EMPIR Call 2018 – Health, SI Broader Scope, Normative and Research Potential

Selected Research Topic number: **SRT-s13**
Version: 1.0

Title: Realising the redefined kelvin

Abstract

The redefinition of the SI is expected to be formally implemented on World Metrology Day May 2019 initiating the larger and more comprehensive research phase of realisation and dissemination of the redefined units. Through practical primary thermometry *direct* traceability to the redefined kelvin becomes possible as opposed to, as now, through the intermediary of defined scales (e.g. ITS-90). Proposals addressing this SRT should enable traceability (and so realisation and dissemination) at high and low temperatures and perform the background research facilitating such traceability to intermediate temperatures. The long-term goal should be to develop the methods and processes to enable realisation and dissemination of the kelvin without recourse to any defined scale.

Keywords

Redefinition of the SI, redefined kelvin, temperature, primary thermometry, traceability, *mise en pratique*, MeP-K, ITS-90, PLTS-2000

Background to the Metrological Challenges

This SRT aims to take the primary thermometry approaches described in the *MeP*-K-19 namely Johnson Noise Thermometry (JNT) at low temperatures, and primary radiometry at high temperatures and turn them into practical means for realising and disseminating thermodynamic temperature. This should be demonstrated with uncertainties competitive with or better than the current defined scales. In addition the realisation of ITS-90 below 25 K is complex and hardly ever done by NMIs. Here primary thermometry, capable of uncertainties competitive with ITS-90 in the temperature range below 25 K, should be established and dissemination demonstrated.

The current state of the art at high temperatures is that there are only three high temperature fixed points (HTFPs) available for potential use by the thermodynamic temperature realisation approach described in the *MeP*-K-19. It is therefore necessary to make available a wider range of HTFPs, with low uncertainty thermodynamic temperatures for both NMIs and industrial users. This would allow thermodynamic temperature at high temperatures to be established in ranges appropriate to need, e.g. between the silver freezing point and any HTFP.

Low temperatures (<1 K) are currently traceable to the unsatisfactory PLTS-2000. Below 25 K the ITS-90 is hardly realised anywhere because of its complexity. Practical JNT could be used to realise and disseminate thermodynamic temperature in accordance with the *MeP*-K-19 and so demonstrate that the PLTS-2000 could be replaced by practical primary thermometry. Use of the primary thermometry approaches below 25 K detailed in the *MeP*-K-19 and of novel fixed points, such as the lambda point (~2 K), could demonstrate a practical way to realise and disseminate low temperatures.

The ITS-90 is the current state of the art with respect to temperature realisation and dissemination. However, it has a number of issues, both technical and political, which need to be addressed. Resolving scale "non-uniqueness" and finding alternative fixed points to the Hg triple point (e.g. Xe, SF6) would ensure that the ITS-90 still continues to meet user needs into the 2020s and also give time for primary thermometry methods to be developed and established, without the cost and inconvenience of introducing a new scale.

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 JRP shall focus on the measurement of temperature traceable to the redefined kelvin.

The specific objectives are

1. To demonstrate and establish traceability directly to the redefined kelvin from the silver freezing point to ~3000 K. Through the mechanism of the *MeP*-K-19, high temperature fixed points should be used to realise and disseminate thermodynamic temperature with uncertainties (U) competitive with the ITS-90 (target U < 0.05 %).
2. To demonstrate practical primary thermometry for the realisation and dissemination of thermodynamic temperature using two methods below 1 K and to develop reliable low uncertainty primary thermometry below 25 K and so demonstrate; a) PLTS-2000 can be superseded by primary thermometry (target U = 1 %) and b) primary thermometry approaches can be used to replace the ITS-90 scale realisation arrangement below 25 K (target U = 0.2 mK).
3. To extend the life of the current defined scale (ITS-90) by reducing its scale non-uniqueness uncertainty by 30 % and identifying a suitable fixed-point replacement for the mercury triple point.
4. To reduce the uncertainty in a range of different primary thermometry methods, approved for use in the *MeP*-K-19, and so facilitate their extension for temperature realisation and dissemination into the temperature region 25 K to 1235 K. Uncertainties of the calculated thermophysical and electromagnetic properties of thermometric fluids (e.g. He, Ne, Ar) should be reduced.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by engaging standardisation bodies and international organisations (CCT, EURAMET and other RMO TC-Ts), the measurement supply chain (accredited laboratories, instrument manufacturers) and end users (CERN, quantum computing and fundamental materials science communities).

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research work, the involvement of the larger community of metrology R&D resources outside Europe is recommended. A strong industry involvement is expected in order to align the project with their needs and guarantee an efficient knowledge transfer into industry.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this.

In particular, proposers should outline the achievements of the EMRP and EMPIR projects SIB01 InK and 15SIB02 InK 2 and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.8 M€, and has defined an upper limit of 2.1 M€ for this project.

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

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 JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the thermometry sector.

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 EMPIR 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

Time-scale

The project should be of up to 3 years duration.