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ASPECTS REGARDING THE TRACEABILITY IN TEMPERATURE MEASUREMENTS

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ABSTRACT

The traceability of national standards to a reference measurement is essential to correctly translate the information about customer preferences described in international standards as a prerequisite which exists for the design of goods that comply with the expected characteristics.

The traceability of national and reference measurement standards to the International System (S.I.) is achieved by: comparisons with the primary measurement standards of other countries and periodic calibration with respect to measurement standards of other international and national institutes of metrology, whose traceability to the SI is already proven and widely recognized internationally.

This paper discusses how traceability is possible or it is ensured in temperature measurements, by using measuring instruments that are traceable at International Temperature Scale of 1990 (ITS-90) [1].

KEYWORDS: temperature, traceability, measurements, management, standard

1. Introduction

The quality and development of products and services is dependent on accurate measurements.

The duty of Bureau International des Poids et Mesures (BIPM) [2] is to provide at global level uniformity of measurements and their traceability to the to the International System of Units (SI).

BIPM Key Comparison Database (KCDB) [3] supports the Mutual Recognition Arrangement of the CIPM (acronym CIPM MRA or in short MRA) [4].

The MRA was born from the desire to remove the unnecessary technical barriers. One example for such barrier is the requirement of traceability to a national metrology system.

MRA provides a system that allows customers and government to trust in calibration and measurement certificates of institutions from their country, institutions which participate in the MRA and this fact gives them the right to recognize those calibration certificates. This can be concluded in the expression "calibrated once, accepted everywhere".

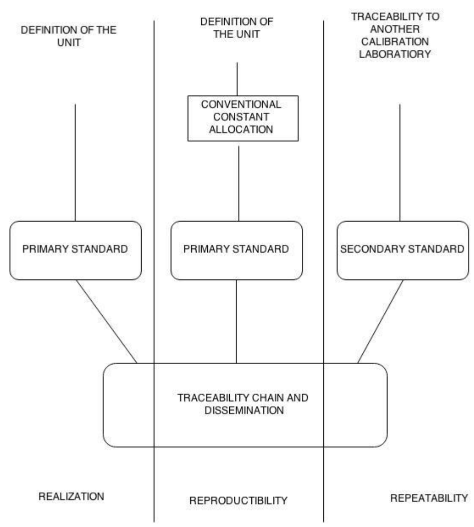

Fig. 1. *Traceability scheme*

Traceability can be defined as "property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of calibrations, each contributing to the measurement uncertainty" (2.41 VIM) [5].

The word *traceable* has a wide range of colloquial meanings, the most appropriate being 'able to be followed to the source' [6] (Figure 1).

The National Institute of Metrology (acronym INM) [7] maintains the Romania national standards for temperature.

Each country has similar national standards laboratories, which accomplish the same goal.

Traceability in temperature is supported by platinum resistance thermometers over a significant portion of temperature scale (ITS-90).

The fixed point is the most accurate instrument and it is realized by pure metals enclosed in a sealed, inert environment.

They work in conjunction with apparatus which surrounds them and provides the operational condition required for melting and freezing to obtain the reference plateau. The housing incorporates isothermal blocks with wells into which the probes are placed. Since fixed point temperatures are defined by physical laws, comparison of the test probe to a reference probe is not required.

Hierarchy of standards and temperature measuring instruments aim at achieving submission of temperature unit from the national standard and reference to working measuring instruments.

Scheme hierarchy of standards and temperature measuring instruments apply to the fundamental unit "thermodynamic temperature", symbol "T" which the SI unit is "Kelvin", symbol "K", that is equal in value to the "degree Celsius" symbol "C", SI unit of "Celsius temperature", symbol "t".

International Temperature Scale is a conventional scale, based on a series of fixed points, reproducible. The measuring instruments calibrated at these fixed points and the mathematical relationships, serve to establish interdependence of the indications of measuring and respectively temperature. Fixed points of definition are represented by reproducible equilibrium states (melting points, freezing points and triple points) of some high purity substance.

The ITS-90, which was designed so as the measured temperature in this scale to be a good approximation of thermodynamic temperature numerically corresponding. The relation between T_{90} and t_{90} is similar between T and t.

$$t_{90} = T_{90} - 273{,}15\ K \qquad (1)$$

Such a scale must satisfy three requirements:

- to be accurate and reproducible;
- to be carried out independently in all laboratories in the world with financial and time resources achievable;
- temperature values in this scale to be as close as possible with thermodynamic temperature values the best estimates made from suitability made when adopting scale.

ITS-90 it is based on:

- a set of fixed definition;
- interpolation methods specified between fixed points.

Table 1. *ITS-90 Fixed Points*

No.	Temperature		Substance[a]	Type[b]
	T_{90}lK	t_{90} °C	Ar	Triple
1	83,805 8	-189,344 2	Hg	Triple
2	234,315 6	- 38,834 4	H_2O	Triple
3	273,16	0,01	Ga	Melting
4	302,914 6	29,764 6	In	Freezing
5	429,748 5	156,598 5	Sn	Freezing
6	505,078	231,928	Zn	Freezing
7	692,677	419,527	Ar	Triple

[a] natural isotopic composition
[b] triple point- temperature at which the solid phases, liquid and gaseous are in equilibrium; freezing , melting point- temperature, at a pressure of 101 325 Pa, in the solid and liquid phases are in equilibrium

The purpose of this paper is to present how traceability of measurements is achieved in Temperature Laboratory of National Institute of Metrology (INM) by declaration of Calibration and measurement capabilities (CMCs), which are realized with international Key Comparison. For Romania, the CMC's are found in Appendix C from Key Comparison Database (KCDB) [3].

2. Experimental

In the hierarchy scheme for measuring temperature (Figure 2) it is represented the synthetic process of disseminating of temperature in the unit (-189.244 2 ... 660.323) °C, the national standard / primary to working standards, to ensure metrological traceability of measurable results. Dissemination unit is based on the type of measuring instruments to be calibrated and their metrological quality resulting into different uncertainties measurement [8].

Transfer unit at the highest metrological level is carried out by sending the information directly from the primary standard directly to the working standard.

At INM, the temperature unit is transmitted from the primary / national standard to the fixed points of reference cells by comparing their direct values with cell components of / national standard through platinum resistance thermometers.

This procedure of unit dissemination, is the largely conserved of realisation temperature unit.

Calibration uncertainties values of fixed point cells in (-189.244 2 ... 660.323) ◦C presented in Hierarchy Scheme were confirmed and internationally recognized through EUROMET.T-K3 and EUROMET.T-K4 key comparisons.

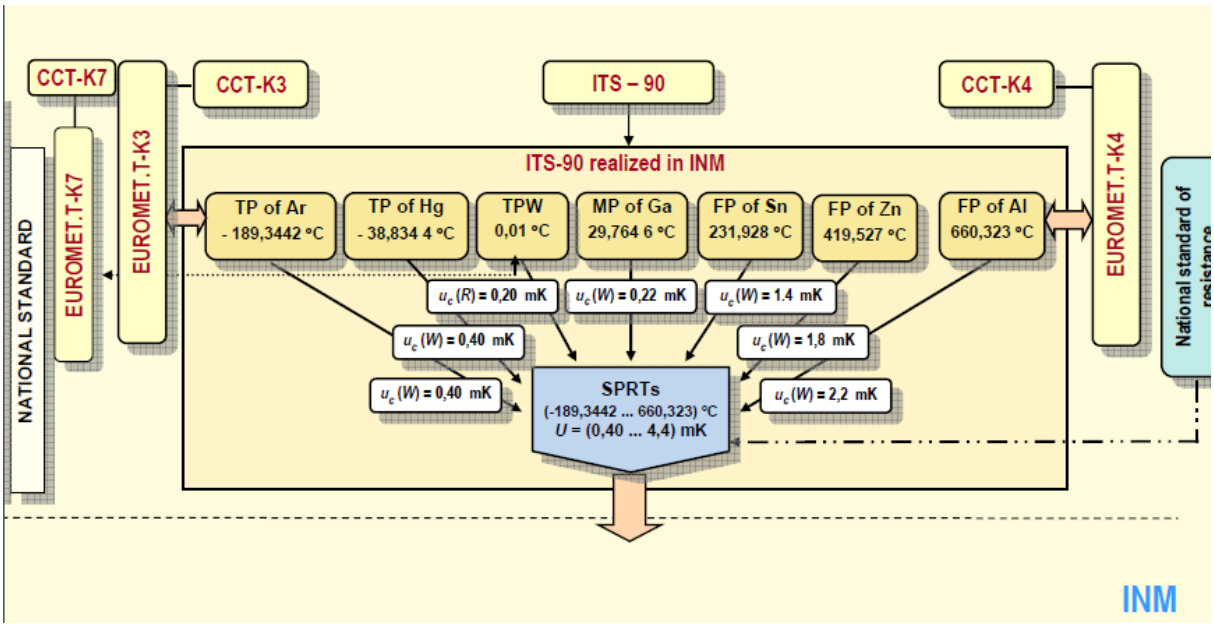

Fig. 2. Hierarchy scheme of measuring temperature through Standard Precision Resistance Thermometer

With respect to the next levels of accuracy, dissemination of national scale of temperature is performed by:

- direct measurement reference cells for fixed points;
- direct/indirect Comparison with reference standards.

2.1. Direct measurement reference cells for fixed points

A method is used to calibrate the standard thermometers resistance, S-type thermocouples and digital thermometers which are directly calibrated reference cells for fixed points.

For this method, we chose from the project "National standard characterisation of "Kelvin" unit of international temperature in the range (273.16 … 1 357.77) K" [9], the project is done annually for a better dissemination of temperature.

Primary standard of the temperature unit, within the range (-189.344 2 and 961.78) ºC represents practical realisation of fixed point of ITS-90, associated with calibration of platinum resistance thermometers (acronym PRT)- interpolation instruments specified in ITS-90. The system used in the laboratory for achieving a fixed point and for platinum resistance thermometers calibration in relation to this reference is shown in Figure 3.

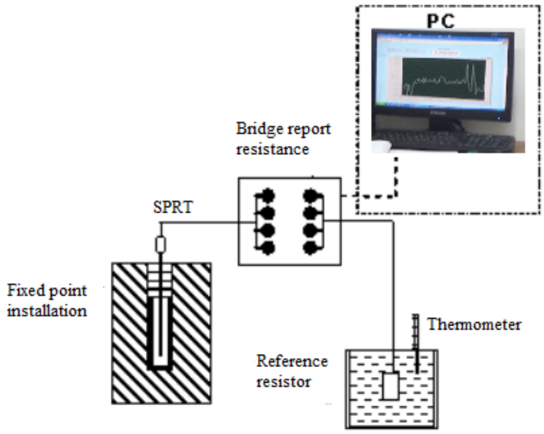

Fig. 3. Realization of fixed points and platinum resistance thermometers calibration

PRT is placed vertically upon the installation of materialisation fixed point. Its electrical resistance is measured with ASL F18 Automatic bridge ratio resistant. Bridge measuring the ratio of electric resistance is to be calibrated PRT and electrical resistance of reference resistor is held in a constant temperature bath. The bath temperature is monitored with a thermometer. The electrical resistance values of the reference resistor are corrected for temperature using the thermometer references.

Data provided by ASL F 18 Automatic bridge ratio are purchased and processed by a PC, using an IEEE 488 interface and LabVIEW programming environment (Figure 4).

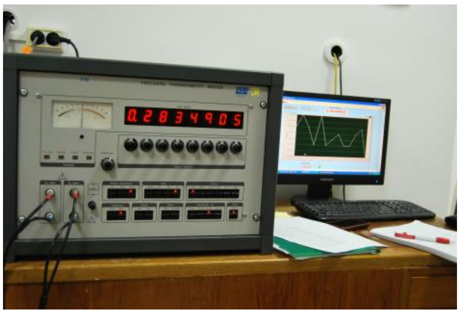

Fig. 4. *ASL F18 Automatic bridge ratio and monitored with LabVIEW programming environment*

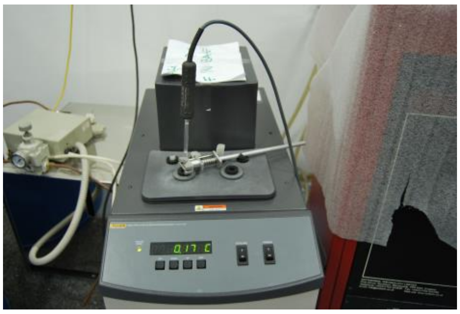

Fig. 5. *PRT calibration at triple point of water – TPW*

In Figure 6 we observe that at TPW calibration, the PRT is very stable and maximum fluctuations is within the range of 0.05 mK.

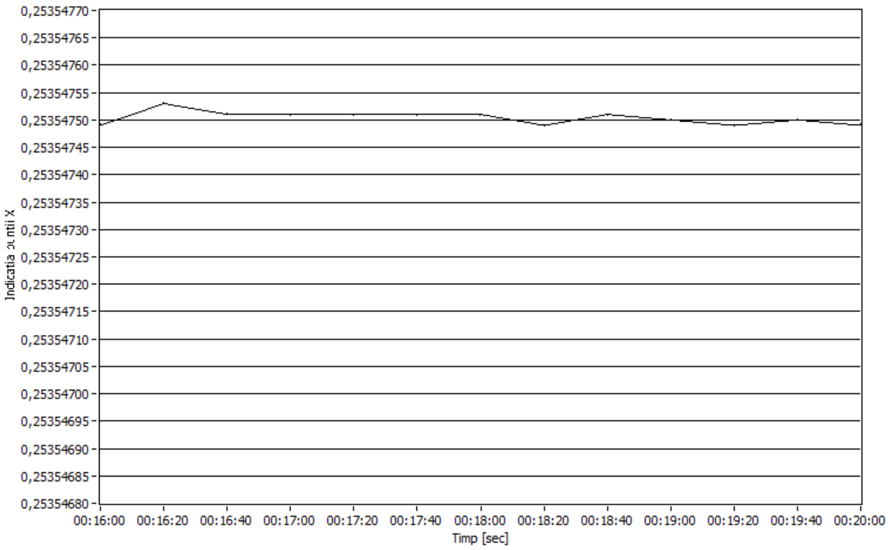

Fig. 6. *Outcome monitoring PRT in LabView at TPW for 4 minutes*

2.1 Direct / Indirect Comparison with reference standards

The method is used for calibrating platinum resistance thermometers, thermocouples, Liquid glass thermometers, digital thermometers, etc., direct or indirect comparison with reference standards in ovens and baths.

In Figure 7 we have a thermobalance with a temperature sensor which is calibrated at 3 specific points of temperature chosen by beneficiary.

It is known that balances are influenced by temperature. In this way, it is important to know what temperature has a huge influence on the sensor of thermobalance.

After calibration, the data from Table 2 was obtained.

Fig. 7. *Calibration thermobalance sensor at 15°, 20° and 30 °C*

Table 2. *Data obtained from calibration thermobalance sensor at temperatures: 15°, 20° and 30 °C*

Value/°C				Uncertainty
Temperature set	**Indicated**	**True**	**Correction**	
15	14.9	14.92	-0.02	0.3
20	20.0	19.98	-0.02	
30	30.0	30.07	+0.07	

The current measurements measuring the true value are:

$$Tct = (Tind + C) \pm U \ (°C) \qquad (2)$$

where:

Tct = conventional true temperature;
Tind = indicated temperature;
C = correction;
U = expanded uncertainty.

If we apply the correction obtained in the Table, we will find the true temperature according to relation (2).

The uncertainty attributed is expanded uncertainty obtained by multiplying the standard uncertainty with coverage factor $k = 2$. The results are traceable according to the International System of Units. Traceability of measurement is achieved and maintained by international comparisons and calibration in agreement with SR EN ISO/CEI 17025:2005 [10].

3. Conclusions

Traceability can be achieved in practice, if we think that a substantial community effort is required.

To achieve traceability is necessary to follow the three main requirements for an international measurement system, such as:

- Primary physical standards are required to provide a unique definition of the measurement scales. All measurements should refer to the same SI unit.

- With temperature measurements, it is sometimes necessary to agree on a measurement protocol or to follow the same scale (for temperatures it is necessary to refer to ITS-90) in order to be able to make comparable measurements.

- Documentary standards are also used to define other protocols, some of which have a direct effect on measurements. These include standardized responses for platinum resistance thermometers and thermocouples, mechanical specifications for electrical instruments, etc.

Temperature measurements are not like many of the products that we buy. Given that a calibration or testing laboratory has followed documentary standards and calibrated its equipment, it must be demonstrated that it has conformed to the community expectation with respect to measurement standards and technical procedures.

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