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Influence of temperature in the performance of the LED lamp

Influência da temperatura no desempenho de lâmpada LED

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ABSTRACT

In this work, we analyze the temperature of the LED lamp of white emission with 9 W with or without the influence of the cooling process using a fan. The investigation was carried out by seven different methods: (1) Analysis of temperature close to LEDs inside the bulb (diffuser); (2) Analysis of temperature on LEDs without bulb; (3) Analysis of temperature on LEDs without bulb with cooling using a fan; (4) Analysis of temperature on LEDs board out of body lamp without bulb; (5) Analysis of temperature on LEDs board out of body lamp without bulb with cooling using a fan. This last analysis 5 exhibited better results, decreasing the significant temperature on the LED surface from ≈130ºC (found in analysis 2) to ≈45ºC. Due to good results exhibited in analysis 5, it was used in the illuminance measurements of the LED lamp without cooling in the analysis 6, and with a fan as analysis 7. Both results compared showed that using a fan had a great influence, and difference on the illuminance values by elapsed time from ≈47,000 lux without a fan (analysis 6) to ≈55,300 lux with fan (analysis 7), and also the use of a fan exhibited the lowest time of stabilization in 1 minute only.

Keywords: LED lamp, Heat sink, Temperature, Illuminance, Lifespan.

RESUMO

Neste trabalho, nós analisamos a temperatura de lâmpada LED de emissão branca de 9 W com e sem a influência de processo de resfriamento usando um ventilador. A investigação foi realizada por sete diferentes métodos: (1) Analise de temperatura próxima aos LEDs dentro do bulbo (difusor); (2) Análise de temperatura sobre os LEDs sem o bulbo; (3) Análise da temperatura sobre os LEDs sem o bulbo com refrigeração usando um ventilador; (4) Análise de temperatura sobre a placa de LEDs fora do corpo da lâmpada sem o bulbo; (5) Analise de temperatura sobre a placa de LEDs fora do corpo da lâmpada com refrigeração usando um ventilador. Esta última análise 5 é exibida melhores resultados, diminuindo a temperatura significante sobre as superfícies dos LEDs de ≈130ºC (encontrada na análise 2) para ≈ 45ºC. Devido aos bons resultados exibidos na análise 5, foi usada medidas de iluminância da lâmpada LED sem refrigeração na análise 6, e com o ventilador na análise 7. Ambos resultados comparados mostraram que usando o ventilador teve a grande influência, e diferença sobre os valores de iluminância pelo tempo decorrido de ≈ 47.000 lux sem ventilador (análise 6) para ≈ 55.300 lux com ventilador (análise 7), e também o uso do ventilador exibiu o menor tempo de estabilização em 1 minuto apenas.

Palavras-chave: Lâmpada LED; Dissipador de calor, Temperatura, Iluminância, Tempo de vida.

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INTRODUCTION

LED (light-emitting diode) is a semiconductor electroluminescent device that has defined the electromagnetic spectrum available with high brightness very used in lamps to the production of white emission and promoting energy consumption economy[1-3]. In the lighting market, there are some types of LEDs with different advantages and applications. In this case, three LED types are most common, known as[4-6] MICRO (used in the displays to the production of images); COB (chip on board used in reflectors), and SMD (surface mounted device used in lamps). MICRO and COB LEDs have similar characteristics as: performance up to 120 lm/W (double performance of SMD); opening angle up to 160º (degree); the most intensity of light; extensive lifespan (because both require no electronic driver); multi-direction of the light produced, and present greater stability in the electrical current, if the line presents any variation in the voltage, while the SMD LED present performance from 60 to 70 lm/W; an increase of opening angle up to 360º (degree), and the performance is dependent of the lifespan. Figure 1 shows the LED types previously mentioned[7].

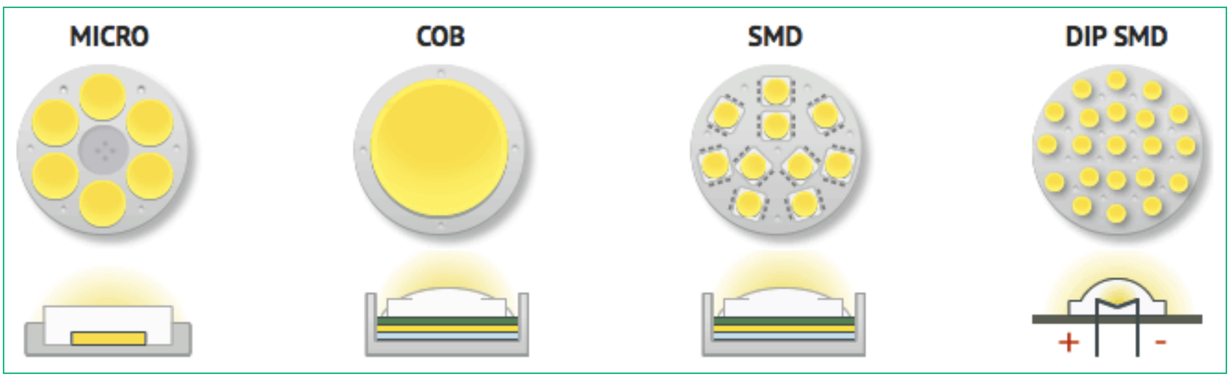

Figure 1: Different LED types with white light emission available in the lighting market[7].

In comparison with all light sources projected by a human, the LED lamps have presented good characteristics, due to the benefits offered. Table I shows a comparison among different light sources most common with the mean characteristics[8].

Table 1: Comparison among different light sources presenting different characteristics[8].

Type	Incandescent	Fluorescent	LED
			
Durability	1 Year	5 Years	15 Years
Consumption	50 W	10 W	5 W
Economy	No	Up to 80%	Up to 95%
Heat emission	High	Moderate	Low
Ecological	No mercury	Mercury	No mercury
Efficiency	Low	Moderate	High

The LED lamps offer other properties, such as[9-11]: dimerization effect; low operating voltage; resistance to impacts and vibrations; ecologically correct; "green" engineering; low light depreciation; dynamic color control; instant activation; variable intensity control; vivid and saturated colors; direct light; and no use of ballast.

The fact that LED lamps reach lifespan much less than that of the values described on the packaging is attributed to new products present in the lighting market. The low quality of electronic components (for example, electrolytic capacitors) used in the composition of electronic drivers and the difficulty of expelling the intern heat are factors that have decreased the lifespan considerably. These electronic drivers are composed by electrical circuits containing electronic components responsible for the conversion of power line AC in DC to the polarization of LEDs[12,13]. They are composed basically by three basic elements: (1) electrical circuit of input energy; (2) control circuit of electrical energy; and (3) energy used by LED[14,15].

A LED lamp of 7 watts was disassembled. Figure 2(a) shows the electronic driver with some electronic components on the printed circuit board, and Fig. 2(b) shows the verse of the same electronic driver with SMD electronic components.

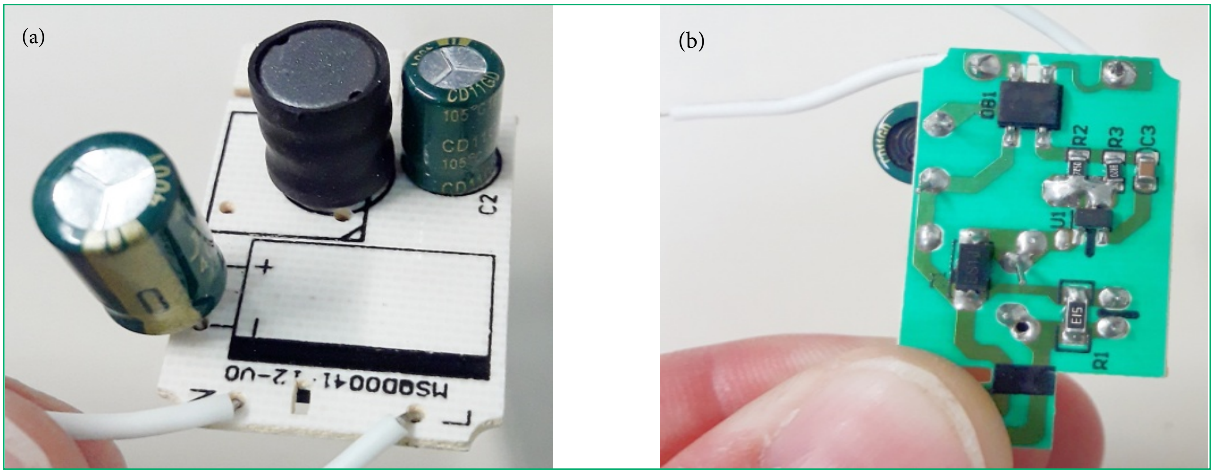

Figure 2: Electronic driver of the LED lamp of 7 watts: (a) front and (b) verse. Authors' source.

In Figs. 2 (a) and (b), it is possible to observe diversified electronic components, such as electrolytic capacitors, integrated circuits, and resistors.

The most common problem that occurs in the electrolytic capacitors is the leak of the intern dielectric (material capable of storing energy) that is generated by the increase of the internal heat of the LED lamp[16]. Later, the electrical current necessary to store energy is considerably decreased, which influences the normal performance of the other electronic components and, as a consequence, the LED lamp presents different behaviors, as quickly oscillations of the light intensity, intermittent flashes of light, abrupt tuned-off and lowest intensity of light than that normal as the manufacturer describes on packing (these defective features were observed in other investigations not reported here). Figure 3 shows the same LED lamp of 7 watts disassembled with a body, electronic driver, 8 LEDs mounted on board, and diffuser bulb.

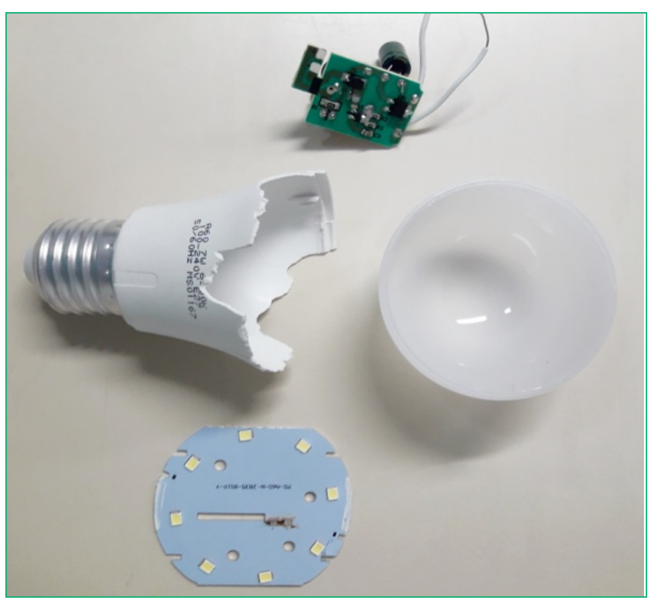

Figure 3: The LED lamp of 7 watts disassembled with all components used. Authors' source.

Another LED lamp of 12 watts was disassembled and revealed the use of a metal sheet under LEDs' board to the better heat sink, due to the high temperature reached[17]. Figure 4 shows the LED lamp of 12 watts disassembled, and Fig. 5(a) shows the electronic driver with some electronic components at the printed circuit board, and Fig. 5(b) shows the verse of the same electronic driver with integrated circuits and SMD resistors.

In the electronic driver of the LED lamp with 12 watts is observed a large number of electronic components confined inside the lamp in comparison with the LED lamp of 7 watts, including an inductor and large resistor as showed in Fig. 5 (a), both responsible for the creation of oscillation filter.

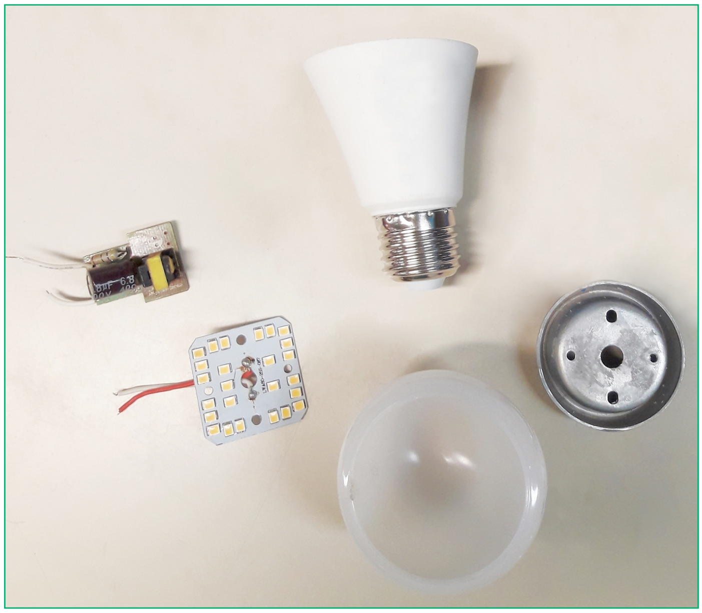

Figure 4: LED lamp of 12 watts disassembled with all components used. Authors' source.

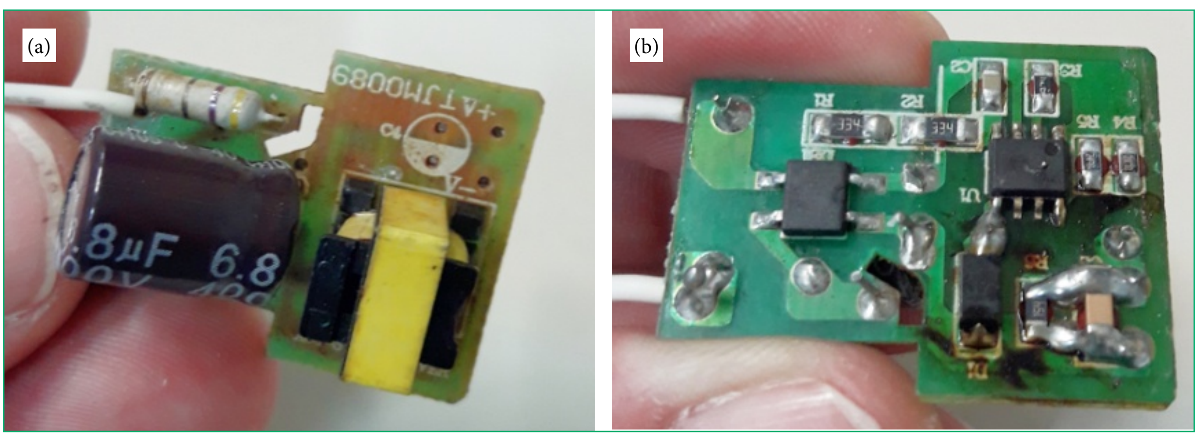

Figure 5: Electronic driver of LED lamp with 12 watts: (a) front and (b) verse. Authors' source.

The large number of electronic components confined (less ventilation) in a small physical area contributes even more to increase the intern heat. Then two different sources of temperature are observed inside the lamp: the first caused by the energy consumption of the electronics components used in the electronic driver and the second promoted by energy operation of LEDs. In this case, the second source of temperature can be most important, because if the energy consumed by a single LED is interrupted, the energy supplied to all LEDs is also interrupted and, consequently, the LED lamp is automatically turned off. This behavior is caused by the serial electrical connection of all LEDs in the electrical circuit.

So, to considerably increase the useful life of LED lamps, it is necessary to understand the influence caused by the internal temperature on the LEDs, which has been a common problem in many cases.

The heat sink is an initial point of view to obtain better performance and considerably increase the LED lamps lifetime.

MATERIALS AND METHODS

In the experiments, a commercial LED lamp was used (available in the Brazilian lighting market, but made in China), model BDA6-0800-02 with some characteristics described on the packaging: power of 9 W; white emission of 6,500 K; bivolt of 100-240 V; frequency of 50/60 Hz; electrical current of 73/44 mA; connector base of E27; luminous flux of 803 lm; luminous efficiency of 89 lm/W; beam angle of 200° (degree); color rendering index ≥ 80; power factor - PF > 0.90; mounted with aluminium and plastic materials; dimensions of 60 x 110 mm; weight of 60 g; lifespan (L-70) of 25,000 hours.

The analysis of the LED lamp was carried out with or without a diffusing bulb. Figure 6 shows the disassembled LED lamp with the diffusing bulb and 9 LEDs on board, and Fig. 7 shows details of the numbered LEDs on board, also revealing also the total voltage operation of 94 V.

Figure 6: Disassembled LED lamp with diffuser bulb. Authors' source.

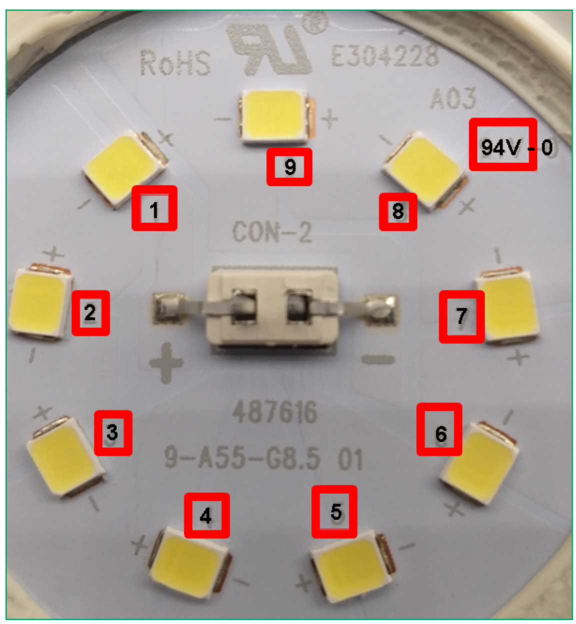

Figure 7: Detail of the LED board numbered from 1 to 9 and total voltage operation of 94 V. Authors' source.

In this investigation, seven different analyses were performed for a LED lamp:

Analysis 1: the temperature of the LED lamp was measured with thermocouple K type (chromel/alumel, with a range from -200 to 1,300°C) connected with digital multimeter manufactured by Minipa, model ET-2042E. Four equidistant positions were marked with a pen on the lamp body, and a slit on the diffuser bulb was performed to insert the tip of the thermocouple positioned around LEDs (maximum distance up to 0.5 mm). Figure 8 shows the method used in the analysis 1.

The diffuser was turned on the body lamp to obtain the intern temperature for each different position (from 1 to 4). The temperature was also measured in the center of LEDs board (near to anode and cathode electrodes). Another five slits were also carried out on the top of the diffuser bulb in the center to obtain the internal temperature close to the surface.

Analysis 2: the bulb of the LED lamp was removed, and the temperature for each LED was measured using an infrared thermometer, manufactured by Instrutherm Company, model TI-860. The target (luminous point) of the infrared beam was positioned in the active area of each LED. In the arrangement was used the universal scientific support (the same used in the chemical experiments) to hold the LED lamp and the infrared thermometer that it was positioned with a distance of 8.0 cm.

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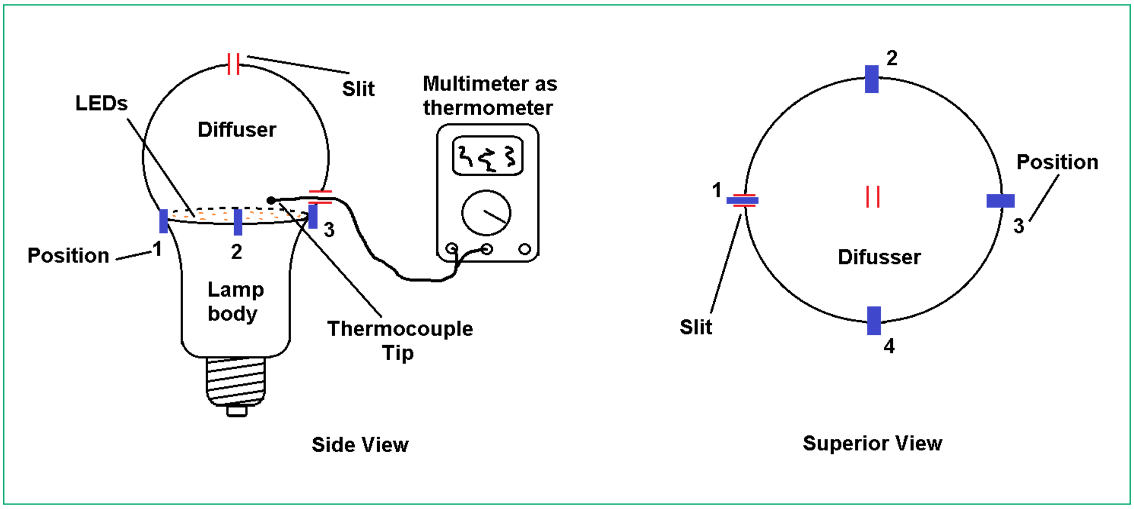

Figure 8: Method to obtain the temperature of a LED lamp used in analysis 1. Authors' source.

Analysis 3: the same experiment of analysis 2 was used, but a fan manufactured by Yate Loon Electronics Company, model D90SH-12 DC (M-GP1) with 12 V and 0.27 A, and geometry of 9.0 x 9.0 cm polarized by ATX power supply, manufactured by Multilaser Company, model PSU - GA200 BU (the same used in a microcomputer) was used to cool the LED lamp. The distance used between the fan and the LED lamp was 2.0 cm. Figure 9 shows the method used in the analysis 3. The idea of a fan used in the experiment is based on the Sunon Company. This manufacturer has offered a wide range of customized thermal solutions for the lighting market of LED with fans and heat sinks systems[18,19].

Figure 9: Method to obtain the temperature of a LED lamp used in analysis 3. Authors' source.

Analysis 4: the LED board was removed from inside of the LED lamp and polarized with a self-electronic driver using two copper wires that were welded in the anode and cathode electrodes. In the analysis of temperatures, the infrared thermometer was used and the same arrangement with the universal scientific support. Figure 10 shows the method used in analysis 4.

Analysis 5: it was used the same experiment of analysis 4 but with the lateral wind as employed in the configuration of analysis 3.

Analysis 6: the illuminance of LEDs board was obtained using the configuration of analysis 4. In the experiments were obtained three measurements using a lux meter manufactured by Minipa Company, model MLM-1011 positioned with 8.0 cm of LEDs board.

Analysis 7: the illuminance of LEDs board was analyzed with a side wind, as used in the configuration of analysis 3.

For all experiments, the lamp was maintained with the LEDs board positioned at the top, and the interval of each measurement the lamp was cooled to reach room temperature. In the analysis of illuminance with or without the use of a fan, the position of the LEDs board and lux meter were not affected.

Figure 10: Method to obtain the temperature of a LED lamp used in analysis 4. Authors' source.

RESULTS

In analysis 1, a similar temperature is verified around of the LEDs board compared to four positions reaching values from ≈85 to ≈90°C. The temperature measured at the center of the bulb is a region farther from the concentration of LEDs and, for this reason, it had a lower temperature value of ≈ 47°C.

After 7 minutes, the temperature is practically stable with only very low variations that can be influenced by ambient temperature conditions or variation in the power line.

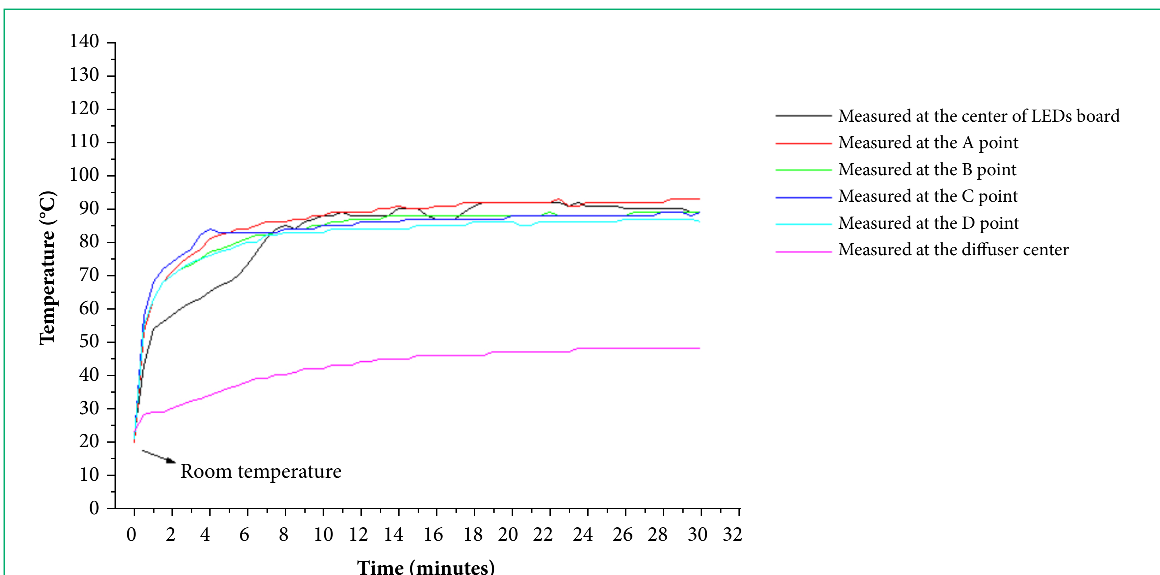

Figure 11: Temperature analyses near to LEDs at four different points including the diffuser center.

In general terms, it is possible to observe that in this lamp there is a poor heat sink that is proportional to the high power of light output for all devices, the fact of confinement only increases the internal temperature of the lamp. This characteristic causes stress on the LEDs over time, affecting the normal performance of LEDs for the elapsed time of use.

The results of analysis 2 reveal in the first few minutes a fast increase of temperature and elevated heat on the phosphor surface with stable temperature from ≈127 to ≈132°C after 10 minutes of elapsed time. Then, there is a hypothesis that the temperature on LEDs reaches highest values with the use of the diffuser bulb as the LED lamp is originally commercialized.

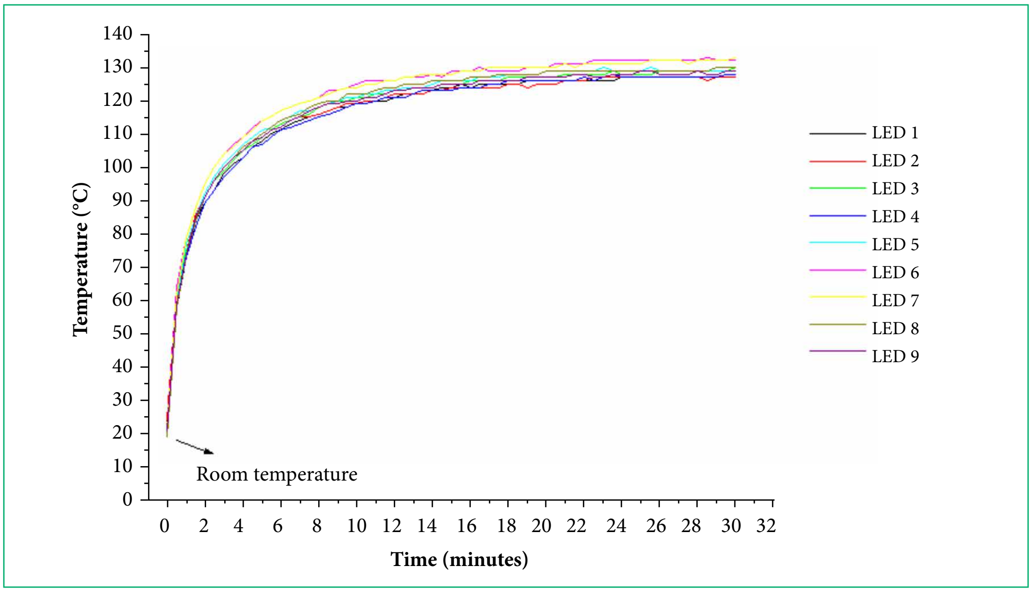

Figure 12: Temperature vs. time for LEDs measured in analysis 2.

As an example, in the datasheet of model 3528LED, the temperature range from -40 to +100°C is reported by Edison Opto., but this Company does not reveal some information related to the measurement method used[20]. It also reveals that the increase injunction temperature from 20 to 120ºC causes a decrease in the direct voltage from 6.15 to 5.15 V. The high temperature can cause dark spots on the surface of LEDs formed by silver sulfide (Ag_2S from electronic components of driver) decreasing gradually the luminous flux. As an example, Fig. 13 shows another LED lamp without bulb containing 20 LEDs with some dark spots.

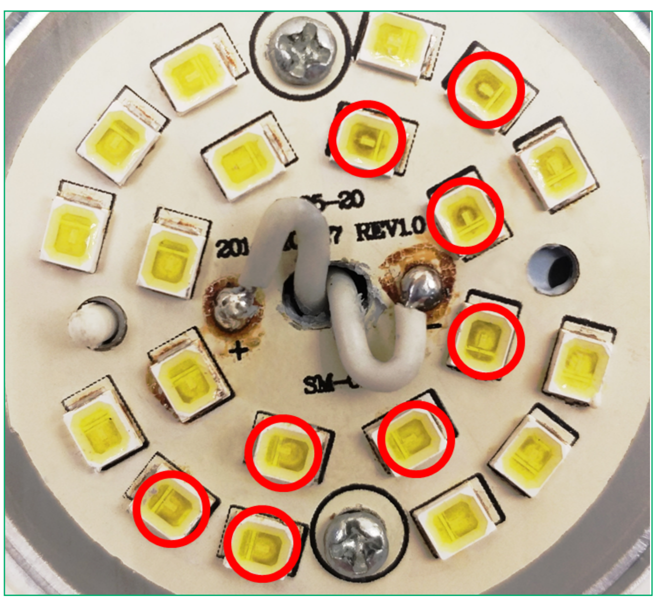

Figure 13: Dark spots (red circle) on surface of LEDs (lamp: 10 W, 110/220 V and 6,500 K).

Another problem that causes dark spots on the LED surface is related to the electrical components of the driver, which spread gas containing: sulfur, chlorine, and bromine, and these materials react with the nitrogen of atmospheric air generating corrosive gas promoting corrosion of the LED[20].

In the results of analysis 3, it is possible to verify a range of different temperatures from ≈35 to ≈75°C, indicating the influence caused by the cooling process. The hypothesis for this behavior can be explained by current flux of the LEDs positioned closer of electrical contacts (anode and cathode) reached highest temperatures, while the LED devices positioned further reached lowest temperature, as can be seen in Fig. 7. In general terms, the influence of the wind directly on the LED devices caused a very significant difference in decreasing the temperature.

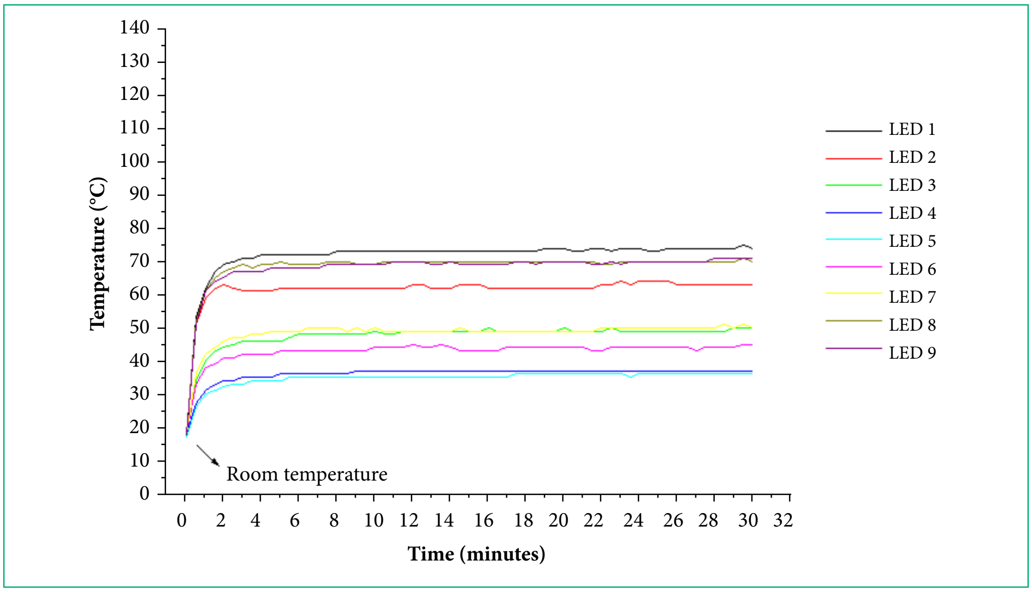

Figure 14: Temperature vs. time for LEDs measured in analysis 3.

In analysis 4, high-temperature levels are verified from ≈100 to ≈120°C, indicating the absence of the wind as a method of cooling process.

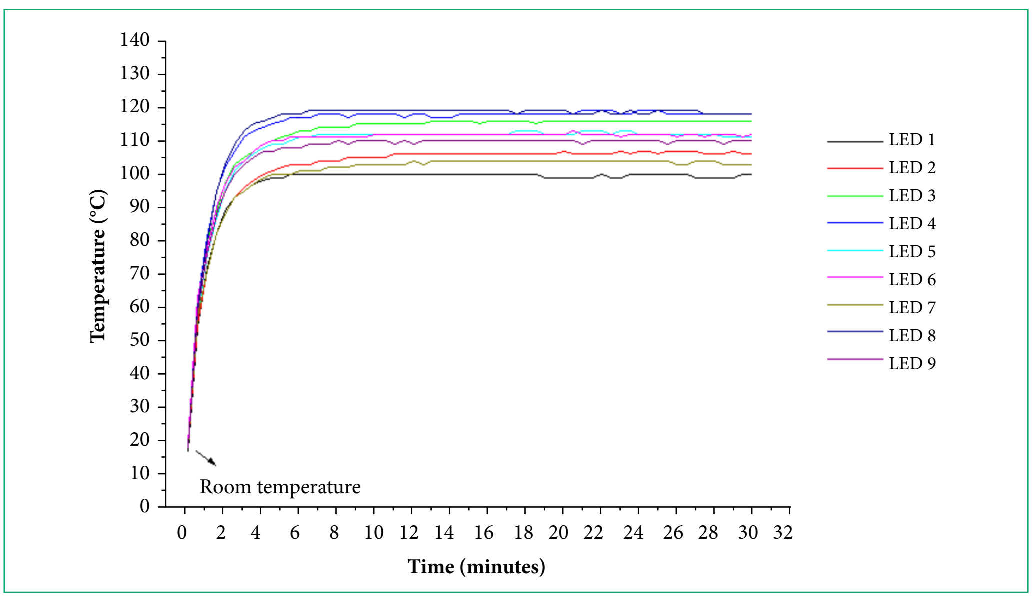

Figure 15: Temperature vs. time for LEDs measured in analysis 4.

A hypothesis for this behavior in Fig. 16, related to the different temperature values found, can be explained by the absence of the heat also caused by the electronic driver inside the lamp body. There is a possibility that the heat generated by the electronic driver will influence the temperature of the LEDs board, and this fact is best evidenced in analysis 5 of the ventilated LEDs board. In this case, the temperature range from ≈30 to ≈60°C had a great influence caused by a fan, showing rapid stabilization in the first minute of measurement in comparison with all the analyzes previously obtained.

Figure 16 shows the temperature vs. time for analysis 5.

Due to the analysis 5 to present the lowest values of temperature vs. time, the illuminance of the LEDs board was measured with or without a fan. The measurements with illuminance vs. time revealed significant influences caused by the temperature in the performance of LEDs and it is possible to verify a considerable decrease of the illuminance by elapsed time. Figure 16 shows analysis 6 with illuminance vs. time results.

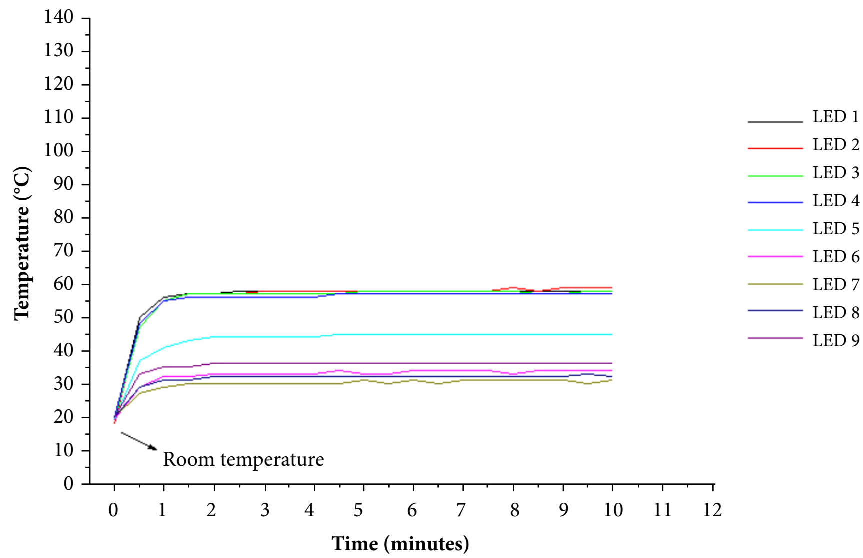

Figure 16: Temperature vs. time for LEDs measured in analysis 5.

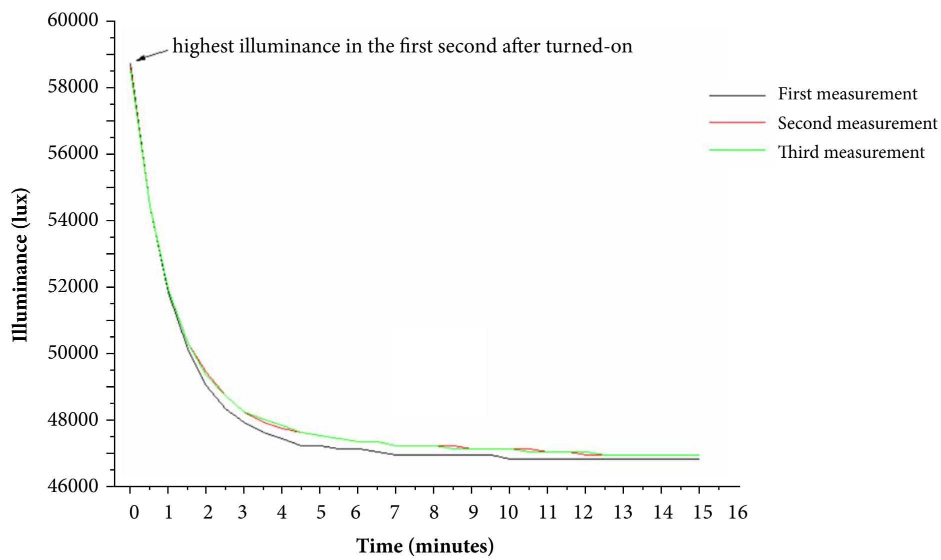

Figure 17: Illuminance vs. time for LEDs measured in analysis 6.

The illuminance results show a range from ≈58,700 to ≈47,000 lux, and after 6 minutes, the values show a tendency to stabilize. This behavior has a similar aspect to that observed in the same experiment of analysis 4. In other words, as the operating of the LEDs begins to stabilize, the illuminance values also begin to show the smallest variations, although the difference of ≈11,700 lux does not is perceived by human eyes, due to the high measured levels.

In comparison with analysis 6, the results of analysis 7 presented in Fig. 18, there is a range from ≈58,700 to ≈55,300 lux. This difference in ≈3,400 lux is much lower than that presented by analysis 6. This behavior proves the influence caused by a fan on the LEDs' operation method.

As a reference, Michael Royer, from the U.S. Department of Energy, reported that the LED submitted at 105°C shows 14,000 hours with production of 70% lumen and a projection of 26,000 hours with 50%; at 85ºC shows 54,000 hours with the production of 70% lumen and projection of 100,000 hours with 50% and at 55°C shows 60,000 hours with production of 70% lumen and projection above of 239,000 with 50%[21]. These results presented by Michael Royer are very important to obtain a considerable increase in the use of LED lamp reaching 25,000 hours, as described on the packing of LED lamps commercialized in the lighting market.

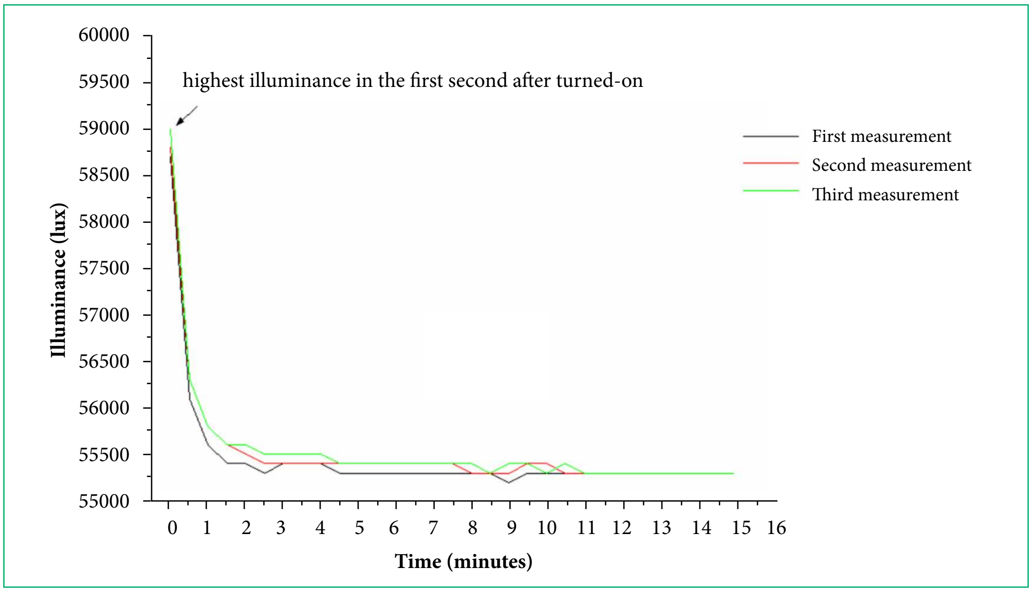

Figure 18: Illuminance vs. time for LEDs measured in analysis 7.

CONCLUSION

The temperature analysis of temperature on the LED lamp with white emission shows that the heat generated has significant influence on performance. The results show that the heat sink is a problem that needs to be improved. The internal heat of the LED lamp is generated in two forms: (a) temperature of the LEDs on a board and (b) heat caused by electronic driver components. Seven analyzes were carried out with or without a cooling method. The significant results showed that the use of fan-cooled LEDs board caused by the lowest temperature on the LED surface, decreasing from ~130°C (analysis 2) to ≈45°C (analysis 5). The results presented with the use of a fan had a significant influence and difference in the illuminance values for the elapsed time, increasing from ≈47,000 lux without fan (analysis 6) to ≈55,300 lux with fan (analysis 7) with shorter stabilization time. These differences in temperature and illuminance values are necessary to show a good performance of the LED with cooling method, avoiding dark spots on surface of LED, and increase the useful life.

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