University of Ljubljana
Faculty of Electrical Engineering

LMK LABORATORIJ ZA METROLOGIJO IN KAKOVOST

Laboratory of metrology and quality
Holder of the national standard
for thermometry and humidity

Hybrid comparison report – EURAMET project 1491

Title: Hybrid comparison with resistance thermometer MIRS/UL-FE/LMK and NSAI 2019

Date:
27.11.2019

Items:
i. standard platinum resistance thermometer

Issuing NMI:
University of Ljubljana, Faculty of Electrical Engineering
Laboratory of Metrology and Quality (MIRS/UL-FE/LMK)
Tržaška cesta 25, SI-1000 Ljubljana, Slovenia
Prof. dr. Jovan Bojkovski

TABLE OF CONTENTS

1 Introduction

The subject of this report is the evaluation of a hybrid comparison in the field of temperature measurement. The hybrid comparison was organized by the University of Ljubljana, Faculty of Electrical Engineering, Laboratory of Metrology and Quality.
Technical supervision of this interlaboratory comparison was provided by prof. dr. Jovan Bojkovski, as an expert in the field. The issuing NMI UL-FE/LMK provided equipment for the hybrid comparison. UL-FE/LMK is the Slovenian national standard laboratory for thermodynamic temperature and humidity and is accredited for calibration in the field of temperature and humidity by the Slovenian Accreditation Institute (LK-002). MIRS/UL-FE/LMK, as the national laboratory for thermodynamic temperature and humidity, is an associated member of EURAMET (see http://www.euramet.org) and has its CMCs published in the BIPM KCDB Annex C, https://www.bipm.org/kcdb/.

The test item was packed in the special carrying case and hand carried. The transport didn't affect the circulated item, as can be seen from the stability of the measurements at the triple point of water, made before and after transportation.

2 Specification of the hybrid comparison

The purpose of the hybrid comparison was to compare the results of the participating laboratories through calibration of the standard platinum resistance thermometer by comparison in calibration baths:

The circulating item was:

i. Accumac, type AM1860-25, serial number 1620703, the range of the hybrid comparison was -98 °C to 0 °C

The reported expanded uncertainty of measurement was stated as the standard uncertainty of measurement multiplied by the coverage factor *k*, which corresponds to a coverage probability of approximately 95%. The standard uncertainty of measurement was determined in accordance with the publication EA-4/02 and Evaluation of measurement data – Guide to the expression of uncertainty in measurement JCGM 100:2008.

It was recommended that the participant used its standard procedures during the temperature calibration and, if possible avoid making extra time-consuming measurements, as described in the hybrid comparison protocol.

Prior to the calibration, test measurements (calibration of the standard platinum thermometer in the triple point of water cell) were performed in order to assess stability of the instruments. From the measurements it has been concluded that the thermometer was stable enough and its short-term stability didn't influence the final results of the hybrid comparison.

Calibration was carried out at an ambient temperature of nominal 23 °C. The ambient temperature was reported.

The results were reported electronically.

In the report form, the participant was also asked to fill in details about the applied method, uncertainty analysis, equipment and traceability.

3 Participants

3.1 Issuing NMI

University of Ljubljana, Faculty of Electrical Engineering
Laboratory of Metrology and Quality (UL/FE-LMK),
Tržaška cesta 25, SI-1000 Ljubljana, Slovenia

Contact persons in case of technical or administrative questions:
Prof. dr. Jovan Bojkovski (Coordinator)
Tel.: +386 1 4768 798,
GSM: +386 51 388 659
E-mail: jovan.bojkovski@fe.uni-lj.si

3.2 Applicant NMI

NSAI National Metrology Laboratory (NSAI NML)
Griffith Ave. Extension, Glasnevin
Dublin 11, D11 E527, Ireland

Contact person: Dubhaltach MacLochlainn
Tel.: +353 1 8082647
GSM: +353 857 175 729
E-mail: Dubhaltach.MacLochlainn@nsai.ie

3.3 Time schedule and deadlines

The deadline for the calibrations was determined on a basis of email agreement between the Issuing NMI and the Applicant NMI. The Applicant NMI normally takes care about the transport between both laboratories. In this exceptional case, the Issuing NMI hand-carried the thermometer to the Applicant NMI.

The deadline for reporting the results was 2 weeks after the equipment has left the laboratory. It was important that the deadline was met since the results were being analyzed continuously by the Issuing NMI. If there were any problems or doubt regarding the results of the Applicant NMI, the laboratory would be contacted immediately. Any suspicion that the equipment was defective or had drifted, would lead to return of the equipment to the Issuing NMI, which then would make an extra check and take an appropriate action.

The Issuing NMI acted as the third party, responsible for the final check of the hybrid comparison report. The measurements and analysis of the results were performed in September to December 2019.

4 Results and their uncertainties

The SPRT was calibrated by comparison in the calibration baths at increasing temperatures at the following points:
0,01 °C (triple point of water), -98 °C, -85 °C, -75 °C, -50 °C
At the end the measurement was repeated at 0,01 °C (triple point of water).

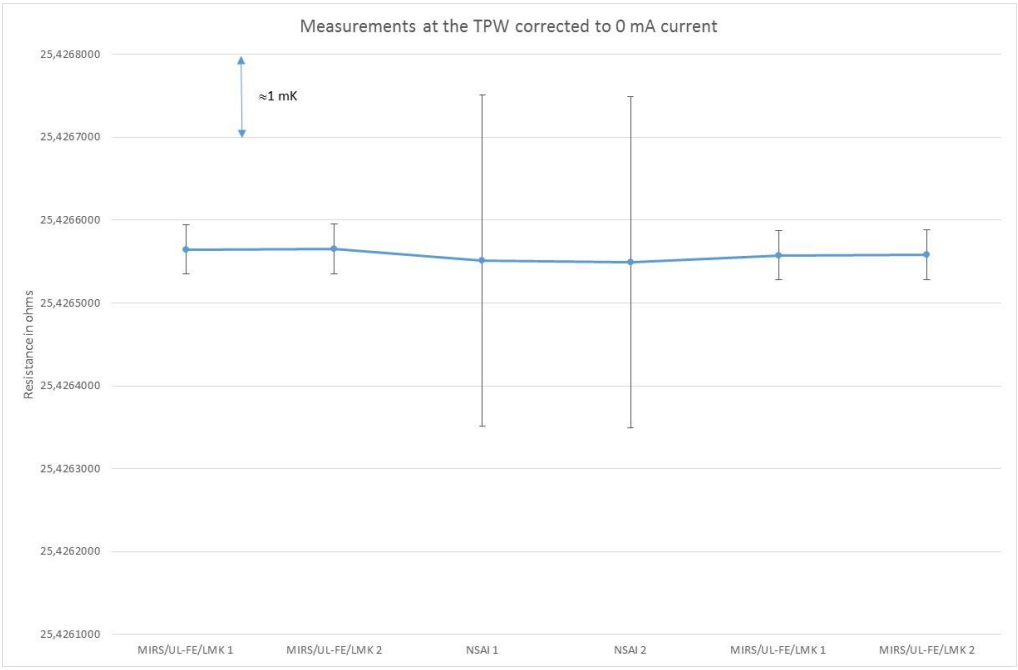


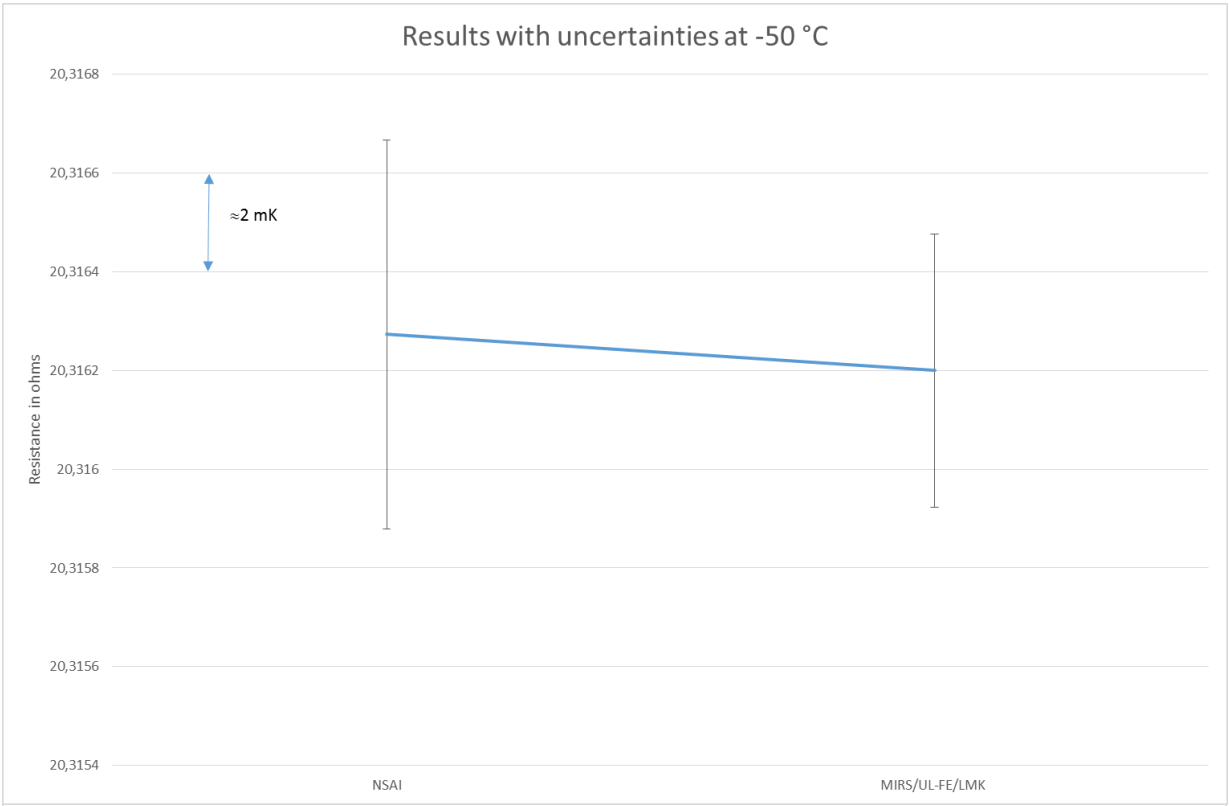
Figure 1: Summary of all the measurements made at the triple point of water (0,01 °C)

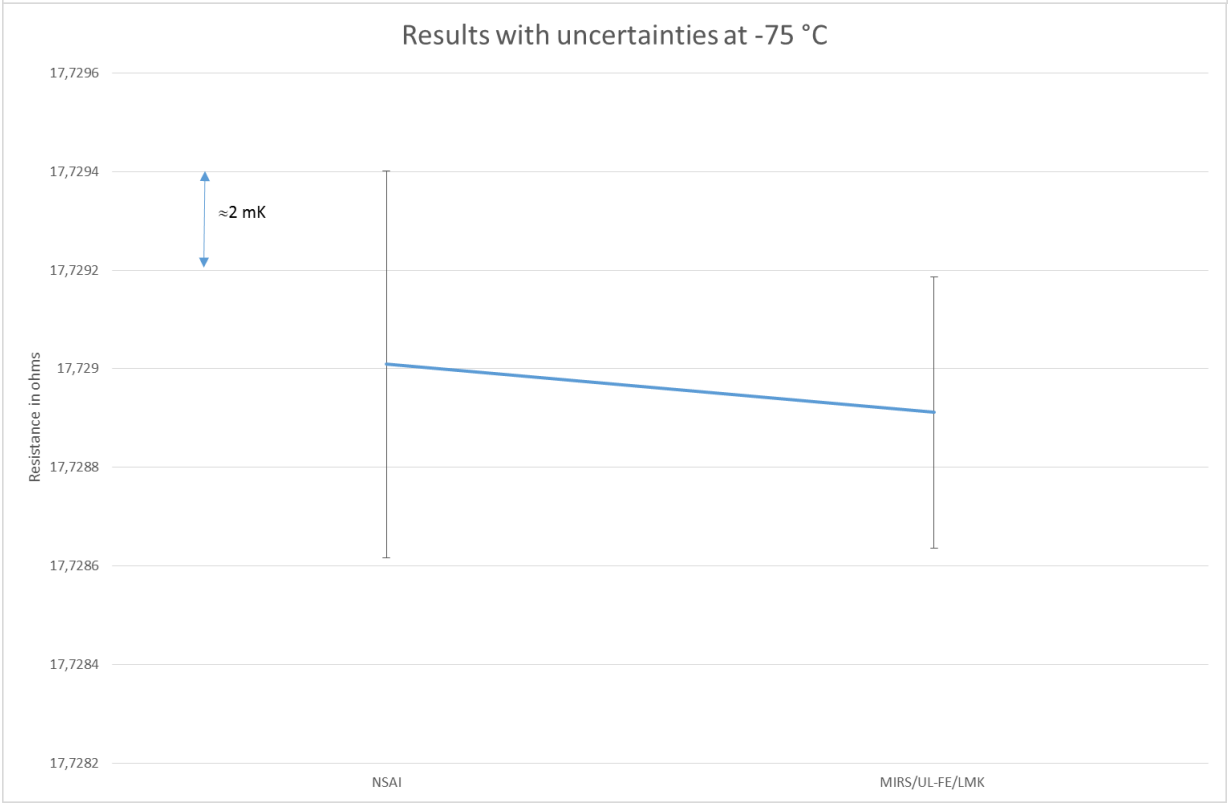
Since measurements at the participating laboratories were not performed at exactly the same temperature, the results of MIRS/UL-FE/LMK at the nominal temperatures of NSAI were calculated from a, b ITS-90 coefficients for temperatures t_{90}<0,01 °C and sensitivity coefficient of the used SPRT. The additional uncertainty due to this was added.

Table 1: Summary of all the results and difference/combined uncertainty.

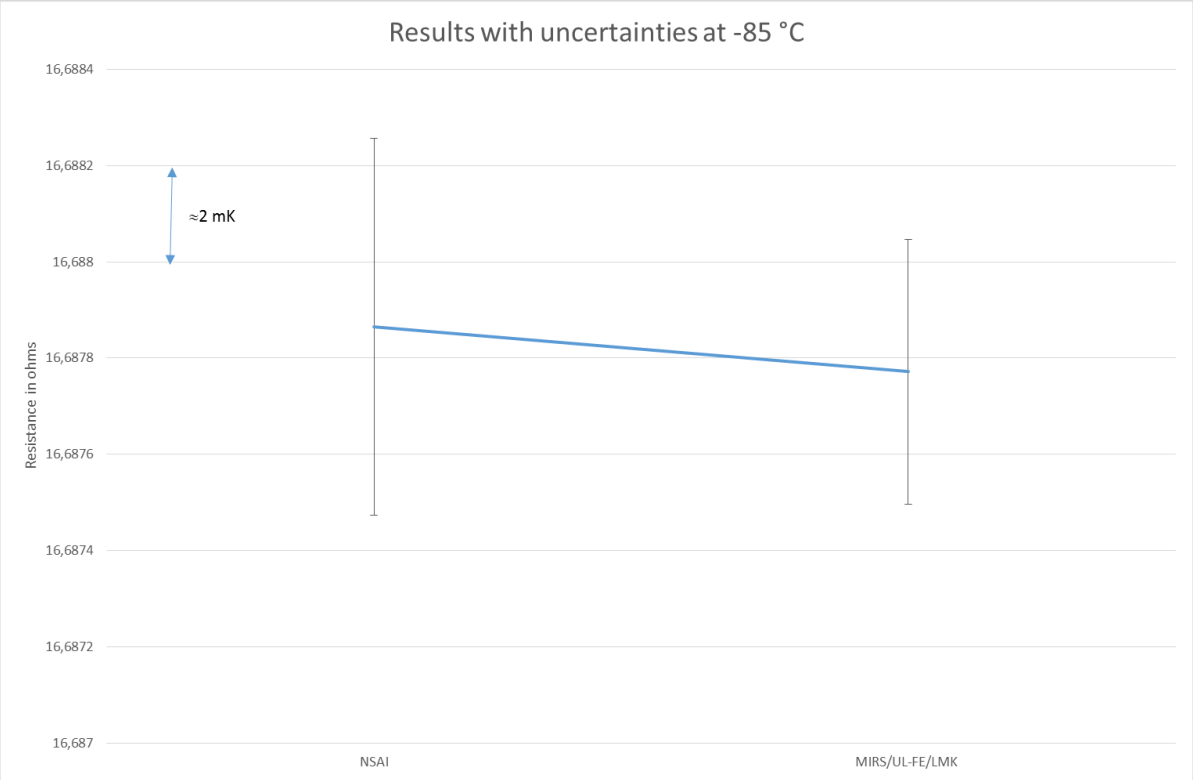
	NSAI		**MIRS/UL-FE/LMK**		
reference temperature	measured resistance	uncertainty	average resistance for reference	uncertainty	difference/combined uncertainty
°C	Ω	Ω	Ω	Ω	
0.01	25.4265503	2.0E-04	25.42656132	3.6E-05	0.05
-98.006544	15.3270734	3.9E-04	15.32698817	2.7E-04	-0.18
-84.999627	16.6878646	3.9E-04	16.68777185	2.7E-04	-0.19
-75.001653	17.7290094	3.9E-04	17.72891186	2.8E-04	-0.20
-49.995360	20.3162731	3.9E-04	20.31620016	2.8E-04	-0,15

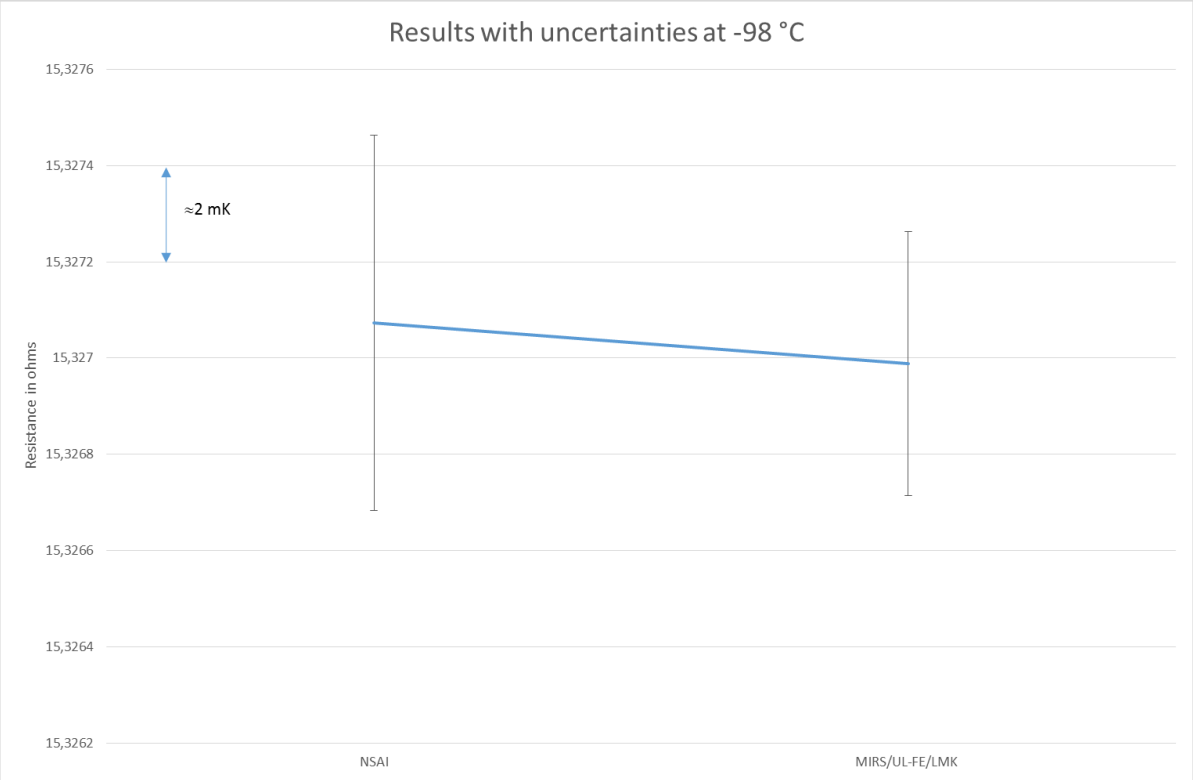
Report of Hybrid comparison with resistance thermometer MIRS/UL-FE/LMK and NSAI 2019





Report of Hybrid comparison with resistance thermometer MIRS/UL-FE/LMK and NSAI 2019





4.1 Measurement Uncertainty

The uncertainty analysis was done in accordance with the GUM (Guide to the Expression of the Uncertainty in Measurement). The following uncertainty contributions were taken into account;

Calibration Uncertainty of reference SPRT This is the uncertainty associated with the calibration of the reference SPRT used to compare to the measurements obtained with the transfer standard.

SPRT drift This is the maximum expected drift of the reference SPRT between calibrations.

Resistance Bridge tolerance This is the maximum allowable deviation in resistance readings of the resistance bridge used to measure the reference SPRT transfer standard.

Standard Resistor Calibration Uncertainty The uncertainty associated with the calibration of the reference standard resistor, used in conjunction with the resistance bridge.

Standard Resistor drift The maximum expected drift of the standard resistor used in the calibration between calibrations.

Temperature Medium Stability The amount of variation in temperature over time associated with the ability of the calibration bath to maintain constant temperature conditions.

Temperature Medium Gradients The variation in temperature within the calibration volume of the calibration bath, due to temperature inhomogeneity in the liquid medium.

Table 2: Summary of all uncertainty contributions

Uncertainty source in mK	MIRS/UL-FE/LMK				NSAI			
	-98 °C	-85 °C	-75 °C	-50 °C	-98 °C	-85 °C	-75 °C	-50 °C
Calibration Uncertainty of reference SPRT	0,75	0,75	0,75	0,75	0,50	0,50	0,50	0,50
SPRT drift	0,29	0,29	0,29	0,29	1,73	1,73	1,73	1,73
Resistance Bridge tolerance	0,06	0,06	0,06	0,06	0,16	0,16	0,16	0,16
Standard Resistor Calibration Uncertainty	0,25	0,25	0,25	0,25	0,25	0,25	0,25	0,25
Standard Resistor drift	0,12	0,12	0,12	0,12	0,23	0,23	0,23	0,23
Temperature Medium Stability	0,25	0,25	0,25	0,25	0,35	0,35	0,35	0,35
Temperature Medium Gradients	1,02	1,02	1,02	1,02	0,29	0,29	0,29	0,29
standard uncertainty	1,35277	1,3528	1,3528	1,3528	1,8956	1,8956	1,8956	1,8956
expanded uncertainty	2,71	2,71	2,71	2,71	3,79	3,79	3,79	3,79

LABORATORIJ ZA METROLOGIJO IN KAKOVOST

Report of Hybrid comparison with resistance thermometer MIRS/UL-FE/LMK and NSAI 2019

Results of hybrid comparison between NSAI and and MIRS-UL/FE-LMK

Name of Laboratory:	MIRS-UL/FE-LMK
Equipment calibrated (date, period):	Accumac AM 1860-25 25 Ω SPRT, SN: 1620703, 3 Sep 2019 to 5 Sep 2019

Initial check in the triple point of water

thermometer resistance	25.4265648	ohm
reference temperature	0.01	°C
uncertainty of the reference temperature	0.0003	°C

Measurement results

Based on measured resistance the participant should calculate ITS-90 coefficients of the calibrated SPRT

Set[1)]	measured resistance [1)]	reference temperature [2)]	*U RT (95%)* [3]	CMC [4)]	Measurement current
°C	Ω	°C	°C	°C	mA
0.01	25.4265648	0.01	0.0003	0.0003	1
-98.0	15.331812	-97.960737	0.0028	0.006	1
-85.0	16.6946302	-84.933909	0.0028	0.006	1
-75.0	17.7340021	-74.952833	0.0028	0.006	1
-50.0	20.3131769	-50.024908	0.0028	0.006	1
0.01	25.4265657	0.01	0.0003	0.0003	1

Ambient temperature	20±5	°C
Ambient relative humidity	15-75	% r.h.

Notes

1)	Average value of measured resistance
2)	Reference temperature of calibration bath or furnace measured by the participant
3)	Expanded uncertainty of calibration
4)	Calibration and measurement capability (CMC)

Description of equipment used

State, if required, details concerning the used calibration procedure

Measurements were made in accordance with internal procedures LMK_CP_GECP_05.05, LMK_CP_ICEP_05.00, LMK_CP_INDT_05.03, LMK_ITS_REA_04.05

Used reference standards and traceability

Reference standards (range)	Traceability*
VSL 17 T 042 Triple Point of Water Cell, (0.01 °C)	Fixed Points, MIRS/UL/FE-LMK
ASL F700B Bridge, serial number 1337 009 449 (-98 °C to +0.01 °C)	SIQ, Slovenia
ASL FR 4, 25 ohm reference resistor, serial number 015522	SIQ, Slovenia
Fluke 25 Ω SPRT, SN: 0847 (-98 °C to -50 °C)	Fixed Points, MIRS/UL/FE-LMK

* by comparison or fixed points, institute/laboratory

Used auxiliary measurement equipment and traceability

Auxiliary measurement equipment (range)	Traceability*
Omega Ambient Monitoring System (See amibient conditions above)	By comparison, MIRS/UL/FE-LMK

* by comparison or primary calibration, institute/laboratory

LABORATORIJ ZA METROLOGIJO IN KAKOVOST

Report of Hybrid comparison with resistance thermometer MIRS/UL-FE/LMK and NSAI 2019

Results of hybrid comparison between NSAI and and MIRS-UL/FE-LMK

Name of Laboratory:	NSAI
Equipment calibrated (date, period):	Accumac AM 1860-25 25 Ω SPRT, SN: 1620703, 10 Sep 2019 to 11 Sep 2019

Initial check in the triple point of water

thermometer resistance	25.4265506	ohm
reference temperature	0.01	°C
uncertainty of the reference temperature	0.002	°C

Measurement results

Based on measured resistance the participant should calculate ITS-90 coefficients of the calibrated SPRT

Set[1)]	measured resistance [1)]	reference temperature [2)]	*U RT (95%)* [3]	CMC [4)]	Measurement current	
°C	Ω	°C	°C	°C	mA	
0.01	25.4265506	0.01	0.002	0.002	1	Initial
0.01	25.4265881	0.01	0.002	0.002	√2	Root(2)
0.01	25.4265516	0.01	0.002	0.002	1	Repeat
0.01	25.4265511	0.01	0.002	0.002	1	Average 1 mA
0.01	25.4265141	0.01	0.002	0.002	0	Zero Current
-98.0	15.3270734	-98.006544	0.004		1	
-85.0	16.6878646	-84.999627	0.004		1	
-75.0	17.7290094	-75.001653	0.004	0.004	1	
-50.0	20.3162731	-49.995360	0.004	0.004	1	
0.01	25.4265495	0.01	0.002	0.002	1	
0.01	25.4265125	0.01	0.002	0.002	0	Zero Current

Ambient temperature	20±2	°C
Ambient relative humidity	44±5	% r.h.

Notes

1)	Average value of measured resistance
2)	Reference temperature of calibration bath or furnace measured by the participant
3)	Expanded uncertainty of calibration
4)	Calibration and measurement capability (CMC)

Description of equipment used

State, if required, details concerning the used calibration procedure

Used reference standards and traceability

Reference standards (range)	Traceability*
Hart 5901A Triple Point of Water Cell, Serial Number: Q-1011 (0.01 °C)	Fixed Points, NPL
Fluke 1595A Bridges, SN: B16047, B17052 (-98 °C to +0.01 °C)	Electrical Section, NSAI
Tinsley 100 Ω Standard Resistor, SN: 260092 (0.01 °C)	Electrical Section, NSAI
Tinsley 100 Ω Standard Resistor, SN: 270757 (0.01 °C)	Electrical Section, NSAI
Tinsley 100 Ω Standard Resistor, SN: 263428 (-98 °C to -50 °C)	Electrical Section, NSAI
Accumac 25 Ω SPRT, SN: 1620470 (-98 °C to -50 °C)	Fixed Points, NPL

* by comparison or fixed points, institute/laboratory

Used auxiliary measurement equipment and traceability

Auxiliary measurement equipment (range)	Traceability*
Systemteknik Readout and Pt100 PRT SN: 3386, 101 (0.01 °C)	By comparison, NSAI
Hart 1521 Thermometer Readout with Pt100 SN: 761039, File: 0731 (-98 °C to -50 °C)	By comparison, NSAI
Hanwell Radiolog Ambient Monitoring System (See amibient conditions above)	By comparison, NSAI

* by comparison or primary calibration, institute/laboratory

LMK LABORATORIJ ZA METROLOGIJO IN KAKOVOST

Report of Hybrid comparison with resistance thermometer MIRS/UL-FE/LMK and NSAI 2019

Results of hybrid comparison between NSAI and and MIRS-UL/FE-LMK

Name of Laboratory:	MIRS-UL/FE-LMK
Equipment calibrated (date, period):	Accumac AM 1860-25 25 Ω SPRT, SN: 1620703, 18 Sep 2019 to 20 Sep 2019

Initial check in the triple point of water

thermometer resistance	25.4265578	ohm
reference temperature	0.01	°C
uncertainty of the reference temperature	0.0003	°C

Measurement results

Based on measured resistance the participant should calculate ITS-90 coefficients of the calibrated SPRT

Set[1)]	measured resistance [1)]	reference temperature [2)]	*U RT (95%)* [3]	CMC [4)]	Measurement current
°C	Ω	°C	°C	°C	mA
0.01	25.4265578	0.01	0.0003	0.0003	1
-98.0	15.3302787	-97.975192	0.0028	0.006	1
-85.0	16.682302	-85.051625	0.0028	0.006	1
-75.0	17.703362	-75.247457	0.0028	0.006	1
-50.0	20.3195432	-49.962785	0.0028	0.006	1
0.01	25.426558	0.01	0.0003	0.0003	1

Ambient temperature	20±5	°C
Ambient relative humidity	15-75	% r.h.

Notes

1)	Average value of measured resistance
2)	Reference temperature of calibration bath or furnace measured by the participant
3)	Expanded uncertainty of calibration
4)	Calibration and measurement capability (CMC)

Description of equipment used

State, if required, details concerning the used calibration procedure

Measurements were made in accordance with internal procedures LMK_CP_GECP_05.05, LMK_CP_ICEP_05.00, LMK_CP_INDT_05.03, LMK_ITS_REA_04.05

Used reference standards and traceability

Reference standards (range)	Traceability*
VSL 17 T 042 Triple Point of Water Cell, (0.01 °C)	Fixed Points, MIRS/UL/FE-LMK
ASL F700B Bridge, serial number 1337 009 449 (-98 °C to +0.01 °C)	SIQ, Slovenia
ASL FR 4, 25 ohm reference resistor, serial number 015522	SIQ, Slovenia
Fluke 25 Ω SPRT, SN: 0847 (-98 °C to -50 °C)	Fixed Points, MIRS/UL/FE-LMK

* by comparison or fixed points, institute/laboratory

Used auxiliary measurement equipment and traceability

Auxiliary measurement equipment (range)	Traceability*
Omega Ambient Monitoring System (See amibient conditions above)	By comparison, MIRS/UL/FE-LMK

* by comparison or primary calibration, institute/laboratory