Е. В. Карцева, А. А. Флаксман

Учебное пособие по английскому языку

METROLOGY AND STANDARDIZATION

Нижний Новгород
2021

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METROLOGY AND STANDARDIZATION

Утверждено редакционно-издательским советом университета
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Цель учебного пособия – формирование базовых знаний по специальности, ознакомление с терминологией специальности, овладение профессионально-ориентированным языком, формирование профессиональной, коммуникативной и социокультурной компетенций в рамках профессиональной подготовки специалистов.

Предназначено для студентов I, II курсов, обучающихся по направлению подготовки 200500.62 «Метрология, стандартизация и сертификация» очной формы обучения.

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Contents

Введение

Учебное пособие по английскому языку «Metrology and Standardization» предназначено для студентов I, II курсов, обучающихся по направлению подготовки 200500.62 «Метрология, стандартизация и сертификация» очной формы обучения.

Целью учебного пособия является формирование базовых знаний по специальности, ознакомление с терминологией специальности, овладение профессионально-ориентированным языком, формирование профессиональной, коммуникативной и социокультурной компетенций в рамках профессиональной подготовки специалистов.

Учебное пособие состоит из 10 модулей, описывающих основные понятия метрологии и стандартизации. Каждый модуль имеет текстовую описательную часть и набор заданий, содержащих вопросы и темы для устных сообщений на практическом занятии с последующим обсуждением в форме дискуссии, а также краткий тематический словарь. Кроме этого, пособие содержит дополнительный информационный материал в приложениях.

UNIT 1. WHAT IS METROLOGY?

1. What do you know about metrology. Discuss it with your group mates.
2. Read the text about metrology and compare your ideas with the information from the text.

What is Metrology and Why is It Important in Digital Revolution?

To understand the importance of metrology, we have to understand what it is. Metrology, simply put, is the science that has to do with measurements. It is a field of study that establishes a common and standardized understanding of units which many (if not all) human activities are based on.

Think about the specific units of measurement you encounter everyday – the kilometer- or miles-per-hour reading on your car's speedometer or even just the day's temperature from the daily weather report. All these and other measurement units came from metrology, along with how they've become standardized.

Metrologists use various equipment – more than just rulers and meter sticks and thermometers – to get the measurements that they need. Some of this equipment includes dial indicators, force gauges, calipers, and optical laser probes.

Metrology is divided into three specific fields:

- **Scientific Metrology.** This field of metrology deals with the organization, development, and maintenance of measurement standards (SI units). There are many specialty areas in this particular field, with some examples being mass metrology, volume metrology, chemical metrology, and temperature metrology. Scientific metrology also signifies the highest level of accuracy within the given scope of measurement.
- **Industrial Metrology.** This field concerns the application of measurement to industrial manufacturing and other similar processes in society. It also involves ensuring the suitability of industrial measurement instruments, their calibration, and their quality control.

- **Legal Metrology.** This field of metrology involves the regulatory and statutory requirements of measuring instruments for the interests of protecting public health, public safety, and the environment. It also involves measurement enabling taxation as well as fair trade.

Why is Metrology Important?

- **Measurements let us know more about the world around us.** In all aspects of research, metrology is always present. It allows us to observe objects and phenomenon more accurately and quantifiably, which in turn allows us to share our observations with our peers. It also helps us build the instruments necessary to make the measurements themselves.
- **Measurements protect public health and life.** Proper measurements can help protect the health of the public as well as save lives. For example, the correct measurement of drug dosages or radiation levels in chemotherapy are crucial for successful patient outcomes. The reliability of measurement instruments in operating theaters and emergency units are critical for survival as well. Other scenarios where measurements can affect life also include mandatory speed limits in public roads to prevent vehicular accidents and pedestrian fatalities, and air/water quality to prevent respiratory diseases and water-borne diseases.
- **Measurements allow the accurate and impartial governing of transactions.** All transactions made between individuals and companies require proper measurements to facilitate commerce and fair trade. Examples include the dosage of foodstuffs, metering fuel at the fuel pump, retail or bulk weighing of produce or mass-produced products. Besides this, metrology also helps form trusted relationships between customers and service providers/contractors because without measurements, it is impossible to guarantee the amount or quality of service rendered in exchange for money.
- **Measurements enable competition and progress.** Without measurements, competition and progress cannot exist. For example, measurements are needed to

objectively quantify whether a product or service has the ability to meet customer requirements and expectations. Individuals and companies also require measurements in order to compare their performance against each other, as well as to figure out where their current services and/or products are lacking in order to improve them.

Conclusion

Metrology may not be the most popular or well-known of the sciences, but it is clearly one of the most important. Not only does it allow other fields of study to measure and quantify objects, elements, and phenomena in an objective and impartial manner, it also has an undeniable effect on our lives, health, welfare, and commerce.

My glossary:

1. Meter stick – рейка, уровень,
2. dial indicator – индикатор с цифровой шкалой,
3. force gauge – динамометр,
4. caliper – калипер, кронциркуль, штангенциркуль,
5. optical laser probe – оптически лазерный измерительный преобразователь,
6. SI unit – единица в системе СИ.

3. *Read the text again and answer the questions:*

1. What is metrology?
2. What measurement units came from metrology?
3. What equipment do metrologists use?
4. What does scientific metrology deal with?
5. What does Industrial metrology involve?
6. What does the field of Legal metrology concern?
7. Why is Metrology important?

4. Make the summary of the text: «Metrology» using the following plan:

1. Definition of metrology;
2. Subfields of metrology;
3. The object of study of scientific metrology;
4. The object of study of the industrial metrology;
5. The object of study of legal metrology.

5. Read the second part of the text.

Metrology is fundamental to all biological, physical and environmental sciences, engineering, and medicine. Standards are required for all measurements. While manufacturing depends on research and development, research and development would not be possible without reliable experimental data, the analytical instrumentation tools and methods to obtain authentic experimental data and the methods to calibrate against standards.

The demands on metrology have grown over the years. This is particularly the situation in a variety of material scenarios. At the macro level, these scenarios include examples such as alloys, bandgap engineered structures, biomaterials, ceramics, composite materials, coatings, electronic materials, liquid crystals, magnetic materials, metals, metamaterials, nanomaterials, optical materials, polymers, semiconductors, smart materials, superconductors etc. The ability to tailor materials, processes, performance and structure, for desired applications, requires pre-knowledge of the material properties. At the device and systems level, applications of metrology include detectors, drug delivery systems, energy sources, filters, imagers, lasers, process control systems, sensors, waveguides etc. The influence of defects and dislocations on properties becomes significant especially when the structures are scaled from micron to the nanoscale.

Fundamental research, both experimental and theoretical, requires metrology. There has been a tremendous growth in computational tools and instrumentation methods; the accuracy, repeatability and reproducibility of the measured data has improved significantly. Throughout the globe, industry, research laboratories and universities have been developing and improving methods for reliable and accurate data that represents the measurement of the physical quantity.

Case studies of such research activities include the development of pyrometry. Pyrometers are the instruments of choice for noncontact in temperature measurements in materials processing. Pyrometers measure the amount of radiation emitted from a material within a narrow wavelength window.

Another example is thermoelectrics. With their ability to recover waste heat and convert it into useful electricity, thermoelectric (TE) materials are promising candidates to achieve the challenge to reduce energy wastage. Most important applications of TE materials are in coolers and power generators to convert thermal energy into electrical energy and vice versa.

Research on biomaterials and related topics is on an exponential rise. This has been catalyzed by increased human life expectancy and, simultaneously, the need to improve the quality of life. Drug delivery systems are being developed to address a variety of ailments and diseases. These systems will require complete understanding of diffusion of drug actives, in the form of molecules through materials as function of their structure and morphology.

My glossary:

1. alloy – сплав, смесь,
2. bandgap – запрещенная зона,
3. smart material – интеллектуальный материал
4. superconductor – сверхпроводящий материал,
5. waveguide – волновод,
6. Pyrometer – пирометр,
7. exponential rise – экспоненциальный рост,
8. ailment – недомогание.

6. Say if the following statements are true or false:

1. Standards are required for some measurements.
2. Research and development is not be possible without reliable experimental data.
3. Fundamental research requires metrology in some cases.
4. Industry, research laboratories and universities have been developing and improving methods for reliable and accurate data.
5. Thermoelectric materials are promising candidates to achieve the challenge to reduce energy waste.
6. Most important applications of TE materials are in coolers and power generators.
7. Research on biomaterials is increasing.

7. Project Work*: «Organizations on metrology in my country»*

Tell the class about any organization on metrology functioning in your country on the following plan:

1. When was this organization founded?
2. Where is it situated?
3. What kind of services does this organization provide?
4. Is it the only organization in metrology in your country?
5. What specialists work there?
6. In what spheres of human activity does this organization provide metrological services? Give the examples.
7. What metrological laboratories does this organization include?
8. Is this organization important in your country?
9. Are you planning to work in this organization in the future?
10. Have you ever visited this organization?

UNIT 2. HYSTORY OF METROLOGY

1. Read the text about the history of metrology.

A brief history of metrology: past, present, and future

Part 1

1. Introduction

In these times where significant changes in the International System of units (SI) are taking place, it may be worth to establish a short assessment about when and why the question of metrology has emerged. As a matter of fact, the history of metrology has included plenty of events. Since enough books and courses already have thoroughly treated this subject, we shall highlight here only the most significant of them. It is especially interesting to try to understand what have been the difficulties encountered, and which answers have then been found to overcome them.

We shall conclude by an overview of what are today the metrological performance attained for the different physical quantities and contexts, and what are our current expectations for the future.

2. Some historical confusions, having hampered metrology

2.1 The confusion between weight and volume

The difference between weight and volume was not so clear in the remote past. Actually, the measurement value associated to weight, for a given amount of goods, is exact, whereas the measurement of volume is approximate; it remains today something of this, would it be only in the today non-modifiable name "Bureau des Poids ET Mesures".

For most goods, the equivalence between weight and volume remained sufficient for commercial operations during centuries, at least, for instance, for liquid goods. But an important sector for trade was seeds. It is clear that in this field the confusion may lead to inaccuracy, and moreover to treachery.

Legal institutions did their best to take into account the consequence of this confusion. For instance, in France, Minister Colbert (1670) clarified the notions of "mesure rase" (flat surface of a seed barrel) and "mesure comble" (curved surface of a seed barrel). Even so, the seed quantity remained dependent on the pressure exerted on the upper surface of the barrel, and on the barrel cross-area.

2.2 The confusion between weight and mass

Still today in current life, the distinction between the two parameters is often ignored, whereas the weight is a force, depending on the location, and the mass is a scalar, and intrinsic to an object. The no longer used unit kilogram-force was in this respect not helpful to raise the ambiguity.

2.3 The confusion between temperature and heat flux

A similar observation, i.e. a distinction still today ignored, concerns temperature and heat flux. But it should be noted that a scientific interpretation of both concepts took place very early in history. At the time of Boltzmann, very little was yet known about the intimate structure of matter, in terms of atoms and particles; and despite of this, a theory for thermodynamics based on statistical distribution of kinetic energies could be elaborated.

3. Does physics obey to political power?

For the quantities most important for trade, i.e. weight and length, the definition of units was extremely diverse, regarding geographic dispersion. This was an obvious obstacle to equitable and efficient transactions.

As we shall see, in many countries political authorities tried, therefore, to impose their views on the subject, so as, at the same time, to confirm their authority.

My glossary:

1. non-modifiable – немодифицируемый,
2. treachery – вероломство, предательство,
3. exert – приводить в действие, оказать давление,
4. force – сила, мощность, воздействие, нагрузка,
5. cross-area – площадь поперечного сечения,

6. scalar – шкала, масштаб, градация,

7. intrinsic – свойственный чему-либо,

8. ambiguity – неопределенность, двусмысленность,

9. heat flux – тепловой поток,

10. Boltzmann – Больцман,

11. dispersion – рассеивание, разбрасывание,

12. equitable – беспристрастный, объективный,

13. elaborate – уточнить, объяснить подробно

2. Read the text and answer the questions:

1. What is the confusion between weight and volume?
2. What was an important sector for trade? Why?
3. Who clarified the notions of "mesure rase" (flat surface of a seed barrel) and "mesure comble" (curved surface of a seed barrel)?
4. What is the weight?
5. What is the mass?
6. What was an obvious obstacle to equitable and efficient transactions?

3. Read the second part of the text about the history of metrology and find out the meaning of the words in bold.

A brief history of metrology: past, present, and future

Part 2

4. Historical overview

4.1 The most ancient past

The four great antique civilizations, China, India, Egypt, and Mesopotamia, have all had early knowledge of metrology.

In China, archaeological discoveries demonstrate the use of a **decimal metric system** as soon as 1600 BC. Around 200 BC, at the same time the whole country was unified, a unique unit system was also spread into it.

The accurate dimensioning of Egyptian pyramids **witnesses** of an advanced mastery.

Significant research works on the subject have been led by University Paris 7.

The well-known papyrus of Hunefer (1300 B.C.) brings a poetic illustration thereof (Fig. 1).

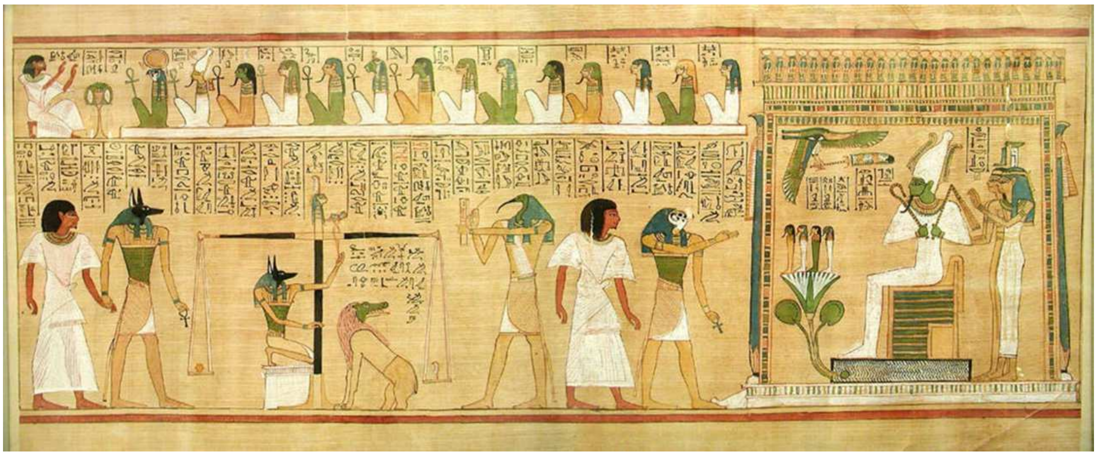

Fig. 1 Weighting of the heart at the judgement of the soul. Source: British Museum.

4.2 The Middle Ages and monarchic times

Although very different, these two long history periods present common features concerning metrology.

The political power was much disseminated in the Middle Ages, and was on the contrary much centralised under monarchy, which sometimes confined to absolutism. The feudal system, characterised by dispersion, subsisted in some way under monarchy. The problem regarding metrology was the same in both cases: the **affirmation** of authority. Every king, lord, town council, monastery, etc. had a tendency to define its own units, as a sign of its power, according to the principle “a king, a law, a weight, a measure”.

Hence, a great number of different units, also different according to the nature of the goods, measured. Thus, a pound of weight was different for wheat, barley, or flour.

Just to illustrate the problem (but, in fact, innumerable examples of this could be given), the measurement of surfaces in the Généralité de Paris (the surroundings of Paris), in 1780–although a late date – made use of the unit arpent, for which existed at least 48 definitions. Moreover, each of these definitions used specific subunits, the length perche being worth here 20 feet, there 25 feet, and yet elsewhere 22 feet 6 inches].

Very complicated transactions resulted of this, **voluminous manuals** and many calculations were required for the unavoidable conversions.

4.3 The progress brought by illuminism and the French Revolution

The intervention of the French Revolution in the field of measurement and metrology had social and ethical purposes. The unit system should be unique and **equal** for all, a goal consistent with the motto of the Republic, and with the expectations of the population as collected by the cahiers de doléances (peoples' claim books).

The use of the decimal system introduced drastic simplifications, especially for the determination of **surfaces** and **volumes**. These simplifications applied to any citizen, enabling him to proceed to easier exchanges with others, and hence increasing in general welfare.

In fact, the Revolution imposed both things, still unfamiliar, which were decimal numeration and a simplified measurement unit system.

In most domains the proposed reforms were successful, and progressively adopted by other countries, first in Europe, and later beyond (Fig. 2).

However, it should be noted that the attempts of revolutionists in the domain of time were unsuccessful. The goal was to implement, in addition to the revolutionary calendar, weeks of 10 days, hours of 100 min, and minutes of 100 s. But the way to count and display hours and days is something so familiar to everyone, that this reform has always remained unpopular and was finally never applied.

Fig. 2 New decimal units.

4.4 From 17th to 21th century

The main evolutions in the field of metrology during this last period have been the development of scientific discoveries, the intensification of exchanges, and the **settlement** of international institutions.

5. Today's situation

5.1 The international institutions

The context today for metrology is fortunately more cooperative than competitive. A set of international institutions, closely linked to one another, have taken place:
Conférence Générale des Poids et Mesures (CGPM);
Comité International des Poids et Mesures (CIPM); and
Bureau International des Poids et Mesures (BIPM).

These institutions have received authority to act in matters of world metrology from the Convention of the Metre (a diplomatic treaty between 51 nations initially, but today approved by almost all nations).

This particularly concerns the demand for measurement standards of ever increasing accuracy, range, and diversity, and the need to demonstrate equivalence between national measurement standards. The Convention was signed in Paris in 1875 by representatives of 17 nations.

The National Metrology Institutes (NMIs), such as PTB in Germany, or LNE in France, constitute the local relays of the international institutions.

The global organization is completed by World Regional Institutes (RMOs), according to the map in Figure 3.

The regional institutes are less known than NMIs; however, their role is important. They have responsibilities:

· to facilitate traceability to primary realisations of the SI;

· to coordinate comparisons of national measurement standards;

· to make mutual reviews of technical competencies and quality systems;

· to cooperate in metrology research and development;

· to operate joint training and consultation; and

· to share technical capabilities and facilities.

Examples of RMOs are:

EURAMET (Association Européenne des Instituts Nationaux de Métrologie);

AFRIMET (Intra-Africa Metrology System – supported by the Technical Cooperation of PTB);

COOMET (Euro-Asian Cooperation of National Metrological Institutions); and

APMP (Asia Pacific Metrology Programme).

For a more efficient organisation, world regions are sometimes splitted into subregions.

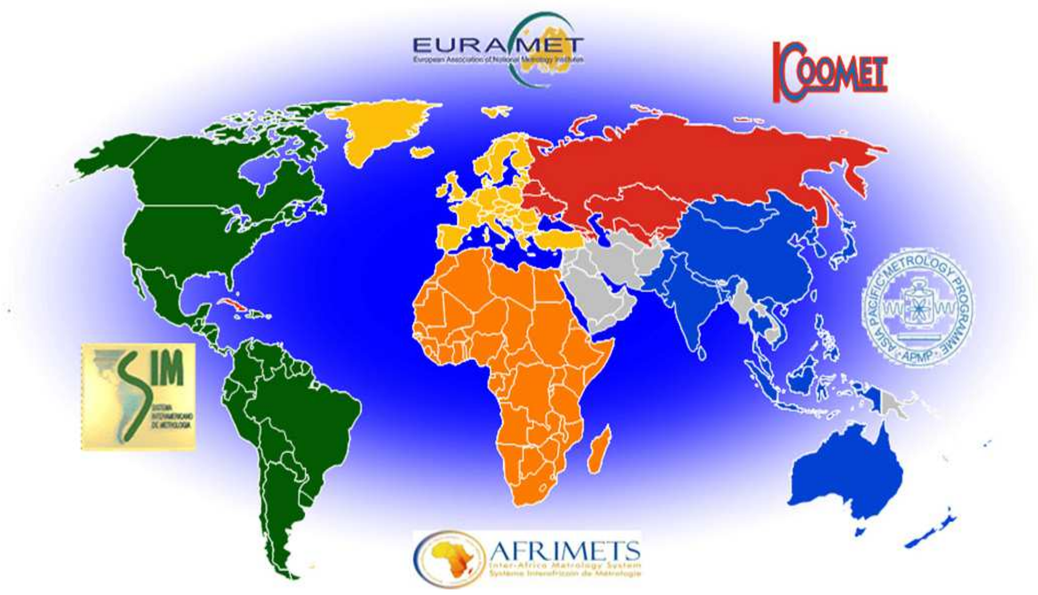

Fig. 3 RMOs around the world.

5.2 The unit system

The 11th CGPM (1960) adopted the name Système International d'Unités (International System of Units, abbreviation SI), for the recommended practical system of measurement units.

SI units are divided into two classes: base units (7) and **derived** units.

To have a realistic approach of practices, these two-unit sets are completed by the so-called SI-compatible units, SI-temporarily compatible units, and SI-non-compatible units. Base units are the following:

· second **s** (time);

· metre **m** (length);

· kilogram **kg** (mass);

· ampere **A** (current);

· Kelvin **K** (temperature);

· Candela **c** (luminosity);

· mole **m** (matter).

5.3 The most recent changes

The 26th CGPM has taken place in November 2018, and has approved several significant changes through its Resolution A. Goals of this evolution have been recalled, i.e. to build a system that would be “uniform and accessible world-wide for international trade, high-technology manufacturing, human health and safety, protection of the environment, global climate studies and basic science …, stable in the long term, internally self-consistent, and practically realizable”.

Thus, values of seven general constants, as described hereunder, whose numerical value was initially obtained by experimentation, have been defined as exact values.

My glossary:

1. dimensioning - задание размеров,
2. disseminated - рассредоточенный,
3. dispersion - рассеивание,
4. pound - фунт,
5. arpent - арпан, французская единица площади,
6. illuminism – иллюминатство,
7. traceability – прослеживаемость,
8. SI-compatible units – совместимые устройства по международной системе СИ,
9. luminosity – светосила, (оптика),
10. mole – моль, единица количества вещества в Международной системе единиц

4. Match the words and make word combinations.

1. antique	a. transactions
2. archaeological	b. value
3. research	c. reviews
4. specific	d. institutions
5. complicated	e. civilizations
6. decimal	f. system

7. international	g. subunits
8. mutual	h. works
9. numerical	i. discoveries

5. Read the text again and answer the following questions.

1. What ancient civilizations have known about metrology?
2. What problems regarding metrology existed in the Middle Ages?
3. How did the French Revolution influence the field of measurement and metrology?
4. When were international institutions founded?
5. What are responsibilities of regional institutions?
6. What are the main classes of SI units?

*6. **Project Work**: "History of metrology".*

Make a presentation about the metrology in the past. Choose any time period you want and tell about it.

UNIT 3. FUTURE OF METROLOGY

1. Read the text about the future of metrology and explain the words in bold.

An analysis

The difficulties encountered by metrology progress

The badly understood distinction between volume and weight has long been, as already said, a factor for progress slowdown. This problem may be regarded as solved today.

However, the unit **stère** for a volume of 1 cubic meter of wood is still in use, although a quite inaccurate measure of the quantity concerned, but practical, because it allows visual estimation of the quantity.

Resistance to changes also has often impacted progress

The human mind presents some inertia. Understanding of new discoveries is sometimes difficult; daily ways of thought and habits can be hard to change.

This resistance explains the upkeep of SI-compatible units (angle degrees, liter, electron-volt, etc.) and even SI-non-compatible units (carat in jewelry, faraday in chemistry, bar in meteorology, horsepower in mechanics, calorie for food, and all the **Anglo-Saxon units**).

We certainly would not, in the future, express distances in seconds, although it would be quite logical: 1 m corresponds to 3.335 ns, referring to the speed of light in vacuum. This state of things will persist. At the same time, we currently accept the light year as a distance.

Economic competition has sometimes played a negative role

Specific unit systems have – or still are – in some cases to be considered as a tool for the protection of trade. This probably explains the (rare) cases of countries still resisting to the use of the metric system. Even in these cases, the local standards institutions, such as IEEE, do so as to provide appropriate guidance documents.

2. Answer the questions:

1. Why is the unit stère for a volume of 1 cubic meter of wood still in use?
2. Why is understanding of new discoveries sometimes difficult?
3. Why would it be it quite logical in the future to express distances in seconds?

3. Read the second part of the text.

The next steps

What does metrological performance mean?

This performance relies on the following factors:

· the range accessible to measurement; and

· the accuracy of such measurement, i.e. the associated uncertainties.

Performance aimed at fundamental research

About accuracy, a present state of the art for the different physical quantities may be established as follows.

The most accurate quantities are “mechanical” ones, i.e. time, length, and mass. Among these, time is the most precise.

Performance of electrical quantities comes after, and is quite good; thermal quantities are somehow under, and lastly luminous quantities have rather limited accuracy, due to the fact that physiological aspects necessarily enter into the measurement process.

Nonetheless, the need for accuracy is not the same for fundamental research, for industry, and for trade.

Performance aimed at industry

Considering industry in general, it may be observed that provisions are progressively taken to anticipate and implement the new SI definitions.

Concerning, more precisely, electrical industries, it can be regularly observed, during accreditation assessments of test laboratories, that the designers of a product have used as little as possible of costly materials, such as copper. Hence, product characteristics are sometimes very close to the limits permitted by international standards.

Conformity decisions, taken in such situations, may be difficult. Accurate measuring equipment can help in some way to raise the difficulty, but in any case, if the measurement uncertainty is not taken into account, the decision remains doubtful.
Anyway, strictly speaking, a measurement value without uncertainty remains meaningless.

A farther future

The domains covered by fundamental and applied physics extend every day. So must do metrology.

Beyond its traditional goal to help specification and understanding of objective reality, metrology today also investigates the domain of human perception (i.e. the so-called “soft metrology”) (Fig. 6).

This is to be applied for instance to:

- psychometric measurement or perceived feeling (colour, taste, odour, and touch);
- qualitative measurements (perceived quality, customer satisfaction, etc.);
- econometrics and sociometry (opinion); and
- measurements related to human sciences: biometry, behaviour, intelligence, etc.

Soft metrology sections are already active at NIST (USA) and NPL (UK). Also, the European Commission has funded some research within the N.E.S.T. programme “Measuring the Impossible”.

There is likely a wide future for such works.

Fig. 6

Metaphorical illustration of “soft metrology”. Source: Laura Rossi, Inrim.

A conclusion proposal

Metrology at start has been developed to support human economic activities (trade and exchanges). The level of metrological performance attained today largely exceeds the actual needs in this field; further progress is now more requested to facilitate scientific progress. A still higher accuracy level is necessary today for specific domains of science such as spatial, astrophysics, medical care, etc.; all these domains contribute in fact to human welfare.

It is also encouraging to observe that metrology is one of the (rare) domains where an efficient and sincere cooperation takes place between the nations of the world. Almost all nations acknowledge the metric system (with the remaining exception of the USA); and more than 100 laboratories worldwide have signed the document quoted above, called CIPM-MRA agreement.

Going forward with metrology is a path to a more peaceful world.

My glossary:

1. Stere – кубический метр,

2. Inertia – инертность, вялость, инерция,

3. Faraday - число Фарадея,

4. Bar – единица давления и механического напряжения,

5. IEEE - Институт инженеров по электротехнике и радиоэлектронике,

6. Sociometry – социометрия, изучение межличностных отношений в группе,

7. NIST - Национальный институт стандартов и технологии,

8. NPL – National Physical Laboratory – National Measurement Institute,

9. CIPM - Comitato Internazionale dei Pesi e Misure - Международный комитет мер и весов,

10. CIPM-MRA agreement - Следствием этого Соглашения явилось формирование в Международном бюро мер и весов (МБМВ) базы данных калибровочных и измерительных возможностей стран, Национальные метрологические институты которых подписали Соглашение.

4. Fill in the gaps with missing prepositions. Use both parts of the text.

1. The unit stère is still … use.
2. We certainly would not, … the future, express distances … seconds, although it would be quite logical: 1 m corresponds … 3.335 ns.
3. The metrological performance relies … different factors.
4. The need … accuracy is not the same for fundamental research, for industry, and for trade.

5. Product characteristics are sometimes very close … the limits permitted … international standards.

6. If the measurement uncertainty is not taken … account, the decision remains doubtful.

7. Metrology … start has been developed to support human economic activities.

8. Different domains contribute … human welfare.

9. Going … … metrology is a path to a more peaceful world.

5. Answer the questions.

1. What factors are important for the metrological performance?
2. What are the most accurate quantities?
3. What quantities take the second place in accuracy?
4. What does the so-called "soft metrology" mean?
5. How can you interpret the statement "Going forward with metrology is a path to a more peaceful world"?

*6. **Project Work**: Make a presentation about*

a) SI-compatible units (angle degrees, liter, electron-volt, etc.), or

b) SI-non-compatible units (carat in jewelry, faraday in chemistry, bar in meteorology, horsepower in mechanics, calorie for food), or

c) the Anglo-Saxon units, or

d) "soft metrology".

UNIT 4. THE METER

1. Can you define what the meter is. Discuss it in your group.

2. Read the text about the meter and compare your ideas with the information from the text.

Where International Standard Units Come From, Part One: The Meter

There are seven base units in the international metric system, and over the past century, metrologists (people for whom measurement isn't the start of science—it is science) have gotten increasingly picky about defining these seven quantities. And it turns out that some of the best tools metrologists have to make measurements are elements on the periodic table. Unlike even the top measuring instruments, elements are exactly the same everywhere, allowing for perfectly reproducible results. And the sheer variety of the table ensures that, no matter what obscure task you have in mind, there's probably an element for that.

The Meter

The first definition of the meter wasn't bad, for the 1790s: Exactly one ten-millionth of the distance between the Equator and the North Pole, as measured through Paris. Unfortunately, scientists botched the measurement, and the length of the meter that came into common use was later found to be 0.2 mm off the supposed definition, an intolerable gap.

So, in 1889 scientists replaced the meridian definition with a long bar made of the elements platinum and iridium. Someone made a scratch near one end of the bar, then made a scratch near the other, and the distances between the scratches became, from then on, 1.000000... meter, to as many decimal places as you like.

But defining a meter this way only evoked more questions. Like what temperature are we talking about? Things expand when they heat up, after all. And what's the geometry here? A rod that length will droop if not supported properly, and will droop differently depending on where it's supported. To head off any ambiguities, scientists decided the rod had to be measured at 0°C and standard atmospheric pressure, and supported on two cylinders one centimeter in diameter, with each of the cylinders in the same horizontal plane and 571 millimeters apart.

Naturally, this definition was no good, either. For one reason, it's questionable to use centimeters and millimeters to define a meter. For another, on a microscopic scale the scratches have their own width—where does the measurement start? Even worse, metrologists hated that the definition relied on an artifact, a man-made object, since this was supposed to be a universal unit, not the property of one country. (Indeed, the fact that scientists from other countries sometimes had to hike it to Paris and cool things down to 0°C and make their own scratches on an identical rod and bring it back home was a hindrance to spreading the standard.)

What metrologists coveted was an "operational" definition—they wanted to discover a physical process that would produce something with a magnitude of exactly one meter every time. To put it more colloquially, and anachronistically, scientists were after an "e-mailable" definition—a purely verbal set of instructions that could be sent around the world, and that would allow scientists anywhere to perform an experiment and reproduce the same meter.

Scientists finally achieved this goal in the 1960s, with the noble gas krypton. All noble gases (think of "neon" lights) emit strong, colored light when excited, and krypton happens to emit a real beauty, a sharp beacon of orange light that's easy to measure. So, a meter became 1,650,763.73 wavelengths of this orange light from a krypton-86 atom. That's an e-mailable definition, since all krypton atoms are identical, and scientist could just pick up a krypton discharge tube if he needed it. Scientists had finally relegated the platinum-iridium rod to the velvet casket of a museum.

Never satisfied, though, metrologists redefined the meter again in 1983, getting rid of even the krypton atom. A meter is now the distance light travels in a vacuum in 1/299,792,458th of a second.

Of course, that definition assumes you know how long a second really is...

My glossary:

1. Botch – делать небрежно,
2. Intolerable – недопустимый,
3. Rod – стержень,
4. Droop – снижать(ся),
5. Ambiguities – неясности,
6. Head off – преодолевать,
7. Hindrance – препятствие, помеха,
8. Covet – желать,
9. Colloquially – неофициально,
10. noble gases – благородные газы,
11. beacon – маяк,
12. discharge tube – газоразрядная лампа,
13. velvet casket – бархатная шкатулка.

3. Read the text again and say if the following statements are true or false.

1. There were seven base units in the metric system in the past.
2. Metrologists are people for whom measurement is the start of science.
3. Elements are exactly the same everywhere.
4. The first definition of the meter was good for the 1790s.
5. It's questionable to use centimeters and millimeters to define a meter.
6. Metrologists are happy with the definition of the meter.

4. Answer the questions.

1. How many base units are there in the international metric system?
2. When did the first definition of the meter appear?
3. Why did the scientists replace the meridian definition in 1889? How did they do it?

4. Why did the new definition of the meter evoke more questions? What did they do to head off any ambiguities?
5. Why did metrologists hate that the definition relied on an artifact, a man-made object?
6. What kind of "operational" definition did metrologists want to discover?
7. When and how did scientists finally achieve this goal?
8. When did metrologists redefine the meter again?
9. What is the definition of the meter now?

5. Write a short summary of the text about the meter.

UNIT 5. THE SECOND

1. Can you define what the second is. Discuss it in your group.
2. Read the text about the second and compare your ideas with the information from the text.

Where International Standard Units Come From, Part Two: The Second

The definition of the second used to be 1/86,400th of one spin of the earth around its axis (less formally, the number of seconds in one day). But a few pesky facts made that standard inconvenient.

The length of a day varies with every trip around the sun because of the **sloshing of ocean tides**, which drag and slow **the Earth rotation**. And metrologists (measurement scientists) didn't want to tie a supposedly universal unit of time to the transit of a small rock around a mediocre star.

To rectify this, scientists turned to the element **cesium**. More specifically, they turned to cesium's lone electron. Like all the entries in its column on **the periodic table**, cesium has one more electron than the full set it really desires. This electron—which resides at a higher energy level than other electrons and is therefore more exposed—

normally zooms around the cesium nucleus on a specific orbit. But if light strikes the electron, it can jump to an even higher orbit. Now, depending on whether its "spin" (an inborn property) is up or down, an electron can jump to a slightly higher or lower orbit. If the original jump was like moving up an octave from G to G, this jump is from G to G-sharp or to G-flat. These slightly different levels are known as the fine structure. And if you measure things even more precisely and take even more factors into account (like the electron's charge and nucleus's magnetic field), you can observe an electron jumping between levels separated by even smaller amounts—like a musical difference not of a halftone but of a quarter-tone, or even an eighth-tone. This is known as the hyperfine structure.

Metrologists exploited those hyperfine differences to create the first atomic clocks with cesium-133. Inside these "beam clocks," a gas of cesium atoms is gathered into a chamber with a pressure of about one-trillionth of **normal atmospheric pressure** and excited by an intense maser (a microwave laser). This strumming with the maser excites the cesium electrons and causes them to jump to a certain hyperfine level. The key point is that the electron cannot stay excited for long, so it soon drops back down to another hyperfine level. And when it does, it emits light. This cycle of jumping up and down repeats itself over and over, and each cycle is perfectly elastic and therefore takes the same amount of time. The precision of the maser ensures that all the cesium atoms are in synch, so the atomic clock can measure time simply by counting emitted photons.

Cesium proved convenient as the mainspring for **atomic clocks** because the solitude of its electron means that scientists don't have to worry (as they might with other elements) about other electrons jumping up and down and shooting their own photons off.

Scientists picked that ungainly number instead of cutting themselves off at 9,192,631,769 or letting things drag on until 9,192,631,771 because it matched their best guess for a second back in 1955, when they built the first cesium clock. Regardless, 9,192,631,770 is now fixed as the definition. And nowadays, metrologists rely not on beam clocks but cesium "fountain clocks," which operate on the same basic physics but at much lower temperatures, barely above absolute zero. Some of these clocks are accurate to within one second every 30 million years.

But while the cesium standard has profited science by ensuring precision and accuracy worldwide, humanity has undeniably lost something. Since before even the ancient Egyptians and Babylonians, human beings used the stars and seasons to track time and record their most important moments. Cesium certainly lacks the mythic feeling of the moon or sun.

My glossary:

1. Pesky –досадный,
2. Sloshing – колебание жидкости,
3. Ocean tides – океанские приливы,
4. Earth rotation – вращение Земли вокруг своей оси,
5. Mediocre – средний, невыдающийся,
6. To rectify – исправлять,
7. Lone electron – одиночный электрон,
8. Strumming – бренчание,
9. Hyperfine – сверхтонкий,
10. Maser – квантовый генератор сверхвысокочастотного диапазона,
11. Synch – синхронизация,
12. emitted photons – испускаемые фотоны,
13. mainspring - главная движущая сила,
14. lumbering – неуклюжий.

3. Read the text again, translate the words in bold and explain the meaning of these words in English.

4. Answer the questions:

1. How much did the definition of the second use to be?

2. What made that standard inconvenient?
3. What element did the scientists choose to rectify this? Why?
4. Metrologists created the first atomic clocks with cesium-133. How did it work?
5. Why did Cesium prove convenient as the mainspring for atomic clocks?
6. Why do metrologists rely not on beam clocks but cesium "fountain clocks"?
7. How can you explain the fact, that while the cesium standard has profited science by ensuring precision and accuracy worldwide, humanity has undeniably lost something?

5. *Write a short summary of the text about the second.*

UNIT 6. THE CANDELA

1. Can you define what the candela is. Discuss it in your group.

2. Read the text about the candela and compare your ideas with the information from the text.

Where International Standard Units Come From, Part Three: The Candela

Most of the seven base metric units were pretty consistent from the beginning. Scientists agreed on what each unit meant and were confident that people in different countries meant the same thing. The big exception to this consistency was the candela—the unit for the luminosity of light.

As the name implies, candelas were based on the burning of candles, and scientists tried as hard as they could to define a standard candle. The English standard, for instance, called for candles made of spermaceti (what sailors dug out of the skulls of whales in Moby Dick) weighing a sixth of a pound and burning at a precise rate per hour, presumably in a windless and otherwise pitch-black room. But the French had their own formula for candles, as did the Germans, and regardless, none of the candles satisfied scientists. Because, as anyone who ever tried to study by candlelight knows, the output is a little bipolar even in the best of circumstances.

Mr. Edison's incandescent bulbs improved the situation, and by 1909, many countries had adopted a standard for luminescence based on a carbon filament. But as metrologists began to scrutinize filaments, they found them wanting, too, since even the output of a filament flickers too much for their liking. So, they turned instead to blackbody radiation—the radiative heat emitted from all warm bodies. It's the property that makes hot metal glow red or white, and it's why infrared goggles can spy live bodies or illicit home-gardening operations through walls.

Every substance emits slightly different radiation at different temperatures, though, so scientists had to pick one element as the standard. And, showing rather refined tastes, they picked platinum, which gave a nice, steady glow. Of course, being metrologists, they had to specify a little bit more than that. The definition of a candela became the amount of light given off by a crucible of molten platinum as it froze (at 3,200° F) from liquid to solid and measured "in the perpendicular direction [from] a surface of 1/600,000 square meters ... under a pressure of 101,325 Newtons per square meter."

Still not satisfied—it proved harder than expected to measure consistently the light emitted by molten platinum—scientists re-redefined the candela in 1979 and got rid of the platinum altogether. A candela has since become "the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 x 1012 hertz and that has a radiant intensity in that direction of 1/683 watt per steradian." Which is a heck of a lot more precise than trying to guess the output of a candle, but certainly lacks the charm.

My glossary:

1. Candela – кандела.

2. Luminosity - светимость, освещенность, яркость света,

3. Incandescent - раскаленный, накаленный, сверкающий, ослепительный, накаленный добела,

4. carbon filament - угольная нить накала; угольный волосок; углеродная нить,

5. to scrutinize - изучать, рассматривать, тщательно исследовать, внимательно рассматривать,

6. flicker - мерцание, вспышка, дрожание,

7. infrared goggles - очки ночного видения ОНВ; инфракрасные очки,

8. glow - светиться, гореть, пылать, сиять, сверкать,

9. crucible – тигель,

10. steradian – стерадиан, спектральная плотность энергетической яркости пучка в Дж/ср/сек,

11. a heck of a lot – чертовски много.

3. Read the text again and answer the questions:

1. What is the candela?
2. What is the English standard for the candle?
3. Why did none of the candles satisfy the scientists?
4. Whose invention improved the situation?
5. Why did metrologists turn to blackbody radiation—the radiative heat emitted from all warm bodies?
6. Why did they choose platinum as a standard?
7. What was the new definition of a candela?
8. Why did the scientists re-redefine the candela in 1979?
9. What is the current definition of a candela?

4. *Write a short summary of the text about the candela.*

UNIT 7. *THE MOLE*

1. What do you know about the mole? Can you explain this term?

2. Read the text about the mole. What information about the mole is new for you?

Where International Standard Units Come From, Part Four: The Mole Manufacturing Perfect Silicon

To create pure and crystallographically perfect samples for this study, researchers used the float-zone method, manufacturing spheres of silicon crystals from the two bulges forming in the polycrystalline rod pictured here. We all have an intuitive idea of what a meter or a second is, and even a candela seems pretty straightforward. The mole is different, probably the hardest metric standard to grasp at first.

Basically, a mole measures the amount of a substance, but measures it in a clever way. Let's say you wanted to manufacture calcium sulfide, CaS, and you worked in a very competitive industry where you couldn't waste any calcium or sulfur. That means you need the exact same amount of each to mix together. But defining amount gets tricky here, because a sulfur atom has fewer neutrons and protons and therefore weighs less than a calcium atom. So, if you have ten kilos of both, you actually have far more sulfur atoms than you need. The mole solves this problem: It provides a way to convert from kilograms (or whatever) into the amount of X that will react with Y. In this case, you'd want to mix one mole of each element to get a perfect yield.

The international definition of a mole has been based on common elements like oxygen and hydrogen in the past, but ever since 1960, scientists have defined one mole as exactly the number of atoms in 12.0000 grams of carbon-12. But really, this definition papers over some predicaments—it fudges things.

You might remember a number, Avogadro's number, associated with a mole—a mole always has 6.022141793... x 1023 particles of whatever. Counting one atom per second, with thirty million or so seconds in your average year, it would take twenty million billion years to count that high, over a million times the age of the universe. So, while you might know you have exactly one mole of carbon twelve, you only have a vague idea of how many atoms that is: Because after the ellipsis in 6.022141793..., it's anyone's guess—and there are a lot of decimal places to go.

What's more, if you've had a sneaking suspicion this whole time that the mole sounds a little redundant—since the "amount of a substance" is an awful lot like the "mass of a substance"—you're onto something. In fact, issues related to enumerating atoms have led to even bigger problems with defining the last standard we'll look at, the kilogram.

My glossary:

1. Mole – моль, единица количества вещества,
2. float-zone method - метод плавающей зоны; метод зонной плавки,
3. bulge - выпуклость, выступ, раздув, преимущество, выпячиваться, деформироваться,
4. rod - штанга, стержень,
5. predicament - затруднительное положение, затруднение,
6. fudge - делать кое-как, недобросовестно,
7. vague - расплывчатый, смутный, неопределенный, неясный, рассеянный, неуловимый,
8. Enumerate - перечислять, точно подсчитывать.

3.Match the words and make word combinations, then make up sentences with these collocations.

1. perfect	a. a yield
2. silicon	b. elements
3. competitive	c. crystals
4. solve	d. standard

5. vague	e. samples
6. metric	f. the problem
7. to get	g. idea
8. common	h. industry

4. Read the text again and answer the questions:

1. What method did researchers use to create pure and crystallographically perfect samples for this study?
2. What does the mole measure?
3. Why does a sulfur atom weigh less than a calcium atom?
4. How does the mole?
5. What is the definition of the mole?
6. How is Avogadro's number, associated with a mole?

5. *Write a short summary of the text about the mole.*

UNIT 8. STANDARDIZATION

1. Read the text about standardization.

The purposes and goals of standardization

Standardization is the activity directed on working out and an establishment of requirements; Norms, rules, characteristics both obligatory for performance, and recommended, providing the right of the consumer to acquisition of the goods of appropriate quality for the comprehensible price, and also the right to safety and comfort of work. Goals of standardization - achievement of optimum degree in this or that area by means of wide and repeated use of the established positions, requirements, norms for the decision of real-life, planned or potential problems. Increase of degree of conformity of a product (service) to a functional purpose, elimination of technical barriers in the international barter, assistance to scientific and technical progress and cooperation in various areas should be the basic results of activity on standardization.

The purposes of standardization

Standardization aim is to protect interests of consumers and the state concerning quality of production, processes and services. Besides, standardization is carried out in following purposes:

- increase of the level of safety of a life or health of citizens, property physical or legal bodies, the state or municipal property, ecological safety, safety of a life or health of animals or plants and assistance to observance of requirements of technical regulations;
- increase of the level of safety of objects taking into account risk of occurrence of extreme situations of natural and technogenic character;
- maintenance of scientific and technical progress;
- increase of competitiveness of production, works and services;
- rational use of resources;
- technical and information compatibility;
- comparability of results of researches (tests) and measurements, technical and economic-statistical data;
- interchangeability of production.

For achievement of the social and technical and economic purposes standardization carries out certain functions.

1. Streamlining function - overcoming of unreasonable variety of objects (unnecessary variety of documents). It is reduced to simplification and restriction.

2. Security (social) function - maintenance of safety of consumers of production (services), manufacturers and the state, association of efforts of mankind on protection of the nature against technogenic influence of a civilization, protection of a life or health of animals and plants.

3. Resource-saving function is caused by limitation material, power, labour and natural resources and consists of an establishment the proved restrictions on an expenditure of resources.

4. Communicative function provides interaction of people, in particular experts, by a personal exchange or use of documentary means, hardware (computer, satellite and so forth) systems and message transfer channels. This function is directed on overcoming of barriers in trade and on assistance to scientific and
technical and economic cooperation.

5. Civilising function is directed on improvement of quality of production and services as to a component of quality of a life.

6. Information function. Standardization provides production of goods, a science and technics and other spheres with standard documents, standards of measures, production approved samples, production catalogues as carriers of the valuable technical and administrative information.

My glossary:

1. Conformity – соответствие,
2. working out – разработка,
3. Elimination – устранение,
4. Acquisition – приобретение,
5. Compatibility – совместимость,
6. Comparability – сопоставимость,
7. interchangeability – взаимозаменяемость,
8. Streamlining function – функция оптимизации.

2. Give a definition of the term "standardization".

3. Tell the class about goals of standardization.

4. List the functions of standardization.

5. Prepare a mini presentation about the methods of standardization.

UNIT 9. ISO STANDARDS

1. Discuss in your group: What do you know about ISO standards?

2. Read the paragraph about ISO standards and compare the information from the it to your ideas.

What are ISO standards?

ISO management system standards provide a model to follow when setting up and operating a management system. Like all our standards, they are the result of international, expert consensus and therefore offer the benefit of global management experience and good practice.

These standards can be applied to any organisation, large or small, whatever the product or service and regardless of the sector of activity.

3. Watch video: What ISO standards do for you? (https://www.iso.org/standards.html) *and answer the question.*

Below the most common ISO standards in use today are described:

Quality management standards to help work more efficiently and reduce product failures.

With more than a million organizations certified to ISO 9001, it's the most widely recognized standard in the world. ISO 9001:2015 sets out requirements for quality management systems, and is suitable for all types of organizations.

- Enables you to better align and integrate multiple management standards

- Takes a risk-based approach, becoming a tool for preventive action
- Moves away from prescriptive paperwork

ISO 9001 sets out the criteria for a quality management system and is the only standard in the family that can be certified to (although this is not a requirement). It can be used by any organization, large or small, regardless of its field of activity.

In fact, there are over one million companies and organizations in over 170 countries certified to ISO 9001.

This standard is based on a number of quality management principles including a strong customer focus, the motivation and implication of top management, the process approach and continual improvement. These principles are explained in more detail in ISO's quality management principles. Using ISO 9001 helps ensure that customers get consistent, good-quality products and services, which in turn brings many business benefits.

Environmental management standards to help reduce environmental impacts, reduce waste and be more sustainable.

Developed with today's complex marketplace in mind, ISO 14001:2015 provides an integrated approach to environmental management – putting sustainability at the heart of business.

- Better environmental management reduces waste and energy use
- Improve efficiency to cut the cost of running your business
- Demonstrate compliance to expand your business opportunities
- Meet legal obligations to win greater stakeholder and customer trust
- Prepare for the changing business landscape confidently

4. *Watch video ISO and the environment* (https://www.iso.org/iso-14001-environmental-management.html) *and be ready to discuss the idea ISO's environmental standards, the tools for translating passion into effective action.* Globally.

Ocupational Health and Safety standards to help reduce accidents in the workplace.

OHSAS 18001 sets out the minimum requirements for occupational health and safety management best practice. Bring work health and safety into your business and you can achieve the maximum return for your employees, your operations and your customers.

- Create the best possible working conditions across your organization
- Identify hazards and put in place controls to manage them
- Reduce workplace accidents and illness to cut related costs and downtime
- Engage and motivate staff with better, safer working conditions
- Demonstrate compliance to customers and suppliers

For organizations that are serious about improving employee safety, reducing workplace risks and creating better, safer working conditions, there's ISO 45001.

According to the International Labour Organization, more than 7 600 people die from work-related accidents or diseases every single day. That's why an ISO committee of occupational health & safety experts set to work to develop an International Standard with the potential to save almost three million lives each year. Structured in a similar way to other ISO management systems, the approach will be familiar to users of standards such as ISO 14001 or ISO 9001. ISO 45001 builds on the success of earlier international standards in this area such as OHSAS 18001, the International Labour Organization's ILO-OSH Guidelines, various national standards and the ILO's international labour standards and conventions.

Food safety standards to help prevent food from being contaminated.

ISO 22000 is an internationally recognised standard designed to systematically ensure food safety at every link of the supply chain. ISO 22000 incorporates HACCP principles and is compatible with ISO 9001 quality management systems, making it the ideal basis for implementing a comprehensive, cost effective food safety management system.

- Achieve better customer satisfaction by consistently meeting customer requirements

- Reduce operating costs through continual improvement of processes and resulting operational efficiencies
- Improve stakeholder relationships, including staff, customers and suppliers
- Ensure legal compliance through internal audits and management reviews
- Improve risk management

Whatever their size, or product, all food producers have a responsibility to manage the safety of their products and the well-being of their consumers. That's why ISO 22000 exists.

The consequences of unsafe food can be serious. ISO's food safety management standards help organizations identify and control food safety hazards, at the same time as working together with other ISO management standards, such as ISO 9001. Applicable to all types of producer, ISO 22000 provides a layer of reassurance within the global food supply chain, helping products cross borders and bringing people food that they can trust.

5. *Watch video ISO and food safety* (https://www.iso.org/iso-22000-food-safety-management.html) *and answer the question: Who benefits from ISO's food standards?*

Energy management standards to help cut energy consumption.

For organizations committed to addressing their impact, conserving resources and improving the bottom line through efficient energy management, we developed ISO 50001.

Designed to support organizations in all sectors, this ISO standard provides a practical way to improve energy use, through the development of an energy management system (EnMS).

6. Watch video Energy Management Standard (https://www.iso.org/iso-50001-energy-management.html) *and answer the question: How can the new ISO 50001 standard for energy management systems help safeguard our future?*

IT security standards to help keep sensitive information secure.

When it comes to keeping information assets secure, organizations can rely on the ISO/IEC 27000 family.

ISO/IEC 27001 is widely known, providing requirements for an information security management system (ISMS), though there are more than a dozen standards in the ISO/IEC 27000 family. Using them enables organizations of any kind to manage the security of assets such as financial information, intellectual property, employee details or information entrusted by third parties.

My glossary:

1. setting up – создание,
2. Quality management standards - комплекс мер по обеспечению качества продукции и услуг,
3. set out – предусматривать, выставлять,
4. align – упорядочить,
5. consistent – соответствующий,
6. environmental impacts – воздействие на окружающую среду,
7. sustainability – устойчивое развитие,
8. compliance – соответствие стандартам,
9. stakeholder – заинтересованное лицо, 10. Ocupational Health and Safety – охрана здоровья и безопасность,
11. hazard – риск, препятствие, опасное явление,
12. Downtime – простой, внерабочее время,
13. HACCP – система анализа опасных факторов и контроля в критических точках (сокр. от Hazard Analysis and Critical Control Points,
14. Comprehensive – исчерпывающий, детальный,
15. bottom line – наиболее важный аспект, основной момент,
16. IT security standards – стандарты по информационной безопасности.

7. Make a presentation about one ISO Standard.

UNIT 10. CERTIFICATION

1. What do you know about the process of certification? Discuss in you group.

2. Read the text about certification. What information from the text about the certification is new for you?

Certification

Certification is a procedure of acknowledgement of conformity of result of industrial activity, the goods, service to standard requirements by means of which the third-party documentary certifies, that production, work (process) or service corresponds to the set requirements. As consequence, the conformity certificate is that document which confirms conformity of certificated production to the established requirements. The third party of process of certification is absolutely independent, professional organisation which makes check and an estimation of quality of production. Thus, the first party is the manufacturer or the seller of the goods or service, and the second - its buyer or the consumer. Thus, the third party is obliged to undergo preliminary procedure of accreditation which represents an official recognition of possibilities of the organisation to make certain type of check or tests.

Certification main objectives are:

- to help buyers in realisation of a correct choice of the goods or service
- realisation of protection of buyers from poor-quality production, the unfair seller or the manufacturer
- check of safety of the goods or services
- check of the conformity, declared by the manufacturer, indicators of quality of production the real

Concept definition "conformity acknowledgement " has appeared thanks to the problem of quality of production quickly developing, recently, and services; tendencies to international trade globalisation; to the huge assortment, similar under the functional characteristics, the goods which possess a different degree of quality; to high level of a competition between manufacturers of the goods; and also, requirements for maintenance of the guaranteed level of safety of production for the consumer.

Certification of products. An order of realization of certification of products.

Certification is procedure by means of which body on conformity acknowledgement in writing certifies conformity of production, services to the established requirements. Conformity acknowledgement is the procedure, which result is the documentary certificate (in the form of the declaration on conformity or the conformity certificate) conformity of object to the requirements established by technical regulations, standards, or to conditions of contracts. The conformity certificate is the document certifying conformity of production, service to the requirements established by technical regulations, positions of standards or other documents. The declaration on conformity is the document which the manufacturer (executor) certifies conformity of released production, services to the established requirements. Voluntary acknowledgement of conformity is procedure by means of which acknowledgement of conformity of production is carried out, services, the processes, spent at the initiative of the manufacturer (executor) or the seller on conformity to the standard, other document or special requirements of the applicant. Obligatory acknowledgement of conformity is procedure by means of which acknowledgement of conformity of production to the requirements established by technical regulations is carried out.

Certification of services is carried out on conformity to safety requirements for a life and health of citizens, the preservation of the environment, established in acts and standard documents. Procedure of certification of services includes:

- application in body on certification;
- consideration of the demand and a choice of the scheme of certification;

- contract registration between body on certification and the applicant on work on certification;
- carrying out of tests (check) of service and (or) estimations of process of rendering of service of skill of the executor, certification of the enterprise, certification of systems of quality;
- the analysis of received results and decision-making on possibility of delivery of the certificate of conformity;
- delivery of the certificate and its entering into the State register of certificates of conformity;
- carrying out of the inspection control over the certificated service.

My glossary:

1. Acknowledgement – признание,
2. Conformity – соответствие,
3. the conformity certificate - сертификат соответствия,
4. estimation – оценка, оценивание.

3. Read the text again and answer the questions:

1. What is Certification?
2. What are the main objectives of Certification?
3. How did the definition "conformity acknowledgement appear?
4. Give the definition of Certification f products.
5. What types of acknowledgement of conformity can you name?
6. What does Procedure of certification of services include?

4. How do you think: What should a certificate of conformity include?

Now read the information about it.

Elements that should be included in a CoC are:

1. Product identification
   - Description of the product covered in the CoC
2. List of all safety regulations the product must pass
   - The CoC must clearly list each of the safety regulations the product must be tested for
3. Importer or manufacturer's identification
   - Provide the name, full mailing address, and telephone number of the importer or U.S. domestic manufacturer certifying the product
4. Contact information for the individual maintaining records of test results:
   - Provide the name, full mailing address, e-mail address, and telephone number of the person maintaining test records in support of the certification.
5. Date and place where the product was manufactured
   - At last the month and year should be shown and the city, state, and country needs to be shown.
6. Provide the date(s) and place when the product was tested for compliance with the consumer product safety rule(s) cited above:
   - Provide the location(s) of the testing and the date(s) of the test(s) or test report(s) on which certification is being based.
7. Identification of any third-party laboratory on who's testing the certificate depends:
   - The certifier must provide the name, full mailing address, and telephone number of the third-party laboratory.

5. Read an example of the certificate of conformity. Does it include all the elements mentioned in exercise 4?

INSTYTUT NAFTY I GAZU – Państwowy Instytut Badawczy
PL 31-503 Kraków, ul. Lubicz 25 A
tel.: +48 12 421 00 33
www.inig.pl office@inig.pl

BIURO CERTYFIKACJI
tel.: +48 12 430 38 64
e-mail: swat@inig.pl

PCA POLSKIE CENTRUM AKREDYTACJI CERTYFIKACJA WYROBÓW AC 010

CERTIFICATE OF CONFORMITY No. 5 / 18

Instytut Nafty i Gazu – Państwowy Instytut Badawczy hereby states that the products:

Plastic coating made of winding materials
for corrosion protection of buried or immersed steel pipelines
NoRust coating system, made of:

1. **NoRust - Mastic**
2. **NoRust Tape, wrap 2 x with overlap 50%**
3. **NoRust Cover, wrap 1 x with overlap 50%**

Marking: coating EN 12068 – A30

placed on the market under the name or trade mark of:

A-SPE Europe sp. j.
82-310 Gronowo-Górne, ul. Agatowa 5

fulfill the requirements of national technical specification:

PN-EN 12068:2002 [EN 12068:1998]

Manufacturer has determined the product type, implemented the system of FPC as understood by certification Programme PCW-16 and also submitted the product for assessment by accredited testing laboratory. INiG-PIB Certification Office has performed: verification of correctness of product's performance assessment as understood by certification Programme PCW-16, including the sampling of products to test carried out by manufacturer; initial inspection of factory and FPC and performs the continuous surveillance, assessment and acceptance of FPC in relation to products' performance declared by manufacturer described by a/m technical specification. Certification process has been carried out according to Certification Programme PCW - 16 (programme type 3 acc to PN-EN ISO/IEC 17067:2014-01)

This certificate was issued on 28^{th} **March 2018** and will remain valid until as long as neither the technical specification, the product itself nor the manufacturing conditions are modified significantly, unless suspended or withdrawn by the certification body.

Certification Office Manager
Magdalena Swat

Instytut Nafty i Gazu * Państwowy Instytut Badawczy * 4

Kraków, 28-03-2018

Director of the INiG-PIB
Maria Ciechanowska

The validity of certificate can be confirm by email: swat@inig.pl

6. Translate this certificate into Russian.

7. Make a presentation about the certification procedure in Russia / the EU / the USA.

Appendix 1

Where International Standard Units Come From, Part Five: The Controversial Kilogram

The kilogram really sticks in the craw of metrologists. Six of the seven fundamental units of the metric system have "operational" definitions—you can define them purely in words, by describing a physical process that produces something of exactly one meter, or whatever. But the kilogram has resisted all attempts to define it that way.

It's like a feeling everyone knows and shares but cannot quite articulate. Instead, the kilogram is the last metric standard still bound to a human artifact.

That artifact is the Kilogram—a two-inch-wide, 90-percent platinum, 10-percent iridium cylinder in Paris. By fiat, it has a mass of exactly 1.000000... kilogram, and it lives a rather pampered existence. Because the Kilogram is a physical object and therefore damageable, and because the definition of a kilogram ought to stay constant, the scientists that care for it must make sure it never gets scratched, never attracts a speck of dust, never loses (they hope!) a single atom. For if any of that happened, its mass could spike to 1.000000...1 kilograms or plummet to 0.999999...9 kilograms, and the mere possibility induces ulcers in a metrologist.

So like phobic mothers, scientists constantly monitor the Kilogram's temperature and the pressure around it to prevent microscopic bloating and contracting, stress that could slough off atoms. It's also swaddled within three successively smaller bell jars to prevent humidity from condensing on the surface and leaving a nanoscale film. And the Kilogram is made from dense platinum and iridium to minimize the surface area exposed to unacceptably dirty air, like the kind we breathe. Platinum also conducts electricity well, which cuts down on the buildup of "parasitic" static electricity (the scientists' word) that might zap stray atoms.

Other countries have their own official 1.000000... kg cylinder, so they don't have to fly to Paris every time they want to measure something precisely. But since the Kilogram is the only standard, each country's knockoff has to be compared against it periodically. The United States has had its official kilogram, called K20 (the twentieth official copy), which resides in a government building in exurban Maryland, calibrated just once since 2000, and it's due for another calibration, says Zeina Jabbour, group leader for the NIST mass and force team. But calibration is a multimonth process, and security regulations since 2001 have made flying K20 to Paris a hassle. "We have to hand-carry the kilograms through the flight," Jabbour explains, "and it's hard to get through security and customs with a slug of metal, and tell people they cannot touch it." Even opening K20's customized suitcase in a "dusty airport" could compromise it, she says, "and if somebody insists on touching it, that's the end of the calibration."

Usually, the BIPM uses one of six official copies of the Kilogram (kept under two bell jars only) to calibrate the knockoffs. But the official copies have to be measured against their own standard, so every few years scientists remove the Kilogram from its vault (using tongs and wearing latex gloves, of course, so as not to leave smudges—but not the powdery kind of gloves, because that would leave a residue—oh, and not holding it for too long, because the person's body temperature could heat it up and ruin everything) and calibrate the calibrators.

Alarmingly, though, scientists noticed during calibrations in the 1990s that, even accounting for atoms that rub off when people touch it, in the past few decades the Kilogram had lost an additional mass equal to that of a fingerprint, half a microgram per year. No one knows why.

This failure to keep the Kilogram constant has renewed interest in an operational definition for the kilogram. Some options, like counting atoms, have so far been too impossibly involved to succeed. But in recent weeks, German scientists announced that they counted an impressively high fraction of the number of atoms in a sphere of pure silicon, and think they can do even better. (The team did so by measuring the sphere's volume very precisely with lasers, then calculating the volume of individual atoms.). Another promising idea is using a Watt balance, which would measure how much electricity it takes to suspend something with a mass of 1.000... kilogram in the air.

If the either scheme succeeds, the kilogram will have gained immortality at last, and can join the pantheon of other ethereal standards of measurement. The happiest dream of every scientist who obsesses over that mollycoddled cylinder in Paris—making it obsolete—will have finally come true.

Appendix 2

Examples of Role of Metrology in Materials Science & Engineering

Metrology is fundamental to all biological, physical and environmental sciences, engineering, and medicine. Standards are required for all measurements. While manufacturing depends on research and development, research and development would not be possible without reliable experimental data, the analytical instrumentation tools and methods to obtain authentic experimental data and the methods to calibrate against standards. It is within this context that The Journal of Scientific and Industrial Metrology is timely and relevant.

The demands on metrology have grown over the years. This is particularly the situation in a variety of material scenarios. At the macro level, these scenarios include examples such as alloys, bandgap engineered structures, biomaterials, ceramics, composite materials, coatings, electronic materials, liquid crystals, magnetic materials, metals, metamaterials, nanomaterials, optical materials, polymers, semiconductors, smart materials, superconductors etc. The ability to tailor materials, processes, performance and structure, for desired applications, requires pre-knowledge of the material properties. At the device and systems level, applications of metrology include detectors, drug delivery systems, energy sources, filters, imagers, lasers, process control systems, sensors, waveguides etc. The influence of defects and dislocations on properties becomes significant especially when the structures are scaled from micron to the nanoscale. The enormous progress that has been made in two-dimensional materials such as graphene, transition metal dichalcogenides/layered metal dichalcogenides (TMDC/LMDC) such as molybdenum disulfide, tungsten disulfide and related materials, makes it imperative that the properties of these materials be available to advance the science and applications.

Fundamental research, both experimental and theoretical, requires metrology. There has been a tremendous growth in computational tools and instrumentation methods; the accuracy, repeatability and reproducibility of the measured data has improved significantly. Throughout the globe, industry, research laboratories and universities have been developing and improving methods for reliable and accurate data that represents the measurement of the physical quantity.

Case studies of such research activities include the development of pyrometry. Pyrometers are the instruments of choice for noncontact in situ temperature measurements in materials processing. Pyrometers measure the amount of radiation emitted from a material within a narrow wavelength window. The ratio of the emitted radiation by the material to that of a blackbody under the same conditions of temperature, wavelength, angle of incidence, and direction of polarization is referred to as emissivity. Emissivity of materials is a complicated function of both temperature and wavelength. In addition, it is also sensitive to surface roughness. Emissivity is obtained from simultaneous measurements of hemispherical transmittance, reflectance and absorptance. The related fundamental optical constants, refractive index and extinction coefficient, and their wavelength dependence in the infrared range of wavelengths, are required in a variety of process monitoring applications. The knowledge of these fundamental optical constants has significant implications in developing non-contact sensors as well as in developing measurement techniques such as spectroscopic ellipsometry and time resolved reflectivity.

Another example is thermoelectrics [8]. With their ability to recover waste heat and convert it into useful electricity, thermoelectric (TE) materials are promising candidates to achieve the challenge to reduce energy wastage. Most important applications of TE materials are in coolers and power generators to convert thermal energy into electrical energy and vice versa. A dimensionless quantity, ZT ($ZT=S^2\sigma T/\kappa$), and the power factor ($S^2\sigma$), are used to evaluate the performance of thermoelectric (TE) materials; S is the Seebeck coefficient (or thermoelectric power), σ is the electrical conductivity, κ is the thermal conductivity and T is the temperature (in K). Measurements of S are not always easily available for a number of materials.

Research on biomaterials and related topics is on an exponential rise. This has been catalyzed by increased human life expectancy and, simultaneously, the need to improve the quality of life. Drug delivery systems are being developed to address a variety of ailments and diseases. These systems will require complete understanding of diffusion of drug actives, in the form of molecules through materials as function of their structure and morphology.

With the global emphasis now on “Material is the Device”, metrology will play a key role in realizing this goal. The need for an infrastructure and a platform that provides access to standards is critical. By bringing together research that is performed by researchers, scientists and engineers, throughout the world, The Journal of Scientific and Industrial Metrology expects to provide that infrastructure. On behalf of the Publishers and the Editorial Board, I invite authors to submit their manuscript for consideration for publication to the Journal.

Appendix 3

Measurement Accuracy: The Good, The Bad and The Ugly

By Jim Tennermann

Measurement accuracy is a subjective concept applied to all kinds of measurements. Generally speaking, accuracy refers to the degree of "closeness" of the measurement to a "true value." This definition is usually good enough, but not always. The subjective nature of accuracy allows for a wide variety of claims that may technically be true, but misleading at the same time.

Let's consider this in the context of measuring relative humidity (RH). RH is expressed as a percentage, so the possible range of RH is 0 to 100%. Manufacturers of RH measurement equipment typically specify accuracy as a ± value of some percent. For example, one might say that a certain device is accurate to ± 3% RH. Due to the competitive nature of the instrumentation manufacturing business, makers of a different device may claim to be more accurate with ± 2% RH. Superficially, with all other things being equal, this ±2% device would appear to be "better." Beware, because this is not always the case and can be misleading until you dig deeper. In this article we'll look at how you start digging.

Measurement Characteristics

Accuracy specifications come in many forms. For example, accuracy may or may not include other measurement characteristics. One characteristic is the difference in the measurement value when the true value is approached from a higher value versus a lower value, otherwise known as hysteresis. If a device has a lot of hysteresis, this can be left out of the accuracy specification and justified by reporting accuracy based on measurement values that always start from a higher value (or a lower value). This may be accurate, but it is misleading because it does not address a significant element of the measurement performance.

The Concept of "True Value"

Another issue with measurement accuracy is the concept of the "true value." When a device is calibrated, it is compared to a reference standard that can be considered to be the true value. However, all reference standards embody some imperfection. There is always some variation from the true value that we hope to achieve. What if the variation in one reference standard is different from another standard? In this case, a measurement device calibrated and adjusted to one standard may achieve its stated accuracy, but when compared to a different standard, it could be out of tolerance. This is where the concept of measurement uncertainty becomes helpful.

Measurement Uncertainty

A simple (and incomplete) explanation of measurement uncertainty is that multiple measurements made in the same way with one device are never precisely the same. As a result, the measurement device is likely to provide a range of values centered on the true value or offset from it. Similarly, all reference standards vary from the true value in some way. Because the reference standard is never precisely the true value, its variation has to be considered when specifying the overall performance of any given measurement device.

When using measurement uncertainty, it is possible to say that the uncertainty (variability) of the reference standard and the process of calibration is a specific value, such ± 0.5% RH. This can be statistically combined with the instrument accuracy to arrive a range of measurement performance that is likely to be correct 95% of the time. This value is always bigger than the accuracy of the measurement device, regardless of how accuracy is defined. (Keep in mind that this is in the calibration laboratory, not in the real world.)

Additional Uncertainties

Measurement uncertainty actually applies to individual measurements. In the real world, calibration and device accuracy are not the only influencers of a specific measurement. Additional factors might include environmental conditions (different from the conditions in the calibration laboratory) operator error, inconsistent methodology between operators; and unknown additional variables. These, and other, additional uncertainties from the real world can be statistically factored in (if they are known) to the overall measurement performance. Again, the total value of uncertainty increases.

There is more. Returning to the concept of the combined calibration uncertainty and device accuracy, consider that this might vary when the value of the reference standard is adjusted to achieve multiple calibration points. For example, a generated RH value of 20% RH at 25° C may have less uncertainty than a generated value of 80% RH at 40° C. Similarly, performance of the measurement device might change at the extreme ends of its measurement range. If known, this goes into the uncertainty budget. Total measurement uncertainty almost always increases when devices are used at the extremes of their operating range.

Let's add an additional complication. Measurement uncertainty, as described above, provides a statistical probability as to how often the measurement is within specification. If this value is 95%, what about the other 5% of measurements? It's possible to use a different statistical model to achieve 99% probability, but once again, the total value of uncertainty will increase even more. In fact, this value is likely to be substantially greater than the "accuracy" that we started with, perhaps by multiples.

The takeaway here is that "accuracy" never tells the entire story about measurement performance. If measurement performance is critical, scrutinize the device and manufacturer's specifications and ask questions about anything that is unclear or seems inadequately defined.

Appendix 4

The Tracks of Traceability:

A calibrated $2 thermometer is still a $2 thermometer

By Jim Tennermann

Everyone in the quality profession has heard the term “NIST traceable.” Having calibration traceability to the National Institute of Standards and Technology (NIST) is desirable for most measurement devices. It is also enshrined as a requirement in some regulatory documents. Unfortunately, NIST traceability does not ensure measurement quality. Here’s why...

National Institute of Standards & Technology (US)

NIST, a U.S. government organization based in Maryland, is the official keeper of the flame for the highest level of measurement accuracy. If you want to know how good your thermometer is, you can send it to NIST, and it will compare it to the very best temperature standards (“calibration” is simply the comparison of one device to another) and send it back with a report. Of course, this isn’t practical; NIST cannot calibrate the millions of thermometers that are in daily use, and the service is expensive.

This is where the concept of traceability comes in. If you have one thermometer that has been calibrated at NIST, it can become your “standard,” and you can calibrate all of your other thermometers with it. All of these thermometers will have NIST-traceable calibration. This batch of thermometers can be used to calibrate other thermometers, which can in turn be used to calibrate still more thermometers. With proper documentation, all of these thermometers will have NIST-traceable calibration. Traceability requires an unbroken chain of calibrations that goes all the way back to NIST. The chain could be several calibrations long or a hundred calibrations long; it doesn’t matter, as long as the chain is unbroken.

What NIST traceability is NOT

Now for the bad news: NIST traceability does not necessarily provide a reliable and high-quality measurement. Remember, calibration is only a comparison between two devices. It’s possible to calibrate a $2 thermometer against the best thermometer in the world, but it’s still a $2 thermometer. Imagine this scenario: You are responsible for the proper operation of a stability chamber that is actively in use. After 12 months of operation, you remove the temperature sensor that controls the chamber environment and have it calibrated. The calibration report shows the thermometer to be out of specification. Now what? In the best case, the deviation is small, and a backup thermometer functioned properly for 12 months, providing quantitative data regarding the actual chamber temperature. In the worst case, someone will have to analyze the potential effect of “out of control” temperature on the products inside the chamber. If the effect is significant or cannot be determined, this can be costly, setting back a stability study by several months.

Now for the good news: You can prevent measurement disasters. If you are responsible for a temperature measurement, start by selecting the right thermometer for the job. If you’re not sure how to do this, consult a metrologist in your organization, or contact a reputable vendor of thermometers for technical assistance. Set up a calibration program for this thermometer (and make sure your calibrations are traceable to NIST). Finally, consider using a second, independent thermometer for a backup measurement.

Accreditation is the difference

Returning to NIST traceability, there are other issues to consider. First, all calibration documents should be in a format that is generally acceptable. ISO/IEC 17025 defines the key

elements of an acceptable calibration document. In fact, this is a global standard for quality systems of testing and calibration laboratories. If you are outsourcing calibration, consider using a vendor that is accredited to this standard. Visit the sites of the American Association for Laboratory Accreditation (A2LA) and the National Voluntary Laboratory Accreditation

Program (NVLAP) to learn more and to find firms that have accreditation.

National Metrology Institutes and International Standards

As you might imagine, other countries also have national metrology institutes (NMIs) that serve similar functions to NIST. In Canada the equivalent organization is NRC. In Mexico it is CENAM. It is entirely possible that organizations located in different countries might request calibration traceability to their own NMI. This can be particularly challenging if your own organization has operations in more than one country. But there is more good news. Many NMIs "recognize" each other. This recognition is formally organized by the Bureau International des Poids et Measures (BIPM). It does not necessarily mean that your company or your customers will freely accept calibration documents traceable to any of the BIPM signatories. However, if you see any logistical advantages, you may be able to modify your quality system to allow for this.

I have used the example of a thermometer for simplicity. NIST is the keeper of many standards—pressure, time, frequency, voltage, humidity, and many more. All traceability issues remain the same, regardless of the measurement parameter.

Appendix 5

Capacitive Humidity Sensors: Advantages and Disadvantages

Jim Tennermann

Winston Churchill reportedly said, “Democracy is the worst form of government, except for all the others.” So, it is with capacitive humidity sensors. These sensors can perform amazingly well in some environments and terribly in others. There are many benefits and disadvantages to capacitive humidity sensors. Let’s look at some of them.

Fundamental vs. Secondary

Fundamental measurement devices depend on some intrinsic physical phenomenon to provide consistent, high performance measurement. In the world of humidity, chilled mirror hygrometers achieve this by controlling the temperature of a surface so that condensation remains in an equilibrium state on that surface. The temperature of the surface is measured, yielding a very accurate dew point measurement expressed in the International System of Units. By contrast, the capacitive humidity sensor is a secondary device. It relies on a dielectric material and how that material changes as a function of relative humidity. The dielectric material can be “fooled” into responding to substances other than water vapor, and it can drift over time due for a variety of reasons. So, why doesn’t everyone use a chilled mirror hygrometer? For starters, they can be two to three orders of magnitude more expensive than capacitive sensor-based devices. They are heavy, complex, sensitive to flow rates, and need regular maintenance. The tradeoff between the two technologies: users of capacitive sensors sacrifice some performance for price, simplicity and ease of use.

Simplicity

Capacitive humidity sensors are simple. They consist of two plates sandwiching a dielectric material. Each plate has a “leg” for an electrical connection. The sensor is attached to an appropriate device for measuring capacitance. What could be easier? Well, it’s not really that easy. First of all, the plates have to be permeable to water vapor or the response time of the sensor would be far too slow. The plates are typically very thin layers of metal, often sputtered onto a base material. This requires sophisticated equipment and process knowledge. Some sensors are manufactured in clean rooms to obtain uniformity and consistency. This is not simple. Furthermore, the actual change in the sensor’s capacitance is quite small over the humidity range of 10 - 90%. Electronic circuits for measuring the sensor have to be designed carefully to measure this small change, and stray capacitance has to be eliminated in all wiring that connects the sensor to the electronics. These are not issues for users, but knowledge of these details might help users understand the differences in price and performance between instruments that appear to be the same.

Contamination

All humidity sensors must be in contact with the gas that they measure. Anything in the gas that “disagrees” with the sensor can alter the sensor’s performance. For example, small oil droplets in aerosol form can coat the sensor, forming a barrier that limits water vapor permeability. Dust can accumulate on the sensor with a similar effect. The most difficult contaminants are chemicals that interfere with or change the nature of the dielectric material.

These contaminants can be sneaky. When the sensor is exposed to them, they create measurement error. In some cases, when the sensor is removed from service for calibration, the contaminants may outgas and the measurement error disappears. Other contaminants may cause permanent damage to the dielectric. Sensors from different manufacturers may react differently because of differences in dielectric material or sensor design. All sensors have strengths and weaknesses when it comes to contamination, but sorting them out is nearly impossible without direct testing. This is the nature of capacitive humidity sensors. Unfortunately, every humidity measurement technology is also subject to degradation due to contamination.

Environmental Conditions

Capacitive humidity sensors are big winners when it comes to environmental conditions. They can withstand high and low temperatures. They can measure in saturated conditions and "dry as a bone" conditions. They outperform most technologies when it comes to extremes. Clever tricks can extend the sensor performance. For example, when measuring warm and moist conditions, condensation may form on the sensor and corrupt the measurement. This can be avoided by heating the sensor prior to exposing it to warm and moist conditions. Caution: Don't use a torch to heat the sensor. Look for a humidity instrument that has this function in the design.

In conclusion, capacitive humidity sensors are not a universal solution for humidity measurement, but they're pretty darn close. They are suitable for the vast majority of humidity measurement applications.

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