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GULFMET.PR-K4.2021.2

Luminous flux

KEY COMPARISON

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GULFMET Bilateral comparison GULFMET.PR-K4.2021.2 between TÜBITAK UME and NIS for

Luminous Flux.

Final Report

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ABSTRACT

This report describes the Bilateral Comparison GULFMET.PR-K4.2021.2 between TÜBİTAK UME and NIS for Luminous Flux, conducted by the Regional Metrology Organization "the Gulf Association for Metrology" (GULFMET). The comparison was, in fact, a combination of two bilateral comparisons with the same link/pilot laboratory – TÜBITAK Ulusal Metroloji Enstitüsü (TÜBITAK UME), Türkiye. The non-link laboratories were the National Measurement and Calibration Center at Saudi Standards, Metrology and Quality Organization (SASO NMCC), The Kingdom of Saudi Arabia, and the National Institute of Standards (NIS), Egypt. The comparison was registered as GULFMET.PR-K4.2021, and based on CCPR WG-KC feedback to avoid confusion, two separate reports have been prepared. Accordingly, a separate report has been prepared regarding the comparison of luminous flux between TÜBİTAK UME and SASO-NMCC (GULFMET.PR-K4.2021.1).

The aim of the comparison was to link the NIS measurement result to the CIPM key comparison CCPR-K4, conducted by the Consultative Committee for Photometry and Radiometry (CCPR).

Three Polaron LF200W type of the lamps, produced as the transfer standard for luminous flux measurements and belonging to the pilot laboratory, were used as artefacts. The sequence of measurements was pilot – participant – pilot.

The analysis of the comparison was performed following the approach described in the Appendix A of the Guidelines for CCPR and RMO Bilateral Key Comparisons (CCPR-G5).

CONTENTS

1 Introduction

This report describes the bilateral comparison (GULFMET.PR-K4) on luminous flux between The Scientific and Technological Research Council of Turkey – National Metrology Institute (TÜBITAK UME) and National Institute of Standards (NIS) in the frame of the Project of Development and Realization Measurement and Calibration System as a GULFMET bilateral comparison. This key comparison was carried out under the auspices of the Gulf Association for Metrology (GULFMET), which is the Regional Metrology Organization (RMO) established under the auspices of GCC Standardization Organization (GSO). According to paragraphs T.8 and T.9 of the MRA, a bilateral key comparison was carried out between two institutes as outlined in CIPM Guideline for key comparisons [1]. The scheme for performing comparisons within the framework of EURAMET is presented in Euramet Guidelines on Conducting Comparisons [2]. RMO key comparisons in the field of photometry and radiometry are performed in accordance with the Guidelines for CCPR and RMO Bilateral Key Comparisons (CCPR-G5) [3] and Guidelines for RMO PR Key Comparisons (CCPR-G6) [4].

In 1997, the Comite International des Poids et Mesures (CIPM) had initialized two key comparisons CCPR-K3a of luminous intensity and CCPR-K4 of luminous flux with the Physikalisch-Technische Bundesanstalt (PTB), Germany, acting as pilot laboratory. The maintained units of 16 national metrological laboratories and of the Bureau International des Poids et Mesures (BIPM) were compared in a 'star-type' structure, using more than 200 lamps as transfer standards. The results of these comparisons are key comparison reference values (KCRV) for the two quantities. All results were published1 in 1999 and the DOEs are listed in the data base [5] of the BIPM.

In 2010, under the auspices of the European Association of National Metrology Institutes (EURAMET) as the RMO two international key comparisons on luminous intensity (EURAMET.PR-K3.a) and luminous flux (EURAMET.PR-K4) were carried out [6]. The units are transferred by batches of incandescent lamps from the participants to the pilot laboratory, the PTB. When it was decided to carry out the EURAMET Key Comparison, the Institute National de Métrologie (BNM-INM / CNAM, France) and the Instituto Nazionale di Ricerca Metrologica (INRIM, Italy) agreed to act as link laboratories for both units. Key comparisons are intended to determine the Degrees of Equivalence (DoE) for each non-link participant and the associated expanded uncertainty. The DoE for a quantity states for a participant the relative difference of his value with the related Key Comparison Reference Value (KCRV).

In 2015, under the auspices of EURAMET as RMO, one bilateral key comparison on luminous flux (EURAMET.PR-K4.3) was organised. The participants for this bilateral comparison were IO-CSIC and TÜBITAK UME. IO-CSIC was a link laboratory (IO-CSIC participated in CCPR-K4) and TÜBITAK UME is linked to the CCPR-K4 KCRV [7].

On the bases of the referenced documents, the luminous flux comparison between TÜBITAK UME and NIS was carried out within the scope of GULFMET.PR-K4, whose technical protocol was approved by WG-KC of CCPR in November 2021 [8]. TÜBITAK UME (Türkiye) acts as pilot and linking laboratory for this comparison (TÜBITAK UME is connected to CCPR-K4 through EURAMET.PR-K4.3 comparison [7]). TÜBITAK UME is responsible for developing the comparison protocol, registering the comparison, for Pre-Draft A and subsequent work. This bilateral comparison is intended to determine the Degree of Equivalence (DoE) for the participant (NIS (Egypt)) and its associated expanded uncertainty. The DoE sets the relative difference of the participant (NIS (Egypt)) measurement results to the KCRV, which was determined in the CCPR-K4 key comparison. Since CCPR-K4, KCRV are maintained by the participants of CCPR-K4. TÜBITAK UME transfers its maintained values by a set of lamps to NIS.

A third party (CCPR-WG-KC Secretary) was designated for the comparison, and all the measurement results (from the non-link laboratories (NIS (Egypt)) and the linking laboratory (TÜBITAK UME)) were submitted to the third party upon completion of each measurement cycle, to ensure blindness of the comparison. At completion of all measurements, the third party sent all the data received to the linking laboratory.

This document reports the final results of the bilateral comparison of luminous flux between TÜBITAK UME and NIS, and comparison with the KCRV and the DoE for the non-link laboratory. All main information, the data collection and the evaluation are given in the following sections, and are supplemented with more details in the Appendix.

2 GENERAL INFORMATION

2.1 List of Participants

The acronyms of the participating are listed in the first column of Table 1. The names of the institute and the contact person with the e-mail address are given in the second column. The third column shows the country and the city of each participant. In the last column, role of each laboratory is entered.

Table 1. List of participant and contact information

Acronym	**Institute name** ***Contact person / Email***	**Country** ***City***	**Role**
TÜBITAK UME	TÜBITAK Ulusal Metroloji Enstitüsü Ferhat Sametoglu, Email : ferhat.sametoglu@tubitak.gov.tr	Türkiye *Kocaeli*	Pilot
NIS	National Institute of Standards Ahmed Eid Gaballah, Email : gaballah.nis@gmail.com	Egypt *Giza*	Participant

2.2 Time Schedule

Preparation of full protocol agreed by participants was finished in October 2021 and protocol and notification of the comparison were sent to GULFMET TC-PR Chairman in October 2021. In November 2021, the protocol was approved by CCPR-WG-KC and registered at KCDB. According to the protocol, the comparison was carried out in the form of a star comparison. After that, the first measurements of three luminous flux lamp standards were performed at TÜBITAK UME in December 2022 and then information about the measurement results with expanded uncertainties were sent to the third party (Joële Viallon, jviallon@bipm.org) via email. After that the lamps were sent to NIS. NIS started measurements late due to declared financial resource problems. This situation has been reported to the third party (Joële Viallon, jviallon@bipm.org) via email. Therefore, there was a delay in the comparison process. Measurements at NIS were performed in May 2023 and information about the measurement results with expanded uncertainties were sent to the third party (Joële Viallon, jviallon@bipm.org) via email. Subsequently, the lamps were returned to TÜBITAK UME, in where the second measurements were performed in July 2023 and obtained results were sent to third party (Joële Viallon, jviallon@bipm.org) via email (10 July 2023). After collection of all the results, the third party sent all the data to the pilot laboratory (TÜBITAK UME), which implemented Pre-Draft A procedures.

When the Pre-Draft A procedures were completed in October 2023, TÜBITAK UME prepared the Draft A report following the CCPR Guideline G5 “Guidelines for CCPR and RMO Bilateral Key Comparisons”. Subsequently, Draft B report following the CCPR Guideline G5 “Guidelines for CCPR and RMO Bilateral Key Comparisons” was prepared and sent for approval in November 2023. Draft B report was revised and resubmitted for review in light of the CCPR-WG-KC feedback received in September 2024. All comments have been considered and the report is deemed approved.

2.3 Comparison Artefact (Transfer Standard)

In the comparison, three Polaron LF200W type of the lamps produced as the transfer standard for luminous flux measurements were used (serial numbers: 352, 353 and 355). A picture of one of the lamps is shown in Figure 1.

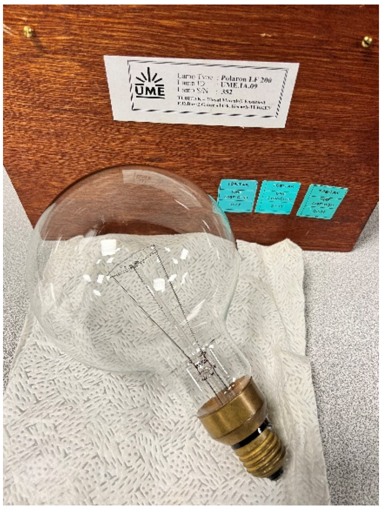

Figure 1. Image of transfer standard lamp (Polaron LF200W) used for GULFMET.PR-K4.2021.

The measurement artefacts were provided by the pilot laboratory (TÜBITAK UME) and were hand-carried by expert personnel for the comparison measurements. Additional information of the LF200W lamps is given below:

- Lamp base: E27 Edison screw base.
- Nominal luminous flux: 1900 lm.
- Rated operating current: around 2 A. Rated operating voltage: around 90 V.
- Typical value of CCT (or distribution temperature): 2740 K.

2.4 Measurement Conditions

The measured quantity was the luminous flux of a lamp. This photometric quantity was measured for the defined operating conditions of each lamp, where the operating current acted as the setting parameter. The lamps were powered by a DC power supply with the polarity as it was defined at TÜBITAK UME. The exact values of the lamps operating current and voltage were measured and reported by the participants. The measurements were carried out under appropriate laboratory conditions with the room temperature staying between 19 ºC and 25 ºC. The operating DC current, the lamp voltage and the color temperature were recorded and reported together with the measured luminous flux values. The luminous flux of the lamps was measured independently three times. Each independent measurement was carried out for the lamp being realigned in the measurement facility and being switched off and on after a break of two hours for each lamp. In all laboratories, all lamps were measured using an integrating sphere based measurement system. The lamps were vertically installed in the center of the sphere, the lamp cap pointing upwards. The photometer/spectrometer used with the sphere did not receive direct radiation from the lamp. The lamps were aligned following the usual laboratory procedures. Before installing in the facility, the lamps were inspected for damage or contamination of the lamp bulb or cap. No damage or contamination was recorded during the comparison.

No drift of the traveling lamps was noticed during the period of the comparison. Therefore no drift correction and corresponding uncertainty were applied.

3 Measurements performed at NIS

The luminous flux of these lamps was measured using the NIS integrating sphere model (LMT) with a diameter of 2.5 m, a schematic diagram of the integrating sphere is shown in Figure 2. The sphere is equipped with V(λ) cosine corrected detector, a baffle screen, an auxiliary lamp, and a temperature sensor. The LMT standard photometer with an opal glass diffuser is used as the V(λ) corrected detector connected with a photometer display unit model (U1000). The sphere wall was coated with barium sulphate paint with a diffuse reflectance of approximately 0.97 in the visible region. Based on these characteristics, the total luminous flux can be measured in direct substitution with standard lamps of any wattage. The integrating sphere is also equipped with an auxiliary tungsten lamp of 100 W placed on the sphere wall to measure the self-absorption effects of a lamp under test.

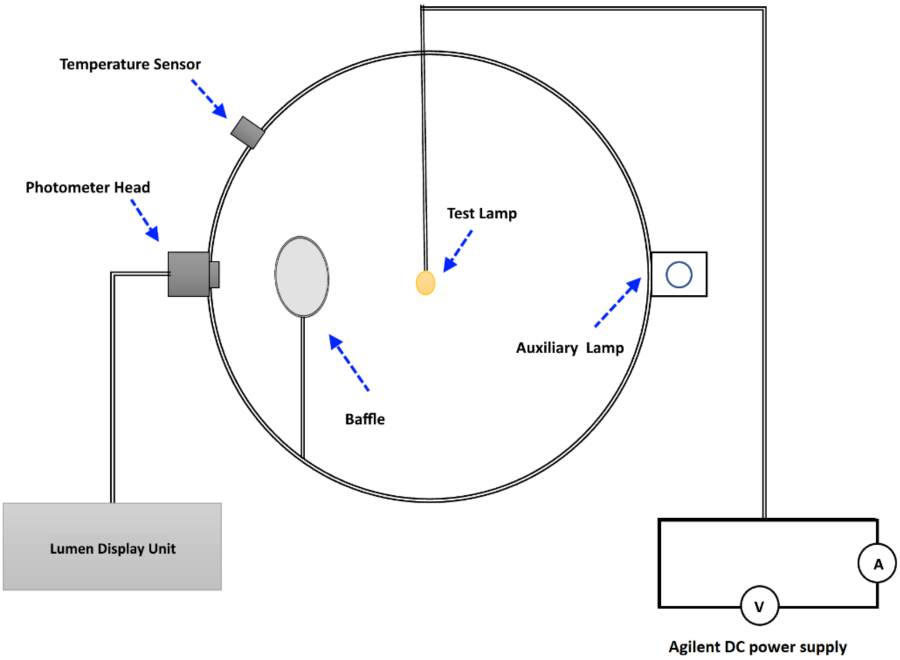

Figure 2. Luminous Flux Measurement System of NIS

3.1 Measurement Conditions

The total luminous flux was determined using LMT U1000 photometer with a spectral responsivity correction to correspond to the V(λ) equipped with cosine correction diffusers, 4 digits attenuator, calibrated for spectral irradiance at PTB with expanded uncertainty of 0.6 %. The tested lamps were compared with a group of specially constructed NPL calibrated tungsten filament standard lamps with 0.7 % expanded uncertainty at k = 2 and with colour temperature close to the colour temperature of the test lamps measured by optronic FMS 10 X-Rite tristimulus colorimeter calibrated at Magna Technologies Inc. traceable to the PTB with expanded uncertainty of 0.5 % in color temperature.

3.2 Geometric Conditions

The measurements were performed at Photometry Metrology Laboratory using integrating sphere photometer (LMT) with a diameter of 2.5 m, The lamp holder moves vertically up and down for lamp adjustment to the centre of the sphere.

3.3 Electrical Conditions

The lamps were operated at fixed polarity using Agilent N5770A DC power supply at stabilized current mode with a current stability of better than 0.01 % during the testing period. The power supply was calibrated at the High Voltage Laboratory, NIS, Egypt with traceability to NVLAP. The lamp current was measured by Keithley 2182A Nanovoltmeter across the 0.1 Ω standard resistance calibrated at NIS with expanded uncertainty equal to 0.8 ppm all traceable to NVLAP Accredited calibration laboratory.

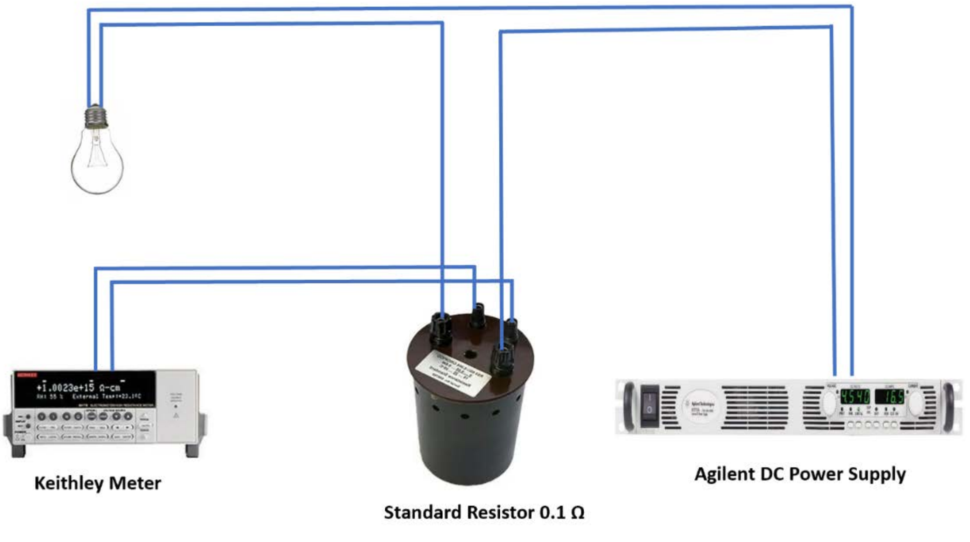

Figure 4. Electrical connection for Flux Measurement System of NIS

3.4 Thermodynamic Conditions

The environmental conditions were controlled by an air conditioner set at 24 °C. The temperature was measured using a digital thermocouple at random locations inside the sphere.

3.5 Temporal Conditions

The lamp's stabilization time is determined by the stability of the lamp output parameters at its current nominal values (average 20 to 30 minutes).

3.6 Determination of the Luminous Flux

The total luminous flux was measured using a 2.5 m diameter NIS integrating sphere and the direct luminous flux reading this LMT U1000 photometer with a spectral responsivity correction to correspond closely to the V(λ) equipped with cosine correction diffusers, four-digits attenuator, and a temperature sensor, calibrated for spectral irradiance at PTB with expanded uncertainty of 0.6 %. the tested lamps were compared with a group of specially constructed NPL calibrated tungsten filament standard lamps with 0.7 % expanded uncertainty at k =2 and with color temperature close to the color temperature of the test lamps measured by optronic FMS 10 X-Rite tristimulus colorimeter calibrated at Magna Technologies Inc. traceable to the PTB. With expanded uncertainty of 0.5 % in color temperature.

3.7 Reporting of the Results

Luminous Flux Results performed at NIS:

Values obtained by NIS for luminous flux of the comparison transfer standard lamps are presented in Table 2 (more details are given in the Appendix section).

Table 2. Comparison measurement results of NIS within the scope of GULFMET.PR-K4.2021.

Lamp No.	**Lamp current** I **/ A**	**Luminous flux** Φ **/ lm**
352	1.9000	1928
353	1.9000	1863
355	1.9000	1893

3.8 Uncertainty of Measurements

Table 3 shows the uncertainty budget in measurements of luminous flux al NIS.

Table 3. Uncertainty Budget of NIS for the Determination of Luminous Flux

Source of uncertainty	**Standard uncertainty (%)**
Sphere Reflectance factor	0.40
Sphere Spatial non-uniformity	0.0080
Absorption measurements	0.010
Luminous flux of reference lamp	0.35
Stability of lamp current	0.030
Mismatch index of lamp current	0.021
Distribution temperature	0.050
Photometer temperature coefficient	0.010
Non-linearity	0.010
Mismatch index of distribution temperature	0.10
Temperature coefficient of shunt resistance	0.020
Repeatability	0.20
Combined standard uncertainty (k = 1)	0.58
Combined expanded uncertainty (k = 2)	1.2

4 Measurements performed at TÜBITAK UME

For the bilateral comparison GULFMET.PR-K4, TÜBITAK UME used the same standard luminous flux facility that was used during EURAMET.PR-K4.3 [7]. The luminous flux measurements were carried out using a 2 m in diameter integrating sphere, by direct substitution with standard lamps. The integrating sphere is equipped with a V(λ)-corrected, cosine corrected photometer, a baffle screen, an auxiliary lamp and a temperature sensor. A baffle of 38 cm in diameter is set to a distance of about 1/3 of the distance from the detector to the sphere centre. The integrating sphere is also equipped with an auxiliary lamp (100 W / 24V, tungsten) on the sphere wall. It is used to measure the self-absorption effects of a lamp in the sphere. A temperature sensor is mounted at the back side of the baffle, and the air temperature inside the sphere during measurements is monitored.

Since EURAMET.PR-K4.3 the KCRV has been maintained at TÜBITAK UME by means of a group of luminous flux standard lamps. The lamps were compared with each other at least once every two years. These measurements allowed to estimate an uncertainty $u_{TÜBITAK\ UME,st}$ associated with stability of TÜBITAK UME scale between EURAMET.PR-K4.3 and GULFMET.PR-K4:

$$u_{\text{TÜBITAK UME,}} = 0.46\%$$

At TÜBITAK UME, the lamps were devices by substitution method as comparison with two standard lamps. The three lamps are a part of a larger batch of lamps maintaining the luminous flux unit realized at TÜBITAK UME. The results of TÜBITAK UME measurements of luminous flux for the GULFMET.PR-K4 comparison lamps are presented in Table 4 (more details are given in the Appendix section).

Table 4. Comparison measurement results of TÜBITAK UME with NIS within the scope of GULFMET.PR-K4.2021

Lamp No.	Lamp current I / A	Luminous flux Φ / lm	
		Before	After
352	1.9000	1911	1915
353	1.9000	1845	1851
355	1.9000	1877	1881

Total random uncertainty of TÜBITAK UME measurement during the GULFMET.PR-K4 comparison consists of the following components: reproducibility of the independent measurements, instability of lamp power supply and self-absorption correction. Same facility was used during EURAMET.PR-K4.3, then we assume that the random uncertainty was the same during both comparisons. Budget of the random uncertainty is presented in Table 5.

The measurements at TÜBITAK UME were carried out at room temperature of (23.0 ± 1.0) °C and humidity of (45.0 ± 10.0) %rh.

Table 5. Budget of random uncertainty (uncorrelated effects) of TÜBITAK UME measurements during EURAMET.PR-K4.3 and GULFMET.PR-K4.

Source of uncertainty	Relative standard uncertainty of luminous flux, %
Repeatability of independent measurements	0.030
Power supply instability	0.030
Self-absorption correction	0.020
Total random uncertainty $U_{TÜBITAK\ UME,\ r}$	**0.047**

5 LINK TO THE CCPR KCRV

5.1 Summary of Measurement Results

The luminous flux values measured between TÜBITAK UME and NIS are summarized in Table 6.

Table 6. The results of the measurements for all three lamps by TÜBITAK UME and NIS

Lamp serial number	**Current I / A**	**Luminous flux / lm**		
		NIS $\Phi_{NIS,i}$	**TÜBITAK UME before** $\Phi_{TÜBITAK\ UME,i}$	**TÜBITAK UME after** $\Phi_{TÜBITAK\ UME,i}$
352	1.9000	1928.2	1911	1915
353	1.9000	1862.8	1845	1851
355	1.9000	1893.2	1877	1881

5.2 Degree of Equivalence of NIS

Unilateral Degree of Equivalence (DoE) was evaluated in accordance with the Equation (2) of the "Guide for CCPR and RMO Bilateral Key Comparisons (CCPR-G5) [3]

$$D_{NIS} = D_{TÜBITAK\ UME} + {}^{y_{NIS}}/_{y_{TÜBITAK\ UME}} - 1$$

Where

- D_{NIS} is the unilateral DoE for NIS
- $D_{TÜBITAK\ UME}$ = 0.65% is the unilateral DoE for TÜBITAK UME, calculated during the EURAMET.PR-K4.3 [7]
-
- ${}^{y_{NIS}}/_{y_{TÜBITAK\ UME}} - 1 = \bar{\Delta}$ is the average value of the ratio between the NIS result and the TÜBITAK UME average result for the 3 lamps that have circulated in this bilateral comparison, subtracting unity to obtain DoE.

The mean values and the relative differences are presented in Table 7.

Table 7. Results of the comparison between NIS values and TÜBITAK UME values.

Lamp **Serial number**	**Current** ***I* / *A***	**Luminous flux / lm**		**Relative difference**
		TÜBITAK UME $\Phi_{TÜBITAK\ UME}$	**NIS** $\Phi_{IO\text{-}CSIC,i}$	
352	1.9000	1913	1928	0.00795
353	1.9000	1848	1863	0.00801
355	1.9000	1879	1893	0.00754
			Mean difference $\bar{\Delta}$ =	**0.00783**

then

$$D_{NIS} = 0.65\% + 0.78\% = 1.43\%$$

5.3 Uncertainty of DoE

The uncertainty on the unilateral degree of equivalence of a participant non-link laboratory is calculated according to the following equation

$$u^2(D_{\text{non-link lab}}) = u^2_{\text{non-link lab}} + \underbrace{u^2(x_{\text{ref}})}_{\text{CCPR-K4}} + \underbrace{u^2_{\text{link}}}_{\text{linking quality}} + \underbrace{u^2_{BC}}_{\text{Bilateral Comparison}}$$

Where

1) $u_{\text{non-link lab}}$ is the total standard uncertainty of the non-link laboratory for a single artifact. This includes uncertainties due to both correlated and uncorrelated effects. According to uncertainty budgets given in the Section 3.8:

$$u_{NIS} = 0.58\%$$

2) $u(x_{\text{ref}})$ is the relative standard uncertainty associated with the Key Comparison Reference Value ($u(x_{\text{ref}})$ = 0.1% see KCDB on BIPM website).

3) The third contribution considers the quality of the link provided by the link laboratory

$$u_{link}^2 = u_{\text{TÜBITAK UME,st}}^2 + u_{\text{TÜBITAK UME,EURAMET.PR-K4.3}}^2 + u_{\text{TÜBITAK UME,BC}}^2$$

It includes

- The standard uncertainty associated with stability (reproducibility) of the link laboratory's scale between the EURAMET.PR-K4.3 and BC, $u_{\text{TÜBITAK UME,st}}$
- The standard uncertainty associated with uncorrelated effects (random uncertainty) of the link laboratory during the EURAMET.PR-K4.3, $u_{\text{TÜBITAK UME,EURAMET.PR-K4.3}}$
- The standard uncertainty associated with uncorrelated effects (random uncertainty) of the link laboratory during the BC, $u_{\text{TÜBITAK UME,BC}}$

These three components were analyzed in the Section 4 and estimated as 0.46%, 0.047% and 0.047% respectively.

4) The last contribution u_{BC} (in CCPR-G5 it's represented by the symbol s_{BC}) is the bilateral comparison effect. The only effect that we can consider as BC effect is instability of the artifact. We estimated the standard uncertainty associated with the lamp's instability as the maximum drift of all three lamps (Table 4). Therefore this value for NIS is given below:

$$u_{BC,NIS} = 0.33\ \%$$

Combining all estimated components, we can calculate the target uncertainties for the participant non-link laboratory:

$$u(D_{SASO\ NIS}) = \sqrt{0.58^2 + 0.10^2 + 0.46^2 + 0.047^2 + 0.047^2 + 0.33^2} = 0.82\%$$

The expanded uncertainties of the non-link laboratory was obtained as follows:

$$U(D_{NIS}) = 2u(D_{NIS}) = 1.6\%$$

6 SUMMARY OF COMPARISON RESULTS

The determined degree of equivalences of the non-link laboratory (NIS) and its associated expanded uncertainty are summarized in Table 8.

Table 8. Degrees of equivalence (DoE) and associated expanded uncertainties of non-link laboratories participating in the luminous flux comparison (GULFMET.PR-K4.2021.2)

Non-link Laboratory	DoE $D_{non\text{-}link\ laboratory}$	Expanded uncertainty (k = 2) $U(D_{non\text{-}link\ laboratory})$
NIS	1.43%	1.6%

7 LITERATURE

[1] Guidelines for CIPM key comparisons, 1 March 1999

[2] Guide No.3, Euramet Guidelines on Conducting Comparisons Ver 02.7 (2002)

[3] Guidelines for CCPR «Guidelines for CCPR and RMO Bilateral Key Comparisons»(CCPR-G5, October 10th, 2014).

[4] Guidelines for RMO PR Key Comparisons (CCPR-G6 Version 1.0, 10 October 2014)

[5] CCPR-K4 report, http://kcdb.bipm.org/appendixB/appbresults/ccpr-k4/ccpr-k4.pdf.

[6] BIPM database: http://kcdb.bipm.org/appendixB/appbresults/EURAMET.PR-K3.a/EURAMET.PR-K3.a_Technical_Protocol.pdf

[7] A. Pons, J. Campos, F. Sametoglu. Bilateral comparison of luminous flux (EURAMET.PR-K4.3), Final Report, February 2019.

[8] https://www.bipm.org/kcdb/comparison?id=1789

8 Appendix

8.1 Detailed measurements results

8.1.1 Measurements results at TÜBITAK UME (round 1)

Lamp S. No	Current I (A) ± U(A)	Voltage U (V) ± U(V)	Luminous Flux Φ (lm) ± U(lm)	Correlated Color Temperature T (K) ± U(K)
352	1.90000 ± 0.00023	86.5070 ± 0.0030	1913 ± 33	2753 ± 25
			1909 ± 33	2752 ± 25
			1910 ± 33	2752 ± 25
		average	**1911 ± 33**	**2752 ± 25**
353	1.90000 ± 0.00022	86.0681 ± 0.0031	1846 ± 32	2730 ± 25
			1843 ± 32	2730 ± 25
			1847 ± 32	2730 ± 25
		average	**1845 ± 32**	**2730 ± 25**
355	1.90000 ± 0.00023	87.7782 ± 0.0032	1879 ± 33	2745 ± 25
			1873 ± 33	2745 ± 25
			1880 ± 33	2745 ± 25
		average	**1877 ± 33**	**2745 ± 25**

8.1.2Measurements results at NIS

Lamp S. No	Current *I* (A) ± *U*(A)	Voltage *U* (V) ± *U*(V)	Luminous Flux *Φ* (lm) ± *U*(lm)	Correlated Color Temperature *T* (K) ± *U*(K)
352	1.90001±0.00019	86.9011±0.0039	1923 ± 22	2719 ± 54
			1928 ± 22	2719 ± 54
			1933 ± 22	2719 ± 54
		average	**1928 ± 22**	**2719 ± 54**
353	1.90001±0.00019	86.5011±0.0039	1858 ± 22	2720 ± 54
			1867 ± 22	2720 ± 54
			1865 ± 22	2720 ± 54
		average	**1863 ± 22**	**2720 ± 54**
355	1.90001±0.00019	88.2211±0.0039	1888 ± 22	2716 ± 54
			1897 ± 22	2716 ± 54
			1894 ± 22	2716 ± 54
		average	**1893 ± 22**	**2716 ± 54**

8.1.3Measurements results at TÜBITAK UME (round 2)

Lamp S. No	Current *I* (A) ± *U*(A)	Voltage *U* (V) ± *U*(V)	Luminous Flux *Φ* (lm) ± *U*(lm)	Correlated Color Temperature *T* (K) ± *U*(K)
352	1.90000 ± 0.00022	86.5049 ± 0.0011	1913 ± 33	2752 ± 25
			1916 ± 33	2752 ± 25
			1915 ± 33	2752 ± 25
		average	**1915 ± 33**	**2752 ± 25**
353	1.90000 ± 0.00023	86.0918 ± 0.0012	1851 ± 32	2730 ± 25
			1853 ± 32	2730 ± 25
			1849 ± 32	2730 ± 25
		average	**1851 ± 32**	**2730 ± 25**
355	1.90000 ± 0.00023	87.7780 ± 0.0019	1883 ± 33	2745 ± 25
			1880 ± 33	2745 ± 25
			1880 ± 33	2745 ± 25
		average	**1881 ± 33**	**2745 ± 25**