CCT member and observer Activity Report

Period: January 2022 to March 2024

Institute: National Research Council Canada

State economy: Canada

Number of persons involved in thermometry of the institute: 7

Short summary of research and development:

10th International Temperature Symposium (ITS10)

At the 10th International Temperature Symposium (ITS10), held in Anaheim, California, USA in April 2023, NRC co-authored 6 oral and 3 poster presentations, including the closing plenary presentation [1]. 5 papers have been accepted for publication in the ITS10 proceedings [1, 2, 3, 4, 5].

Emerging technologies

Work continues on the metrological evaluation of emerging thermometry technologies. The performance of ring-resonator thermometer was evaluated in [6, 7, 12, 15], including the detailed uncertainty budget of 10 mK in [7] for the packaged device, and the overall review of the field of emerging technologies in thermometry was published in [18].

International Temperature Scale of 1990

Recent ITS-90 research has focused on SPRT subrange inconsistency (Type 1 non-uniqueness) [5, 11], and the implications of the coming mixed dissemination environment in which thermometers carrying direct thermodynamic temperature calibrations coexist alongside those calibrated on the ITS-90 [1, 4].

Primary thermometry

First proof-of-concept measurement results from the new NRC acoustic gas thermometer were presented at the ITS10 conference. NRC has also joined the EURAMET "Dissemination of the redefined kelvin" (DireK-T) project as a collaborator, focusing on the 25 K to 273 K range.

Short summary of recent comparison activity:

CCT-K7.2021 water triple point comparison

Substantial efforts were devoted to the completion of the CCT-K7.2021 key comparison of triple-point-of-water cells (Final Report published in the KCDB in May 2023 [13]). Besides the Final Report, 4 peer-reviewed articles were published on: the comparison preparatory work [16], the uncertainty budget [17], the applied statistical methods [2], and a critical evaluation of the results [3] with respect to the previous key comparison. The comparison was completed in record time (2 years), and, compared to CCT-K7, the spread of the national realizations was reduced by almost a factor of two and the distribution of the results was only slightly asymmetric (no outliers).

Short summary of other activities:

NRC chairs CCT-WG-KC and CCT-TG-Dig, and also actively contributes to the work of CCT-WG-CTh, CCT-WG-NCTh, CCT-TG-CTh-ET, and CCT-WG-SP. CCT-TG-Dig was created at the last CCT meeting, and has focused on digitalization of CCT documents: extraction of data for Application Programming Interface (API) creation, machine-friendly restructuring of the *MeP*-K, and development of guidelines for indexing and archiving. A recent main output of CCT-WG-CTh has been the first update of the T - T_{90} consensus estimate in over 10 years [14].

Link to bibliography or list of bibliography (last 5 years):

[1] P M C Rourke 2024 **Future of the International Temperature Scale in a Mixed Dissemination Environment** *AIP Conference Proceedings* (ITS10) in press

[2] A Peruzzi *et al.* 2024 **Applying Different Analysis Methods to CCT-K7.2021 Key Comparison** *AIP Conference Proceedings* (ITS-10) in press

[3] S Dedyulin *et al.* 2024 **From CCT-K7 to CCT-K7.2021: Approaching the definition of the triple point of water temperature** *AIP Conference Proceedings* (ITS10) in press

[4] D Imbraguglio *et al.* 2024 **From ITS-90 to Thermodynamic Temperature: Hybrid CSPRT Calibrations with LNE-Cnam Acoustic Gas Thermometry** *AIP Conference Proceedings* in press

[5] J V Pearce *et al.* 2024 **Realizing the redefined kelvin: Extending the life of the ITS-90** *AIP Conference Proceedings* (ITS10) in press

[6] S Janz *et al.* 2024 **Measurement accuracy in silicon photonic ring resonator thermometers: Identifying and mitigating intrinsic impairments** *Optics Express* **32** 551 https://doi.org/10.1364/OE.499055

[7] S Dedyulin *et al.* 2023 **Practical ring-resonator thermometer with an uncertainty of 10 mK** *Measurement* **221** 113453 https://doi.org/10.1016/j.measurement.2023.113453

[8] J M Mantilla *et al.* 2023 **Construction and comparison of high temperature fixed points at NRC and CEM** *Journal of Physics: Conference Series* **2554** 012007 https://doi.org/10.1088/1742-6596/2554/1/012007

[9] S Dedyulin and M Gotoh 2023 **Caesium- and sodium-filled pressure controlled heat pipe at NRC** *Journal of Physics: Conference Series* **2554** 012005 https://doi.org/10.1088/1742-6596/2554/1/012005

[10] A D W Todd 2023 **Preface to the Proceedings of TEMPMEKO and TEMPBEIJING 2019** *Journal of Physics: Conference Series* **2554** 011001 https://doi.org/10.1088/1742-6596/2554/1/011001

[11] V Žužek *et al.* 2023 **Least squares approach to standard platinum resistance thermometer subrange inconsistency reduction with redundant gallium and indium fixed points** *Measurement* **220** 113400 https://doi.org/10.1016/j.measurement.2023.113400

[12] S Dedyulin *at al.* 2023 **Nonlinear optical impairments in silicon ring resonator thermometers and their mitigation** *2023 Photonics North (PN)* https://doi.org/10.1109/PN58661.2023.10222952

[13] A Peruzzi *et al.* 2023 **CCT-K7.2021: CIPM key comparison of water-triple-point cells** *Metrologia* 60 03002 https://doi.org/10.1088/0026-1394/60/1A/03002

[14] C Gaiser *et al.* 2022 **2022 Update for the Differences Between Thermodynamic Temperature and ITS-90 Below 335 K** *Journal of Physical and Chemical Reference Data* **51** 043105 https://doi.org/10.1063/5.0131026

[15] S Dedyulin *et al.* 2022 **Progress on Silicon Photonic Thermometry for Secondary and Working Measurement Standards** *2022 Photonics North (PN)* https://doi.org/10.1109/PN56061.2022.9908405

[16] S Dedyulin and A Peruzzi 2022 **No country for old borosilicate triple-point-of-water cells** *Metrologia* **59** 055009 https://doi.org/10.1088/1681-7575/ac8d0f

[17] A Peruzzi and S Dedyulin 2022 **NRC measurement set-up and preparatory work for CCT-K7.2021 key comparison of triple-point-of-water cells** *Metrologia* **59** 045011 https://doi.org/10.1088/1681-7575/ac7bc1

[18] S Dedyulin *et al.* 2022 **Emerging technologies in the field of thermometry** *Measurement Science and Technology* **33** 092001 https://doi.org/10.1088/1361-6501/ac75b1

[19] A Peruzzi *et al.* 2022 **A comparison of relative humidity calibration facilities at temperatures up to 170 °C** *Measurement* **189** 110435 https://doi.org/10.1016/j.measurement.2021.110435

[20] G Leblanc *et al.* 2021 **A practical validation of uncooled thermal imagers for small RPAS** *Drones* **5** 132 https://doi.org/10.3390/drones5040132

[21] P M C Rourke 2021 **Perspective on the refractive-index gas metrology data landscape** *Journal of Physical and Chemical Reference Data* **50** 033104 https://doi.org/10.1063/5.0055412

[22] P M C Rourke 2021 **ITS-90 reproducibility, xenon fixed point substitution and new interpolating equations between 13.8033 K and 273.16 K** *Metrologia* **58** 055004 https://doi.org/10.1088/1681-7575/abfd8e

[23] A Peruzzi *et al.* 2021 **Survey of subrange inconsistency of long-stem standard platinum resistance thermometers** *Metrologia* **58** 035009 https://doi.org/10.1088/1681-7575/abe8c1

[24] S Dedyulin *et al.* 2021 **Accurate measurements of a wavelength drift in high-temperature silica-fiber Bragg gratings** *Metrology* **1** 1 https://doi.org/10.3390/metrology1010001

[25] A D W Todd *et al.* 2021 **On the uncertainties in the realization of the kelvin based on thermodynamic temperatures of high-temperature fixed-point cells** *Metrologia* **58** 035007 https://doi.org/10.1088/1681-7575/abe9c5

[26] A Peruzzi *et al.* 2021 **Metrological evaluation of deep-ocean thermometers** *Journal of Marine Science and Engineering* **9** 398 https://doi.org/10.3390/jmse9040398

[27] D Grobnic *et al.* 2021 **Fiber Bragg grating wavelength drift in long-term high temperature annealing** *Sensors* **21** 1454 https://doi.org/10.3390/s21041454

[28] Y Yamada and A Todd 2021 **Special section on TEMPMEKO 2019: a feature on the XIV International Symposium on Temperature and Thermal Measurements in Industry and Science & IV International Temperature Conference, Beijing (TEMPMEKO & TEMPBEIJING 2019) and Metrology for Meteorology and Climate (MMC 2019)** *Measurement Science and Technology* **32** 020101 https://doi.org/10.1088/1361-6501/abac89

[29] S N Dedyulin *et al.* 2020 **On the long-term stability of the triple-point-of-water cells** *Metrologia* **57** 065032 https://doi.org/10.1088/1681-7575/abb52f

[30] A Merlone *et al.* 2020 **Gas-controlled heat pipes in metrology: more than 30 years of technical and scientific progresses** *Measurement* **164** 108103 https://doi.org/10.1016/j.measurement.2020.108103

[31] S Janz *et al.* 2020 **Photonic temperature and wavelength metrology by spectral pattern recognition** *Optics Express* **28** 17409 https://doi.org/10.1364/OE.394642

[32] D R White and P M C Rourke 2020 **Standard platinum resistance thermometer interpolations in a revised temperature scale** *Metrologia* **57** 035003 https://doi.org/10.1088/1681-7575/ab6b3c

[33] S Dedyulin *et al.* 2020 **Packaging and precision testing of fiber Bragg grating and silicon ring resonator based thermometers: current status and challenges** *Measurement Science and Technology* **31** 074002 https://doi.org/10.1088/1361-6501/ab7611

[34] P M C Rourke 2020 **Thermodynamic temperature of the triple point of xenon measured by refractive index gas thermometry** *Metrologia* **57** 024001 https://doi.org/10.1088/1681-7575/ab57f2

[35] S Dedyulin *et al.* 2019 **Silicon photonic chips using remote interrogation for secondary and working standards in thermometry** *2019 Photonics North* Article number 8819562 https://doi.org/10.1109/PN.2019.8819562

[36] P M C Rourke *et al.* 2019 **Refractive-index gas thermometry** *Metrologia* **56** 032001 https://doi.org/10.1088/1681-7575/ab0dbe

[37] P P M Steur *et al.* 2019 **Comparison of xenon triple point realizations** *Metrologia* **56** 015008 https://doi.org/10.1088/1681-7575/aaee3a