Trilateral interlaboratory with SSL (WLEDi) luminaire

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Abstract. The IEE/USP laboratory and two others, all belonging to RBLE (Brazilian Network of Test Laboratories) participated in a trilateral comparison performed from measurement independently of participants interaction. The results from electric and photometric measurements carried out on samples of Solid State Lighting - SSL, Inorganic White Light Emitting Diode (WLEDi) luminaires by three accredited laboratories were considered in order to point out mutual deviations and to verify the confidence in a bilateral comparison. The first analysis revealed a maximum deviation of 4.2 % between the luminous intensity attributed by one laboratory and the arithmetic mean value from three laboratories. The largest standard uncertainty value of 1.9 % was estimated for Total Harmonic Distortion of electric current THDi and the lowest value, 0.4 %, to the luminous flux. The extreme deviation for one parameter results was 7.2 % at maximum luminous intensity and the lowest was 1.7 % for luminous flux.

1. Introduction

According to relevant documents [1, 2] the comparison of results from measurements carried out in different laboratories is a valid instrument of metrology and can be used for quality assessment. Although statistic is an important tool for assessment of laboratory practices, the present paper does not embrace sampling protocols, it has focus on measurement results obtained by three laboratories belonging to the RBLE (Brazilian Network of Test Laboratories accredited by Inmetro), looking for critical points which will require treatments. Assertive decisions are facilitated when the results are properly presented.

In the bidding process conducted by USP (University of São Paulo) to provide Inorganic White Light Emitting Diode (WLEDi) technology for outdoor lighting on their campi, at CUASO campus there was an initial stage in which report containing electric and photometric data on each type of luminaire offered were submitted and a second stage, in which samples were received and tested at the IEE/USP (Institute of Energy and Environment, USP) laboratory.

The results obtained from IPT (Instituto de Pesquisas Tecnológicas) report, considered as results from test of type for the WLEDi 50 W luminaire [3] in the USP bidding process were compared with parameter assessed at the IEE/USP laboratory from four luminaires removed from the product batch supplied (before field installation). From four test reports results [4], where there is indication on the use of goniometer during the measurement process, the assessed data were processed (arithmetic
average and the standard uncertainty was estimate). The results from those measurements were compared with data contained from a type test report supplied by the USP Campus Prefecture - PUSP-C [4]. The results from a bilateral experiment is been considered at the first part of this article, which results are presented at section 3.1. The trilateral methodology used is considered at section 2.

2. Methodology (one luminaire and three Labs)
The second part of this article was based on measurements of the same luminaire performed in three laboratories identified as Lab I, Lab II and Lab III to obtain electric power; electric current; total harmonic distortion of electric current (THDi); total harmonic distortion of voltage (THDv); power factor (PF); luminous flux (LF); luminous efficiency (LE) and maximum luminous intensity (MLI). Figure 1 shows the WLEDi 120 W luminaire used at three laboratories for all tests.

Figure 1. The WLEDi 120 W luminaire supplied on electric power line of 220 V.

At each Lab the luminous flux was determined with the aid of the goniophotometer procedure. The arithmetic average for each parameter was determined and the uncertainty estimated. In the case of THDv and THDi, due to the results of Lab. II, the average value determination was calculated with only two elements. The WLEDi 120 W luminaire used was energized at the rated electric voltage of 220 V, a stabilization period should be applied as a precondition before the measurement starts according to the particular procedure of each laboratory.

Note: The IESNA LM-79 [5] was used as the reference document at the IEE-USP Lab. for the light output and electric power stabilization period.

Both electric and photometric data were sampled during each luminaire test.

Relative standard deviation from laboratories results was calculated. For the uncertainty estimation or the dispersion around the assigned value (average) the standard uncertainty was used [6]. The results are presented in the section 3.2 and 3.3 by seven tables with assigned value associated, absolute uncertainty and relative deviation from each Lab in relation to the arithmetic average obtained.

3. Results and Discussion

3.1. Parameter from type and samples tests (luminaires and two Labs)
Table 1 (at the IEE column) presents arithmetic average (four samples) and average standard deviation for seven parameters quantities considered of the WLEDi 50 W luminaries from USP CUASO campus installation [4], and at the IPT column presents data from the report assessed [3] and each uncertainty declared is for luminaire code AP-SL-50W, all luminaires are from Alper (a brazilian brand). The relative deviation, the column at the right, table 1, was calculated considering the difference between the results from both laboratories in relation to the IPT result.

On the results, using at least four parameters (luminous flux, electric current, luminous efficiency, THDi), it does not indicate conformity consistency between the type and the samples extracted from the batch.
Table 1. Absolute value for seven parameters of the WLEDi 50 W luminaire, the estimated uncertainty and the relative deviation from one Lab result.

| Luminaire Parameter       | IEE a | IPT b | Relative deviation (%) |
|---------------------------|-------|-------|------------------------|
| Electric Current (mA)     | 250 ± 2 | 230 ± 20 | 8.8                   |
| Electric Power (W)        | 53.6 ± 0.4 | 50.45 ± 0.05 | 6.2                  |
| Power Factor              | 0.9725 ± 0.0005 | 0.99 ± 0.01 | -1.8                |
| THDi (%)                  | 7.34 ± 0.29 | 7.99 ± 0.05 | -8.1                 |
| Luminous Flux (klm)       | 4.97 ± 0.04 | 4.30 ± 0.15 | 15.6                 |
| Luminous Efficiency (lm/W)| 92.75 ± 1.30 | 85.3 | 8.7                   |
| Correlated Color Temperature - Tc (K) | 4236 ± 57 | 3822 ± 50 | 10.8                |

a arithmetic average and expanded standard deviation were estimated from result of four luminaries sampled [4]; and
b Data from test report, luminaire model AP-SL-50W (luminaire submitted to test, whose, document/report was presented at bidding phase) [3].

3.2. Electric parameter (one luminaire and three Labs)

3.2.1. Electric Current. Table 2 presents the arithmetic average value, estimated uncertainty of the arithmetic average to the electric current for WLEDi 120 W luminaire, the relative standard deviation was calculated for each laboratory in relation of the arithmetic average value.

Table 2. Relative deviation from the average for each laboratory measurement of the electric current, values in %.

| Laboratory Identification | Electric Current (578.5 ± 8.0) mA; (± 1.4 %) |
|---------------------------|----------------------------------------------|
| Lab. I                    | - 3.1                                       |
| Lab. II                   | 0.43                                        |
| Lab. III                  | 2.7                                         |

The range of maximum variation between the three labs for the electric current is estimated at 5.8 %.

3.2.2. Electric Power. Table 3 presents the arithmetic average value and uncertainty for the electric power of WLEDi 120 W luminaire, relative deviation was calculated for each laboratory in relation of the arithmetic average value.

Table 3. Relative deviation from the average for each laboratory measurement result of electric power, values in %.

| Laboratory Identification | Electric Power (123.0 ± 1.5) W; (± 1.2 %) |
|---------------------------|---------------------------------------------|
| Lab. I                    | - 2.9                                       |
| Lab. II                   | 1.6                                         |
| Lab. III                  | 1.3                                         |

The maximum variation range between three laboratories for the electric power is estimated at 4.5 %.
3.2.3. Total harmonic distortion of the electric current (THDi) and total harmonic distortion of the electric voltage sources (THDv). Table 4 presents the arithmetic average value calculated to estimate the THDi of WLEDi 120 W luminaire (and THDv of each luminaire-source combination) and each relative deviation calculated in relation to the arithmetic average value.

Table 4. Relative deviation from the average for each laboratory measurement result of THDi and THDv, values in %.

| Laboratory Identification | THDi       | THDv       |
|---------------------------|------------|------------|
|                           | (9.25 ± 0.18) | (0.25 ± 0.03) |
| Lab. I                    | 2.7        | -16        |
| Lab. II                   | ***        | ***        |
| Lab. III                  | -2.7       | 16         |

* Laboratory II do not supplied THDv measurement result and for this reason the THDi (value 1.6 %) was not incorporated at table 4.

The maximum range variation between the three laboratories for the measurement of the THDv is estimated at 32 % and 5.4 % (for THDi).

The algebraic sum of the relative deviation of each parameter is null, this is a strong indication of consistency in the procedure used.

3.2.4. Power Factor (PF). Table 5 presents the arithmetic average value calculated to estimate the PF of WLEDi 120 W luminaire and each relative deviation in relation to the arithmetic average value.

Table 5. Relative deviation from the average for each laboratory measurement result of the PF, values in %.

| Laboratory Identification | Power Factor |
|---------------------------|-------------|
|                           | (0.966 ± 0.007) |
|                           | (± 0.7 %)    |
| Lab. I                    | 0.2         |
| Lab. II                   | 1.4         |
| Lab. III                  | -1.7        |

The maximum range variation between the three laboratories for the measurement of the power factor is estimated at 3.1 %.

3.3. Photometric parameter (one luminaire and three Labs)

3.3.1. Luminous Flux (LF). Table 6 presents the arithmetic average value, the uncertainty of the average luminous flux of WLEDi 120 W luminaire, the relative deviation calculated for each laboratory determination in relation to the average value.

Table 6. Relative deviation from the average for each laboratory determination of the luminous flux, values in %.

| Laboratory Identification | Luminous Flux |
|---------------------------|---------------|
|                           | (13.15 ± 0.05) klm; |
|                           | (± 0.4 %)     |
| Lab. I                    | -0.9          |
| Lab. II                   | 0.07          |
| Lab. III                  | 0.8           |
The maximum range variation between the three laboratories for the determination of the luminous flux is estimated at 1.7 %.

3.3.2. Luminous Efficiency (LE) [7]. Table 7 presents the arithmetic average value, the uncertainty of the average luminous efficiency of WLEDi 120 W luminaire and each relative deviation in relation to the average value.

| Laboratory Identification | Luminous Efficiency [7] (107 ± 1) lm/W; (± 0.9 %) |
|---------------------------|--------------------------------------------------|
| Lab. I                    | 2.2                                              |
| Lab. II                   | -1.7                                             |
| Lab. III                  | -0.5                                             |

The maximum range variation between the three laboratories for the determination of the luminous efficiency is estimated at 3.9 %.

3.3.3. Maximum Luminous Intensity (MLI). Table 8 presents the arithmetic average value, the uncertainty for the average value to the maximum luminous intensity (I_{MAX}) of WLEDi 120 W luminaire and each relative deviation in relation to the average value.

| Laboratory Identification | MLI (I_{MAX}) (8.98 ± 0.16) kcd; (± 1.8 %) |
|---------------------------|--------------------------------------------|
| Lab. I                    | 3.0                                        |
| Lab. II                   | 1.2                                        |
| Lab. III                  | -4.2                                       |

The range of maximum variation between the three laboratories for the (I_{MAX}) is estimated at 7.2 % (the wider range obtained).

Due to the coexistence and possible use of two different systems (European, CIE and North America, IESNA) for photometry of public luminaire, the vertical and horizontal angles were not here considered.

4. Conclusions
According to Table 1, and for at least four parameters (luminous flux, electric current, luminous efficiency, THDi), the difference showed between the type and samples test results of WLEDi 50 W luminaires, it does not support conformity and suggest to be very different the lighting products.

The result from laboratory measurement of three accredited laboratories (RBLE), eight parameters of one SSL luminaire (WLEDi, 120 W) were considered in this work. For the analysis of results the relative deviations of each Lab and in relation to the arithmetic average value determined were used. The smaller amplitude of variation in relation to the average value occurred for luminous flux and was 1.7 %; followed by PF 3.1 %; luminous efficiency 3.9 %; electric power 4.5 %; THDi 5.4 %; electric current 5.8 %; maximum luminous intensity 7.2 % and for THDv 32 %.

As each Lab used different electric power supply for the measurements further investigations are suggested to THDv consideration.
The luminous flux determination resulted in the lowest relative standard uncertainty (0.4 %) and THD\textsubscript{i} the largest (1.9 %).

If THD\textsubscript{i} parameter is not taken in consideration, the largest amplitude of the relative deviations for all the magnitudes from one laboratory was 6.9 % (Lab. III); the lowest 3.3 % (Lab. II).

The estimated values for standard uncertainty (non-expanded) for the results from WLED\textsubscript{i} 120 W luminaire and three laboratories considered are less than 2 %, a level that can be considered acceptable without the THD\textsubscript{i} been considered.

The algebraic sum of the relative deviation of each parameter from all Labs results was found close to zero, this is an indication of consistency in the procedure used.

The large deviation observed on THD\textsubscript{i} suggest a better knowledge development and control over the type of electric source been used.

The wide differences shown for the maximum luminous intensity, electric current and for others electric parameters suggest further investigations.

Acknowledgments
The authors are grateful to the financial support from the Brazilian agency CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior), two country project nº 048/2013; to the Eng. Enea from the PUSP-C for the luminaires samples (50 W) and test reports [4] and to Eng. Mauro from the Demape Company who supplied reports from two laboratories and one luminaire (120 W).

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