

## A bilateral comparison on illuminance using a photometer between IPT and LABELO

A F G Ferreira Junior <sup>1 3</sup> and C J R Bindé Junior <sup>2</sup>

<sup>1</sup> Instituto de Pesquisas Tecnológicas do Estado de São Paulo, São Paulo, SP, 05508-901, Brazil

<sup>2</sup> Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre, RS, 90619-900, Brazil

<sup>3</sup>Corresponding author's e-mail: [agentil@ipt.br](mailto:agentil@ipt.br)

**Abstract.** This work presents the result of bilateral illuminance comparison obtained from a photometer calibration. The bilateral comparison was performed comparing the calibration results from the same photometer at LABELO and IPT laboratories, which take part of Brazilian calibration network. Occasionally LABELO was chosen as a pilot laboratory and was responsible to calibrate the photometer at the beginning and end of comparison and define the reference illuminance value of photometer calibration. The illuminance calibration points ranged from 20 to 2000 lx and the comparison evaluation criterion was the normalized error ( $E_n$  numbers). The laboratory measurements are in agreement according to the evaluation criterion.

### 1. Introduction

One fundamental point of metrology is the measurement intercomparison. It is used to validate measurement equivalence among the National Metrology Institutes (NMIs) in the Mutual Recognition Arrangement of the General Conference of Weights and Measures (CIPM) [1]. It occurs in other levels of a metrological chain concerning the national metrological networks, test laboratories and factory laboratories, mostly based on laboratories accreditation standards [2].

Illuminance comparisons among NMIs are performed in ranges from 14 lx to 500 lx [3-5]. In the last key comparison a photometer was used as transference standard for the first time and it was observed that approximately 30 % of participant NMIs obtained a result out of reference values considering an uncertainty with  $k = 2$  [3]. In another comparison in the Asia Pacific Metrology Program it was observed a drift of 30 % for one laboratory which could be explained by a drift on its primary standard [4]. These comparison results among the National Metrology Institutes plays an important task indicating that additional work should be done to assure a trustful measurement.

The purpose of this comparison is to confirm the metrological competence to perform the calibration of photometers by IPT and LABELO, within the scope of accreditation in Brazil, regulated by the General Coordination for Accreditation. The development of this comparison program and the results are reported in this paper.



## 2. Experimental method

### 2.1. The photometer

The photometer used as comparison equipment in this work was manufactured by Minolta, model T10 and is presented in figure 1. This equipment is a control standard at LABELO. It presents a very stable performance which was verified in this work by a calibration before and after comparison measurements.



**Figure 1.** Photometer used in the comparison as comparison equipment.

### 2.2. Comparison procedure

The bilateral comparison was done comparing the calibration results of a photometer by both laboratories. The photometer circulated between the two laboratories and its drift was considered in reference values uncertainty estimation. LABELO was defined as pilot laboratory and evaluated the photometer at the beginning and the end of the program.

Each laboratory performed the photometer calibration at environment temperature of  $(23 \pm 3) ^\circ\text{C}$ . The photometer reference plane for the calibration was a plane tangent to its diffuser. The calibration points were defined as: 20; 110; 400; 1000; 1600 and 2000 lx. The calibration procedure was the same used by each laboratory to calibrate equipment on Brazilian metrological network (RBC).

The traceability of measurements from LABELO is a standard lamp type Wi 41/G calibrated in luminous intensity at Physikalisch-Technische Bundesanstalt (PTB) of Germany. LABELO uses the Inverse Squared Law as a calibration methodology to obtain reference illuminance.

The traceability of measurements from IPT is a standard lamp type FEL 1000 W calibrated in luminous intensity at Physikalisch-Technische Bundesanstalt (PTB) of Germany and a standard photometer calibrated in illuminance at National Institute Metrology, Quality and Technology (INMETRO) of Brazil. IPT uses illuminance measurement comparison as calibration methodology and the standard lamp is used to ensure high illuminance traceability, such as 2000 lx.

### 2.3. Comparison agreement criterion

The comparison agreement criterion was the normalized error ( $E_N$ ) [6], which was obtained according to equation (1) using the participant laboratory's measurement ( $M_{\text{Lab}}$ ), the pilot laboratory's measurement ( $M_{\text{Ref}}$ ), the participant laboratory's uncertainty ( $U_{\text{Lab}}$ ) and the pilot laboratory's uncertainty ( $U_{\text{Ref}}$ ). If a measurement has absolute value of  $E_N$  is smaller than or equal to the unity ( $|E_N| \leq 1$ ), this is a satisfactory result otherwise ( $|E_N| > 1$ ) the result is doubtful.

$$E_N = \frac{M_{Lab} - M_{Ref}}{\sqrt{U_{Lab}^2 + U_{Ref}^2}} \quad (1)$$

### 3. Results

The results of photometer calibration obtained by each laboratory are presented at tables 1 and 2 including reference illuminance ( $E_{REF}$ ), measured photometer illuminance ( $E_{MEA}$ ) and the uncertainty with a coverage factor of 2 for a confidence level of approximately 95 %. The uncertainty results from LABELO, table 1, include the photometer drift observed during the comparison.

**Table 1.** LABELO photometer calibration results.

$E_{REF}$ (lx)	$E_{MEA}$ (lx)	Uncertainty (%)
19,74	20,00	3,7
106,4	110,0	3,1
398	400	3,7
1008	1000	3,9
1619	1600	4,0
1972	2000	4,1

The photometer drift obtained in the comparison is presented in table 3 where for each reference illuminance ( $E_{REF}$ ) is presented the percentage of drift. The maximum drift value is small when compared to measurement uncertainty, though it is not negligible. Thus the photometer drift increased the pilot laboratory uncertainty in less than 20 % which do not invalidate this comparison.

**Table 2.** IPT photometer calibration results.

$E_{REF}$ (lx)	$E_{MEA}$ (lx)	Uncertainty (%)
19,80	20,00	3,3
108,4	110,0	3,4
395	400	3,3
987	1000	3,4
1581	1600	3,4
1981	2000	3,5

The normalized error ( $E_N$ ) obtained is presented in table 4 and is related to each IPT reference illuminance ( $E_{REF}$ ). For each calibration point of IPT result the  $E_N$  is calculated according to equation 1. The  $E_N$  result shows that all the calibrated points presented a satisfactory result in this comparison.

**Table 3.** Photometer drift in comparison.

$E_{REF}$ (lx)	Photometer Drift (%)
19,74	0,6
106,4	0,1
398	0,5
1008	0,4
1619	0,3
1972	0,4

**Table 4.** Normalized error for IPT results.

$E_{REF}$ (lx)	$E_N$
19,80	-0,06
108,4	-0,40
395	0,15
987	0,41
1581	0,45
1981	0,08

#### 4. Conclusions

A bilateral comparison of illuminance in the range of 20 to 2000 lx was performed between IPT and LABELO and throughout this range all results were satisfactory considering the normalized error as evaluation criterion and confirming the convergence of results.

The photometer used in the comparison presented a drift which was included in pilot laboratory uncertainty. The obtained photometer drift corresponded to one fifth of calibration uncertainty.

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