COOMET.PR-S10

Supplementary comparison

COLOUR TRANSMITTED

(COOMET project 640/BY-a/14)

Technical protocol

(Final version 31.10.2016)

2016

Minsk

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1 INTRODUCTION

1.1 At its meeting in April 2011, the COOMET Technical Committee «Photometry and radiometry» (TC1.7) made a decision to carry out a supplementary comparison of tristimulus values and L* a* b* of transparent colour glasses.

1.2 The purpose of this comparison is to determine the metrological equivalence of national measurement standards of participants in the field of colourimetry of transparent colour glasses.

1.3 The comparison will support the following CMCs from the Classification of Services in Photometry and Radiometry :

6.3 Colour, transmitted, x, y, Y
6.4 Colour, transmitted, L*a*b

2 ORGANISATION

2.1 Participants

2.1.1 BelGIM (Republic of Belarus) was appointed to act as a pilot laboratory in this comparison.

2.1.2 Other participants of the comparison are listed in section 2.2.

2.1.3 Each participant must be able to demonstrate traceability to its own independent realization of the units of tristimulus values and L*a*b or make clear the route of
traceability of its measurements to the quantity via another named laboratory.

2.1.4 All participants shall meet the terms and requirements stipulated in CCPR documents related to key and supplementary comparisons as well as terms and requirements provided in this technical protocol.

2.1.5 This technical protocol has been drawn up by the pilot laboratory, agreed by all the participants, and approved by COOMET TC1.7. The protocol will be sent to CCPR WG-KC for review and comments. The protocol covers the technical procedure to be followed during measurement of transfer standards within this comparison.

2.1.6 Once the technical protocol has been approved, no amendments to the protocol may be made without prior agreement of all participants and the COOMET TC1.7.

2.2 Participant Details

Laboratory Name	Acronym	Address /Country	Contact person
Belarusian State Institute of Metrology	**BelGIM (Pilot)**	93 Starovilensky trakt, 220053 Minsk, **Republic of Belarus**	**Olga Tarasova** optic@belgim.by Phone: +375 017 335 50 61 Fax: +375 017 233 57 99
All-Russian Research Institute for Optical and Physical Measurements	**VNIIOFI**	46 Ozernaya st., 119361 Moscow, **Russia**	**Tatiana Gorshkova** **Stanislav Shirokov** gortb@vniiofi.ru stas.shirokov@gmail.com Phone: +7 495 437-33-11 Fax: +7 495 437-29-92
All-Ukrainian state research and production center for standardization, metrology, certification and consumers' rights protection	**Ukrmetrteststandart**	4 Metrologicheskaya st 03143 Kiev, **Ukraine**	**Natalia Parhomenko** parkhomenko@ukrcsm.kiev.ua Phone: + 38 044 526 11 72 Fax: + 38 044 526 36 98
National Scientific Centre «Institute of Metrology».	**NSC IM**	42 Mironositskaya st, 61002 Kharkov, **Ukraine**	**Alexsandr Kupko** kupko@meta.ua Phone: +38-068-963-10-69 Fax:+38-057-700-34-47
National Metrology Institute of the Republic of Moldova	**INM, Moldova**	28 Eugen Coca st., MD 2064 Chisinau **Republic of Moldova**	**Anatolii Bescupschii** fizico_chimice@metrologie.md Phone: +373 22 903 141 Fax: +373 22 903 111
Kazakh Institute of Metrology	**KazInMetr**	11 Orynbor st., 010000 Astana, Left coast, **Kazakhstan**	**Natalya Vyrodova** natalya_14@mail.ru Phone: 8(7172) 793 290 Fax: 8(7172) 793299
National Institute of Metrology (Thailand)	**NIMT**	3/4-5 Moo 3, Klong 5, Klong Luang, Pathumthani 10120 **Thailand**	**Rojana Leecharoen** rojana@nimt.or.th Phone: +662 577 5100 ext 2311 Fax: +662 577 5097
National Metrology Institute of Turkey	**UME**	TÜBİTAK Gebze Yerleşkesi, 41470, **Turkey**	**Seval Cenk** seval.cenk@tubitak.gov.tr Phone: +90 262 679 50 00 Fax: +90 262 679 50 01
National Institute of Metrology of China	**NIM**	No.18, Bei San Huan Donglu Rd., Bldg 13, Rm 107, Chaoyang District, Beijing, 100029 **P.R.China**	**Ms. Zhang Qiaoxiang** **Dr. Gan Haiyong** zhangqiaoxiang @nim.ac.cn ganhaiyong@nim.ac.cn Phone: +86 10 6452 4806 Fax: +86 10 6421 8651

2.3 Form of Comparison

2.3.1 The comparison will principally be carried out through calibration of artefacts composing of transparent colour glass filters. Detailed description of the artefacts is provided in the section 3 of this Technical Protocol.

2.3.2 Two sets of filters (Set 1 and Set 2) will be used in the comparison. The pilot laboratory will measure both sets two times. Each of the other participants will measure only one set one time. Therefore, the measurements will be performed in two parallel routes with the following sequences:

Set 1: BelGIM → Ukrmrtrteststandard → NSC IM → KazInMetr → BelGIM → VNIIOFI → BelGIM.

Set 2: BelGIM → NIMT → UME → INM → BelGIM → NIM → BelGIM.

2.3.3 Set 1 and set 2 will initially be calibrated by the Pilot laboratory. Then they will be distributed to participants for calibration. When all participants' measurements are completed, both sets will be returned to the Pilot who will carry out a repeat measurement for verification of the artefact stability.

2.3.4 Each participant has 3 months for calibration and transportation of the artefacts.

2.3.5 If for some reason, the measurement facility is not ready or customs clearance takes too much time in a country, a participant must contact the Pilot immediately to discuss the further steps and possible correction of the comparison schedule.

2.4 Timetable

Activity	Date
Registering comparison at KCDB	September 2016
First measurement by the pilot laboratory	September 2016
Measurements at Ukrmetrteststandart (Set 1) |and at NIMT (Set 2)	September to November 2016
Measurements at NSCIM (Set 1) and at UME (Set 2)	November 2016 to January 2017
Measurements at KazInMetr (Set 1) and at INM (Set 2)	January 2017 to March 2017
Second measurement by the pilot laboratory	March 2017 to May 2017
Measurements at VNIIOFI (Set 1) and at NIM (Set 2)	May 2017 to July 2017
Final measurement by the pilot laboratory	July 2017 to August 2017
Pre-Draft A start	November 2017

Activity	Date
Distribution of Draft A	January 2018
Submission of Draft B	March 2018

2.4.1 Upon completion of the measurement, each participant must submit a measurement report to the pilot laboratory within 6 weeks.

2.4.2 When all measurements are completed, the participants will be given a deadline date for submitting the results, and if they do not meet the deadline, they might be disqualified.

2.4.3 If, for any reasons, a participant is unable to carry out measurements on time, or customs procedures take too long, the participant should immediately contact the pilot laboratory to discuss next steps and probable changes in the comparison schedule. In case of failure to meet these terms, the participant might be excluded from the comparison. Exclusion may also occur if the results are not submitted within the agreed timeframe without an approved excuse from the pilot laboratory.

2.5 Handling the artefacts

2.5.1 The artefacts should be examined immediately upon receipt at final destination. The condition of the artefacts and associated packaging should be noted. The form in Appendix B.1 should be filled in and sent to the pilot laboratory via email.

2.5.2 The artefacts should only be handled by authorized persons wearing lint-free gloves.

2.5.3 The artefacts should be stored in such a way as to prevent damage.

2.5.4 Cleaning should not be carried out unless there is clear evidence of filter contamination. Dust could be removed with a stream of dry gas (avoid cans with liquid propellants). Should further cleaning be required, the laboratory should consult with the pilot laboratory and if cleaning is approved:

- make a measurement before cleaning;
- use your own standard cleaning method, which must be described in your measurement report;
- make a measurement after cleaning.

2.5.5 Cleaning must be indicated in the measurement report and documented using the form in Appendix B.2.

2.5.6 If a filter appears damaged, a replacement may be available from the pilot laboratory.

2.5.7 When the measurements are completed the form in Appendix B.2 must be filled in and forward (via email) to the pilot laboratory and the next participant.

2.6 Transportation of artefacts

2.6.1 It is of the utmost importance that the artefacts be transported in a manner in which they will not be lost, damaged or handled by unauthorised persons.

2.6.2 The artefact packaging should be marked as “fragile”.

2.6.3 If possible, the artefacts should be transferred as carry-on.

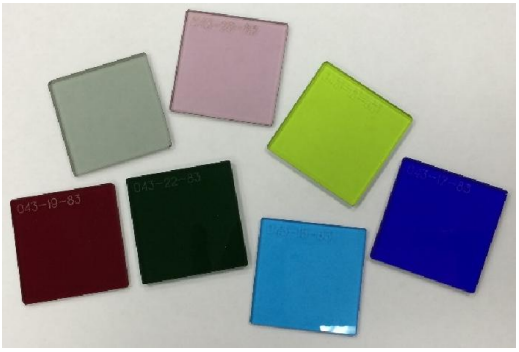
2.6.4 Generally, the cost for transportation will be covers by the participant transporting the artefacts to the next participant. For instance, the Pilot will cover the transportation cost to the first participants in each rout. However, if further transportation will be performed via the Pilot, a participant may be requested to cover the costs of both ways transportation: from the Pilot and back to the Pilot (or to the next participant).

2.6.5 If necessary the pilot laboratory will arrange an ATA CARNET to accompany the artefacts. If the ATA CARNET is not used, the artefacts might be accompanied by other documents (contract, invoice, technical protocol of comparisons) if necessary.

2.6.6 Each participating laboratory covers the costs for its own measurements, transportation and any customs charges as well as for any damage that may have occurred within its country.

3 DESCRIPTION OF THE ARTEFACTS

3.1 The artefact consists of two identical sets of filters. Each set contains 7 coloured glass filters. Size of each filter is 40 mm × 40 mm. The filters are shown below:



3.2 Each filter has an identifier written on the top left corner.

3.3 The main characteristics of the filters are summarized in the table below:

Colour	Nominal thickness, mm	Filter type identifier
Light blue	~ 2.5 mm	XX - 15 - XX
Light green	~ 2.5 mm	XX - 13 - XX
Light red	~ 2.5 mm	XX - 26 - XX
Dark blue	~ 3.2 mm	XX - 31 -XX
Dark green	~ 3.2 mm	XX - 22 - XX
Dark red	~ 2.6 mm	XX - 19 - XX
Light gray	~ 2.6 mm	XX - 00 - XX

4 MEASUREMENT INSTRUCTIONS

4.1 Traceability

4.1.1 Temperature measurements should be made using the international Temperature Scale of 1990 (ITS-90).

4.2 Measurand

4.2.1 The measurand is the tristimulus values (of a colour stimulus) Y, x, y and L^* a^* b^* of each filter

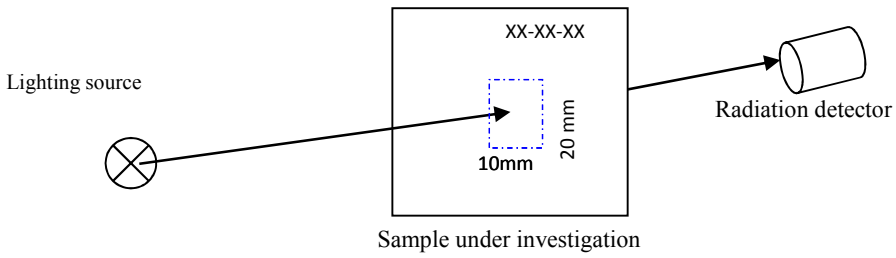
- for the area of the size 10 mm in width x 20 mm in height in the middle of the filter,
- for geometry of lighting/observation: $0^\circ/0^\circ$,
- for illuminant CIE: D65,
- for standard colorimetric observer CIE: 10°,
- at a temperature of 23 °C,
- and at a relative humidity not exceeding 60 %RH.

4.3 Measurement instructions

4.3.1 Before measurement, each filter should be inspected for damage or contamination. Any initial or subsequent damage or cleaning should be documented using the appropriate form in Appendix B.1 or B.2.

4.3.2 The measurement should be performed in suitable laboratory accommodation maintained at a temperature as close as possible to 23 ^oC and at a relative humidity not exceeding 60 %RH. The temperature and relative humidity of the laboratory during the time of the measurements should be reported.

4.3.3 Orientation of a filter in a measuring facility should be as it shown below:



4.3.4 Each filter must be measured independently several times. The number of measurements used should be stated in the measurement report but only the mean or final declared value of each filter of the set is required to be included.

4.3.5 The light beam from the instrument lighting source shall fit into a spot of 10 mm × 20 mm locating at the centre of the filter. When failed to do so, the participant shall

indicate it in its measurement report. In that case the pilot laboratory may introduce a correction to compensate for the filter inhomogeneity.

4.3.6 If the colorimetric values are based on measurement of spectral transmittance of the filters, the spectral measurements should be performed in the wavelength range from 360 nm to 780 nm with a step of 1 nm. The preferred spectral bandwidth is 1 nm. The spectral range, the step and the bandwidth should be stated in the measurement report.

4.3.7 No information relating to the comparison, such as measurement results, obtained by a participant during the course of comparison shall be communicated to any parties other than the pilot laboratory. The pilot laboratory will be responsible for disseminating information to other participant and any other release of information. In the latter case the pilot laboratory will seek permission of all participants before releasing any information.

5 MEASUREMENT UNCERTAINTY

5.1 Measurement uncertainty shall be estimated according to the ISO Guide to the Expression of Uncertainty in Measurement (http://www.bipm.org/utils/ common/ documents/jcgm/JCGM_100_2008_E.pdf).

5.2 In order to achieve optimum comparability, a list containing the principal influence parameters for calibration of Y,x,y and L^* a^* b^* is given below. The participating laboratories are encouraged to follow this breakdown as closely as possible, and adapt it to their instruments and procedures if necessary. Other additional parameters that seem appropriate can be added to the list. These include dependence on specific measurement facilities and should be added with an appropriate explanation and/or reference. As well the value associated with the uncertainty, participants should give an indication of the basis for their estimate. All values should be given as absolute uncertainties for a coverage factor of k = 1.

5.3 The reproducibility of measurements can be determined by calculating the standard deviation of a set of measurements with realignment and repositioning of the filter between each individual measurement. It is this value which has to be taken into account for the uncertainty evaluated according the type A method.

5.4 Type B uncertainty components may include the followings:

- component due to variation of temperature of the filter during measurement;
- component due to non-linearity of the detector over the dynamic range of the detector used for the measurements;
- component due to the uncertainty in the wavelength setting of the monochromator;
- component due to stray light;
- component due to deviation of beam size and beam position;
- component due to inter-reflection between the filter and the various optical and mechanical components of the experimental set-up;

- component due to alignment of the filter;
- component due to polarization of the light;
- component due to drift of the sources during the measurements;
- component due to bandwidth;
- any other uncertainty components specific to the apparatus used for the measurements.

6 REPORTING OF RESULTS

6.1 Submitting measurement results

6.1.1 The final results should be submitted to the pilot laboratory at the latest within six weeks from completion of measurements. The tables in appendices A.1 and A.2 should be completed and sent back electronically to the Pilot.

In any case, the signed report including the results must also be sent in paper form by mail, or in PDF or JPG format of the signed report scanned and sent by e-mail.

In case of any discrepancies, the paper versions are considered to be the definitive version.

6.1.2 In completing the description of the participant's measurement facility, Appendix A.1, a schematic diagram of the facility should be included.

6.1.3 Following receipt of all measurement reports from the participating laboratories, the pilot laboratory will follow the procedure outlined in the latest versions of the CCPR "Guidelines for RMO PR Supplementary Comparisons" (CCPR-G7) and the "Guidelines for CCPR Key Comparison Report Preparation" (CCPR-G2).

6.2 Pre-Draft A process

6.2.1 After completion of all measurements, sections 1, 2, 3, and 4 of the Guidelines for CCPR Comparison Report Preparation (CCPR-G2) must be followed by the pilot laboratory before preparing Draft A. The measurement results by participants cannot be revised after the Pre-Draft A process ended.

6.3 Preparation, distribution and review of the Draft A

6.3.1 After the Pre-Draft A process is completed, the pilot laboratory prepares and distributes Draft A to all the participants, which discloses the absolute results of the comparison with identification of all the participating labs.

6.3.2 The Draft A should be distributed within 6 months after completion of all the measurements of the comparison.

6.3.3 The results will be analysed basically following the *Guidelines for CCPR Comparison Report Preparation (CCPR-G2)*, but the procedures in the final steps for this (supplementary) comparison will be different. Because "KCRV" does not exist for supplementary comparisons, the resulting reference value will be simply called "Reference

Value (RV)". No Degrees of Equivalence will be presented in the report. The RV and the results of each participant with respect to the RV, and their uncertainties, will be presented.

6.3.4 Draft A must be approved by all the participants. If necessary, revised documents (Draft A-1, A-2, …) will be distributed. The version finally approved by all the participants becomes Draft-B

6.4 Draft B

6.4.1 The Draft-B will be submitted to COOMET TC1.7 for review and approval. Then it is approved by TC, the Draft-B will be submitted to WG-KC Secretary (copy to WG-KC Chair) through the RMO PR TC Chair.

References

1. CIE Publication 15:2004
2. BIPM IEC ILAC IUPAP and OIML 2008 Guide to the Expression of Uncertainty in Measurement (Geneva: International Organization for Standardization
3. CCPR – k6.2010. Key Comparison Spectral Regular Transmittance Technical Protocol.

Appendix A.1 Description of measurement facility and measurement method

Laboratory:

.....

Table A-1 Details of Measurement Setup

Make and type of spectrophotometer	
Additional stray light rejection	
Source drift monitoring	
Detector	
Temperature [(a)]	
Humidity	
Beam Size	
Measurement sequence[(b)]	
Bandwidth	

[(a)] i.e describe method of temperature monitoring of filters and range of temperatures;
[(b)] i.e describe number of measurements and whether filter orientation with respect to beam changes between measurements

If any damage, contamination or cleaning of filters was carried out, please give details

Signature: ..... Date (dd/MM/yyyy): .....

Appendix A.2 Measurement results

Laboratory: .....

Address: .....

Date of Measurement: .....

1. Measuring conditions:

1.1 Ambient temperature (^{o}C):	
1.2 Relative humidity (%RH) :	
1.3 Type of illuminant (specified according to CIE standard illuminant. default is CIE D65)	
1.4 Spectral bandwidth (nm), if applicable:	
1.5 Spectral range (nm), default range is from 360 nm to 780 nm	
1.6 Spectral interval (nm), if applicable:	

2. Description and procedure of independent realization of the unit (or traceability of the results to another named NMI)

3. Description and diagram of the standard measuring instrument

Pleas reproduce the following table for each of the seven filters. All uncertainties should be reported as absolute measurement uncertainties

Property	**Y**	**x**	**y**	**L^***	**a^***	**b^***
Number of measurements						
…….						
Type A Uncertainty [(a)]						
Type B Uncertainty [(b)]						
Total Uncertainty [(c)]						

[(a)] The uncertainty associated with the values attributed to reproducibility of the measurement.
[(b)] The uncertainty associated with the values attributed to all type B sources.
[(c)] The total of the measurement for a coverage factor of $k = 1$.

Signature: ..... Date (dd/MM/yyyy): .....

Appendix A.2 - 1 Type B uncertainty budget[(a)]

Fill out the table below for the uncertainty contributions in measurement. All uncertainties should be reported as absolute uncertainties.

Property	Y	x	y	L^*	a^*	b^*
Nonlinearity						
Temperature						
Wavelength						
Stray Light						
Beam size & position						
Inter-reflection						
Obliquity						
Polarization						
Source drift & fluctuation						
Bandwidth						
Other						
Total type B uncertainty [(b)]						

[(a)] Please record any uncertainties considered negligible as zero (rather than e.g \\ some value).
[(b)] Add lines to the table as necessary, itemizing other components of uncertainty considered

Signature: ..... Date (dd/MM/yyyy): .....

Appendix B.1 Receipt of artefacts

To Laboratory:

.....

From Laboratory:

.....

After visual inspection

Has the aftefacts' transportation package been opened during transit, e.g. by Custom authority? ☐ Yes ☐ No

If yes, please give details:

Is there any damage to the packaging? ☐ Yes ☐ No

If yes, please give details:

Are there any visible signs of damage or contamination on the filters? ☐ Yes ☐ No

If yes, please give details:

Signature: ..... Date (dd/MM/yyyy): .....

Appendix B.2 Condition of the transfer standards on departure

Laboratory: .....

Were the filters contaminated or damaged in any way while at your laboratory?
☐ Yes ☐ No

If yes, please give details:

Was any cleaning of filters undertaken while at your laboratory? ☐ Yes ☐ No

If yes, please give details:

Signature: ..... Date (dd/MM/yyyy): .....

Appendix B. 3 Confirmation of transfer standards receipt

To: Tarasova Olga. BelGIM, Starovilensky trakt 93, 220053, Minsk, Belarus

Fax + 375 17 288 09 38, e-mail: optic@belgim.by

From:
Please provide first and last name, company name and participant address, shipper name and transfer standard details.

We confirm, that we received transfer standard

Please provide your first and last name, your company name and address.

During visual check of transported standard it was revealed that: no damages were found.

Note: If damage persists, please provide details.

Signature: / Date (dd/MM/yyyy):

..... (signature, in letters)

Appendix C Calculation of tristimulus values

$$X = k \int S(\lambda)\bar{x}(\lambda)T(\lambda)d\lambda$$

$$Y = k \int S(\lambda)\bar{y}(\lambda)T(\lambda)d\lambda$$

$$Z = k \int S(\lambda)\bar{z}(\lambda)T(\lambda)d\lambda$$

where
$T(\lambda)$ is the spectral transmittance of a sample,
$S(\lambda)$ is the relative spectral power distribution of the illuminant (in our case standard source D65, CIE 15:2004, section 11.1, table T.1),
$\bar{x}(\lambda), \bar{y}(\lambda), \bar{z}(\lambda)$ are colour matching functions of a standard colorimetric observer (CIE 1964, CIE 15:2004,section 11.5, table T.5),
k is the constant

$$k = \frac{100}{\int S(\lambda)\bar{y}(\lambda)d\lambda}$$

Calculation of L*,a*,b*

$$L^* = 116F(Y) - 16$$

$$a^* = 500[F(X) - F(Y)]$$

$$b^* = 200[F(Y) - F(Z)]$$

where,

$$F(X) = (X/X_N)^{\frac{1}{3}} \text{ if } (X/X_N) > (24/116)^3 \quad \text{else}$$
$$F(X) = (841/108) \cdot (X/X_N) + 16/116$$

$$F(Y) = (Y/Y_N)^{\frac{1}{3}} \text{ if } (Y/Y_N) > (24/116)^3 \quad \text{else}$$
$$F(Y) = (841/108) \cdot (Y/Y_N) + 16/116$$

$$F(Z) = (Z/Z_N)^{\frac{1}{3}} \text{ if } (Z/Z) > (24/116)^3 \quad \text{else}$$
$$F(Z) = (841/108) \cdot (Z/Z_N) + 16/116$$

X, Y, Z are the tristimulus values of the sample,
X_N, Y_N, Z_N are the tristimulus values of a perfect transmittance object or tristimulus values of the light source. For D65 light source X_N=94.81, Y_N=100, Z_N = 107.32

Appendix D Parameters of participant facilities

NMI	Size of a beam (WxH, mm)	Type of a lamp
BelGIM (Pilot laboratory)	5x7.5 mm	Halogen lamp
VNIIOFI	5x10 mm	Halogen lamp
Ukrmetrteststandart	4 × 12 mm	Halogen lamp
NSC IM	5 × 11 mm	Halogen lamp
INM, Moldova	4 × 12 mm	Halogen lamp
KazInMetr	4 × 12 mm	Halogen lamp
NIMT	2x13 mm	Halogen lamp
UME	4 × 12 mm	Halogen lamp
NIM	4 × 12 mm	Halogen lamp