Metrology - in short

EUROMET project no. 595

“Metrology - in short”

1st edition
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Cover:
Photo of Great Belt east bridge, Denmark with light in the catwalk

Each of the east bridge’s 55 prefabricated 48-metre, 500-ton bridge sections were measured in detail in order to adjust the four hangers which carry the section, to ensure the correct tension. The measured, and expected, deviations from the theoretical measurements required a hanger adjustment of $\pm$ 30 mm. The adjustment of each hanger pin was determined to an accuracy of $\pm$ 1 mm.

A wide network of contractors and subcontractors from 10 European countries and USA were involved in building the bridge 1988 - 1997. Reliable and verified measurements were essential in this huge and complex collaboration.

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Summary

The main purpose of "Metrology - in short" is to increase the awareness of metrology and to establish a common metrological frame of reference in Europe. It is meant to supply European users of metrology with a transparent and handy tool to obtain metrological information.

The content of the handbook is a description of scientific, industrial and legal metrology in Europe. The European metrological structure with the 11 subject fields of metrology and metrological units are described, as well as the European organisations and organisations outside Europe which form the international metrological infrastructure. A list of metrological terms is collected primary from internationally recognised standards. References are given to institutions, organisations and laboratories by reference to their homepages.

Table of content

Foreword

It is with pleasure that we present this easy-to-use handbook "Metrology - in short". It is meant to supply European users of metrology with a transparent and handy tool. It targets all who want to be introduced to, know more about metrology or simply gain specific information. It is our hope that "Metrology - in short" will make it easier to approach and work with both the technical and organisational aspects of metrology in Europe.

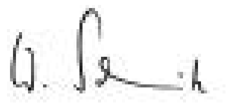
The main purpose of "Metrology - in short" is to increase the awareness of metrology and to establish a common metrological understanding and frame of reference in Europe. This is particularly the case now where the East European countries are in the process of adapting to the European metrological infrastructure.

Metrology develops concurrently with science and ahead of the needs of enterprises, institutions, laboratories and others who use metrology. Therefore, it is the intention to update and develop "Metrology - in short" at regular intervals.

The international version of the handbook is based on “Metrologi - kort og godt”, which since 1998 has been widely used within Denmark. This original version was financed by the Danish Agency for the Promotion of Trade and Industry. The European version was made possible by the CEN who funded this first edition under the Phare / PRAQ III programme.

The practical realisation of the European version was made within the EUROMET project 595 with contributions from the Czech Republic, Denmark, France, Germany, Portugal, Slovakia, Slovenia, Spain, Sweden and Switzerland.

May "Metrology - in short" be widely used and thereby contribute to a common metrological frame of reference in Europe.



Dr. Wolfgang Schwitz
EUROMET Chairman

1. Introduction

1.1 Mankind measures

The death penalty faced those who forgot or neglected their duty to calibrate the standard unit of length at each full moon. Such was the peril courted by the royal site architects responsible for building the temples and pyramids of the Pharaohs in ancient Egypt, 3000 years BC. The first royal cubit was defined as the length of the forearm from elbow to tip of the extended middle finger of the ruling Pharaoh, plus the breadth of his hand. The original measurement was transferred to and carved in black granite. The workers at the building sites were given copies in granite or wood and it was the responsibility of the architects to maintain them.

Even though we feel ourselves to be a long way from this starting point, both in distance and in time, people have placed great emphasis on correct measurements ever since. Closer to home, in 1799 in Paris, the Decimal Metric System was created by the deposition of two platinum standards representing the metre and the kilogram – the start of the present International System of Units (SI system).

In the Europe of today we measure and weigh at a cost equivalent to 6% of our combined GNP! Metrology has become a natural part of our everyday. Planks of wood, and coffee are both bought by size and weight; water, electricity and heat are metered, and we feel the effects on our pockets. Bathroom scales affect our humour – as do police speed traps and the possible financial consequences. The quantity of active substances in medicine, blood sample measurements, and the effect of the surgeon’s laser must also be precise if patients’ health is not to be jeopardised. We find it almost impossible to describe anything without referring to weights and measures: Hours of sunshine, chest measurements, alcohol percentages, weights of letters, room temperatures, tyre pressures ... and so on. Just for fun, try holding a conversation without using words that refer to weights or measures.

Then there is commerce and authorities which are just as dependent on weights and measures. The pilot carefully observes his altitude, course, fuel consumption and speed, the food inspectorate measures bacteria content, maritime authorities measure buoyancy, companies purchase raw materials by weights and measures, and specify their products using the same units. Processes are regulated and alarms are set off because of measurements. Systematic measurement with known degrees of uncertainty is one of the foundations in industrial quality control and, generally speaking, in most modern industries the costs bound up in taking measurements constitute 10-15% of production costs.

Finally, science is completely dependent on measurement. Geologists measure shock waves when the gigantic forces behind earthquakes make themselves felt, astronomers patiently measure the light from distant stars in order to determine their age, atomic physicists wave their hands in the air when by taking measurements in millionths of a second they are able at last to confirm the presence of an almost infinitely small particle. The availability of measuring equipment and the ability to use it are essential if scientists are to be able to objectively document the results they achieve. The science of measurement – *Metrology* – is probably the oldest science in the world and knowledge of how it is applied is a fundamental necessity in practically all science-based professions!

Measurement requires common knowledge

Metrology is hardly ostentatious and the calm surface it shows covers depths of knowledge that only a few are familiar with, but which most make use of – confident that they are sharing a common perception of what is meant by expressions such as metre, kilogram, litre, watt, etc. Confidence is vital in enabling metrology to link human activities together across geographic and professional boundaries. This confidence becomes enhanced with the increased use of network co-operation, common units of measurement and common measuring procedures, as well as the recognition, accreditation and mutual testing of measuring standards and laboratories in different countries. Mankind has thousands of years of experience confirming that life really does become easier when people co-operate on metrology.

Metrology is the science of measurement

Metrology covers three main tasks:
1. The definition of internationally accepted units of measurement, e.g. the metre.
2. The realisation of units of measurement by scientific methods, e.g. the realisation of a metre through the use of laser beams.
3. The establishment of traceability chains in documenting the accuracy of a measurement, e.g. the documented relationship between the micrometer screw in a precision engineering workshop and a primary laboratory for optical length metrology.

Metrology develops …

Metrology is essential in scientific research, and scientific research forms the basis of the development of metrology itself. Science pushes out the frontiers of the possible all the time and fundamental metrology follows the metrological aspects of these new discoveries. This means still better metrological tools to enable researchers to continue their discoveries – and only those fields of metrology that do develop can continue to be a partner for industry and research.

Correspondingly, legal and industrial metrology must also develop in order to keep pace with the needs of society and industry – and remain relevant and useful.

… and people who measure can also make a contribution

It is the intention to continuously develop “Metrology – in short”. The best way of developing a tool is of course to collect the experience of those who use it and the publishers would therefore be grateful for comments, be they criticism or praise. The “remarks coupon” at the back of the book can be used for the purpose. The book will also be kept up to date with changes that follow developments in the metrological area.

1.2 Categories of metrology

In the EU, metrology is separated into three categories with different levels of complexity and accuracy:

1. *Scientific metrology* deals with the organisation and development of measurement standards and with their maintenance (highest level).

2. *Industrial metrology* has to ensure the adequate functioning of measurement instruments used in industry as well as in production and testing processes.

3. *Legal metrology* is concerned with the accuracy of measurements where these have influence on the transparency of economical transactions, health and safety.

Fundamental metrology has no international definition, but it signifies the highest level of accuracy within a given field. Fundamental metrology may therefore be described as scientific metrology, supplemented by those parts of legal and industrial metrology that require scientific competence.

2. Industrial and scientific metrology

Industrial and scientific metrology are two of the three categories of metrology as described in chapter 1.2.

The metrological activities, testing and measurements, are generally valuable inputs to work with quality in industrial activities. This includes the need for traceability, which is becoming just as important as measurement itself. Recognition of metrological competence at each level of the traceability chain can be established by mutual recognition agreements or arrangements.

2.1 Technical function

2.1.1 Subject fields

Fundamental metrology is divided in accordance with the 11 fields: Mass, electricity, length, time and frequency, thermometry, ionising radiation & radioactivity, photometry and radiometry, flow, acoustics, amount of substance and interdisciplinary metrology.

These 11 subject fields are defined by EUROMET. However, the 11th (interdisciplinary metrology) is not a technical field.

There is no formal international definition of the subfields.

Table 2.1: Subject fields, subfields and different important level measurement standards. Only the 10 technical subject fields are included.

SUBJECT FIELD	SUBFIELD	Important measurement standards
MASS and related quantities	Mass measurement	Mass standards, standard balances
	Force and pressure	Load cells, dead-weight testers, force, moment and torque convertors, pressure balances with oil/gas-lubricated piston cylinder assemblies, force-testing machines
	Volume and density Viscosity	Glass areometers, laboratory glass, vibration densimeters, glass capillary viscometers, rotation viscometers, viscometry scale
ELECTRICITY and MAGNETISM	DC electricity	Cryogenic current comparators, Josephson and Klitzing quantum Hall effect, Zener references, potentiometric methods, comparator bridges
	AC electricity	AC/DC convertors, standard capacitors, air capacitors, standard inductances, compensators
	HF electricity	Thermal convertors, calorimeters, bolometers
	High current and high voltage	Measurement transformers of current and voltage, reference high voltage sources
LENGTH	Wavelengths and interferometry	Stabilized lasers, Interferometers, laser interferometric measurement systems, interferometric comparators
	Dimensional metrology	Gauge blocks, line scales, step gauges, setting rings, plugs, high masters, dial gauges, measuring microscopes, optical flat standards, coordinate measuring machines, laser scan micrometers, depth

SUBJECT FIELD	SUBFIELD	Important measurement standards
		micrometers
	Angular measurements	Autocolimators, rotary tables, angle gauges, polygons, levels
	Forms	Straightness, flatness, parallelism, squares, roundness standards, cylinder standards
	Surface Quality	Step height and groove standards, roughness standards, roughness measurement equipment
TIME and FREQUENCY	Time measurement	Cesium atomic clock, time interval equipment
	Frequency	Atomic clock, quartz oscillators, lasers, electronic counters and synthesisers, (geodetic length measuring tools)
THERMOMETRY	Temperature measurement by contact	Gas thermometers, ITS 90 fixpoints, resistance thermometers, thermoelements
	Non-contact temperature measurement	High-temperature black bodies, cryogenic radiometers, pyrometers, Si photodiodes
	Humidity	Mirror dew point meters or electronical hygrometers, double pressure/temperature humidity generators
IONISING RADIATIONS and RADIOACTIVITY	Absorbed dose - High level industrial products	Calorimeters, calibrated high dose rate cavities, Dichromat dosimeters
	Absorbed dose - Medical products	Calorimeters, Ionisation chambers
	Radiation protection	Ionisation chambers, Reference radiation beams/fields, proportional and other counters, TEPC, Bonner neutron spectrometers
	Radioactivity	Well-type ionising chambers, Certified radioactivity sources, Gamma and alpha spectroscopy, 4Π detectors

SUBJECT FIELD	SUBFIELD	Important measurement standards
PHOTOMETRY and RADIOMETRY	Optical radiometry	Cryogen radiometer, detectors, stabilised laser reference sources, reference materials – Au fibres
	Photometry	Visible region detectors, Si photodiodes, quantum efficiency detectors
	Colorimetry	
	Optical fibres	Reference materials – Au fibres
FLOW	Gas flow (volume)	Bell provers, rotary gas meters, turbine gas meters, transfer meter with critical nozzles
	Flow of water (volume, mass and energy)	Volume standards, Coriolis mass-related standards, level meters, inductive flow meters, ultrasound flow meters
	Flow of liquids other than water	
	Anemometry	Anemometres
ACOUSTICS, ULTRASOUND and VIBRATION	Acoustical measurements in gases	Standard microphones, piston phones, condenser microphones, sound calibrators
	Accelerometry	Accelerometers, force transducers, vibrators, laser interferometre
	Acoustical measurements in liquids	Hydrophones
	Ultrasound	Ultrasonic power meters, radiation force balance
AMOUNT of SUBSTANCE	Environmental chemistry	Certified reference materials
	Clinical chemistry	
	Materials chemistry	Pure materials, certified reference materials
	Food chemistry	Certified reference materials
	Biochemistry	
	Micro biology	
	pH measurement	

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2.1.2 Traceability & calibration

Traceability

A traceability chain is an unbroken chain of comparisons which shall make it certain that a measurement result or the value of a standard is related to references at a higher level, ending at the final level with a primary standard.

Industry in Europe ensures traceability to the highest international level by using accredited European laboratories.

In the USA, industry ensures traceability to the highest international level direct from NIST.

Calibration

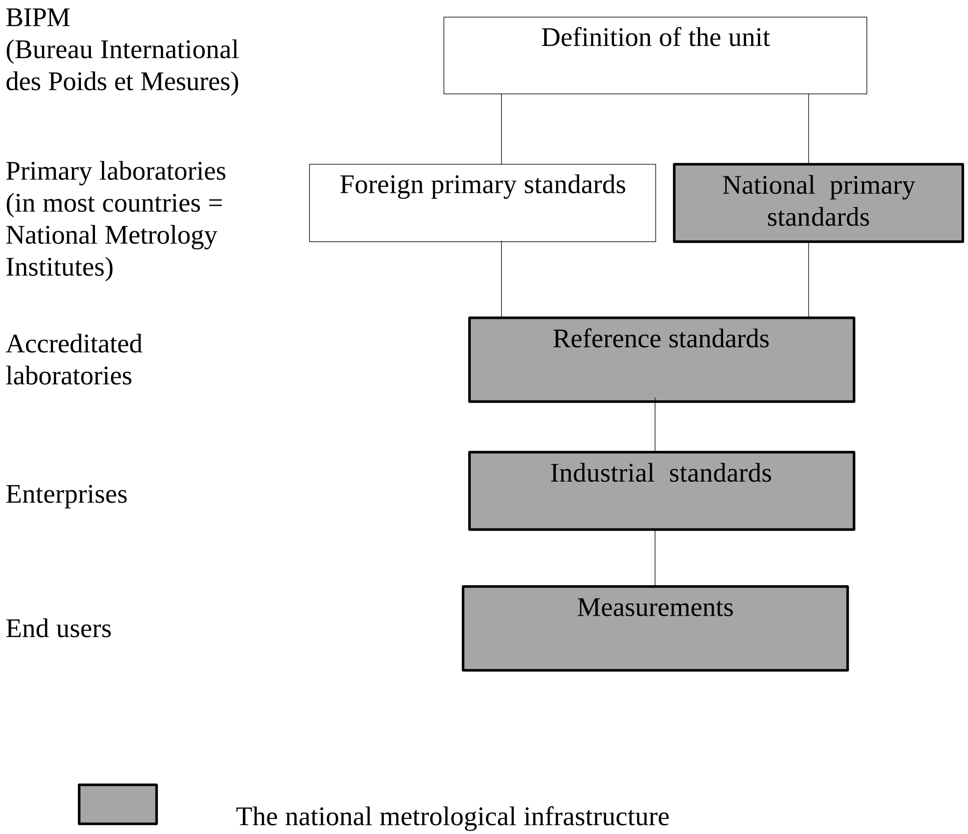
A basic tool in ensuring the traceability of a measurement is measuring instrument calibration. This calibration involves determining the metrological characteristics of an instrument. It is achieved by means of a direct comparison against standards. A calibration certificate is issued and (in most cases) a sticker is attached. Based on this information a user can decide whether the instrument is fit for the application in question.

There are three main reasons for having instruments calibrated:
1. To ensure readings from an instrument are consistent with other measurements.
2. To determine the accuracy of the instrument readings.
3. To establish the reliability of the instrument i.e. that it can be trusted.

By calibrating an instrument it is possible to obtain the following:

- The result of a calibration permits either the assignment of values of measurands to the indications or the determination of corrections with respect to indications.
- A calibration may also determine other metrological properties such as the effect of influence quantities.
- The result of a calibration may be recorded in a document, sometimes called a calibration certificate or a calibration report.

Figure 2.1: The traceability chain



2.1.3 Measurement standards

A measurement standard or etalon, is a material measure, measuring instrument, reference material or measuring system intended to define, realise, conserve or reproduce a unit or one or more values of a quantity to serve as a reference.

Example: The metre is *defined* as the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second. The metre is *realised* on the primary level by the wavelength from an iodine-stabilised helium-neon laser. On sub-levels, material measures like gauge blocks are used, and traceability is ensured by using optical interferometry to determine the length of the gauge blocks with *reference* to the above-mentioned laser light wavelength.

The different levels of standard are shown in figure 2.1. Metrology fields, subfields and important different level measurement standards are shown in table 2.1 in chapter 2.1.1. An international listing of all measurement standards does not exists.

The definitions of the different standards are given in the Vocabulary, chapter 6.

Figur 2.2 : The Metre Convention organisation

The Metre Convention
International convention established in 1875 with 48 member states in 1998.

CGPM Conférence Générale des Poids et Mesures
Committee with representatives from the Metre Convention member states. First conference in 1889. Meeting every 4th year. Approves the SI-system and results from fundamental metrological research.

CIPM Comité Internationale des Poids et Mesures
Committee with 18 representatives from CGPM. Supervises BIPM and supplies chairmen for the CCs. Co-operates with other international metrological organisations.

CEN*

IEC*

ISO*

BIPM Bureau International des Poids et Mesures

International research in physical units and standards.
Administration of interlaboratory comparisons of the national laboratories.

Consultative Committees:
- **CCEM** C C for Electricity and Magnetism
- **CCPR** C C for Photometry and Radiometry
- **CCT** C C for Thermometry
- **CCL** C C for Length
- **CCTF** C C for Time and Frequency
- **CCRI** C C for Ionising Radiation
- **CCU** C C for Units
- **CCM** C C for Mass and related quantities
- **CCQM** C C for Amount of Substance

*) See Vocabulary

2.2 International organisation

2.2.1 The Metre Convention

In the middle of the 19th century, the need for a universal decimal metric system became very apparent, particularly during the first universal exhibitions. In 1875, a diplomatic conference on the metre took place in Paris where 17 governments signed a treaty “the Metre Convention”. The signatories decided to create and finance a scientific and permanent institute: “Bureau International des Poids et Mesures” **BIPM**.

Conférence Générale des Poids et Mesures” **CGPM** discusses and examines the work performed by National Metrology Institutes and the BIPM makes recommendations on new fundamental metrological determinations and all major issues of concern to the BIPM.

Today, 48 states are members of the Metre Convention.

2.2.2 National Metrology Institutes

EUROMET definition of a National Metrology Institute (NMI): Institution designated by national decision to develop and maintain national standards for one or several quantities.

Some countries and economies operate a centralised metrology organisation with one National Metrology Institute. The NMI may devolve the maintenance of specific standards to certain laboratories without these having the status of an NMI.
Other countries and economies operate a decentralised organisation with a multiplicity of institutes, all having the status of an NMI.

An NMI represent the country internationally in relation to the national metrology institutes of other countries, in relation to the Regional Metrology Organisations (RMOs) and to the BIPM. The NMIs are the backbone of the international organisation shown in figure 2.2.

A list of NMIs in Europe is given in the EUROMET Directory, see chapter 4.

2.2.3 Primary laboratories

A nominated laboratory which:
- is internationally recognised for the realisation of a metrology base unit at the primary level, or a derived unit at the highest achievable international level,
- carries out internationally recognised research within specific sub-fields,
- maintains and further develops the unit concerned by maintaining and further developing primary standards,
- participates in comparisons at the highest international level.

Primary laboratories are designated by the NMI in accordance with the metrological plan of action for the different subject fields and in accordance with the metrological policy of the country.

Nominated laboratories are given in the EUROMET Directory, see chapter 4.

2.2.4 Reference laboratories

A nominated laboratory which is capable of calibrating a given measurement quantity at the highest level of accuracy in the country, traceable to a primary laboratory.

More information can be found on the homepages mentioned in chapter 4.

2.2.5 Accredited laboratories

An accredited laboratory possesses third-party recognition of its technical competence, quality assurance and impartiality. Public as well as private laboratories can be accredited. Accreditation is voluntary, but a number of European authorities assure the quality of testing and calibration laboratories within their area of competence by requiring an accreditation from an accreditation body. As required, for example, for laboratories working in the food sector and with the calibration of weights used in retail stores.

Accreditation is granted on the basis of laboratory assessment and regular inspection. The accreditation generally complies with the European/ISO standards EN/ISO 45001, 45002 , 45003 and ISO/CEI 25, now ISO 17025, and a number of more technical specifications and guidelines.

In the framework of EA (European co-operation for Accreditation - see chapter 2.3.2), any calibration certificate, issued by an accredited laboratory

- under the care of a European accreditation body and
- signatory to the Mutual Recognition Agreement MRA,

is equivalent to any calibration certificate in any country signatory to the MRA.

European accreditation bodies

- grant accreditations in their respective countries,
- conduct inspections and
- update the national public register of accredited laboratories and approved GLP-laboratories.

More information are given on the homepages in chapter 4.

2.3 European organisation

See chapter 4 for homepages with more detailed information.

2.3.1 EUROMET

A collaboration between the European metrology institutes founded in 1983. Presently there are 23 members, and several countries are in the process of applying for membership. The basis of the collaboration is to run bottom-up projects concerning research, interlaboratory comparisons, and traceability studies. The projects are managed by so-called rapporteur groups with one member from each country. They form the basis of equivalence between NMIs and traceability in Europe.

EUROMET is the main organisation for metrology in Europe and a stakeholder of the European Commission, and also manages EU projects of interest for the common market. EUROMET is a regional organisation in the CIPM multilateral agreement on the recognition of national measurement standards.

2.3.2 EA European co-operation for Accreditation

The main organisation of accreditation bodies in Europe, founded on a multilateral agreement and based on a mutual peer review system. EA comprises some 15 national accreditation bodies, and has bilateral agreements with corresponding bodies in several other countries.

The intention is that tests and calibrations from accredited laboratories in one member country shall be accepted by the authorities and industry in all other member countries. The metrology infrastructure in most countries consists of National Metrology Institutes (NMIs), reference laboratories and accredited laboratories. The trend is for NMIs and reference laboratories also to seek third-party assessment of their quality systems through accreditation or certification.

2.3.3 EUROlab

A federation of national laboratory organisations covering around 2000 laboratories. Eurolab is a voluntary co-operation representing and promoting laboratory organisation technically and politically, by co-ordinating actions relating to, for example, the European Commission, European standardisation, and international matters.

Eurolab organises workshops and symposia, and produces position papers and technical reports. Many laboratories dealing with metrology are members of Eurolab.

2.3.4 Eurachem

An association of European analytical laboratories. Traceability and quality assurance in chemistry become ever more critical within the EU. Eurachem co-operates with EUROMET with regard to the establishment of reference laboratories, use of reference materials and traceability to the mole.

2.3.5 COOMET

An organisation corresponding to EUROMET with members from central and East European countries.

3. Legal metrology

Legal metrology originated from the need to ensure fair trade.

The main objective of legal metrology is to protect citizens from the consequences of false measurements:
- in official and commercial transactions as well as
- in labour environments, health and safety.

Therefore requirements are laid down in legislation for
- measuring instruments
- measurement and testing methods including
- pre-packages.

3.1 Technical function of legal metrology

People using measurement results in the application field of legal metrology are not required to be metrological experts and the government takes responsibility for the credibility of such measurements. Instruments should guarantee correct measurement results:
- under working conditions
- throughout the whole period of use
- within given permissible errors.

3.1.1 Directives

All over the world, national legal requirements which shall be met by measuring instruments and their use are laid down for the above-mentioned areas. Preventive as well as repressive measures are concerned here.

Preventive measures
Preventive measures are taken before marketing of the instruments, i.e. the instruments have to be type-approved and verified. Manufacturers are granted type approval by a competent body – in most countries by an authority - if the type meets all associated legal requirements. With serially manufactured measuring instruments, it shall be ensured by verification that each instrument fulfils all requirements laid down in the approval procedure.

Regarding instruments in use, inspections or periodic re-verifications are prescribed to guarantee that measuring instruments comply with legal requirements. Such legal requirements, including those on usage, differ from country to country depending on the national legislation.

Repressive measure
Market surveillance is a repressive measure to reveal any illegal usage of a measuring instrument. The standards used for such inspections and tests must be traceable to national or international standards.

Harmonisation
Harmonisation in Europe is based on Directive 71/316/EEC, which contains requirements for all categories of measuring instruments, as well as on other directives covering individual categories of measuring instruments and which have been published since 1971. Measuring instruments which have been granted an EEC type approval and an EEC initial verification can be placed on the market and used in all member countries without further tests or type approvals.

To achieve the free circulation of goods on the European single market a new concept in the field of technical harmonisation and standardisation including metrology was laid down in 1989 by Council decision, the intention being that the directives would be binding on all member states and would not permit national deviations.

The Europen Commission proposal of the Measuring Instruments Directive (MID) has been published.. The MID aims at the elimination of technical barriers to trade, thus regulating the marketing and usage of the following measuring instruments:
- water meters
- gas meters
- electrical energy meters and measurement transformers
- heat meters
- measuring systems for liquids other than water
- automatic weighing instruments
- taximeters
- material measures
- dimensional measuring systems
- evidential breath analysers
- exhaust gas analysers

The instruments will have to meet essential requirements. The manufacturer may lay down technical details or refer to harmonised European standards. Application of the standards facilitates access to the market, i.e. where instruments complying with these standards are concerned, the assumption is that they meet the requirements of the directive.

Conformity assessment

The conformity assessment procedures correspond to those in Directive 93/65/EEC on the modules to be used in all technical harmonisation directives.

A two-stage conformity assessment procedure is provided for electronic measuring instruments. In the first stage a type examination is performed by a third-party certification body. Conformity assessment of the serially manufactured instruments can be carried out by the manufacturer provided that he has an approved and supervised quality system at his disposal. Examination of the individual instruments must otherwise be carried out by the third-party certification body.

Example: Directive 90/384/EEC on non-automatic weighing instruments and Directive 93/42/EEC on medical devices. These instruments will carry a CE-mark before they are marketed in the European Economic Area, provided they have passed an EC conformity assessment procedure.

Certification bodies

Member countries are notified of certification bodies. These notified bodies must possess the technical competence and independence stipulated by the directive, thus enabling them to perform technical and administrative tasks. They may either be private or governmental organisations. Manufacturers are free to choose among these European bodies.

Legal control

The binding legal control of measuring instruments, as mentioned in the directive, is to be left to each member country. Requirements to be met by instruments after they have been put into use have not been harmonised. Re-verifications, inspections and verification validity periods may consequently be laid down by member countries on the basis of their own national legislation.

Consumer protection may differ in various member states. For this reason the requirements governing the use of instruments become the subject of national legislation.

Member states may lay down legal requirements for measuring instruments which are not listed in the MID.

3.1.2 Controlled equipment

For historical reasons the scope of legal metrology is not the same in all countries. The major parts of the categories of measuring instruments harmonised in Europe are listed in Table 1. As soon as the MID is put into force, most of the directives mentioned below will be repealed. The directives can be found in in the Official Journal of the European Communities, see chapter 4.

Directive	**Measuring instrument or product**
71/317	Bar weights of from 1 kg to 50 kg and cylindrical weights of from 1 kg to 10 kg
71/318	Gas volume meters
71/319	Meters for liquids other than water
71/347	Standard mass per storage volume of grain
73/362	Material measures of length
74/148	Weights of from 1 mg to 50 kg
75/33	Cold-water meters
75/107	Bottles used as measuring containers
75/410	Continuous totalising weighing machines
75/443	Speedometer equipment for motor vehicles
76/765	Alcoholometers and alcohol hydrometers
76/766	Alcohol tables
76/891	Electrical energy meters
77/95	Taximeters
77/313	Measuring systems for liquids other than water
78/1031	Automatic check-weighing and weight grading machines
79/830	Hot-water meters
86/217	Tyre pressure gauges for motor vehicles
90/384	Non-automatic weighing machines
93/42	Medical products

Software

Is not included in the above mentioned directives but will be covered by the MID.

3.2 International organisation - OIML

The *International Organisation of Legal Metrology* OIML was established in 1955 on the basis of a convention in order to promote the global harmonisation of legal metrology procedures.

OIML is an intergovernmental treaty organisation with 57 member countries which participate in technical activities and 48 corresponding member countries which join the OIML as observers.

OIML collaborates with the Metre Convention and BIPM on the international harmonisation of legal metrology.

OIML liaises with more than 100 international and regional institutions concerning activities in metrology, standardisation and related fields.

Metrological guidelines
A worldwide technical structure provides members with metrological guidelines for the elaboration of national and regional requirements concerning the manufacture and use of measuring instruments for legal metrology applications.

Model regulations, international recommendations
The OIML develops model regulations, and issues international recommendations which provide members with an internationally agreed basis for the establishment of national legislation on various categories of measuring instruments. The technical requirements in the draft European Measuring Instruments Directive (MID) are to a wide extent equivalent to the International Recommendations of OIML.

The main elements of the International Recommendations are
- scope, application and terminology
- metrological requirements
- technical requirements
- methods and equipment for testing and verifying conformity to requirements
- test report format

OIML draft recommendations and documents are developed by technical committees or subcommittees composed of representatives from member countries. Certain international and regional institutions also participate on a consultative basis. Co-operation agreements are established between the OIML and institutions such as ISO and IEC with the objective of avoiding conflicting requirements. Consequently, manufacturers and users of measuring instrument test laboratories may simultaneously use publications of the OIML and those of other institutions.

OIML Certificate System

A system that gives manufacturers the possibility of obtaining an OIML Certificate and a Test Report to indicate that a given instrument type complies with the requirements of the relevant OIML International Recommendations.

Certificates are issued by OIML member states who have established one or more Issuing Authorities responsible for processing applications from manufacturers wishing to have their instrument types certified. These certificates are the subject of voluntary acceptance by national metrology services.

3.3 European organisation - WELMEC

In connection with the preparation and enforcement of the directives in accordance with the "New Approach", a Memorandum of Understanding was signed by 15 member countries of the EU and three EFTA countries in 1990 on the occasion of the foundation of WELMEC - the "Western European Legal Metrology Co-operation". This name was changed to "*European co-operation in legal metrology*" in 1995 but remains synonymous with WELMEC. Since that time WELMEC has accepted associated membership of countries which have signed agreements with the European Union. At present there are 27 member countries.

WELMEC members
are the national legal metrology authorities in the EU and EFTA member countries. National legal metrology authorities in those countries which are in transition to membership of the EU are associate members. An essential goal of WELMEC is to develop mutual confidence between the legal metrology authorities in Europe, to harmonise legal metrology activities and to foster the exchange of information between all bodies concerned.

WELMEC Committee
consists of delegates from the member and associate member states and observers from EUROMET, the European co-operation for Accreditation (EA), the International Organisation of Legal Metrology (OIML) and other regional organisations with an interest in legal metrology. The committee meets at least once a year. A small Chairman's Group advises the chairman on strategic matters.

Working Groups
meet whenever necessary to discuss a range of important subjects and to make recommendations to the WELMEC Committee. Currently the work of the committee is supported by seven Working Groups:

WG 2	Directive Implementation (90/384/EEC. Secretariat: UK
WG 4	Application of EN45000 standards to notified bodies. Secretariat: Norway
WG 5	Review of Enforcement Activities. Secretariat: UK
WG 6	Pre-packages. Secretariat: Netherlands
WG 7	Software. Secretariat: Germany
WG 8	Measuring Instruments Directive. Secretariat: France
WG 10	Measuring Equipment for Liquids other than water. Secretariat: Netherlands

Examples on published guides on harmonisation in Europe :

- Application of Directive 90/384/EEC on non-automatic weighing instruments
- Type Approval Agreement which implies mutual recognition of type approvals on the basis of OIML Recommendations for some categories of measuring instruments in fields not harmonised so far.
- Guide for Software Requirements for measuring instruments.

WELMEC advises the European Commission and the Council regarding the development of the Measuring Instruments Directive.

4. Metrological information sources

The homepages cited give access to abundant information, not least via their links.

Info about...	Sources	Contact
International metrology organisations	BIPM (Bureau International des Poids et Mesures)	Pavillon de Breteuil, F-92312 Sèvres Cedex, France, www.bipm.fr
The SI system		BIPM www.bipm.fr
National Metrology Institutes EUROMET technical projects and intercomparisons	EUROMET	Secretariat 2000-2001 at OFMET, Lindenweg 50, CH-3003 Bern-Wabern, Switzerland, www.euromet.org
Accredited laboratories Accreditation in Europe	EA	Secretariat at COFRAC, 37 rue de Lyon, FR-75012 Paris, France www.european-accreditation.org
Mesurement, Testing and Analytical Laboratories in Europe	EUROlab	www.eurolab.org
International key comparisons	Published in Metrologia	BIPM www.bipm.fr
Standards	ISO (International Organisation for Standardisation)	www.iso.ch
National standardisation bodies	CEN (European Committee for Standardisation)	www.cenorm.be
Reference materials for chemical analysis	IRMM COMAR database	www.irmm.jrc.be
Legal metrology in Europe	WELMEC	WELMEC Secretariat United Kingdom Tel.: +44-208-943 7211 www.welmec.org
Legal metrology, international	OIML	OIML secretariat at BIML Paris, France Tel.: +33 1 48 78 12 82 www.oiml.org
Community legislation - Metrology	Official Journal of the European Communities CELEX database	www.europa.eu.int/eur-lex/en/lif/reg/en_register_133012.html

5. Metrological units

The idea behind the metric system - a system of units based on the metre and the kilogram – arose during the French Revolution when two platinum artefact reference standards for the metre and the kilogram were constructed and deposited in the French National Archives in Paris in 1799 - later to be known as the Metre of the Archives and the Kilogram of the Archives. The French Academy of Science was commissioned by the National Assembly to design a new system of units for use throughout the world, and in 1946 the MKSA system (metre, kilogram, second, ampere) was accepted by the Metre Convention countries. In 1954, the MKSA was extended to include the kelvin and candela. The system then assumed the name the International Systems of Units, SI, (Le **S**ystème **I**nternational d'Unités).

The SI system was established in 1960 by the 11th General Conference on Weights and Measures (CGPM):

> "The International System of Units, SI, is the coherent system of units adopted and recommended by the CGPM".

The SI system is comprised of seven base units which together with derived units make up a coherent system of units. In addition, certain other units outside the SI system are accepted for use with SI units.

The tables of units below (table 5.1 - 5.7) show the following:

SI units

- table 5.1 SI base units
- table 5.2 SI derived units expressed in SI base units
- table 5.3 SI derived units with special names and symbols
- table 5.4 SI derived units whose names and symbols include SI-derived units with special names and symbols

Units outside SI

- table 5.5 Units accepted because they are widely used
- table 5.6 Units to be used within specific subject areas
- table 5.7 Units to be used within specific subject areas and whose values are experimentally determined

Table 5.1: SI base units (2)

Quantity	**Base unit**	**Symbol**
length	metre	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

Table 5.2: Examples of SI derived units expressed in SI base units (2)

Derived quantity	**Derived unit**	**Symbol**
area	square metre	m^2
volume	cubic metre	m^3
speed, velocity	metre per second	$m \cdot s^{-1}$
acceleration	metre per second squared	$m \cdot s^{-2}$
angular velocity	radian per second	$rad \cdot s^{-1}$
angular acceleration	radian per second squared	$rad \cdot s^{-2}$
density	kilogram per cubic metre	$kg \cdot m^{-3}$
magnetic field intensity, (linear current density)	ampere per metre	$A \cdot m^{-1}$
current density	ampere per cubic metre	$A \cdot m^{-2}$
moment of force	newton metre	$N \cdot m$
electric field strength	volt per metre	$V \cdot m^{-1}$
permeability	henry per metre	$H \cdot m^{-1}$
permittivity	farad per metre	$F \cdot m^{-1}$
specific heat capacity	joule per kilogram kelvin	$J \cdot kg^{-1} \cdot K^{-1}$
amount-of-substance concentration	mol per cubic metre	$mol \cdot m^{-3}$
luminance	candela per square metre	$cd \cdot m^{-2}$

5.1 SI base units

A base unit is a unit of measurement of a base quantity in a given system of quantities (4). The definition and realisation of each SI base unit becomes modified as metrological research discovers the possibility of achieving a more precise definition and realisation of the unit.

Example: The 1889 definition of the metre was based upon the international prototype of platinum-iridium placed in Paris.
In 1960 the metre was redefined as 1 650 763.73 wavelengths of a specific spectral line of krypton-86.
By 1983 this definition had become inadequate and it was decided to redefine the metre as the length of the path travelled by light in vacuum during a time interval of 1/299 792 458 of a second, and represented by the wavelength of radiation from an iodine-stabilised helium-neon laser.
These redefinitions have reduced the relative uncertainty from 10^{-7} to 10^{-11} m.

SI base unit definitions

The metre is the length of the path travelled by light in a vacuum during a time interval of 1/299 792 458 of a second.

The kilogram is equal to the mass of the international prototype of the kilogram.

The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom.

The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2 x 10^{-7} newton per metre of length.

The kelvin is the fraction 1/273,16 of the thermodynamic temperature of the triple point of water.

The mole is the amount of substance of a system that contains as many elementary entities as there are atoms in 0,012 kg of carbon-12.
When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.

The candela is the luminous intensity in a given direction of a source that emits monochromatic radiation of frequency 540 x 10^{12} hertz and has a radiant intensity in that direction of 1/683 watts per steradian.

Table 5.3 SI derived units with special names and symbols

Derived quantity	**SI derived unit** Special name	**Sym-bol** Special symbol	**In SI units**	**In SI base units**
frequency	hertz	Hz		s^{-1}
force	newton	N		$m \cdot kg \cdot s^{-2}$
pressure, stress	pascal	Pa	N/m^2	$m^{-1} \cdot kg \cdot s^{-2}$
energy, work, quantity of heat	joule	J	$N \cdot m$	$m^2 \cdot kg \cdot s^{-2}$
power, radiant flux	watt	W	J/s	$m^2 \cdot kg \cdot s^{-3}$
electric charge, quantity of electricity	coulomb	C		$s \cdot A$
electric potential difference, electromotive force	volt	V	W/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
electric capacitance	farad	F	C/V	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$
electric resistance	ohm	Ω	V/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
electric conductance	siemens	S	A/V	$m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$
magnetic flux	weber	Wb	$V \cdot S$	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$
magnetic induction, magnetic flux density	tesla	T	Wb/m^2	$kg \cdot s^{-2} \cdot A^{-1}$
inductance	henry	H	WB/A	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-2}$
luminous flux	lumen	lm	$Cd \cdot sr$	$m^2 \cdot m^{-2} \cdot cd = cd$
illuminance	lux	lx	Lm/m^2	$m^2 \cdot m^{-4} \cdot cd = m^{-2} \cdot cd$
activity (of a radionuclide)	becquerel	Bq		s^{-1}
absorbed dose, kerma, specific energy (imparted)	gray	Gy	J/kg	$m^2 \cdot s^{-2}$
dose equivalent	sievert	Sv	J/kg	$m^2 \cdot s^{-2}$
plane angle	radian	rad		$m \cdot m^{-1} = 1$
solid angle	steradian	sr		$m^2 \cdot m^{-2} = 1$

5.2 SI derived units

A derived unit is a unit of measurement of a derived quantity in a given system of quantities (4).

SI-derived units are derived from the SI base units in accordance with the physical connection between the quantities.

Example: From the physical connection between
the quantity length measured in the unit m, and
the quantity time measured in the unit s,
the quantity speed measured in the unit m/s can be derived.

Derived units are expressed in base units by use of the mathematical symbols multiplication and division. Examples are given in table 5.2.

The CGPM has approved special names and symbols for some derived units, as shown in table 5.3.

Some base units are used in different quantities, as shown in table 5.4. A derived unit can often be expressed in different combinations of 1) base units and 2) derived units with special names. In practice there is a preference for special unit names and combinations of units in order to distinguish between different quantities with the same dimension. Therefore a measuring instrument should indicate the unit as well as the quantity being measured by the instrument.

Table 5.4 Examples of SI derived units whose names and symbols include SI derived units with special names and symbols (2)

Derived quantity	**Derived unit**	**Symbol**	**In SI base units**
dynamic viscosity	pascal second	$Pa \cdot s$	$m^{-1} \cdot kg \cdot s^{-1}$
moment of force	newton metre	$N \cdot m$	$m^{2} \cdot kg \cdot s^{-2}$
surface tension	newton per metre	N/m	$kg \cdot s^{-2}$
angular velocity	radian per second	rad/s	$m \cdot m^{-1} \cdot s^{-1} = s^{-1}$
angular acceleration	radian per second squared	rad/s^2	$m \cdot m^{-1} \cdot s^{-2} = s^{-2}$
heat flux density, irradiance	watt per square metre	W/m^2	$kg \cdot s^{-3}$
heat capacity, entropy	joule per kelvin	J/K	$m^{2} \cdot kg \cdot s^{-2} \cdot K^{-1}$
specific heat capacity, specific entropy	joule per kilogram kelvin	$J/(kg \cdot K)$	$m^{2} \cdot s^{-2} \cdot K^{-1}$
specific energy	joule per kilogram	J/kg	$m^{2} \cdot s^{-2}$
thermal conductivity	watt per metre kelvin	$W/(m \cdot K)$	$m \cdot kg \cdot s^{-3} \cdot K^{-1}$
energy density	joule per cubic metre	J/m^3	$m^{-1} \cdot kg \cdot s^{-2}$
electric field strength	volt per metre	V/m	$m \cdot kg \cdot s^{-3} \cdot A^{-1}$
electric charge density	coulomb per cubic metre	C/m^3	$m^{-3} \cdot s \cdot A$
electric flux density	coulomb per square metre	C/m^2	$m^{-2} \cdot s \cdot A$
permittivity	farad per metre	F/m	$m^{-3} \cdot kg^{-1} \cdot s^{4} \cdot A^{2}$
permeability	henry per metre	H/m	$m \cdot kg \cdot s^{-2} \cdot A^{-2}$
molar energy	joule per mole	J/mol	$m^{2} \cdot kg \cdot s^{-2} \cdot mol^{-1}$
molar entropy, molar heat capacity	joule per mole kelvin	$J/(mol \cdot K)$	$m^{2} \cdot kg \cdot s^{-2} \cdot K^{-1} \cdot mol^{-1}$
exposure (x and γ rays)	coulomb per kilogram	C/kg	$kg^{-1} \cdot s \cdot A$
absorbed dose rate	gray per second	Gy/s	$m^{2} \cdot s^{-3}$
radiant intensity	watt per steradian	W/sr	$m^{4} \cdot m^{-2} \cdot kg \cdot s^{-3} = m^{2} \cdot kg \cdot s^{-3}$
radiance	watt per square metre steradian	$W/(m^2 \cdot sr)$	$m^{2} \cdot m^{-2} \cdot kg \cdot s^{-3} = kg \cdot s^{-3}$

5.3 Units outside the SI

Table 5.5 gives the units outside the SI which are accepted for use together with SI units because they are widely used or because they are used within specific subject areas.

Table 5.6 gives examples of units outside the SI which are accepted for use within specific subject areas.

Table 5.7 gives units outside the SI which are accepted for use within specific subject areas and whose values are experimentally determined.
The combined uncertainty (coverage factor k=1) on the last two digits of the number is given in parenthesis.

Table 5.5 Units outside SI which are accepted

Quantity	Unit	Symbol	Value in SI units
time	minute	min	1 min = 60 s
	hour	h	1 h = 60 min = 3600 s
	day	d	1 d = 24 h
plane angle	degree	°	1° = (π/180) rad
	minute	′	1′ = (1/60) ° = (π/10 800) rad
	second	″	1″ = (1/60) ′ = (π/648 000) rad
	nygrad	gon	1 gon = (π/200) rad
volume	litre	l, L	1 l = 1 dm^3 = 10^{-3} m^3
mass	metric tonne	t	1 t = 10^3 kg
pressure in air, fluid	bar	bar	1 bar = 10^5 Pa

Table 5.6: Units outside the SI which are accepted for use within specific subject areas

Quantity	Unit	Symbol	Value in SI units
length	mile nautical		1 nautical mile = 1852 m
speed	knot		1 nautical mile per hour = (1852/3600) m/s
mass	carat		1 carat = 2 x 10^{-4} kg = 200 mg
linear density	tex	tex	1 tex = 10^{-6} kg/m = 1 mg/m
strength of optical systems	dioptre		1 dioptre = 1 m^{-1}
pressure in human body fluids	millimetres of mercury bar	mmHg	1 mmHg = 133 322 Pa
area	are	a	1 a = 100 m^2
area	hectare	ha	1 ha = 10^4 m^2
pressure	bar	bar	1 bar = 100 kPa = 10^5 Pa
length	ångström	Å	1 Å = 0,1 nm = 10^{-10} m
cross-section	barn	b	1 b = 10^{-28} m^2

Table 5.7: units outside the SI which are accepted within specific subject areas and whose values are experimentally determined (2)

Quantity	**Unit**	**Sym-bol**	**Definition**	**In SI units**
energy	electron-volt	eV	1 eV is the kinetic energy of an electron passing a potential difference of 1 V in vacuum.	1 eV = 1,602 177 33 (49) · 10^{-19} J
mass	atomic mass unit	u	1 u is equal to 1/12 of the rest mass of a neutral atom of the nuclid ^{12}C in the ground state.	1 u = 1,660 540 2 (10) · 10^{-27} kg
length	astrono-mical unit	ua		1 ua = 1,495 978 706 91 (30) · 10^{11} m

5.4 SI prefixes

The CGPM has adopted and recommended a series of prefixes and prefix symbols, shown in table 5.8.

Rules for correct use of prefixes:

1. Prefixes refer strictly to powers of 10 (and e.g. not powers of 2).
   Example: One kilobit represents 1000 bits *not* 1024 bits

2. Prefixes must be written without space in front of the symbol of the unit.
   Example: Centimetre is written as cm *not* c m

3. Do not use combined prefixes.
   Example: 10^{-6} kg must be written as 1 mg *not* 1 µkg

4. A prefix must not be written alone.
   Example: $10^9/m^3$ must *not* be written as G/m^3

Table 5.8: SI prefixes (2)

Factor	**Prefix name**	**Symbol**	**Factor**	**Prefix name**	**Symbol**
10^1	deca	da	10^{-1}	deci	d
10^2	hecto	h	10^{-2}	centi	c
10^3	kilo	k	10^{-3}	milli	m
10^6	mega	M	10^{-6}	micro	µ
10^9	giga	G	10^{-9}	nano	n
10^{12}	tera	T	10^{-12}	pico	p
10^{15}	peta	P	10^{-15}	femto	f
10^{18}	exa	E	10^{-18}	atto	a
10^{21}	zetta	Z	10^{-21}	zepto	z
10^{24}	yotta	Y	10^{-24}	yocto	y

5.5 Writing of SI unit names and symbols

1. Symbols are not capitalised,
   but the first letter of a symbol is capitalised if 1) the name of the unit comes from a person's name or 2) the symbol is the beginning of a sentence.
   Example: The unit kelvin is written as the symbol K.

2. Symbols must remain unchanged in the plural - no "s" is added.

3. Symbols are never followed by full stops unless at the end of a sentence.

4. Units combined by the multiplication of several units must be written with a raised dot or a space.
   Example: N·m or N m

5. Units combined by the division of one unit with another must be written with a slash or a negative exponent.
   Example: m/s or $m \cdot s^{-1}$

6. Combined units must only include one slash. The use of parenthesis or negative exponents for complex combinations is permitted.
   Example: m/s^2 or $m \cdot s^{-2}$ *but not* m/s/s
   Example: $m \cdot kg/(s^3 \cdot A)$ or $m \cdot kg \cdot s^{-3} \cdot A^{-1}$ *but neither* $m \cdot kg/s^3/A$ *nor* $m \cdot kg/s^3 \cdot A$

7. Symbols must be separated from the numerical value they follow by a space.
   Example: 5 kg *not* 5kg

8. Unit symbols and unit names should not be mixed.

Numerical notation

1. A space should be left between groups of 3 digits on either the right or left-hand side of the decimal place (15 739,012 53). In four-digit numbers the space may be omitted. Commas should not be used as thousand separators.

2. Mathematical operations should only be applied to unit symbols (kg/m^3) and not unit names (kilogram/cubic metre).

3. It should be clear to which unit symbol a numerical value belongs and which mathematical operation applies to the value of a quantity:
   Examples: 35 cm x 48 cm *not* 35 x 48 cm   100 g ± 2 g *not* 100 ± 2g

6. Vocabulary

(x) refers to reference no. *(x)* in chapter 7.

Accredited laboratory *Laboratory with 3rd party approval of the laboratory's technical competence, the quality assurance system it uses, and its impartiality. See chapter 2.2.5.*

Accuracy class *Class of measuring instruments that meet certain metrological requirements intended to keep errors within specified limits. (4)*

Accuracy of a measuring instrument *The ability of a measuring instrument to give responses close to a true value. (4)*

Accuracy of measurement *Closeness of the agreement between the result of a measurement and a true value of the measurand. (4)*

Adjustment of a measuring instrument *Process that brings a measuring instrument into a functional condition corresponding to the purpose for which it is used. (4)*

Artefact *An object fashioned by human hand. Examples of artefacts made for taking measurements are a weight and a measuring rod.*

Basic unit (for measurement) *Unit of measurement for a basic magnitude in a given system of magnitudes. (4)*

BIPM *Bureau International des Poids et Mesures. See chapter 2.2.*

BNM *Bureau National de Métrologie, the national metrological institute of France.*

Calibration certificate *Result(s) of a calibration can be registered in a document sometimes called a calibration certificate or a calibration report. (4)*

Calibration history, measuring equipment *Complete registration of the results from the calibration of a piece of measuring equipment, or measuring artefact, over a long period of time, to enable the evaluation of the long-term stability of the piece of equipment or the measuring artefact.*

Calibration interval *Time interval between two consecutive calibrations of a measuring instrument.*

Calibration report *Result(s) of a calibration can be registered in a document sometimes called a calibration certificate or a calibration report. (4)*

Calibration *Set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material and the corresponding values realised by standards. (4)*

CCEM *Consultative Committee for Electricity and Magnetism. Established 1927.*

CCL *Consultative Committee for Length. Established 1952.*
CCM *Consultative Committee for Mass and related quantities. Established 1980.*
CCPR *Consultative Committee for Photometry and Radiometry. Established 1933.*
CCQM *Consultative Committee for Amount of Substance*
CCRI *Consultative Committee for Ionising Radiation. Established 1958.*
CCT *Consultative Committee for Thermometry. Established 1937.*
CCTF *Consultative Committee for Time and Frequency. Established 1956.*
CCU *Consultative Committee for Units. Established 1964.*
CEM *Centro Español de Metrología, the national metrological institute of Spain.*
CEN *Comité Européene de Normalisation. European standardisation organisation.*
CGPM *Conférence Générale des Poids et Mesures. Held first time in 1889. Meeting every 4th year. See chapter 2.2.*
Check standard *Working standard routinely used to ensure that measurements are made correctly. (4)*
CIPM *Comité Internationale des Poids et Mesures. See chapter 2.2.*
CMI *Czech Metrology Institute, the national metrological institute of the Czech Republic.*
Compound standard *Set of similar material measures or measuring instruments that, through their combined use, constitutes a standard.*
Conventional true value (of a quantity) *Value attributed to a particular quantity and accepted, sometimes by convention, as having an uncertainty appropriate for a given purpose. Sometimes called "assigned value", "best estimate of the value", "conventional value", or "reference value". (4)*
Correction factor *Factor by which the uncorrected measuring result is multiplied to compensate for a systematic error. (4)*
Correction value *Value which added algebraically to the uncorrected result of a measurement compensates for a systematic error. (4)*

DANAK *Danish Accreditation. Allocates accreditation in Denmark under the auspices of the Danish Agency for Trade and Industry, Ministry of Business and Industry. See chapter2.3.2.*
DANIAmet *Cooperation between primary and reference laboratories in Denmark.*
Dead band *Maximum interval through which a stimulus may be changed in both directions without producing a change in response of a measuring instrument. (4)*
Derived unit (of measurement) *See chapter 5.2.*
Detector *A device or substance that indicates the presence of a phenomenon without necessarily providing a value of an associated quantity. E.g. litmus paper. (4)*

Deviation *Value minus its reference value. (4)*

DFM *Dansk Institut for Fundamental Metrologi. The national metrological institute of Denmark.*

Drift *Slow change of a metrological characteristic of a measuring instrument. (4)*

EA *European co-operation for Accreditation, formed by the amalgamation of EAL (European Co-operation for Accreditation of Laboratories) and EAC (European Accreditation of Certification) in November 1997. See chapter 2.3.2.*

EAC *See EA.*

EAL *See EA.*

Error (for a measuring instrument), largest permissible *Extreme values for an error permitted by specifications, regulations, etc. for a given measuring instrument. (4)*

Error (in a measuring instrument), systematic *Systematic indication error in a measuring instrument. (4)*

Error limit (for a measuring instrument) *Extreme values for an error permitted by specifications, regulations, etc. for a given measuring instrument. (4)*

EUROlab *Voluntary co-operation between testing and calibration laboratories in Europe. See chapter 2.3.3.*

EUROMET *Co-operation between 22 national metrological institutes in Europe, Turkey and the European Commission. See chapter 2.3.1.*

Fundamental Metrology *See Metrology, fundamental.*

General conference on measures and weights *See CGPM.*

GLP *Good Laboratory Practice. Accrediting bodies approve laboratories in accordance with the GLP rules of OECD.*

GUM *Guide to the Expression of Uncertainty in Measurement. Published by BIPM, IEC, ISO, OIML and IFCC (International Federation of Clinical Chemistry), IUPAC (International Union of Pure and Applied Chemistry) and IUPAP (International Union of Pure and Applied Physics). (6)*

History, measuring equipment *See calibration history.*

IEC *International Electrotechnical Commission.*

Indication (of a measuring instrument) *Value of a (measurable) quantity provided by a measuring instrument. (4)*

Influence quantity *Quantity that is not the measurand (quantity subject to measurement) but that affects the result of the measurement. (4)*

Instrument constant *Coefficient by which the direct indication of a measuring instrument must be multiplied to give the indicated value of the measurand or be used to calculate the value of the measurand. (4)*

International (measuring) standard *Standard recognised by international agreement as suitable for international use as a basis for determining the value of other standards for a given magnitude. (4)*

IPQ *Instituto Português da Qualidade, the national metrological institute of Portugal.*

IRMM *Institute for Reference Materials and Measurements, Joint Research Centre under the European Commission.*

ISO *International Organisation for Standardisation.*

Justervesenet *The national metrological institute of Norway.*

Legal metrology *See Metrology, legal.*

Maintenance of a measurement standard *Set of measures necessary to preserve the metrological characteristics of a measurement standard within appropriate limits. (4)*

Material measure *Device intended to reproduce or supply, in a permanent manner during its use, one or more known values of a given quantity. E.g. a weight, a volume measure, a gauge block, or a reference material. (4)*

Maximum permissible errors (of a measuring instrument) *Extreme values of an error permitted by specifications, regulations, etc. for a given measuring instrument. (4)*

Measurand *Particular quantity subject to measurement. (4)*

Measure, material *Device intended to take a measurement, alone or in conjunction with supplementary devices. (4)*

Measurement procedure *Set of operations, described specifically, used in the performance of particular measurements according to a given method. (4)*

Measurement *Set of operations for the purpose of determining the value of a quantity. (4)*

Measurement standard, etalon *Material measure, measuring instrument, reference material or measuring system intended to define, realise, conserve or reproduce a unit or one or more values of a quantity to serve as a reference. (4)*

Measurement standard, international *Standard recognised by an international agreement to serve internationally as the basis for assigning values to other standards of the quantity concerned. (4)*

Measurement standard, maintenance *Set of operations necessary to preserve the metrological characteristics of a measurement standard within appropriate limits. (4)*

Measurement standard, national *Standard recognised by a national decision to serve in a country as the basis for assigning values to other standards of the quantity concerned. (4)*

Measurement unit *See Unit of measurement. A particular quantity, defined and adopted by convention, with which other quantities of the same kind are compared in order to express their magnitudes relative to that quantity. (4)*

Measuring chain *Series of elements of a measuring instrument or measuring system that constitutes the path of the measurement signal from the input to the output. (4)*

Measuring error *Result of a measurement minus a true value of the measurand. (4)*

Measuring error, absolute *When it is necessary to distinguish "error" from "relative error" the former is sometimes called "absolute error of measurement". (4)*

Measuring instrument *Device intended to be used to make measurements, alone or in conjunction with supplementary devices. (4)*

Measuring range *Set of values of measurands for which the error of a measuring instrument is intended to lie within specified limits. (4)*

Measuring result *Value attributed to a measured measurand arrived at by measurement. (4)*

Measuring system *Complete set of measuring instruments and other equipment assembled to carry out specified measurements. (4)*

Measuring unit off-system *Unit of measurement that does not belong to a given system of units. (4)*

Metre Convention *International convention established in 1875 for the purpose of ensuring a globally uniform system af measuring units. In 1998 there were 48 member nations. See chapter 2.2.1.*

Method of measurement *Logical sequence of operations, described generically, used in the performance of measurements. (4)*

Metric system *A measuring system based on metres and kilograms. Subsequently developed into the SI system. See chapter 5.*

Metrological subject field *Metrology is divided into 11 subject fields. See chapter 2.1.1.*

Metrology *From the Greek word "metron" = measurement. The science of measurement.*

Metrology, fundamental *There is no international definition of the expression "fundamental metrology" but this expression stands for the most accurate level of measurement within a given discipline. See chapter 1.2.*

Metrology, industrial *Ensures appropriate function of the measuring instruments used in industry as well as in production and testing processes.*

Metrology, legal *Ensures accuracy of measurement where measured values can affect health, safety, or the transparency of financial transactions. See chapter 1.2.*

Metrology, scientific *Endeavours to organise, develop and maintain measuring standards. See chapter 1.2.*

MID *The Measuring Instruments Directive, see chapter 3.1.1.*

MKSA system *A system of measurement units based on Metres, Kilograms, Seconds and Amperes. In 1954 the system was extended to include Kelvins and Candelas. It was then given the name SI. See chapter 5.*

National measurement standard *Standard recognised by a national decision to serve in a country as the basis for assigning values to other standards of the quantity concerned. (4)*

National Metrology Institute NMI *See chapter 2.2.2.*

National reference laboratory *Laboratory that through traceability to primary laboratories in other countries is able to calibrate a given measurand at the highest level of performance in its own country.*

NIST *National Institute of Standards and Technology, The national metrological institute of the USA.*

NMI *Often-used English abbreviation for the national metrological institute of a country. See chapter 2.2.2.*

NMi-VSL *Nederlands Meetinstituut - Van Swinden Laboratorium. The national metrological institute of Holland.*

Nominal value *See value, nominal.*

NPL *National Physical Laboratory. The national metrological institute of Great Britain.*

NRC *National Research Council, Institute for National Measurement Standards, The national metrological institute of Canada.*

OFMET *Office Fédéral de Métrologie, the national metrological institute of Switzerland.*

OIML *Organisation Internationale de Métrologie Légale, International Organisation of Legal Metrology.*

Performance testing (laboratory) *Determination of the testing capability of a laboratory, by comparing tests performed between laboratories.*

Primary laboratory *Laboratory that performs internationally adopted fundamental metrological research and which realises and maintains standards at the highest international level. See chapter 2.2.3.*

Primary method *A method of the highest metrological quality which when implemented can be described and understood completely, and for which a complete uncertainty budget can be provided in SI units, the results of which can therefore be accepted without reference to a standard for the magnitude being measured.*

Primary reference material *See reference material, primary.*

Primary standard *Standard that is designated or widely acknowledged as having the highest metrological qualities and whose value is accepted without reference to other standards of the same quantity (4). See chapter 2.1.3*

Principle of measurement *The scientific foundation of a method of measurement. (4)*

Prototype *Artefact that defines a unit of measurement. The kilogram prototype (1 kg weight) in Paris is today the only prototype in the SI system.*

PTB *Physikalisch-Technische Bundesanstalt, the national metrological institute of Germany.*

Quantity (measurable) *Attribute of a phenomenon, body or substance that may be distinguished qualitatively and determined quantitatively. (4)*

Quantity derived *Quantity defined, in a system of quantities, as a function of base quantities of that system. (4)*

Quantity dimension *Expression that represents a quantity of a system of quantities as the product of powers of factors that represent the basic quantities of the system. (4)*

Random error *Result of a measurement minus the mean that would result from an infinite number of measurements of the same measurand carried out under repeatability conditions. (4)*

Reference conditions *Conditions of use prescribed for testing the performance of a measuring instrument or for the intercomparison of results of measurements. (4)*

Reference laboratory *See National reference laboratory.*

Reference material (CRM), certified *Reference material, accompanied by a certificate, which has one or more properties whose value is certified by a procedure that establishes traceability to the accurate realisation of the unit in which the values of the properties are expressed, and for which each certified value is accompanied by a stated uncertainty with a given level of confidence. (4)*

Reference material (RM) *Material or substance one or more of whose property values are sufficiently homogenous and well established to be used for the calibration of an apparatus, the assessment of a measurement method, and for assigning values to materials. (4)*

Reference material, primary *Reference material that has the highest metrological qualities and whose value is determined by the use of a primary method. (3)*

Reference standard *In general the standard of the highest metrological quality which is accessible at a given location or in a given organisation, and from which measurements taken at the locality are derived. (4) See chapter 2.1.3.*

Reference values *Normally part of the reference conditions of an instrument. See also Values, determined.*

Relative error *Error of measurement divided by a true value of the measurand. (4)*

Repeatability (of a measuring instrument) *The ability of a measuring instrument to give, under defined conditions of use, closely similar responses for repeated applications of the same stimulus. (4)*

Repeatability (of results of measurements) *Closeness of the agreement between the results of successive measurements of the same measurand carried out under the same conditions of measurement. (4)*

Reproducibility (of results of measurements) *Closeness of agreement between the results of measurements of the same measurand carried out under changed conditions of measurement. (4)*

Response *The input signal for a measuring system can be called a stimulus and the output signal can be called a response. (4)*

Result, corrected *Measuring result after correction for systematic error. (4)*

Scale division *Part of a scale between any two successive scale marks.*

Scale range *The set of values bounded by the extreme indications on an analog measuring instrument. (4)*

Scale spacing *Distance between two successive adjacent scale marks measured along the same line as the scale length. (4)*

Secondary standard *Standard whose value is assigned by comparison with a primary standard of the same quantity. (4)*

Sensor *Element in a measuring instrument or a measuring chain that is directly influenced by the measurand. (4)*

SI system *The international system of units (Le Système International d'Unités) continuing the formal definition of all SI basic units, approved by the General Conference on Weights and Measures. See chapter 5.*

SI unit *A unit in the SI system. See chapter 5.*

SMIS *Standards and Metrology Institute of Slovenia, the national metrological institute of Slovenia.*

SMU *Slovensky Metrologicky Ustav, the national metrological institute of the Slovak Republic.*

SP *Sveriges Provnings- och Forskningsinstitut, the national metrological institute of Sweden.*

Span *Modulus of the difference between two limits of a nominal range. (4)*

Stability *The ability of a measuring instrument to maintain constant its metrological characteristics with time. (4)*

Standard deviation, experimental *Parameter s for a series of n measurements of the same measurand, characterises the dispersion of the results and is given by the formula for standard deviation. (4)*

Standard *See Measuring standard.*

Standard, compound *A set of similar material measures or measuring instruments that, through their combined use, constitutes one standard called a compound standard. (4)*

Standard, transfer *Standard used as an intermediary to compare standards. (4)*

Standard, travelling *Standard, sometimes specially composed, for use in making comparisons between standards at different locations. (4)*

Stimulus *The input signal for a measuring system can be called a stimulus and the output signal can be called a response. (4)*

System of measurement units *A number of basic units and derived units defined in accordance with given rules for a given system of values. (4)*

System of units *See System of measurement units.*

Systematic error *Mean that would result from an infinite number of measurements of the same measurand carried out under repeatability conditions minus a true value of the measurand. (4)*

Testing *Technical procedure consisting of the determination of one or more characteristics of a given product, process or service, in accordance with a specified procedure. (5)*

Threshold, resolution capability (discrimination) *Largest change in a stimulus that produces no detectable change in the response of a measuring instrument, the change in the stimulus taking place slowly and monotonically. (4)*

Traceability chain *The unbroken chain of comparisons is defined under Traceability. (4)*

Traceability *Property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties. (4)*

Transfer equipment *The description "transfer equipment" should be used when the intermediate link is not a standard. (4)*

Transfer standard *Standard used as an intermediary to compare standards. (4)*

Transparency *Ability of a measuring instrument not to alter the measurand. (4)*

Travelling standard *See Standard, travelling.*

True value (of a quantity) *The indefinite form rather than the definite form is used in connection with true value, in that there can be many values that are consistent with the definition of a particular quantity. (4)*

Uncertainty of measurement *Parameter, associated with the result of a measurement that characterises the dispersion of values that could reasonably be attributed to the measurand. (4) The estimation of uncertainty in accordance with GUM guidelines is usually accepted.*

Unit (of measurement) *Particular quantity, defined and adopted by convention, with which other quantities of the same kind are compared in order to express their magnitudes relative to that quantity. (4) See chapter 5.*

Unit of measurement (derived) coherent *Derived unit of measurement that can be expressed as the product of basic units in powers with the proportionality coefficient 1. (4)*

Value (of a measurand), transformed *Value of a measuring signal that represents a given measurand. (4)*

Value (of a quantity) *Magnitude of a particular quantity generally expressed as a unit of measurement multiplied by a number. (4)*

Value, nominal *Rounded or approximate value of a characteristic of a measuring instrument that provides a guide to its use. (4)*

Values, derived *Conditions for use intended to keep the metrological characteristics of a measuring instrument within specified limits. (4)*

Working range *Set of values of measurands for which the error of a measuring instrument is intended to lie within specified limits. (4)*

Working standard *Standard normally used routinely to calibrate or check material measures, measuring instruments or reference materials. (4)*

7. References

The references are listed by their reference number (x)

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8. Coupon for comments

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