An Intercomparison of Photometric Measurements in all Lighting Laboratories of a country. Case of study: Ecuador.

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Abstract—This paper presents the results on intercomparison of all photometric laboratories of Ecuador. Three laboratories were involved in the study, one established as conformity assessment body at national level belonging to an Investigation Institute, another one is a University Laboratory and, the last one is a company laboratory that designs and sells lighting fixtures. The lamps and luminaires used were chosen randomly from the larger groups in the exterior illuminating system of Quito. It was used two samples of different manufacturer. It was performed the intensity distribution matrix test with different types of goniophotometers belonging to each Laboratory. The analysis of the results was carried out from two perspectives: an analysis comparing the numerical values point to point and a study of road lighting simulations with DiaLux 4.12.

Index Terms—Intensity distribution matrix.,intercomparison, lamps, luminaires,photometric laboratories, road lighting, goniophotometers.

1 Introduction

THELighting Laboratory who belongs to National Institute of Energy Efficiency and Renewable Energy (INER), an Investigation Institute, is recognized by the Ecuadorian Accreditation System (SAE) as a conformity assessment institution. The INER has developed an intercomparison with all lighting laboratories of Ecuador. Nowadays, the Laboratory is ending the ISO/IEC17025 accreditation process.

In this study are included three laboratories. The General Public Lighting S. A. (GPL) is a company that designs and builds luminaires and it has its own Photometric Laboratory in Guayaquil city, the Catholic University of Cuenca (UCC) located in Cuenca city has another Photometric Laboratory for academic purposes and the INER Lighting Laboratory that is located in Quito city. These are all lighting laboratories in Ecuador. The measures of intensity distribution matrix of each sample were done in all laboratories.

It was randomly chosen two luminaires of different brands from the two more used groups of luminaires. It was financially non feasible do the test in more samples, due to the cost of the transport from the different cities and the careful maintenance of movement of the samples.

2 Methods

The brands of luminaires for road lighting in Ecuador were taken because of its installed quantity. In this case two luminaires of different brands were measured. Luminaire 1: manufacture A, 250 W, High Pressure Sodium and Luminaire 2: manufacture B, 250 W High Pressure Sodium, with 33% and 24% of installation of 250 W respectively, accords to Quito Electrician Company (EEQ). The luminaires were reinforced for repeatable results.

The laboratories involved in the study were mentioned in the previous section. The UCC and GPL goniophotometersare B type and the INER goniophotometer is a C type with rotating mirror. All the measures were taken with steps of 5° in ɣ-Angles and 10° in C-Plane with ɣ-preference. The method to test is according to CIE 121, including ambient conditions.

The reference matrices are the corresponding published by company matrices for each model of luminaire involved in the intercomparision. These will be used in a point to point variation analysis of measured matrices and simulation analysis for general uniformity (Uo), length uniformity (Ul), average luminance (Lm), threshold increment (Ti) and surround ratio (SR)[1] [2] [3].

3Comparing the results of all laboratories

The objective of the experiment is knows the difference between every laboratory and the reference. There was studied the variation of matrix values point to point also there was established parameters to compare simulations of road lighting.

3.1 The point to point analysis

In order to explorer the difference in the photometric results, it has been calculated the relative error point to point between the reference matrix and the result of the test. The percentage variation was calculated taking as a reference the nadir point value of the reference matrix, it was used the equa-

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tion 1.

$$Variation\ percentage = \frac{\left|I_{test\ matrix}\ (\theta_i, \varphi_i) - I_{reference\ \ matrix}\ (\theta_i, \varphi_i)\right|}{I_{nadir\ \ reference\ \ \ matrix}} \quad (1)$$

The repeatability of the results of Luminaire 1 was studied. It was taken a measure before trip around the country and after to finish them, five times in each case. The variation percentage was less than 12% in all points. Particularly in the nadir value was less than 3% that is not a problem due to the expanded uncertainty was 5.23%. The luminaire 2 was not studied because it was broken in the last trip.

The comparison of Luminaire 1 between the reference matrix and the UCC matrix is show in Fig. 1 a). It was high percentage variation in all of its values, most of them with an error around of 100% or more. The comparison of Luminaire 1 between the reference matrix and the INER matrix is show in Fig. 1 b). The higher variations are around 20%, but most of them are less than 10%. The comparison of Luminaire 1 between the reference matrix and the GPL matrix is show in Fig. 1 c). The higher variations are around 40%, but most of them are less than 13%.

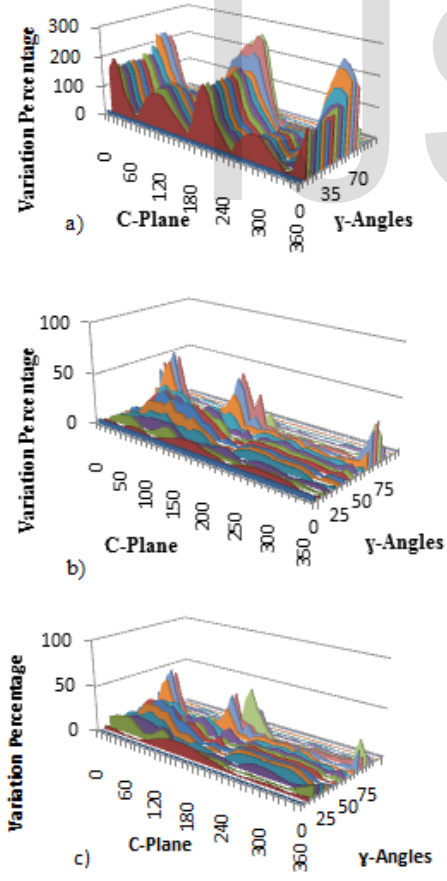

Fig. 1. Variation Percentage of Luminaire 1 between reference matrix and a) UCC matrix b) INER and c) GPL

The reference matrix of Luminaire 2 was measure in different steps of experimental scheme for the C-Plane. To establish de difference point to point, it was used a linear interpolation according to CIE 140.

The comparison of Luminaire 2 between the reference matrix and the UCC matrix is show in Fig. 2 a). It was high percentage variation in all of its values; the higher errors are around the 220% and most of them with an error around of 100%. The comparison of Luminaire 2 between the reference matrix and the INER matrix is show in Fig. 2 b). The higher variations are around 40%, but most of them are less than 10%, equal to GPL results (Fig. 2 c)).

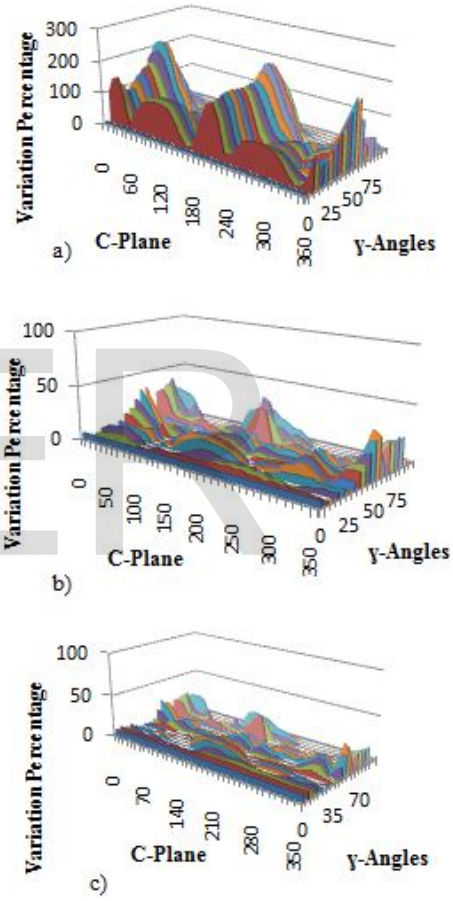

Fig. 2. Variation Percentage of Luminaire 2 between reference matrix and a) UCC matrix, b) INER matrix and c) GPL matrix.

In the Luminaire 2, results show that the UCC laboratory is taking incorrect measures in their goniophotometer tests. The behaviors of errors are similar between GPL and INER laboratories Fig. 2 B) and c), the higher errors are in the same matrix positions, and then they have similar 3D curve. This means that variations are not due to each laboratory measurements. It is because the varying the sample relative to the reference matrix company. It is consistent because of normal linear production in manufacturing.

Higher variation percentages (>10%) in the results of INER

and GPL matrices is over gamma 70°. Over gamma 80° there is not repeatability. However, this variation is not showed in Fig. 2 because the normalization to reference matrix nadir that is a big value compared with the candelas difference. This is a known result that has been found in international comparisons and other works discussed in many congresses like Lux-América and International Commission on Illumination, for example [4]. The reason is that over this angle the values of intensity are small and therefore in two consecutive measurements there is an important difference. However, this difference has not an important weighing in the contribution to the total luminous flux of luminaire.

To verify these discussions it was studied the lighting simulations with the respective laboratories matrices.

3.2 Simulations of road lighting

The simulation was an ideal installation with 3 lanes, total road width 12m, spacing 40m, single-sided arrangement, a maintenance factor 0,89. The road is a M3 class according to CIE115. Same as in the previous section, the INER laboratory measured two times the Luminaire 2 before and after trip around Ecuador. The Table 1 gives the values of lighting quality parameter for each matrix of luminous intensity distribution and their percentage difference.

Simulation	Lm	Uo	Ul	Ti	SR
After trip	1.01	0.41	0.91	6	0.64
Before trip	1.01	0.41	0.84	5	0.64
Percentage difference	0%	0%	8%	17%	0%

Table 1. Percentage difference of quality parameters for luminaire 1 measured before and after the trip in INER laboratory

The Table 1 shows difference only in the longitudinal uniformity of 8%, and threshold increment of 17%. Longitudinal uniformity and threshold increment are calculated with only a few intensities of the whole matrix and regards to observer position. Therefore a change in the position or matrix values specific intensities will change the calculation of longitudinal uniformity and threshold increment. However, those differences in their values are expected due to the change of optical elements by the trip.

Luminous intensity matrix	Lm	% Diff.	Uo	% Diff.	Ul	% Diff.
Luminaire 1						
Reference	1.1	0.00%	0.4	0.00%	0.73	0.00%
UCC	2	81.80%	0.24	40.00%	0.53	27.40%
GPL	1	9.10%	0.44	10.00%	0.84	15.07%
INER	1	9.10%	0.41	2.50%	0.84	15.07%
Luminaire 2						
Reference	1.1	0.00%	0.41	0.00%	0.61	0.00%
UCC	2.3	109.10%	0.34	17.07%	0.7	14.75%
GPL	1	9.10%	0.36	12.20%	0.6	1.64%
INER	1	9.10%	0.35	14.63%	0.6	1.64%

Table 2.Results of simulations and percentage difference (%) between the reference matrix and laboratories matrices for luminaire 1 and 2.

Luminous intensity matrix	Ti	% Diff.	SR	% Diff.
Luminaire 1				
Reference	8	0%	0.7	0.0%
UCC	9	13%	0.7	0.0%
GPL	5	38%	0.6	14.3%
INER	5	38%	0.6	14.3%
Luminaire 2				
Reference	5	0%	0.7	0.0%
UCC	9	80%	0.8	14.3%
GPL	5	0%	0.7	0.0%
INER	5	0%	0.7	0.0%

Table 3.Results of simulations and percentage difference (%) between the reference matrix and laboratories matrices for luminaire 1 and 2.

The Table 2 and Table 3 showthe difference in the designs with the three laboratories. The biggest difference is in the UCC laboratory and its values have not sense. This result is consistent with point to point analysis. It has been communicated to UCC laboratory about its results and nowadays they are checking the operation conditions, their equipment and measurement methodology.

The INER and GPL laboratories have a low percentage in all calculated parameters for Luminaire 1. The GPL laboratory has more difference in general uniformity (Uo), however if this is analyzed in absolute values the difference of the two measurements is according to CIE 115 minimum value.

The general uniformity of Luminaire 2 calculated with INER and GPL matrices is not according to CIE 115, but the percentage difference between reference and each laboratory have similar values (12% and 13%). It is consistent with point to point analysis and their absolute values are characteristics of luminaire of manufacture B, it means that this result is not a measurement problem. The company matrix has different values compared with measured matrices.

In all cases the discussion with the point to point analysis is consistent. The variation of results of simulations give a similar behavior between INER and GPL laboratories, and UCC laboratory a completely out of line values.

4 Concludes remarks

The comparison between INER and GPL laboratories, is very similar in both analysis, point to point and simulations.

UCC has no comparable values of its measures.

The repeatability analysis shows that the Luminaire 1 was not highly affected by the trip. The measures are reliable.

The Luminaire 1 and Luminaire 2 measured differ of its manufacture matrix in the zone of high percentage variation measure (gamma >70°) with either laboratories GPL or INER. The luminaire 2 has more percentage variation, due to the luminaire characteristics.

The UCC laboratory nowadays is in process to analyze the calibration of its goniophotometer and soon will be able to take measure again.production staff in the same order provided by the author.

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REFERENCES

[1] A. R. Bean y R. H. Simons, Lighting fittings performance and design, London: Pergamon Press, 1968.

[2] P. R. Boyce, Lighting for Driving Roads, Vehicles, Signs, and Signals, Boca Raton, Florida: CRC Press Taylor & Francis Group, 2008.

[3] International Commission on Illumination, «Lighting of roads for motor and pedestrian traffic CIE 115,» CIE, Vienna, 2010.

[4] C. Velásquez y F. Espín , «Straylight measurement with solid state light luminaire in a C-Type goniophotometer with rotating mirror,» de *Proceedings of CIE 2016 Lighting Quality & Energy Efficiency*, Melbourne, 2016.

[5] D. L. DiLaura, K. W. Houser, R. G. Mistrick y G. R. Steffy, The Lighting Handbook, New York: Illuminating Engineering Society of North America, 2011.

[6] D. Pelka y K. Patel, «An overview of LED applications for general illumination,» de *SPIE Proceedings, Design of Efficient Illumination Systems*, San Diego, 2003.

[7] W. van Bommel, Road Lighting Fundamentals, Technology and Application, Nuenen: Springer International Publishing, 2015.

[8] C. Velásquez y F. Espín, «Cálculo de la incertidumbre combinada en un goniofotómetro de espejo rotante tipo C y una esfera de Ulbricht,» *I+T+C Investigación, Tecnología y Ciencia,* vol. 9, pp. 29-35, 2015.