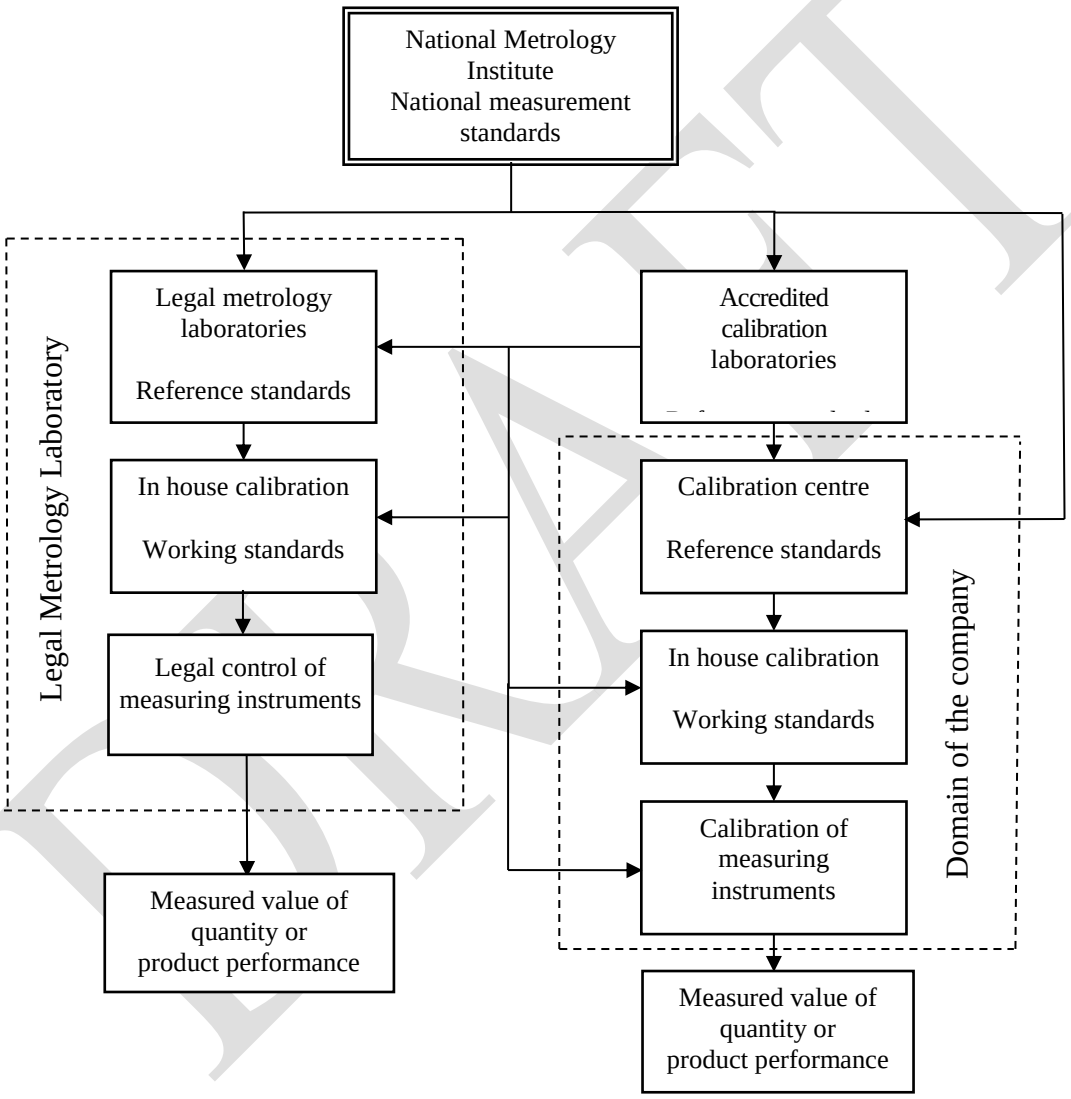


Fig. 1 Hierarchy of calibrations

~~4.5~~4.6 Metrological traceability~~Traceability~~ is characterised by a number of essential elements:

~~–~~a) an unbroken chain of dissemination of units ~~unit transfers~~ going back to a measurement standard acceptable to the parties, usually national measurement standards;

~~–~~b) measurement uncertainty; the measurement uncertainty for each step in the metrological traceability~~traceability~~ chain ~~must~~ shall be calculated according to (agreed

methods, based on) the "Guide to the expression of uncertainty in measurement" [4] and ~~must~~shall be stated in such a way that an overall uncertainty for each following stage of the chain may be calculated;

~~–~~c) documentation; each step in the chain ~~must~~shall be performed according to documented and generally acknowledged procedures; the results ~~must~~shall equally be documented;

~~–~~d) competence; the laboratories performing one or more steps in the chain ~~must~~shall supply evidence for their technical competence (equipment, skills of personnel, environmental conditions, etc.);

~~–~~e) reference to SI units; the chain of ~~comparisons~~ calibrations ~~must~~shall end at primary standards for the realisation of the SI units or at measurement standards, on which metrological traceability~~traceability~~ to primary standard is demonstrable (as far as technically possible or applicable);

~~–~~f) re-calibrations; calibrations ~~must~~shall be repeated at regular intervals depending upon a number of variables, e.g. uncertainty required, frequency of use, way of use, stability of equipment and it should be stated in the documentation of the standard;

g) initial verification; verification of a measuring instrument which has not been verified previously

~~–~~h) subsequent verification; verification of a measuring instrument after a previous verification carried out periodically at specified intervals according to the procedure laid down by the regulations.

~~4.6~~4.7 In many fields, reference materials take the role of physical reference standards. It is equally important that such reference materials are traceable to relevant SI units realised by national or international measurement standards. Certification of reference materials is a method that is often used to demonstrate metrological traceability~~traceability~~ to national or international measurement standards.

Note 1:~~)~~ Reference and working standards and means of dissemination of units~~unit transfer~~ have to be provided by documentation in accordance with valid regulations. The basic document for these measurement standards and means of dissemination of units~~unit transfer~~ is the valid calibration certificate issued either by accredited calibration laboratory or by laboratory demonstrating metrological traceability ~~traceability~~ to national measurement standard.

Note 2:~~)~~ The important parts of metrological traceability ~~traceability~~ documentation are calibration or verification methods and procedures. Calibration or verification procedures have to clearly describe metrological traceability~~traceability~~ of measurements, e.g. have to clearly define, which measurement standards and means of dissemination of units~~unit transfer~~ are used for it. At the same time these procedures have to state the detailed procedure for the uncertainties evaluation of calibrated or verified measuring instruments.

5 Levels of dissemination of units of measurement

5.1 International level

5.1.1 At the international level, decisions concerning the international System of Units (SI) and the realisation of the primary standards are taken by the Conférence Générale des Poids et Mesures (CGPM). The Bureau International des Poids et Mesures (BIPM) is charged with coordinating

the development and maintenance of primary standards and organises intercomparisons on the highest level.

5.2 National metrology institutes

5.2.1 The National Metrology Institutes are the highest authorities in metrology in almost all countries. In most cases they maintain the ~~"~~national measurement standards~~"~~ of the country that are the sources of metrological traceability~~traceability~~ for the associated physical quantities in that country. In some cases, the metrological traceability~~traceability~~ is to the measurement standards ~~held~~ maintained by ~~the~~ BIPM. If the National Metrology Institute has facilities to realise the corresponding SI unit of measurement (the term SI unit includes all derived units), the national measurement standard may be identical to the primary standard realising the unit. If the NMI does not have this facility, it has to ensure that the measurements are traceable to a primary standard maintained in another country, preferably to measurement standards realized at an NMI which is a signature to the Mutual Recognition Arrangement of the Comité International des Poids et Mesures (CIPM MRA)~~CIPM MRA~~. If this is so, then calibration certificates issued by this NMI are considered as internationally acceptable. The National Metrology Institutes ensure that the primary standards themselves are internationally compared within the framework of the CIPM MRA. They are responsible for dissemination of the units of measurement to users, scientists, public authorities, laboratories or industrial enterprises and are therefore at the top level of the metrological infrastructure in a country.

5.3 Accredited calibration laboratories

5.3.1 Calibration laboratories in industry and other organisations accredited by national accreditation bodies according to internationally established criteria (e.g. in accordance with ISO/IEC 17025:2017 [1]) ~~must~~shall be able to demonstrate that calibration of critical equipment and hence their measurement results, relevant to their scope of accreditation are traceable to SI units (as far as technically possible or as far as applicable).

5.3.2 Accredited calibration laboratories are often at the top of a firm's internal calibration hierarchy. Their task is then to compare, at appropriate intervals, the firm's own working standards with reference standards, which are calibrated by a National Metrology Institute or an accredited laboratory with suitable calibration and measurement capability~~best measurement capability~~.

5.3.3 Many accredited laboratories carry out calibrations for third parties, e.g. for organisations that are not equipped with calibration facilities and for private test laboratories as well, which work in the field of product certification. In this case the customer has to be assured that measurement uncertainty achieved in a laboratory is suitable and sufficient for the intended use of the measuring instrument to be calibrated.

5.3.4 The calibration results are documented in a calibration certificate.

5.4 Legal metrology laboratories

5.4.1 Legal metrology laboratories are laboratories of the state legal metrology services or private metrology laboratories charged (authorised) by the national (legal) metrology authority to carry out legal control of measuring instruments within a defined scope.

5.4.2 Legal metrology laboratories according to national legislation shall be able to demonstrate that calibration of measurement standards and of verification devices and hence their measurement results, relevant to their scope of authorisation, are traceable to SI units. Their reference standards are calibrated by a National Metrology Institute or an accredited laboratory with suitable calibration and measurement capability~~best measurement capability~~. The metrological traceability to the standards maintained by NMIs may be checked by the reference to calibration

and measurement capabilities of NMIs as held on the BIPM's key comparison database published on the BIPM web site (www.bipm.org). ~~This may be checked in the case of traceability to the standards held at NMIs by reference to the calibration and measurement capabilities of NMIs as held on the BIPM's key comparison database on the BIPM web site (www.bipm.org).~~

5.4.3 Legal metrology laboratories are in some countries accredited e.g. according to ISO/IEC 17025:~~2005~~ 2017 [1].

5.5 In house calibration

5.5.1 In-house calibration is regular calibration of working standards, measuring and test equipment used in a metrology laboratory or in a company against its own reference standards that are traceably calibrated at an accredited calibration laboratory, a legal metrology laboratory or a National Metrology Institute.

5.5.2 The scope of in-house calibration is at the discretion of the laboratory or company concerned. The results obtained with the in house calibrated measuring and test equipment should be sufficiently accurate and reliable.

5.5.3 The hierarchy of measurement standards and a resulting metrological organisation structure for tracing measurement and test results within a laboratory or a company to national measurement standards in general is shown in Fig. 2.

Measurement standard (measuring equipment)	**Responsibility**	**Tasks**	**Basis** for the legal control, calibration or measurements	**Documentation** of the legal control, calibration and measurements
National measurement standards	**National Metrology Institute (NMI)**	To maintain National measurement standards and disseminate the measuring units	Statutory duty to represent SI units and ensure international comparability	Calibration certificate for reference standard
Reference standards	**Accredited calibration laboratories and Legal metrology laboratories**	Calibration of working standards to safeguard the metrology infrastructure of country	Calibration certificate from NMI or other accredited laboratory	Calibration certificate for working standard
Working standards	**Legal metrology laboratories, accredited calibration laboratories and in-house calibration**	Legal control or calibration of measuring instruments	Calibration certificate from NMI or Legal metrology laboratory or accredited laboratory	Calibration or type approval or verification certificate. Type approval or verification or calibration mark
Ordinary instruments	**User**	Measurement and tests performed by legally controlled or calibrated measuring instruments, or as a part of quality assurance measures	Verification or calibration certificate or verification or calibration mark of measuring instruments from legal metrology laboratory or accredited calibration laboratory– or in-house calibration	Measurement and test results

Fig. 2 The hierarchy of measurement standards and a resulting metrological organisation structure for tracing measurement and test results

6 General principles for the establishment of hierarchy schemes, their structure and practical realisation

Hierarchy scheme for measuring instruments is a graphically illustrated system of gradually arranged measuring instruments determining the unbroken chains of calibration~~comparison~~s from the national measurement standard down to measuring instruments, giving methods of dissemination of units ~~unit transfer~~, important metrological characteristics and mutual links.

6.1 General principles for the establishment of hierarchy schemes

6.1.1 The hierarchy scheme may cover either the overall field of measurements of a particular quantity or only a defined part of it, which is characterised by one or more of the following specifications:

- a) range of values of measured quantity (e.g. high temperatures, low absolute pressures etc.);
- b) specification of certain field in the given quantity (e.g. DC voltage measurements as a part of electricity voltage measurements, power of AC current at certain range of frequencies or power of DC current etc.);
- c) kind of measuring instruments (e.g. line length measuring instruments etc.);
- d) measured medium (e.g. gas flow rate, liquid density etc.).

6.1.2 Each hierarchy scheme for measuring instruments should deal with measuring instruments of one quantity or some interrelated quantities. If reference or working standards of other quantities have to be used in the hierarchy scheme of the given quantity, it is recommended to involve them in the scheme.

6.1.3 The hierarchy scheme for measuring instruments of a certain quantity may be divided into a number of autonomous schemes if it leads to its more efficient arrangement and more rational use.

6.1.4 At establishment of the hierarchy scheme, it is necessary to specify especially:

~~**6.1.4** –~~

- a) kinds of measuring instruments capable of fulfilling the role of reference and working standards for different values or for different ranges of values of the given quantity;
- b) number of levels of reference and/or working standards;
- c) methods and means of dissemination of units~~unit transfer~~.

Note 1: At the point of establishing or reviewing a hierarchy scheme, the relevant authority should review and take into account the experiences from the operation of existing schemes, at both national and international levels. In this comparative analysis, consideration should be given to the economic and societal context in which the new or revised scheme will be established, to ensure that any such experiences are applicable.~~*At establishment of the hierarchy schemes the experiences from hitherto praxis and ways of solution (of hierarchy schemes) adopted by international organisations or internationally testified are taken into account. Even in such cases there is a necessity to consider extent and the way of application upon real conditions.*~~

6.1.5 Choice of kinds of measuring instruments capable of fulfilling the role of reference and working standards is determined by appropriate level of their metrological and technical characteristics in accordance with the specification stated in OIML D 8 ~~„Measurement Standards. Choice, recognition, use, conservation and documentation“~~ [5].

6.1.6 In order to technically and economically optimise the benefits of the hierarchy scheme the number of levels of reference and/or working standards should be determined by considering at least the following:

- a) overall number of measuring instruments of the given quantity as regards kinds of measuring instruments and their accuracy and their distribution,
- kinds of measuring instruments capable of fulfilling the role of reference and working standards of different accuracy levels, their productivity and the mean values of intervals between calibrations and existence of proper methods and means of dissemination of units~~unit transfers~~,

b)

- c) costs of equipment, use and conservation of measurement standards and means of dissemination of units~~unit transfer~~, etc.

6.1.7 The method of calibration ~~comparison~~ indicated in the hierarchy scheme should correspond to one of the following general methods:

- a) direct measurements (used in verification or calibration of an indicating measuring instrument against a measure or of a measure against an indicating measuring instrument);
- b) direct comparison or comparison using a measure (standard of comparison) (used in verification or calibration of a measuring instrument against a measuring instrument);
- c) comparison with the help of a comparator (used in verification or calibration of a measure against a measure);
- d) indirect measurements (used in calibration or verification of measurement standards or measuring instruments using measurement standards calibrated in terms of other physical quantities connected functionally with a measurand).

6.1.8 In calibration of measurement standards and measuring instruments or in verification of measuring instruments, the characteristics of their uncertainty indicated in the hierarchy scheme are defined by calculations with consideration of the characteristics of the total uncertainty of the higher-level measurement standard and methods for dissemination of unit~~transferring the unit~~.

6.1.9 In verification of measuring instruments involving determination of their compliance with the existing requirements, i. e. establishment of their suitability for application in accordance with the legislation, the recommended value of the ratio of uncertainty between working standards and measuring instruments is ~~(~~1:3 to 1:10 or better~~)~~.

Note 1: Uncertainty of measurement standard or measuring instrument is a short term for the uncertainty of measurements carried out by means of this measurement standard or measuring instrument.

6.2 The structure of hierarchy schemes

6.2.1 A hierarchy scheme consists of the graphic part and of commentary of the scheme.

6.2.2 The graphic part provides a visual preview on metrological traceability~~traceability~~ of measuring instruments and only basic information on some, from the metrological traceability ~~traceability~~ view, important characteristics. If the graphic part is wide and complicated, it is possible to divide it into sections, while the commentary remains common.

6.2.3 Commentary of a hierarchy scheme contains all important specifications of hierarchy levels and metrological traceability~~traceability~~ of measuring instruments and all information necessary for

placing measuring instruments into hierarchy scheme, including explanations, recommendations or comments concerning metrological traceability~~traceability~~.

6.2.4 National hierarchy schemes are divided into four fields:

- a) field of national measurement standards,
- b) field of reference standards,
- c) field of working standards,
- d) field of measuring instruments.

In local hierarchy schemes the field of national measurement standards is usually omitted.

6.2.5 Field of working standards can be divided according to accuracy into a number of levels (levels of working standards may by indicated by Arabic numbers where 1st level mark belongs to the measurement standards of highest level in the hierarchy).

6.2.6 In the field of measuring instruments, these are divided not only according to their kinds, but also according to their accuracy and measurement ranges.

7 Contents and practical realisation of hierarchy schemes

7.1 Content of a national hierarchy scheme

7.1.1 The national hierarchy scheme for a certain kind of measuring instrument contains:

- a) name of the scheme, nominal values or ranges of values of quantity,
- *recommended kinds of measuring instruments capable of fulfilling the role of a measurement standard at different accuracy levels and measurement ranges, typical measuring instruments (kinds of verified or calibrated measuring instruments)*
- b)
- c) recommended methods and means of dissemination of units~~unit value transfer~~ between measurement standards themselves and measuring instruments (methods of calibration~~comparison~~, calibration ~~comparison~~ devices),
- d) recommended graduation of accuracy level (uncertainties) of reference and working standards and measuring instruments,
- e) links between elements of the scheme.

7.2 Content of a local hierarchy scheme

7.2.1 The local hierarchy scheme for the certain kind of measuring instrument contains:

- *the name of laboratory, the reference and working standards which are traced to national measurement standards;*
- a)
- *all elements of laboratory metrological traceability~~traceability~~ (reference and working standards, measuring instruments, means of dissemination of units~~unit transfer~~);*
- b)
- c) range of measurement (nominal values or ranges of values of quantities, ranges of the most important conditions of measurements which define the procedure for dissemination

of units~~transferring the unit~~) of all the measurement standards and measuring instruments indicated in the hierarchy scheme;

– *estimation of the accuracy (uncertainty) characteristics of all measurement standards, methods and means of dissemination of units~~unit transfers~~ used;*

d)

– e) all used links between elements of laboratory metrological traceability~~traceability~~ (used verification or calibration procedures);

– f) specification of procedures of uncertainties calculation;

– g) intervals between calibrations of measurement standards;

– h) links between elements of the scheme.

7.2.2 The local hierarchy scheme for a given kind(s) of measuring instruments, along with measurement procedures for the measurement standards included in the scheme, has to unambiguously demonstrate that all requirements for metrological traceability~~traceability~~ in accordance with relevant regulations and guidelines are fulfilled in the given laboratory.

7.3 Graphic part of a hierarchy scheme

7.3.1 Name of hierarchy scheme is given in the header. Fields of national measurement standard, reference and working standards and measuring instruments are separated in the graphic part of hierarchy scheme by full lines. Description of individual fields of the scheme is on the left side of the scheme. Horizontal dashed lines separate individual levels of standards in the field of working standards.

7.3.2 Measurement standards and measuring instruments are presented as rectangles. The designation of the primary standard is enclosed in a rectangle formed by a double line.

7.3.3 Methods and means of calibration and verification are presented either in the field of the measurement standard, which comparison is made to or at the bottom borderline of this field as ovals.

7.3.4 Graphical representation of the procedure for dissemination of units ~~transferring the value of the unit is performed~~performs in accordance with the following principles (see Annex C as an examples):

– a) if calibration or verification of the measurement standard or measuring instrument is carried out by means of two or more ~~than two~~ measurement standards, solid lines representing the dissemination of the value of ~~transfer of the value of~~ the unit (units) to an object of calibration are connected together into a point,

– b) if calibration or verification of a measurement standard or measuring instrument can be performed by means of any of the two or more ~~than two~~ methods or by standards indicated on the scheme, then the solid lines representing the dissemination of ~~transfer of~~ the value of ~~the~~ unit are not connected into a point,

– c) intersection lines (if it is possible to avoid it) are to be shown by a symbol, as it is shown in item 1 of Annex C.

7.3.5 The form of expressing of metrological characteristic (absolute or relative) of measurement standards and of measuring instruments in a single hierarchy scheme should be as similar as possible.

7.3.6 Description given in graphic part of local hierarchy scheme should contain the following data, especially:

- a) for measurement standards: kind and name of measurement standard, identification number of measurement standard, measurement range, metrological characteristics specifying ~~level of~~ the measurement standards, the lower limits of the admitted values of characteristics of their uncertainty, the range of special condition of measurements,
- b) for methods and means of dissemination of units~~unit transfer~~: name of method, name and identification number of mean of dissemination of units~~unit transfer~~, characteristics of the uncertainty of the method,
- c) for measuring instruments: kinds of verified or calibrated measuring instruments, their measurement ranges and basic metrological characteristics (accuracy class, the maximum permissible error, etc.).

Note 1: The simplified example of national hierarchy scheme which contains three levels of measurement standards and field of measuring instruments is in Annex A. An example of graphic part of local hierarchy scheme is in Annex B.

7.4 Commentary to the hierarchy scheme

7.4.1 Commentary to the hierarchy scheme should contain all the data concerning measuring instruments metrological traceability~~traceability~~, including information, requirements and notes, which are not included in the graphic part of scheme for any other reason and cannot be ignored from the metrological traceability~~traceability~~ view.

7.4.2 Specification of (reference and working) standards should at least contain data as follows:

- a) name and identification of measurement standard,
- b) nominal value(s) or measurement range(s) of quantity(ies) value(s) reproduced by the standard and the measurement conditions,
- c) information on important metrological characteristics of measurement standard (accuracy class, errors, uncertainty of values of quantities reproduced by measurement standard, time stability of standard etc.).

It is recommended to also include the following data in this specification:
~~It is recommended include to this specification also following data:~~

- a) name of legal metrology laboratory or accredited laboratory, which the reference or working standard is compared to,
- b) recalibration interval,
- c) location of the measurement standard.

7.4.3 Specification of methods, means and conditions of dissemination of units~~unit transfer~~ should contain at least data as follows:

- a) means of dissemination of units~~unit transfer~~ – name of device, manufacturer, serial or identification number, and basic metrological characteristics.
- b) method of verification or calibration,
- c) verification or calibration procedure,
- d) uncertainty of verification or calibration,
- e) specified measurement conditions of verification or calibration (if necessary).

Note 1: Calibration devices which contain several function parts in one compact unit (e.g. multiquantity calibration devices with built in measurement standards for several quantities, multiquantity calibrators etc.) are usually calibrated as a whole. Such devices are usually a part of different working hierarchy schemes. The position of such a device in individual scheme depends on its measurement ranges and declared metrological characteristics.

7.4.4 Specification of measuring instrument should contain at least the following data:

- a) kinds of verified or calibrated measuring instruments and their measurement ranges,
- b) metrological characteristics of measuring instrument (accuracy class or the maximum permissible errors, nominal range, instrument constant, discrimination threshold, resolution, stability, etc.).

8 References

[1] ISO/IEC 17025:~~2005~~ 2017 General requirements for the competence of testing and calibration laboratories.

[2] OIML V 2-200 International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM), 3rd edition, Edition 2012 (E/F), (Edition 2010 with minor corrections)

[3] VIML (OIML V 1:2013) International vocabulary of terms in legal metrology

[4] OIML G 1-100 Evaluation of measurement data - Guide to the expression of uncertainty in measurement. Edition 2008 (E). Corrected version 2010

[5] OIML D 8 Measurement standards. Choice, recognition, use, conservation and documentation, OIML, Edition 2004

[6] BIPM, OIML, ILAC Common statement and declaration by BIPM, OIML and ILAC on the relevance of various international agreements on metrology to trade, legislation and standardization. 23rd January 2006

[7] BIPM, OIML, ILAC, ISO Joint BIPM, OIML, ILAC and ISO declaration on metrological traceability. 9th November 2011

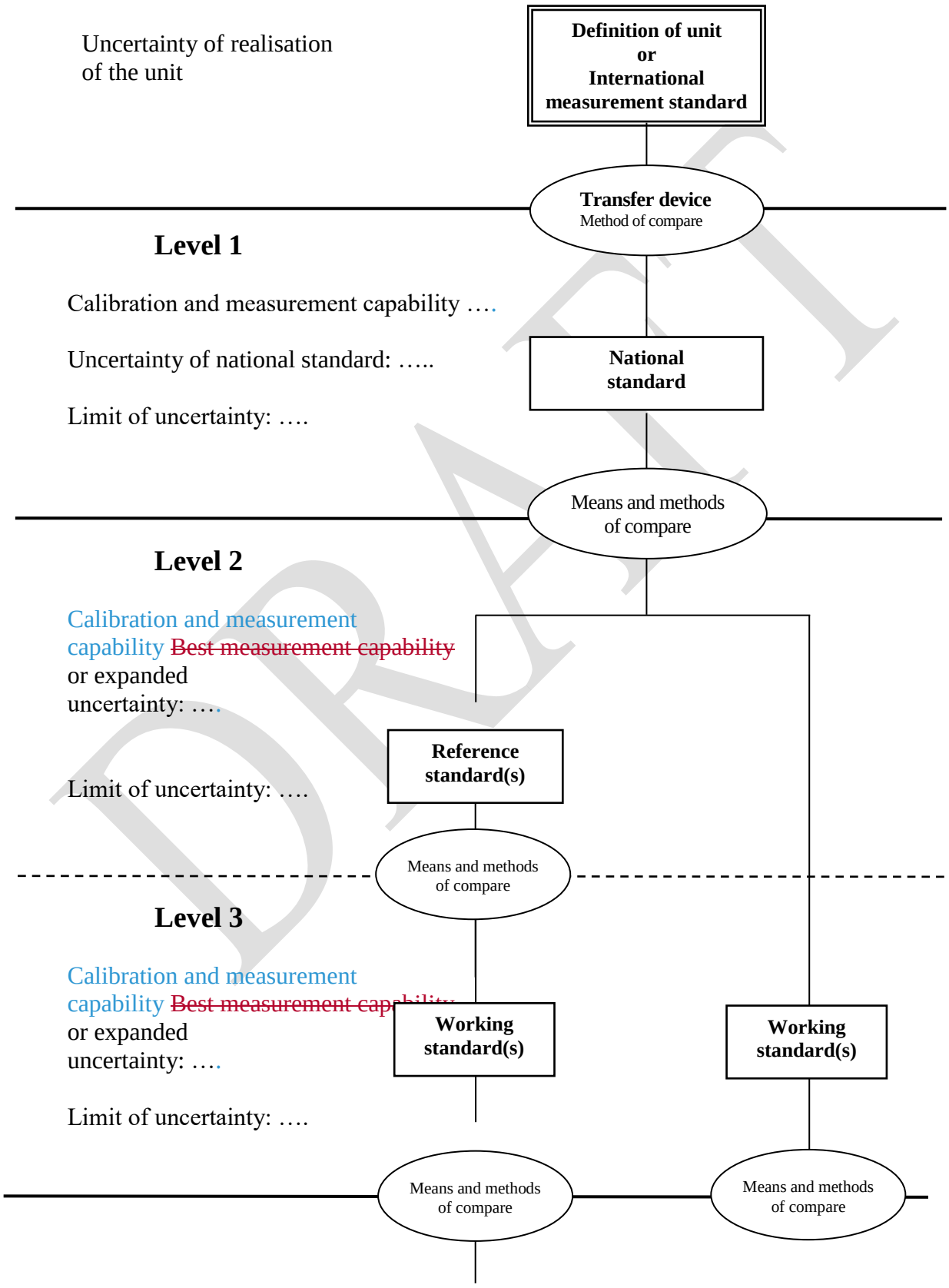
[8] ISO 9001:2015 Quality management systems. Requirements

[9] OIML D 2 Legal units of measurement. Consolidated Edition 2007 (E)

[10] OIML D 1 Considerations for a Law on Metrology. Edition 2012 (E)

Annex A

National hierarchy scheme
(Informative) ~~(example)~~

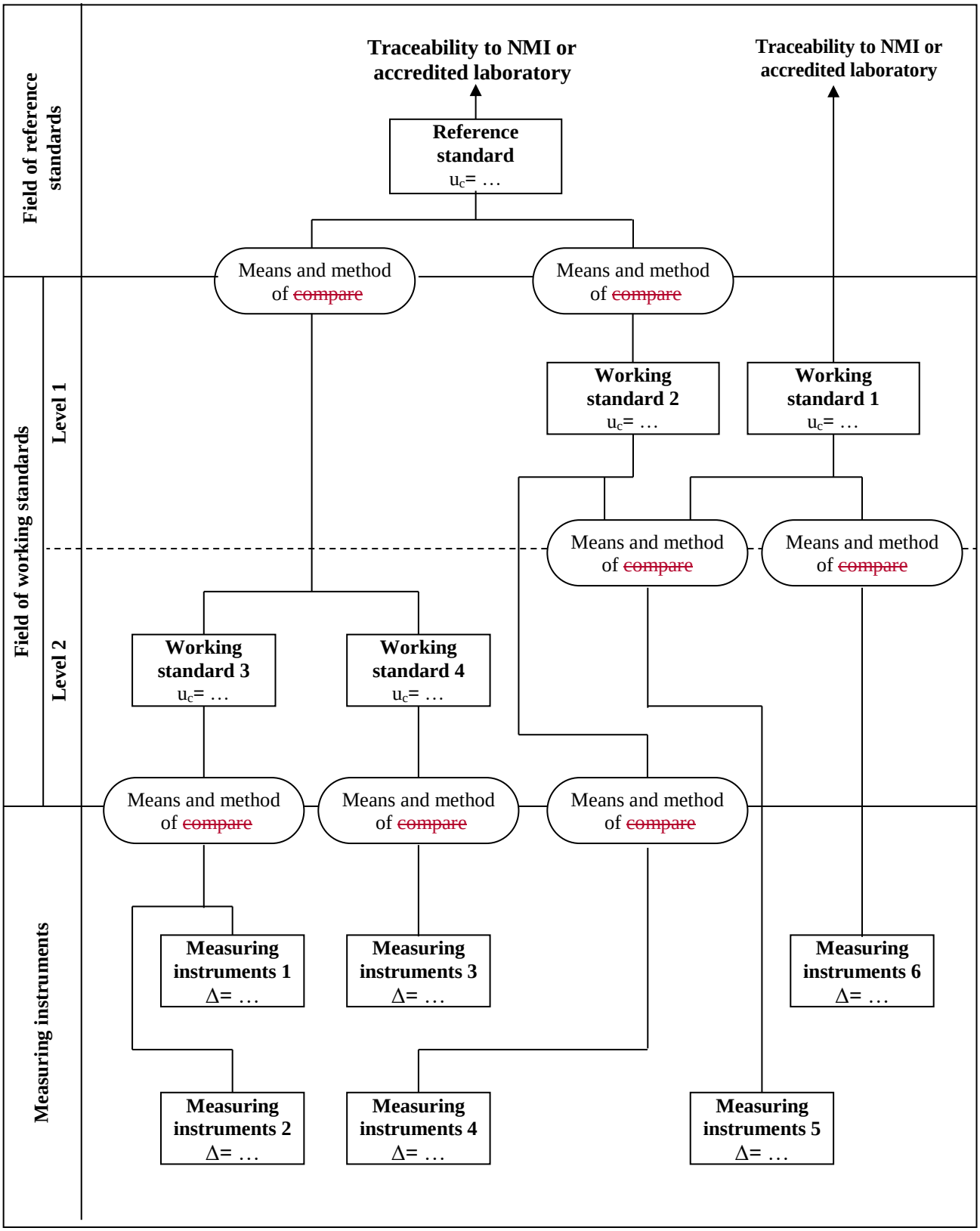


Measuring instruments

Ordinary instrument	**Ordinary instrument**

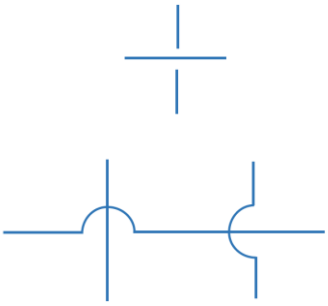
Annex B

Local hierarchy scheme for measuring instruments ~~of ……~~
(Informative) ~~(example)~~



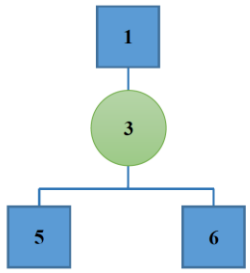
Annex C

The ways of expression different links ~~(~~and the ways of dissemination of unit~~transferring the value of unit)~~ between structural elements in graphic part of hierarchy scheme (Informative) ~~(examples)~~

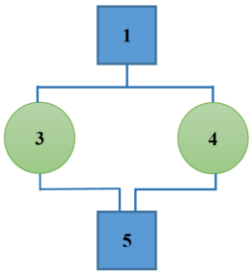


1. Crossing lines

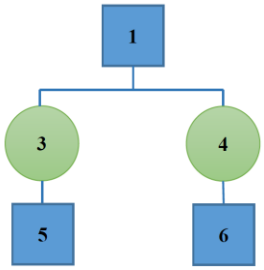
2. From the standard 1 to measuring instrument 5 by the method 3



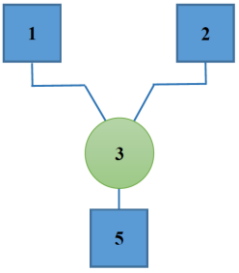
3. From the standard 1 to measuring instrument 5 and 6 by the method 3



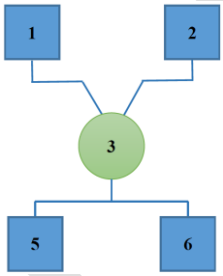
4. From the standard 1 to measuring instrument 5 by the method 3 or the method 4



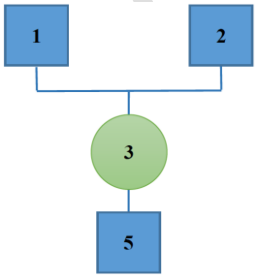
5. From the standard 1 to measuring instrument 5 by the method 3 and to measuring instrument 6 by the method 4



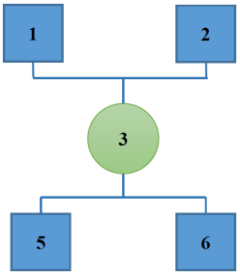
6. From the standard 1 or from the standard 2 to measuring instrument 5 by the method 3



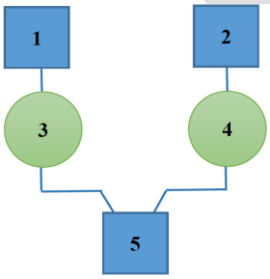
7. From the standard 1 or from the standard 2 to measuring instrument 5 and 6 by the method 3



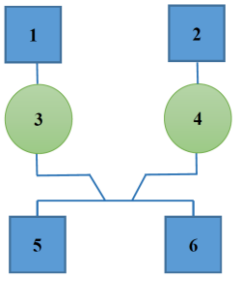
8. From standards 1 and 2 to measuring instrument 5 by the method 3



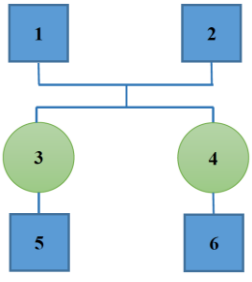
9. From standards 1 and 2 to measuring instrument 5 and 6 by the method 3



10. From the standard 1 to measuring instrument 5 by the method 3 or from standard 2 to measuring instrument 5 by the method 4



11. From the standard 1 to measuring instrument 5 and 6 by the method 3 or from the standard 2 to measuring instrument 5 and 6 by the method 4



12. From standards 1 and 2 to measuring instrument 5 by the method 3 or from the standard 1 and 2 to measuring instrument 6 by the method 4