Determination of spectral mismatch correction factor of luminous intensity standard lamp at Inmetro

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Abstract: Theoretically, the photometer spectral mismatch correction factor *F* is equal to one unit. However, in practice, the photometer is not ideal and the *F* must be determined. This factor depends from the spectral radiant flux of the source and it needs to be calculated separately for each lamp / photometer, concomitant to the luminous intensity measurements. This paper describes the methodology for the assembly of a spectrocolorimetric system at the Inmetro Photometry system to determine the spectral distribution of lamps to be used in *F* calculations to determine the luminous intensity. The results obtained and respective validation will be presented.

Keywords: spectral mismatch correction factor; color temperature; luminous intensity; candela.

1. INTRODUCTION

Inmetro developed a primary system for detector-based luminous intensity measurements using trap photometers with traceability in the spectral responsivity system, validated from comparisons and peer review [1, 2].

The photometer is used for the illuminance measures produced by a lamp and is composed of a detector and a coupled glass filter in order to match the spectral responsivity of this detector to the function of adaptation to the spectral luminous efficiency $V(\lambda)$ CIE [3, 4]. However, in practice, the detector set with $V(\lambda)$ filter does not faithfully reproduce the theory. The effects of the difference of adaptation to the spectral luminous efficiency between a real photometer and a theoretical photometer are quantified by an *F* factor called the spectral mismatch correction factor calculated by equation 1.

$$F(S_t) = \frac{\int_\lambda S_A(\lambda)s(\lambda)d\lambda \int_\lambda S_t(\lambda)V(\lambda)d\lambda}{\int_\lambda S_A(\lambda)V(\lambda)d\lambda \int_\lambda S_t(\lambda)s(\lambda)d\lambda} \quad (1)$$

In equation 1, $F(S_t)$ is the spectral mismatch correction factor to be calculated for the test lamp, $S_A(\lambda)$ is the spectral distribution of the illuminant A [4]; $S_t(\lambda)$ is the spectral distribution of the test lamp *t*; $s(\lambda)$ is the relative spectral responsivity of the photometer and $V(\lambda)$ is the spectral luminous efficiency [3].

The spectral mismatch correction factor should be determined together with the luminous intensity measurements for a lamp / photometer combination, as it depends on the spectral radiant flux of the measured lamp.

The correlated color temperature of the lamp (*CCT*) is measured to specify the operating current corresponding to the illuminant A CIE (2856 K) [4]. The corresponding spectral distribution measured $S_t(\lambda)$ is used to determine the spectral mismatch correction factor.

In order to determine simultaneously the spectral distribution of the lamp during the measurement of light intensity and make it possible to calculate the *F* factor, the Inmetro spectrocolorimetric system [5] was assembled together with the Inmetro photometry system. This work describes the system mounting and the methodology of simultaneous operation with the photometric system, as well as the results obtained.

2. METHODOLOGY AND SYSTEM MOUNTING

The spectrocolorimeter was mounted on a tripod near the photometric bench of the light intensity system as shown in figure 1, using the 0º:45º geometry with a matte white plate of reflectance [5]. The plate was positioned on the photometric bench at a distance of approximately 1 m from the standard lamp to be measured in the system.

In order to minimize scattered light in the system, a black curtain was inserted in the side of the photometric bench and a black tube was positioned in front of the spectrocolorimeter, in addition to all the existing baffles in the system.

The acquisition of the lamp data during spectral distribution measurements was performed by the system composed of the current source, multimeters and resistor.

The system is mounted and aligned as described in figure 1. The lamp to be measured in the system has been adjusted to the current corresponding to the select *CCT* being stabilized for 12 minutes. The matte white plate was placed on the photometric bench in the 0º:45º geometry and the alignment and focus were verified next to the spectrocolorimeter, being necessary for this measurement a dark environment.

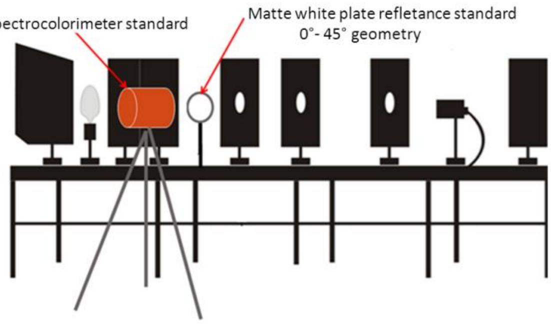

Figure 1. System for measuring standard lamps in correlated color temperature together with the Inmetro' photometry system.

The acquisition of the spectral radiance data was done using home-made software, which allows the voltage to be acquired simultaneously in the lamp and in the resistor, as well as the environmental conditions.

The adopted methodology requires three measurement series, where in each measurement series the lamp was removed, replaced and realigned in the system and *n* spectral measurements were acquired. After determining the spectral distribution of the lamp, the support and the white plate were removed from the photometric bench so that the measurements can be made with the photometer to calculate the luminous intensity.

From the *n* spectral measurements, the average spectral distribution of the lamp in the range of 380 nm to 780 nm, with a step of 4 nm, were calculated. *CCT* was determined from the mean of the spectral distribution for each lamp [4]. With the spectral distribution, the spectral mismatch correction factor *F* was also calculated for each lamp/trap photometer set.

With the lamp data acquired during spectral distribution measurements, the mean and the standard deviation of the voltage in the lamp were calculated from which the current and the measurement uncertainty were calculated.

3. RESULTS AND DISCUSSIONS

Three standard lamps of luminous intensity measurement were measured, two Wi 41G and one Wi 40G, referred to herein as Wi41G_1; Wi41G_2 and Wi40G.

The voltage values were recorded during spectral radiance measurements referring to the 2856 K *CCT* for the 3 lamps and the 3 trap photometers, totalizing 9 sets of measurements. It was verified that the voltage variation was in the order of 10^{-6} V for all measurements performed.

Table 1 shows the *CCT* values, the respective current values used and the calculated *F* factor for each lamp / photometer set, where the 2856 K *CCT* with 15 K uncertainty was considered as reference. The current uncertainty was 0.0004 A and the uncertainty of factor *F* was 0.0011.

Table 1. Results of the 3 sets of lamp / photometer.

Lamp	Photometer	Current i (A)	*CCT* (K)	*F* Factor
Wi 41G_1	Fot-1	5.8933	2857	1.000
	Fot-2	5.8933	2855	1.000
	Fot-3	5.8933	2857	1.000
Wi 41G_2	Fot-1	5.9710	2857	1.000
	Fot-2	5.9710	2864	1.001
	Fot-3	5.9710	2857	1.001
Wi 40G	Fot-1	5.9987	2858	1.001
	Fot-2	5.9986	2865	1.001
	Fot-3	5.9987	2866	1.001

It was verified that the smallest difference found in *CCT* was 0.8 K for the lamp Wi 41G_1, which average among all measurements was 2856.08 K. And the biggest difference was 6.81 K for the lamp Wi 40G, whose average among all measurements was 2862.81 K. The differences found in table 1 are within the estimated measurement uncertainty for the system that is 15 K. The F value variation considering 15 K is 0.01 %, being smaller than the measurement uncertainty of this factor whose main contribution is the uncertainty of spectral responsivity from photometer used.

3.1. System Validation

In order to validate the accuracy of the new system, the calculated *CCT* values (table 2) for a standard lamp (Wi 40G type) were compared with that stated on its calibration certificate, where for a current of i = 5.9240 A with *CCT* = 2856 K (U_{CCT} = 17 K) is U_i = 0.0001 A. The result was evaluated by adopting the normalized error criterion (En) where the comparison was less than 1.

Table 2. *CCT* Comparison in the photometric system.

Current	*CCT*	*CCT* Uncertainty	Error	En
i (A)	(K)	U_{CCT} (K)		
5.9236	2859	17	3.2	0.13

4. CONCLUSION

A methodology for spectral distribution measurement of lamps used in the Inmetro luminous intensity system was established for the purpose of determining the spectral mismatch correction factor *F*, used in the calculation of luminous intensity using methodology based on the detector.

The designed system for the spectral distribution measurements was validated from a *CCT* comparison using a standard lamp previously calibrated in the Inmetro spectrocolorimetric system. The results obtained were compatible, demonstrating the agreement between these systems.

Previously, the colour correlated temperature from lamps was determined using the red / blue methodology in Laraf which is only valid for spectral distribution reasonably close to the Planck radiator. This methodology is comparative and limited to tungsten filament lamps, and it is not possible to determine the spectral mismatch correction factor *F*.

From the methodology developed using the spectrocolorimeter in the Inmetro photometric system, it is possible to determine the uncertainty component of the spectral mismatch correction factor which is one of the contributions of the uncertainty of measurement of the luminous intensity based on the detector. This methodology also allows measurements in different *CCT* values, not only in illuminant A, as well as determines the spectral mismatch correction factor of other types of luminous intensity measurement standards.

5. REFERENCES

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