**European Partnership on Metrology**
**Call 2025 – Health, Integrated European Metrology, Regulation and Research Potential**

Selected Research Topic number: **SRT-r07**
Version: 1.0

# Title: Supporting emerging technology uptake for thermodynamic temperature dissemination

## Abstract

In order to support and strengthen current European leadership in temperature metrology, new traceability routes to the redefined kelvin need to be developed. In addition, there is a critical need to support NMIs/DIs with emerging capabilities in the dissemination of thermodynamic temperature. Proposals addressing this topic should establish the technology, methods and procedures for the calibration and comparison of sensors (e.g. capsule-type standard platinum resistance thermometers) used to realise and maintain wire-scales (i.e. practical interpolation methods) over the range from 4 K up to 300 K, to address end-users needs.

## Keywords

Primary thermometry, ITS-90, temperature dissemination, new kelvin, new SI, standard thermometers, Standard Platinum Resistance Thermometer (SPRT), Capsule-Type SPRT (CSPRT), capsule, cryogenics

## Background to the Metrological Challenges

For any physical quantity, improving the metrological realisation and dissemination of the corresponding measurement unit is a challenging endeavour which requires the capability to progress at two different levels, namely the realisation of primary standards, and the provision of sufficiently performing transfer standards as needed for dissemination purposes. This concept is particularly relevant for the SI unit of temperature, especially in light of the new perspective introduced by the 2019 redefinition of the kelvin. The *mise en pratique* for the definition of the kelvin (*Me*P-K) clearly highlights the advantages of the thermodynamic temperature approach as a preferred direct path for achieving improved standards and ensuring traceability. Along these lines, a new CIPM CCT Task Group was established to address standardisation needs for traceability of practical primary thermometers. Stated perspective and indication were also reinforced by the CCT recommending "…member state NMIs take full advantage of the opportunities for the realisation and dissemination of thermodynamic temperature afforded by the kelvin redefinition and the *mise en pratique* for the definition of the kelvin" [1].

In response to the recognised need, research efforts were made globally towards the development of primary thermodynamic standards. At the European level the investment is significant with three previously funded projects: i) EMPIR project 18SIB02 Real-K establishing direct thermodynamic temperature traceability above 1300 K and below 25 K; ii) Metrology Partnership project 23IND11 ThermoSI developing practical Johnson noise thermometry and the associated metrological/traceability framework, amongst other activities; and iii) Metrology Partnership project 22IEM02 DireK-T, addressing similar tasks as EMPIR project 18SIB02 Real-K for the intermediate range between 25 K and 300 K, and the additional important objective to prove, for the first time, the quality achievable in the direct dissemination of the kelvin by a blind international comparison of thermodynamic calibrations using capsule-type resistance thermometers as transfer standards. While the Metrology Partnership project 22IEM02 DireK-T is still ongoing, its present findings already highlight the crucial role of temperature sensors in ensuring a reliable dissemination of temperature. Also, besides the intrinsic quality of the sensors in terms of sensitivity, long-term stability and robustness, several other open metrological issues are critically involved in dissemination practice, including the experimental procedures, instrument and tools used for their mutual comparison when transferring or verifying calibration, and the definition of the most suitable methods for the analysis of calibration data. Resolving these issues that severely hinder the dissemination of the temperature unit below 300 K is a most urgent need of temperature metrology.

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For temperature traceability and dissemination, the current state of the art is well advanced in the development of primary thermodynamic standards with a variety of methods (gas-based, noise, radiometric) being continuously improved and or simplified over progressively wider temperature ranges. Unfortunately, progress in defining methods and procedures for calibration and comparison of transfer standards lags behind the improved performance of the primary ones. While the design characteristics of most thermodynamic standards make them suitable for calibration of small sized temperature sensors, such as capsule-type resistance thermometers, the procedures for their calibration at the cryogenic fixed points and for wire-scale comparisons below 25 K are well established and documented at the BIPM level only for the dissemination of International Temperature Scale of 1990 (ITS-90). Additionally, the technical capabilities required in this limited context belong to a handful of NMIs worldwide.

To overcome the present situation, the proposal should focus on establishing a similarly firm technical and documentary basis which would allow the use of capsule resistance thermometers as transfer standards over the wide range between 4 K and 300 K, possibly extending up to the freezing point of Indium (430 K). By these means, dissemination of thermodynamic temperature can become a truly complete and effective laboratory practice, positively impacting on the measurement capabilities of a large number of NMIs, reinforcing the European leadership in temperature metrology.

## Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The proposal shall focus on the development of metrology capability in thermodynamic measurements.

The specific objectives are

1. To determine the criteria for temperature sensors to be used for dissemination purposes over the temperature range of 4 K up to 300 K. This includes evaluation and selection of devices such as capsule-type resistance thermometers (of e.g. platinum, platinum cobalt, rhodium iron) and thin-film compact sensors. Performance tests will be carried out at the fixed points temperatures of hydrogen, neon, oxygen, argon, mercury, water and gallium in terms of long-term stability, repeatability and temperature sensitivity.
2. To demonstrate, by direct comparisons between participating NMIs/DIs, the reproducibility of temperature measurements at the triple point of water within 2 ppm (0.6 mK). To develop fit-for-purpose solutions using thermometers selected in objective 1. This will include e.g. designing comparison blocks of new conception, production of best practice guides for measurement methods and data analysis, implementation of deep learning-based methods. These solutions must be compatible with the instruments already available at participating NMIs.
3. To define time- and cost-effective calibration procedures for each type of thermometer and the relevant temperature ranges. To consider alternative calibration schemes with increased accuracy, using most suitable interpolating equations (e.g. ITS-90 / thermodynamic hybrid calibrations, deviation from Matthiessen’s rule) and simplification to further harmonise international agreement on a mathematical / software basis. Targets for the degree of equivalence $d_{0.95}$ are 2 mK at the fixed points and 4 mK in the temperature intervals between them.
4. To produce protocols and guidelines for the dissemination of the thermodynamic temperature on a wire-scale and submit these to CCT Working Group for Contact Thermometry (CCT-WG-CTh). This includes i) protocols that define the procedures needed for international comparisons of thermodynamic temperature, and ii) guidelines that are complementary to the technical sections comprised within the Guide to the Realization of ITS-90. In addition, to make these available for adoption by the metrological community pursuing methods for the dissemination of thermodynamic temperature.
5. To facilitate the take up and long-term operation of the capabilities, technology and measurement infrastructure for thermodynamic measurements developed in the project, by the measurement supply chain (NMIs/DIs, calibration and testing laboratories), standards developing organisations (CCT-WG-CTh) and end users (e.g. industry, instrument manufacturers, regulators). The approach should be discussed within the consortium and with other EURAMET NMIs/DIs, e.g. via EURAMET TC-T, to ensure that a coordinated and optimised approach to the development of traceability in this field is developed for Europe as a whole.

Joint Research Proposals submitted against this SRT should identify

- the particular metrology needs of stakeholders in the region,
- the research capabilities that should be developed (as clear technical objectives),
- the area for which the capabilities will be built (Green Deal, Digital Transformation, Health, Integrated European Metrology, Industry, Normative or Fundamental Metrology) and in which future main call the developed research capabilities are planned to be employed,
- the impact the developed research capabilities will have on the industrial competitiveness and societal needs of the region,
- how the research capability will be sustained and further developed after the project ends.

Where relevant, proposals are encouraged to build on, or seek collaboration with, existing projects and develop synergies with other relevant European, national or regional initiatives and funding programmes. In particular, links are encouraged with (i) the projects funded under earlier relevant topics of the Horizon Europe programme; or (ii) other relevant European Partnerships.

Proposers should establish the current state of the art and explain how their proposed research goes beyond this. In particular, proposers should outline the achievements of the EMPIR project 18SIB02 Real-K and the Metrology Partnership projects 22IEM02 DireK-T and 23IND11 ThermoSI, and how their proposal will build on those.

The development of the research potential should be to a level that would enable participation in other TPs.

Proposers should note that the programme funds the activity of researchers to develop the capability, not the required infrastructure and capital equipment, which must be provided from other sources.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 0.7 M€ and has defined an upper limit of 0.9 M€ for this proposal.

EURAMET also expects the EU Contribution to the external funded beneficiaries to not exceed 20 % of the total EU Contribution across all selected projects in this TP.

Any industrial beneficiaries that will receive significant benefit from the results of the proposed project are expected to be beneficiaries without receiving funding or associated partners.

## Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the ’end user’ community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the “end user” community (e.g. letters of support) is also encouraged.

You should detail how your proposal’s results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Provide a lasting improvement in the European metrological capability and infrastructure beyond the lifetime of the project,
- Facilitate improved industrial capability or improved quality of life for European citizens in terms of personal health, protection of the environment and the climate, or energy security,
- Transfer knowledge to the thermometry sector and the metrology community.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”.

You should also detail how your approach to realising the objectives will further the aim of the Metrology Partnership to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically, the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work.

## Timescale

The project should be of up to 3 years duration.

## Additional information

The link provided in this section is only correct at the time of publication up until the end of the Call year.

The reference below was provided by PRT submitters; proposers should therefore establish its relevance.


[1] CIPM CCT: Recommendation 1 of the 28th CCT (2017) https://www.bipm.org/en/committees/cc/cct/28-2017/resolution-1