Influence of the Position of LED Luminaires on their Thermal Regimes in Photometrical Measurements with a Telecentric Photometer

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***Abstract*—The current paper shows experimentally obtained results for the heating of a LED luminaire put in different burning positions during photometric measurements. Two different goniophotometers are considered – telecentric, where the light distribution of the luminaire is measured while the luminaire is positioned with the light sources facing up (this is not its prescribed burning position) and mirror distributive gonio photometer (MDGP), where the light distribution is measured while the luminaire is in its prescribed burning position. The first equipment has the advantage, that although the luminaire is not in its burning position, the measurement is much faster than when MDGP is used, so the thermal regime of the luminaire under consideration remains normal.**

Keywords—LED luminaire photometry, burning position, heating of the luminaire, telecentric photometer

I. Introduction

The specificity of LED light sources, luminaires and products leads to a change of the principles of their photometric measurements. While for all the conventional light sources "relative" photometry is used, for solid state lighting only "absolute" photometry is applicable [1, 2]. When it comes to relative photometry the light source used is not important, but the photometric output is relative to a measured condition. Here the luminaire may be tested using one light source, but it can be used with different lamp/s and its light distribution will not change. When LED light systems are measured, this scenario is not possible, because the single LED is very small in size and usually LED luminaires are designed in such a way that the light source cannot be separated from the luminaire. In this case absolute photometry is used, which is more complicated. The output is measured in calibrated units under specific condition including position, input voltage and ambient temperature.

There are different goniophotometrical systems that can be used for measurement of LED luminaires and products [3]. The recommendation is that the LED luminaire is kept in its operational burning position. The current paper considers the operation of a telecentric photometer, where the LED luminaire is not in its burning position, but the measurement time is very short [4]. The main concern is what changes when this setup is used.

The thermal management of LED lighting products is an important issue. Some of the performance characteristics of LED products may be influenced due to change of their operating temperature. These changes may be recoverable, but in some situations they may lead to unrecoverable degradation or fatal end of the product [5]. The heat generated by a single LED is about 25% from the power that it consumes. When luminaires are designed, according to their power, the expected dissipation of heat from the LEDs to the heat sink should be estimated for its proper sizing. If a good heat dissipation is not ensured (in the point of the p-n junction), the temperature of the LED raises and that is the major reason why the characteristics of LEDs change in a negative direction. The voltage applied raises with the raise of the temperature of the junction and the emission efficiency decreases. The light spectrum also changes. A key factor here is the path of the heat out of the junction to the environment. The more precise the model of the thermal processes in the luminaire is made, the closer to the optimal the real luminaire is. The thermal management of LED Luminaires defines their basic exploitation characteristics-durability and luminous efficacy. That is the reason why in measurement procedures the positioning of the luminaire is important and should be investigated.

II. Measurement of the Temperature of LED Luminaire

A. *Specificity in junction temperature measurement*

Measurement of the temperature of the junction is not a trivial task. Different approaches for this exist: by means of a contact thermometer; measurement with a thermal imaging camera; estimation of the temperature, based on the thermal dependency of the forward voltage drop.

In most cases the temperature of the radiator or in a point near the LED is measured and based on it the junction temperature is calculated. Measurement with a thermometer put on the optics of the LED is not permitted.

The measurements with thermal imaging camera (the investigation in the current paper uses this approach) should be made very carefully and precisely in order to assure correctness of the results. The radiation coefficient, which depends on the characteristics on the surface of the radiator may influence significantly the data from the thermal imaging camera. That is why some preparatory work should be done before the measurement. This measurement approach, however supplies a lot of information for the distribution of the temperature through the luminaire body in all directions.

B. *Influence of the temperature on the LED luminaires*

Usually the bodies of LED street luminaires and their cooling radiators are made of aluminum and have highly reflective surfaces. The situation with the indoor luminaires

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is sometimes similar. This can lead to improper measuring results. In such cases in order to achieve correctness of the experimental data for the heating within the luminaire, special covers or paints are used that do not change significantly the heat paths.

Summarized heat sources in a LED are:

heat generated in the semiconductor;

heat loss in the phosphor;

Joule heat in the conductive parts;

losses in the primary optics.

The temperature of the junction influences directly the luminous flux; the durability of the LED and its reliability, and indirectly the efficiency of the luminaire and its price.

The heat management of the LED light sources is very important and that is why it should be closely monitored during the measurement stage, because improper conditions can lead to damage of the device.

III. Use of Thermal Imaging Camera for Measurement of the Temperature of a LED Luminaire during Calibration

The current paper is dedicated to the observation of the thermal regimes of a LED luminaire during the measurement of its light distribution with a telecentric photometer. The luminaire is positioned upside down on the rotating table of the measuring device and its heating is monitored during the measurement – about four seconds. The temperature monitoring is carried out by means of a thermal imaging camera, operating in the infrared part of the spectrum. The correlated color temperature, spectrum and color characteristics of the light of the luminaire are also monitored during the measurement process. The light distribution of the same luminaire is also measured by means of a mirror distributive goniophotometer, where the luminaire is in its recommended operation position. Again its thermal regime, correlated color temperature and color characteristics are monitored. It is important to note that in this case the measurement procedure is much slower.

Infrared thermography is the process of acquisition and analysis of thermal information from non-contact thermal imaging devices [6]. A thermal imaging camera measures the infrared radiation emitted by an object and converts the energy detected into temperature. Not all of the radiation received comes from the object, so radiation coming from the environment should be removed in the conversion to temperature. This process is called compensation. The total radiation received by the camera (W_{tot}) comes from three sources: the emission of the target object (E_{obj}), emission of the surroundings and reflected by the object (E_{refl}) and the emission of the atmosphere (E_{atmo}). It can be expressed as Equation (1).

$$W_{tot} = E_{obj} + E_{refl} + E_{atm} \quad (1)$$

Not all the radiation from the target objectis received by the camera, because the atmosphere transmits the radiation with a sudden transmission coefficient (τatmosphere), and also because of the absorption of the atmosphere. Also the tested object reflects the infrared radiation emitted by the surroundings. The reflectivity can be calculated from the emissivity. The atmosphere itself is also a source of infrared radiation. Considering this the overall temperature of an object can be calculated by means of Equation 2.

$$T_{obj} = \sqrt[4]{\frac{W_{tot} - (1-\varepsilon_{obj}) \cdot \tau_{atm} \cdot \sigma \cdot (T_{refl})^4 - (1-\tau_{atm}) \cdot \sigma \cdot (T_{atm})^4}{\varepsilon_{obj} \cdot \tau_{atm} \cdot \sigma}} \quad (2)$$

The transmittance of the atmosphere has a value very close to one. The emittance of the atmosphere is very close to zero ($1 - \tau_{atm}$) and has negligible influence on T_{obj}. The emissivity of the object and the reflected temperature have a very high influence on the temperature measurement and must be measured very accurately.

In order to solve Equation (2), the following parameters should be obtained: the emissivity of the object (ε_{obj}), the reflected temperature (T_{refl}), the transmittance of the atmosphere (τ_{atm}) and the temperature of the atmosphere (T_{atm}).

The image of the target object, considered in the current paper is given on Fig. 1

Fig. 1. Target object of the thermal imaging camera – LED lumiaire

A series of thermal images have been taken during the photometric measurement of the light distribution of the luminaire under consideration. For the measurement with the telecentric photometer – the lumiaire is placed upside down and the temperature is measured seven times during the photometric measurement – one for each C plane measured. The minimum and maximum values of the temperature are given on figures 2 to 8.

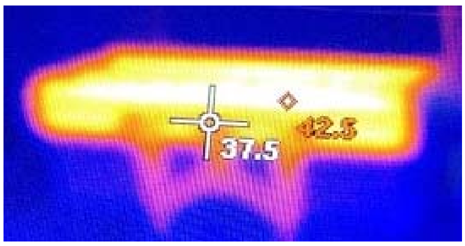

Fig. 2 Thermal image for C0 plane plane – telecentric photometer

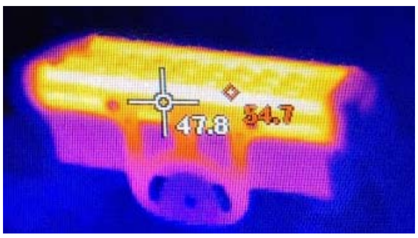

Fig. 3 Thermal image for C15 plane – telecentric photometer

Fig. 4 Thermal image for C30 plane plane – telecentric photometer

Fig. 5 Thermal image for C45 plane plane – telecentric photometer

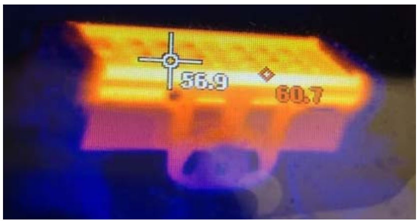

Fig. 6 Thermal image for C60 plane plane – telecentric photometer

Fig. 7 Thermal image for C75 plane plane – telecentric photometer

Fig. 8 Thermal image for C90 plane plane – telecentric photometer

The same photometric measurement is taken by means of a mirror distributive gonio photometer (MDGP). In this case the luminaire is put in a working position. Thermal imaging measurement is made during photometric measurement of the light distrivution of the luminaire in C0, C30, C60 and C90 planes, respectively shown on fig. 9 to 11.

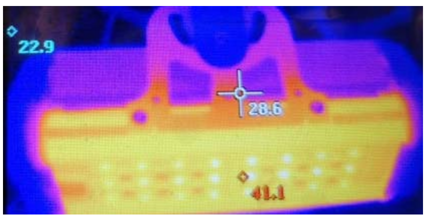

Fig. 9 Thermal image for C0 plane during light distribution measurement on MDGP

Fig. 10 Thermal image for C30 plane during light distribution measurement on MDGP

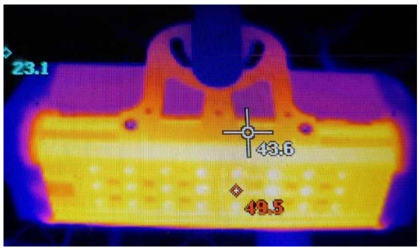

Fig. 11 Thermal image for C60 plane during light distribution measurement on MDGP

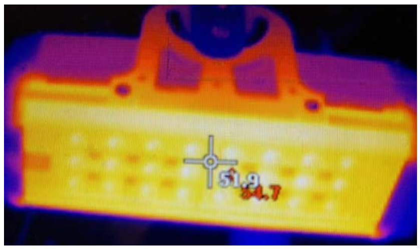

Fig. 12 Thermal image for C0 plane during light distribution measurement on MDGP

IV. Analysis of the Results and Conclusions

The aim of the current paper is to show that when the light distribution of a LED luminaire is measured, the duration of the procedure should also be considered when recommendations about its position during the process are made. Two different situations are used as an example here – the situation when the position of the luminaire during the measurement is not its normal burning position, put the measuring procedure takes short time and the situation when the measurement procedure takes longer, but the burning position is the recommended one.

In order to compare also the worst scenario the light distribution of a randomly selected luminaire with electrical power of 65W is measured manually on a telecentric photometer for the same time period as it is necessary for the same measurement by means of a mirror distribution goniophotometer. When the telecentric photometer is used in automated mode, it measures 50 C planes for about 4 minutes, so the lowest temperature obtained at the end of the measurement is 48.9 degrees and the highest is 56.9 degrees. During a manual measurement the temperature reaches minimum value of 58.9 degrees C and maximum 60.8 degrees C. For the same time period and same photometric measurement, but made by means of a mirror distributive goniophotometer, the temperatures on the luminaire's surface are as following – minimum 51.9 degrees C, maximum 54.7. As it can be observed the temperature never gets higher than 75 degrees C, also in both cases the hottest surface of the luminaire is the optical glass. The temperature difference in the worst case – manual measurement with a telecentric photometer compared to normal automated measurement with MDRP is six degrees C. If the measurement is done by means of a telecentric photometer in automated mode, the maximum temperature, that is reached is 56.9 degrees C or 2.2 degrees higher than when MDRP is used.

As a conclusion it can be stated that additional comparative measurements of the light distribution of different in size and application luminaires should be investigated in order to confirm the results obtained in the current paper and namely that the burning position of LED luminaires during photometrical measurements is not critical for the thermal regimes and the experimental results.

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