Chapter

The Thermal Dissipation of LED Outdoor Lighting Luminaires: Comparative Analysis for a Real Case of Study

Hermoso-Orzáez Manuel Jesús, Hervás-Pulido Manuel Jesús, Unión-Sánchez Juan de Dios, Ogáyar-Fernández Blas and Gago-Calderon Alfonso

Abstract

Today LED technology is being imposed, day by day, in our cities and homes as an efficient way of lighting. The performance of its lighting, durability, energy efficiency, and light, coupled with the economy of its use, is shifting to other classic forms of lighting. However, some problems associated with the durability of equipment associated with thermal dissipation and high-temperature problems, which end up affecting the light intensity and service life, are beginning to be detected. The objective of this paper is to compare the results obtained previously, at different contour temperatures, with the current practical results obtained with a FLUKETI25 thermal imaging camera. The theoretical results will be compared with the current results applied to the different luminaires. Where real thermal dissipation is studied, it is obtained for each of them in the laboratory of illumination with the thermographic camera FLUKE TI. The theoretical and experimental results are evaluated, and the results are discussed. This study shows that instead of LED technology, it is less risky for quality depreciation and durability of lighting if a project has already been achieved that favors optimal thermal dissipation, supported by the importance of choosing an appropriate design and appropriate materials.

Keywords: LED, thermal dissipation, luminaire, outdoor lighting

1. Introduction

1.1 Technological evolution of public lighting

Street lighting has undergone a great technological evolution since 1931, when the first mercury vapor lamps appeared in Europe. The principle of operation of this lamp consists of the closing of a switch producing an arc between the two electrodes of the lamp, ionizing the gas contained inside the tube initiating the main discharge.

The discharge occurs first through the gas since the mercury is at room temperature and at a low pressure. Progressively the mercury increases its temperature and vaporizes, increasing the pressure inside the tube and consequently the voltage between the terminals of the lamp. After a few minutes, the mercury is completely volatilized and the discharge occurs through it. At this time, the luminous flux increases and the color of the source varies. When the balance is reached, the intensity is regulated by the ballast (**Figure 1** and **2**) [1].

These lamps need a reactance that limit the intensity passage through the tube and stabilize the discharge. They do not need starting equipment and have a capacitor connected in series with the lamp whose function will be the correction of the power factor (**Figure 2**).

As of 2015, new public lighting works began to be banned in Spain and their replacement in existing facilities was recommended.

In the year 1955, a more advanced and technological evolution lamp appeared with respect to mercury vapor, called high pressure sodium vapor lamp (VSAP). The characteristics of the street lighting fixtures were improved with these lamps, but the luminous efficiency and the chromatic reproduction were the weak point of these.

The principle of operation is simpler than that of mercury vapor technology and consists in that light is obtained by the emission generated in the collision of free electrons with the gas atoms of the discharge tube. Shocks excite the electrons that pass to a higher energy level. When these electrons return to their natural orbit, the emission of the photons, that is to say, the radiation of light takes place [1].

The radiations emitted by these lamps represent an emission spectrum with wider bands, where the discharge tube of the luminaire can reach up to 1000°C (**Figure 3**).

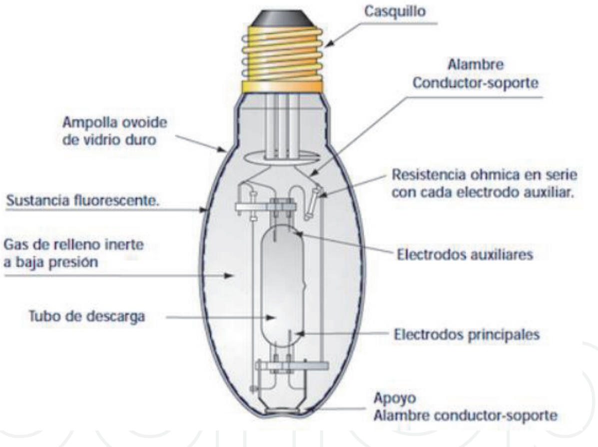

Figure 1.
Components of the mercury vapor lamp. Source: Manual INDAL lighting.

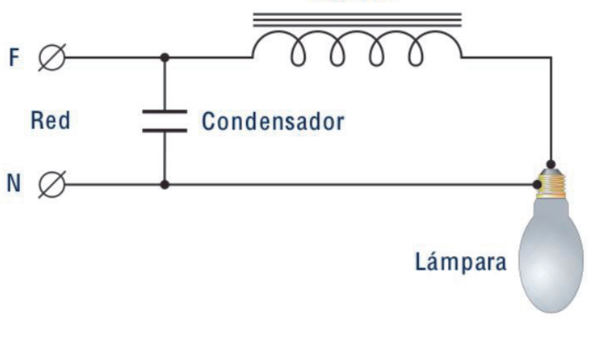

Figure 2.
Mercury vapor lamp operation scheme. Source: Own elaboration.

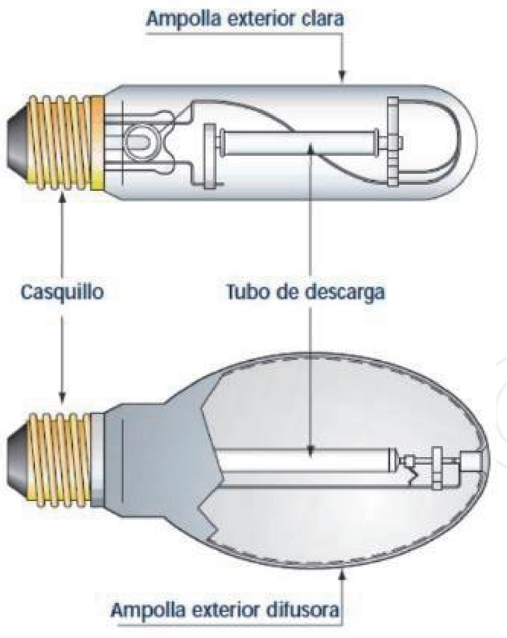

Figure 3.
Parts of the high pressure sodium vapor lamp. Source: Manual INDAL lighting.

High pressure sodium vapor luminaires need high voltage during their start-up process, then they need auxiliary equipment to turn on. The auxiliary equipment consists of a ballast and a starter that can be connected in series or semi-parallel. To correct the power factor a capacitor is connected in parallel (**Figure 4**).

These luminaries have a yellowish golden color, and are used for outdoor lighting, provided that the color rendering does not have to be high.

Parallel to the VSAP lamp and about the year 1960, the first metal halide (HM) lamps appeared. Inside the discharge tube, metal additives are added to enhance certain areas of the visible spectrum so that it increases its performance, both bright and colored. The spectral composition of these lamps is very complete and can be adapted to the needs of the user because it depends on the composition of the metals added.

The principle of operation is very similar to that of the mercury vapor lamp (Hg). The light is obtained by the electric discharge that is generated by the potential difference between the electrodes. This difference causes a flow of electrons to cross the gas, and thus excite the atoms contained in the discharge tube. Depending on the iodide with which the tube is filled the excitation of the atoms will produce different colors (**Figure 5**) [2].

When starting the HM lamps, a very high starting voltage is required due to the halides. To achieve this, it is necessary to connect a starter, which has as a fundamental element a thyristor, responsible for supplying a peak voltage. In addition to the starter, auxiliary starting equipment contains a ballast in series with the

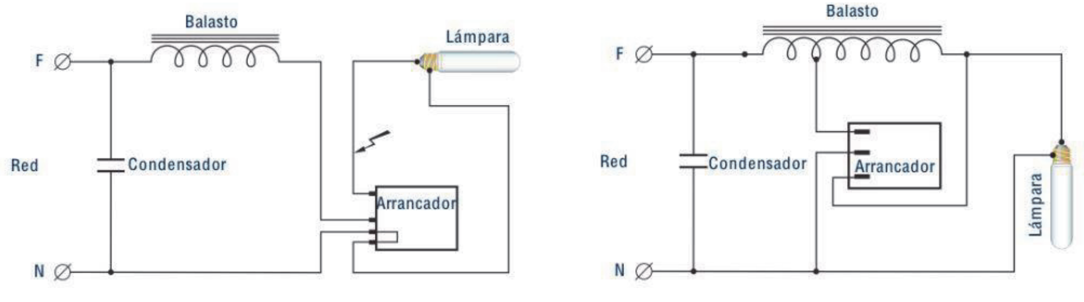

Figure 4.
Scheme with independent starter and scheme with half-parallel starter. Source: Own elaboration.

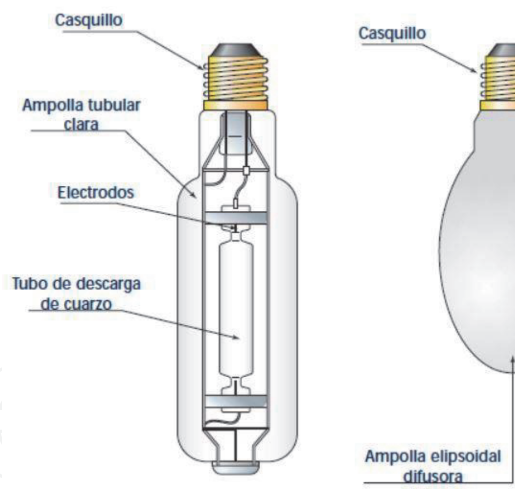

Figure 5.
Parts of the metal halide lamp. Source: Manual INDAL lighting.

discharge pipe to stabilize the discharge and a capacitor to compensate for the power factor. The time necessary to reach the regime conditions is between 3 and 5 min (**Figure 6**).

This type of lamps are used in places where high chromatic performance is necessary, such as sports spaces, shopping centers, facades, monuments, television broadcasts, etc.

It was from the year 2000, when the greatest technological revolution occurred regarding consumption and energy efficiency in public lighting with the development of LED technology luminaires.

These luminaires were based on the development of power LEDs. An LED is defined as a unidirectional semiconductor electronic device. When the LED is directly polarized (the anode voltage is positive, and the cathode voltage is negative) and current flows through them, the free electrons of the N layer move

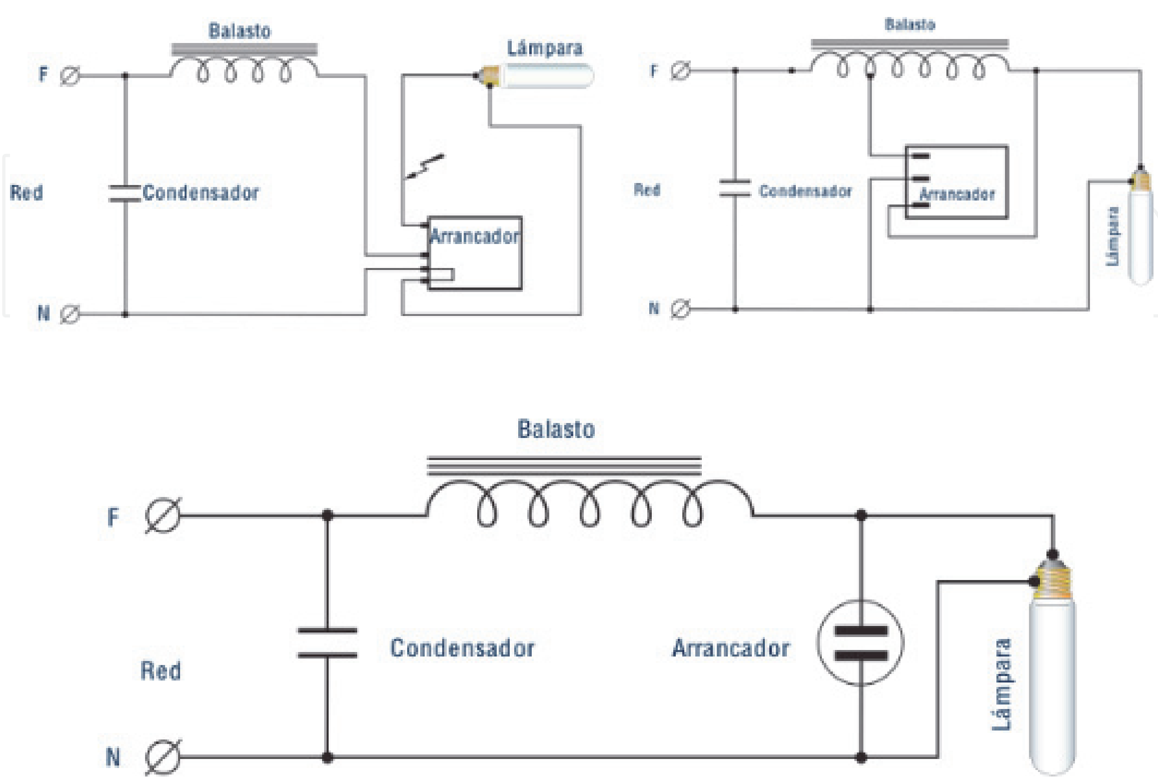

Figure 6.
Wiring diagrams with: independent starter, semi-parallel and parallel. Source: Own elaboration.

through the diode and combine with the hollows of the layer P, implying a fall of the band of conduction to a smaller orbital, so that the electrons release energy in the form of photons (light). The size of the band jump defines the color of the light (**Figures 7** and **8**).

The LEDs are designed to work with specific currents, unlike the previously exposed technologies that are built to work with a certain voltage.

These semiconductor devices are fed with a direct current source through a series resistor to limit and control the current and achieve a correct operation and lengthen the life of the component (**Figure 9**).

The LED luminaires are powered by power supplies (driver), which depend on the configuration of the lamp, of the direct current to provide and control the current that passes through them. The fundamental reason is that voltage variations can cause LED destruction when there is a high voltage increase. On the other hand, a decrease in voltage is used as a method of regulation.

Currently in the field of public lighting, LED diodes of high luminosity are used, they are more complex because they incorporate elements to dissipate the heat that allow to withstand greater currents to provide more luminous flux.

LEDs, thanks to the high resistance they have to environmental conditions and their advantages over incandescent lamps, can be used in any field of outdoor lighting [3].

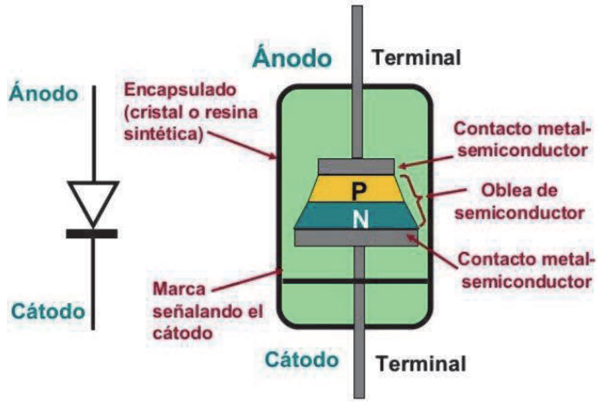

Figure 7.
Structure diode LED. Source: Manual INDAL lighting.

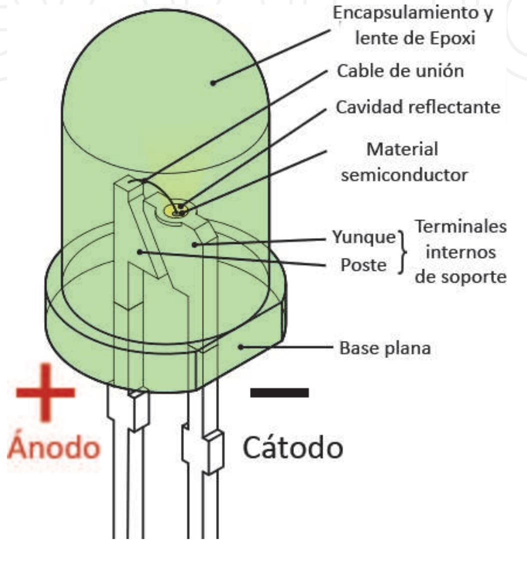

Figure 8.
Components and pinout of the LED. Source: Manual INDAL lighting.

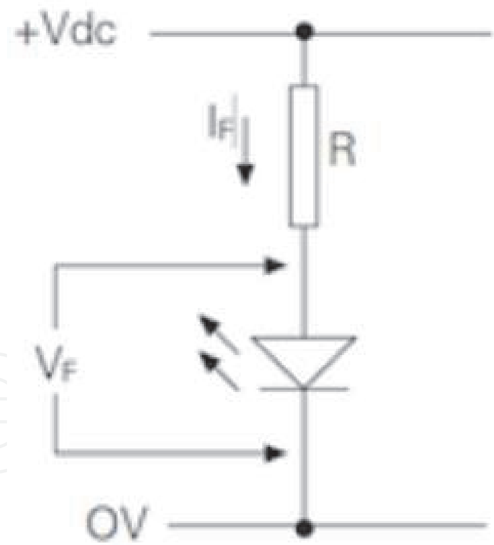

Figure 9.
Connection of an LED lamp. Source: Own elaboration.

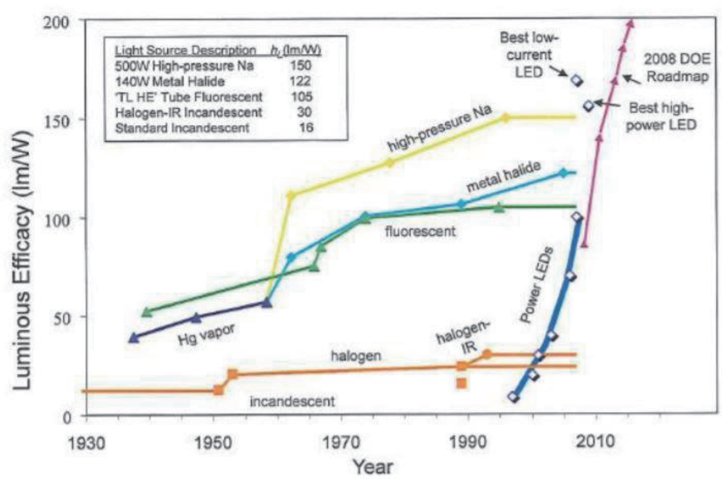

Figure 10.
Graph of evolution of public lighting. Source: INDAL lighting manual.

By way of summary and to give a more general view of the technological evolution and energy efficiency that has suffered public lighting, which has been exposed at this point, you can see the following graph which represents the energy efficiency of each luminaire and its year of appearance (**Figure 10**).

1.2 SWOT analysis LED technology versus download

The SWOT analysis is a map through which the weaknesses, threats, strengths and opportunities of an organization, project, technology, etc. are established. In our case we will perform the SWOT analysis on a technology, in this case the LED against the download technology (**Table 1**).

Through an analysis of the external environment and the internal characteristics of the technology to be analyzed, this tool allows obtaining a graphic representation of:

- Weaknesses: Constitute the limiting aspects of the capacity of technology development, due to its internal characteristics.

	Internal analysis	External analysis
Negative	More expensive technology compared to download	Increased risk of chronic diseases due to its white light
	Poor performance in high temperatures due to electronic components that contain	Alteration of behavior and reproduction of organisms that at night coexist with white light and alter their rhythm of life
	They require a high thermal dissipation to extend their useful life	
Positive	Low energy consumption	They produce less CO_2 emissions to achieve the same lighting
	Long durability	
	High color rendering index	Greater aid and funding for its implementation
	Less light pollution	Reduction of raw materials for its manufacture by having a long useful life

Table 1.
SWOT analysis LED technology versus discharge: own elaboration.

- Threats: These are all external factors that may prevent the development of this technology.
- Strengths: They gather the set of internal resources, positions of power or any type of competitive advantage over other technologies.
- Opportunities: External factors that favor the development of technology or provide the opportunity to implement improvements.

1.3 Problems of LED technology

The use of LED technology in lighting of public lighting seemed to pose a promising revolution with an obvious advantage: the energy savings that would be achieved by using it.

This revolution has been compromised by a series of thermal, electrical and lighting problems that have been studied as this technology began to be implemented in our cities.

Beginning with the part of thermal dissipation, one of the biggest problems that LED technology presents is the large amount of heat that has to be evacuated to the outside with respect to the discharge technology. The large number of electronic components that form a LED luminaire, makes the generation of heat inside it very large [2]. Most of the heat is produced in the driver (80%), and in the light-emitting diodes (approx. 20%) [4]. The heat generated in the driver is very large due to its own operation, since it is responsible for the protection of the LEDs by means of a suitable voltage and intensity.

The operation of a LED driver, is basically a full wave diode rectifier bridge, which transforms the alternating current (AC) into direct current (DC) and adapts the voltage and output currents for the correct operation of the LED. The supply voltage of a LED luminaire is the network (230 V effective), this voltage passes through a transformer of reducing voltage that adapts the voltage to the input of the bridge. The input, consists of a bridge of four diodes that lead two to two, depending on the cycle of the voltage wave (positive or negative) and that completely rectifies the voltage wave, then passes through a capacitor that is responsible for generate the direct current through its own charge and discharge. Once this has been generated, a Zener diode is responsible for stabilizing and cleaning the direct current so that it can be consumed by the load (LED) (**Figures 11** and **12**).

As can be seen, the use of electronic components is large, and the generation of heat is very high, then a poor thermal dissipation causes a very important decrease in the useful life of the luminaire [5].

The second group of problems presented by LED technology is in the electrical part [3]. The large-scale introduction of LED lamps impacts two major disturbances in the quality of energy: distortion or harmonic contamination [6] and peak current at start-up [7].

The harmonic distortion of the LED lamps is higher than the discharge luminaires (due to the electronic components they contain). The concern of network operators is that large quantities of these luminaries will negatively impact the network with high levels of harmonics [6] and supramonics [8]. The concern is that although the absolute value of the emission of a lamp may be low, it is likely that the luminaires will be installed in large quantities and that the combined emission resulting from the lamps may be very important. This will result in heating in the conductors and consequently risk of fire in the installation if the line is not well protected.

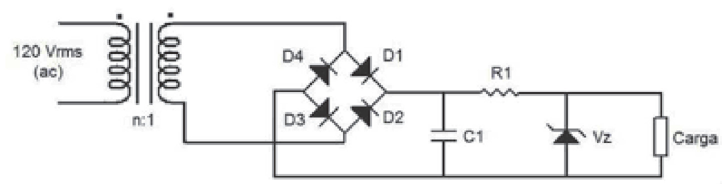

Figure 11.
LED driver components. Source: Own elaboration.

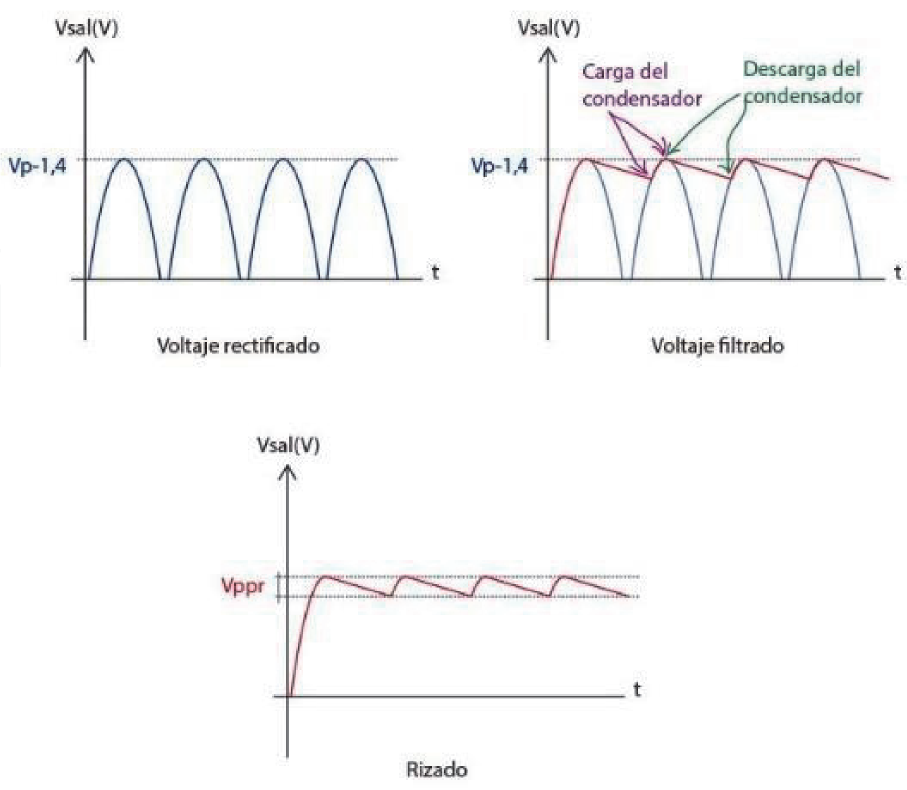

Figure 12.
Wire patterns in the LED driver. Source: Own elaboration.

With regard to peak current at start-up, it can be said that electronic equipment in luminaires significantly improves their luminous efficiency, which increases the energy efficiency of lighting installations. However, the use of electronics [for example the use of electronic ballasts for discharge lamps or drivers for LED luminaires] can also cause some negative effects in the lighting installation. One of these effects is the large input current [7], which can greatly exceed the permissible line load and activate the overcurrent protection devices. To solve this problem, a progressive ignition is carried out by means of circuits, that is to say, turning on luminaire blocks progressively instead of provoking the massive ignition of the lamps, in order to try to mitigate this problem (**Figure 13**) [7].

To finish with the problems that this technology presents, we study the light part. Recent studies have shown that the use of outdoor LED lighting has a significant environmental cost, since light pollution, due to the colder color temperature in LED luminaires, degrades ecosystems throughout our planet [9].

It was expected that with the adoption of LED solutions, developed countries would appear "obscured" in the images taken by a satellite thanks to the lower impact of this technology, but its massive use has meant that this lighting simply remains or even increases (**Figures 14** and **15**).

The results of the study warned of the danger of making light pollution compromise "the well-being of practically any organism of our planet including humans."

This type of light has long been considered an important environmental pollutant that can affect the routines of animals, plants and microorganisms,

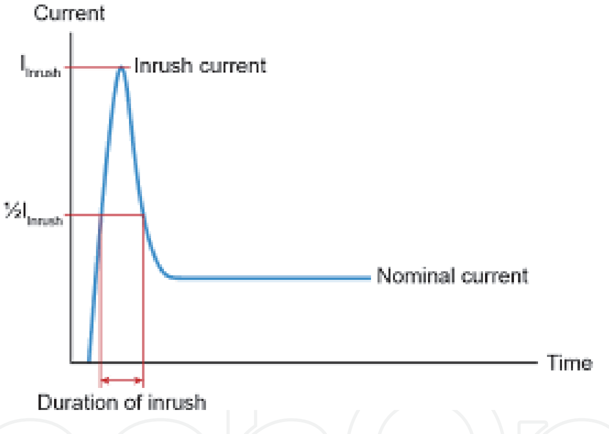

Figure 13.
Peak current in the LED light fixture. Source: eldoLED.

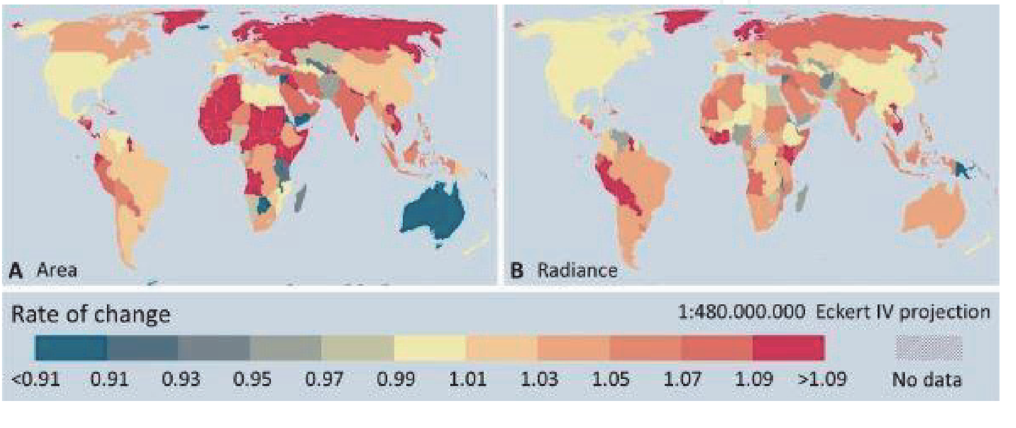

Figure 14.
Geographic patterns of changes in public lighting [6].

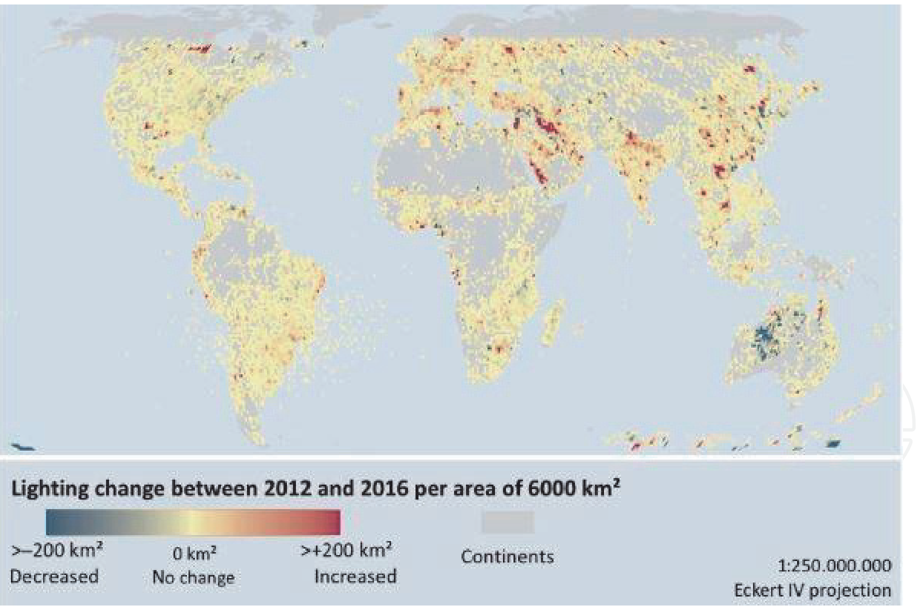

Figure 15.
Absolute change in the illuminated area from 2012 to 2016-Fuente: Ref. [6].

but also that of humans, as it disturbs the circadian rhythm, which can lead to metabolic disorders.

The problem could be minimized by using shorter wavelengths in the luminaires, that is, LED luminaires with warmer lighting. This is achieved by doping the LED, but on the contrary we would be reducing its useful life.

2. Methodology

2.1 Materials and methods

Because LED lighting has the advantage of a longer lifespan and light efficiency has also been improved, as a result, the market for LED lighting devices has grown rapidly recently. However, due to this fact, there is a serious problem of heat dissipation, since almost 70% of the total energy consumed by the LED lighting device is emitted as heat and must be eliminated to obtain greater efficiency and a longer life. The performance and lifetime of LED luminaires will become deficient and short if heat does not dissipate properly [2].

Nowadays, it is required that more power be applied to the LED device to produce more light output, therefore, the total heat generated by the LED luminaire will also be significantly increased. If it is not cooled sufficiently, both the service life and the luminous efficiency of the LED device will be reduced. Therefore, to commercialize high power LED devices, the problem of heat dissipation must be overcome first [10].

The development of an effective cooling technology is considered as an important requirement for a permissible operating regime that does not reduce the useful life of the lighting devices.

In this last study carried out in the present work, we propose a methodology for the study of the effectiveness in the dissipation of heat of the different luminaires under analysis by means of the temperature evolution curve of each one of them. The realization of said curve was carried out with the help of a thermographic camera, which will be described in detail in the following sections (**Figure 16**).

The realization of said thermal study was carried out simulating "real operating conditions" of the luminaires, that is, a nocturnal operating regime was simulated in

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Figure 16.
Experimental set-up for temperature measurement in luminaires. Source: Self made. FLUKE Ti 25 thermal camera. Source: User manual. ThermoFiguraTi25 FLUKE camera.

a totally dark room at a normal ambient temperature of 25°C and with an interval of 8 h. continuous work of the luminaries, which is normally the time they remain lit during the night in a normal day of operation.

This study was carried out studying the five LED luminaires.

3. Experimental analysis and results of actual thermal dissipation in the lighting laboratory using a FLUKE TI 25 thermal imaging camera

For the acquisition of real data of the luminaries a thermographic camera will be used in the lighting laboratory of the University of Jaén. Thermal imaging cameras are devices that convert thermal energy (heat) into visible light to analyze a particular object or scene. The produced image is known as a thermogram and is analyzed through a process called thermography. Thermographic cameras are sophisticated devices that process the captured image and display it on a screen. These images can be used for an immediate diagnosis or processed through specialized software for greater evaluation, accuracy and performance of the report. Thermographic cameras take the measurement temperature to the next level; Instead of getting a number for the temperature, you get an image that shows the

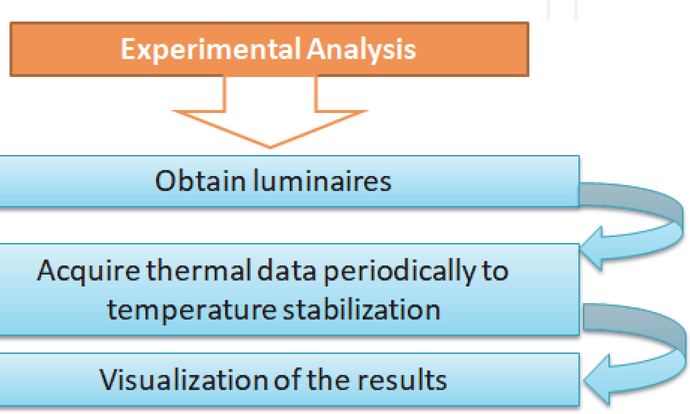

Figure 17.
Flow diagram of the methodology to follow to obtain the theoretical results in the thermal analysis of the five LED luminaires under study. Source: Self made.

Atributo	*Valor*
Sensibilidad Termal	≤90 mK
Rango de Medición de Temperatura	−20 → +350°C
Precisión Máxima de Medición de Temperatura	±2°C
Campo de visión H x V	23 × 17°
Frecuencia de Actualización	9 Hz
Distancia Mínima de Enfoque	15 (Thermal Lens) cm, 46 (Visual Lens) cm
Tipo de Enfoque	Manual
Resolución del Detector	160 × 120 píxel
Tamaño del Display	3.7 plg
Resolución de Display	640 × 480 píxel
Peso	1.2 kg
Altura	267 mm
Anchura	127 mm
Número de modelo	Ti25
Longitud	152 mm

Source: User's manual. Ti 25 FLUKE thermal imager.

Table 2.
Table of specifications of the thermal imager.

temperature differences of a surface [11]. **Figure 17** shows the flow diagram for the acquisition of experimental data from five LED luminaires for further study [12] and comparisons with the theoretical thermal data [13].

3.1 Features of the thermal imager used

The thermal imager used is a FLUKE Ti 25; this camera is manufactured to be used in very adverse work environments. It captures a digital image with an infrared and merges it. The temperature range is from −20 to 350°C with a pressure of 2°C. The thermal sensitivity is 0.1°C at an ambient temperature of 30°C; this describes the smallest difference between two pixels in the temperature that the camera can measure [11]. **Table 1** shows the specifications of the thermal imager used for the study (**Table 2**).

For the study of the images taken with the thermal imager, the SmartView software that is supplied with the camera is used. This software contains functions to be able to analyze the images and organize the stored data [11].

3.2 Emissivity

All objects radiate infrared energy. The amount of energy radiated is based on two main factors: the surface temperature of the object and the emissivity of said surface [11]. Most of the measured objects such as painted metal, wood, water, skin and fabric are very efficient to radiate energy and it is very easy to obtain accurate measurements. For surfaces that are efficient to radiate energy (high emissivity), the emissivity factor is estimated at 95% (or 0.95) [14]. The emissivity varies from 0 to 1, for a black body that radiates the maximum infrared energy its value is 1.

However, this simplification does not work for shiny or metallic surfaces without painting, a correction of the emissivity is necessary [15].

Emissivity is a very important issue for the measurement of surface temperature without being in contact [14]. Depending on the material to be measured, the emissivity will vary [15]. The emissivity determined to obtain the temperatures of the materials has been obtained from a table of emissivities [16].

3.3 Luminaires under experimental study

The luminaires chosen for the acquisition of data with the thermal imager in the lighting laboratory are due to the availability of the manufacturers to provide the luminaires and luminaires that are in the lighting laboratory of the University of Jaén. In particular there are two luminaires that are currently installed throughout the city of Jáen (**Figure 19**).

The first luminaire under study is the ATP Air Series 7 luminaire, see **Figure 18**. This luminaire corresponds to a novel design for the improvement of thermal dissipation and corresponds to Model A, which has performed thermal simulation for the prediction of heat dissipation and air flow [17].

Another available luminaire is the NaviaP model by Sólydi Led Innovation, **Figure 19**, which corresponds to a design in which the heat sink is in contact with the environment, with a total nominal power of 60 W, 32 LEDs with a power of 1.67 W/LED, the heat sink material is aluminum.

The next luminaire corresponds to the LH-GL1A manufactured by Luminhome Lighting (**Figure 20**), with a nominal power of 60 W, which has 18 LEDs with 2 W/LED, the body and housing materials are made of an aluminum alloy [18].

Figure 18.
Series 7 air LED luminaire from ATP lighting. Source: ATP LED catalog lighting February 2018.

Figure 19.
LED NaviaP luminaire by Sólydi LED innovation. Source: Sólydi catalog.

Another luminaire to which the experimental data for the study will be taken is the luminaire T1A-2-80 of Luminhome Lighting (**Figure 21**). The nominal power of the luminaire is 80 W, with 2 modules of 14 LEDs, with 2.3 W/LED. The body and the housing are formed by an aluminum alloy [19].

And the last luminary present in this study corresponds to a Philips luminaire with a nominal power of 20 W, **Figure 22**. It consists of 16 LEDs of a power of 1 W/LED, the body and the housing are integrated by an aluminum alloy.

In **Table 3** the main characteristics belonging to the five luminaires of the present study are collected.

Figure 20.
Luminaire LH-GL1A by Luminhome lighting. Source: Data sheet luminaire LH-GL1A by Luminhome lighting.

Figure 21.
Luminaire T1A-2-80 by Luminhome lighting. Source: Data sheet luminaire T1A-2-80 by Luminhome lighting.

Figure 22.
Philips 20 W luminaire. Source: Self made.

Model	Nominal power (W)	Number of LED	Power by LED (W/LED)	DRIVER power (W)
ATP Aire Serie 7	204	96	2	12
Sólidy NaviaP	60	32	1.67	7
LH-GL1A	60	18	2.7	10
T1A-2-80	80	28	2.3	15
Philips 20 W	20	16	1	4
Source: Self made.				

Table 3.
Summary table of the main characteristics of each luminaire.

3.4 Data acquired with the thermal imager

A progressive data collection has been made from the ignition to the thermal stabilization of the equipment. Taking data periodically until the temperature has remained stable. The images of the thermal imager represent temperature in steady state, once.

3.4.1 Thermographic data Air Series 7

When making measurements of the heatsink with the thermal imager and being a specific material with a certain alloy or formulation in the material compound, several types of emissivities have been used to obtain the exact temperature (**Figures 23–30**).

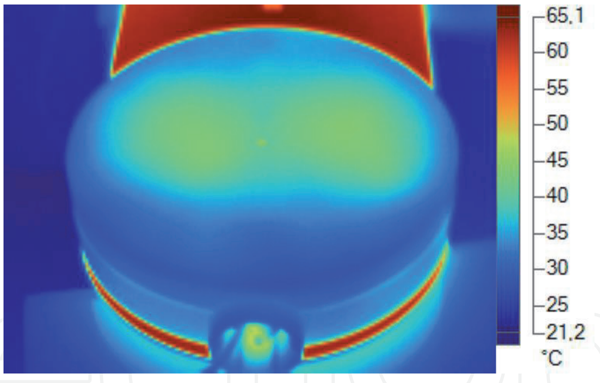

Figure 23.
Thermal data of the cover. Blue and green area. Plastic emissivity 0.92. Source: Own elaboration from software SmartView 4.1 Fluke.

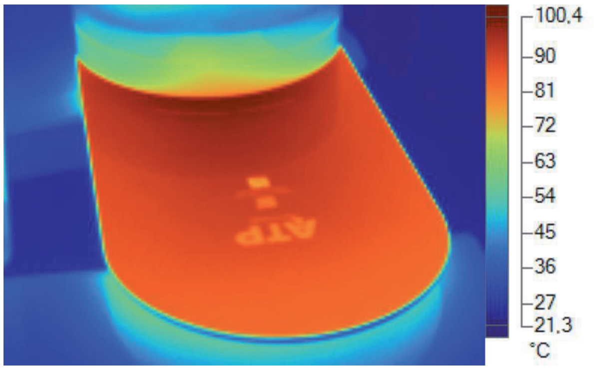

Figure 24.
Thermal data of the heatsink. Reddish area emissivity aluminum alloy 0.5. Source: Own elaboration from software SmartView 4.1 Fluke.

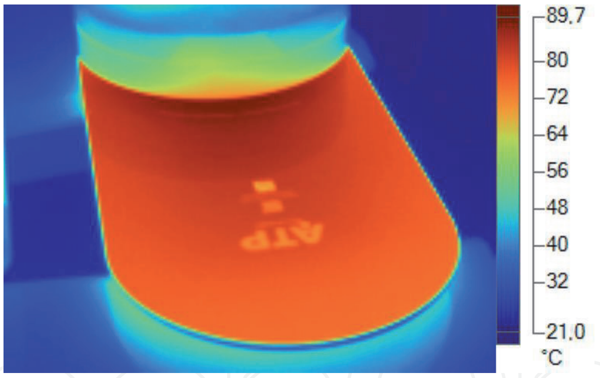

Figure 25.
Thermal data of the heatsink. Reddish area emissivity aluminum alloy 0.6. Source: Own elaboration from software SmartView 4.1 Fluke.

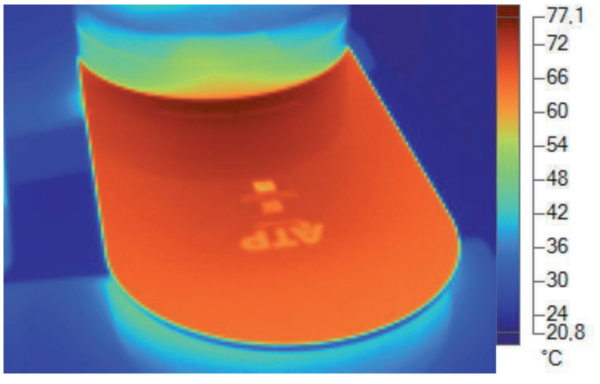

Figure 26.
Thermal data of the dissipator reddish zone. Emissivity anodized aluminum 0.77. Source: Own elaboration from software SmartView 4.1 Fluke.

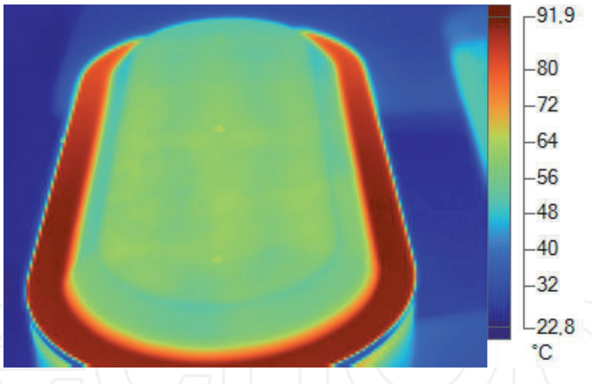

Figure 27.
Thermal data of the heatsink. Reddish area emissivity aluminum alloy 0.5. Source: Own elaboration from software SmartView 4.1 Fluke.

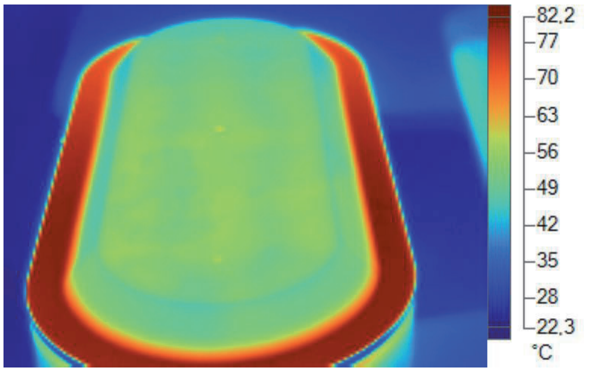

Figure 28.
Thermal data of the heatsink. Reddish area emissivity aluminum alloy 0.6. Source: Own elaboration from software SmartView 4.1 Fluke.

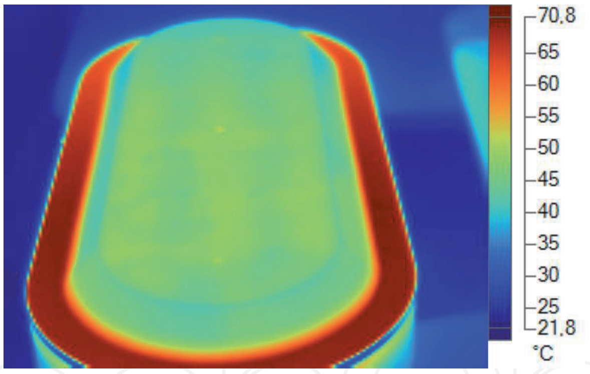

Figure 29.
Thermal data of the heatsink. Reddish area emissivity anodized aluminum 0.77. Source: Own elaboration from software SmartView 4.1 Fluke.

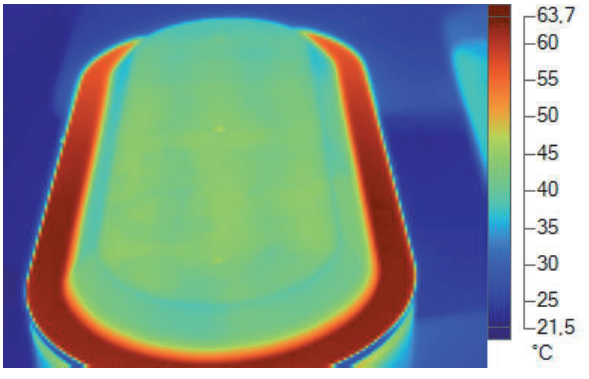

Figure 30.
Thermal data of the diffuser. Green zone plastic emissivity 0.92. Source: Own elaboration from software SmartView 4.1 Fluke.

3.4.2 Thermographic data NaviaP

See **Figures 31** and **32**.

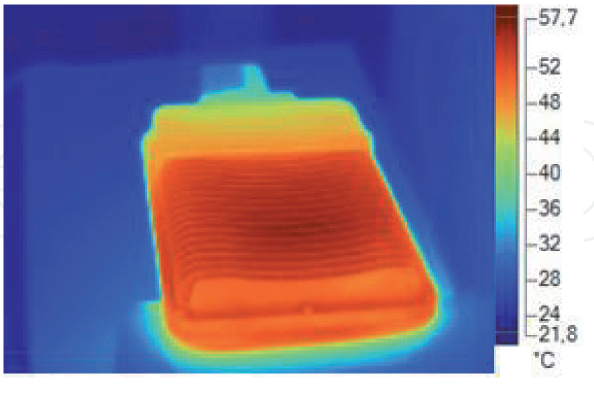

Figure 31.
Thermal data of the heatsink. Reddish area emissivity anodized aluminum 0.77. Source: Own elaboration from software SmartView 4.1 Fluke.

3.4.3 Thermographic data LH-GL1A

See **Figures 33** and **34**.

3.4.4 T1A-2-80 thermographic data

See **Figures 35** and **36**.

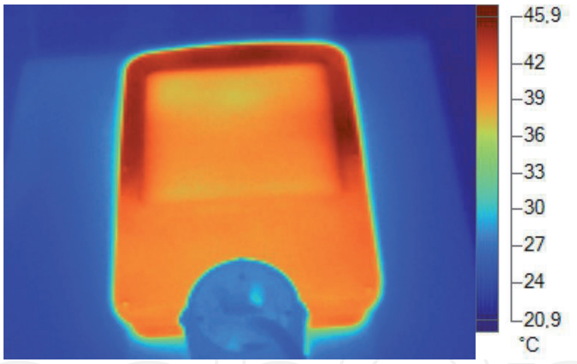

Figure 32.
Thermal data of the diffuser. Square central area orange color. Emissivity glass 0.94. Source: Own elaboration from software SmartView 4.1 Fluke.

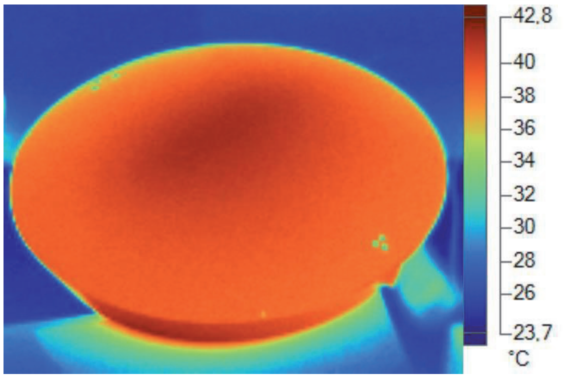

Figure 33.
Thermal data of the housing. Reddish area emissivity anodized aluminum 0.77. Source: Own elaboration from software SmartView 4.1 Fluke.

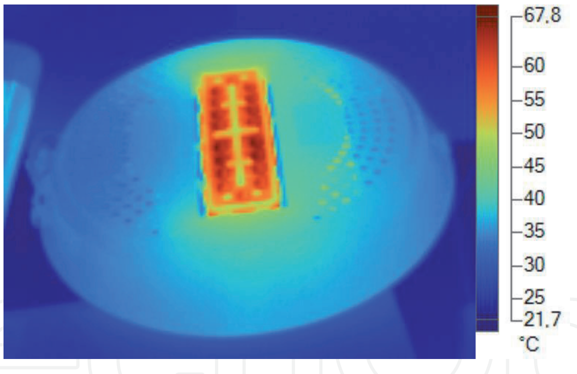

Figure 34.
Thermal data of the diffuser. Reddish area plastic emissivity 0.92. Source: Own elaboration from software SmartView 4.1 Fluke.

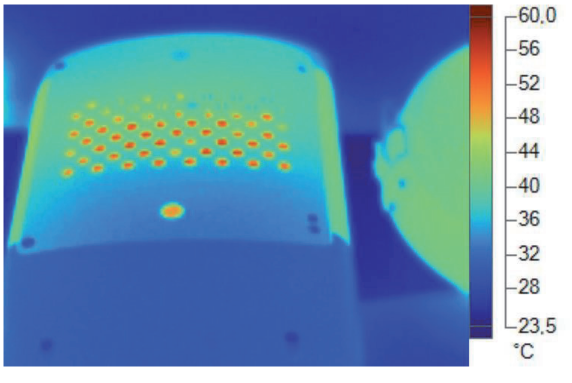

Figure 35.
Thermal data of the housing/heatsink. Reddish area emissivity anodized aluminum 0.77. Source: Own elaboration from software SmartView 4.1 Fluke.

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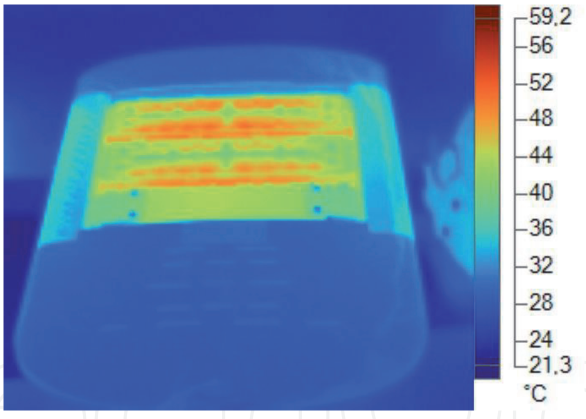

Figure 36.
Thermal data of the diffuser. Reddish area plastic emissivity 0.92. Source: Own elaboration from software SmartView 4.1 Fluke.

3.4.5 Datos termográficos Philips 20 W

See **Figures 37** and **38**.

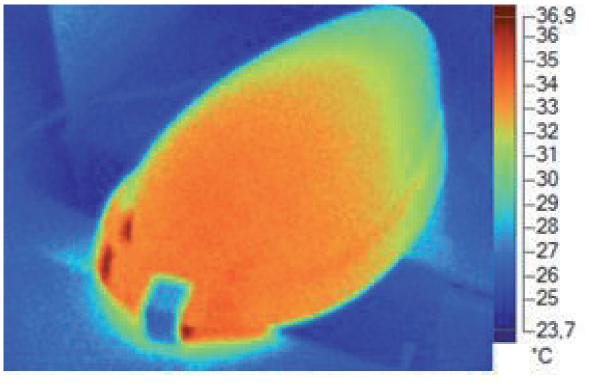

Figure 37.
Thermal data of the housing. Orange zone. Emissivity anodized aluminum 0.77. Source: Own elaboration from software SmartView 4.1 Fluke.

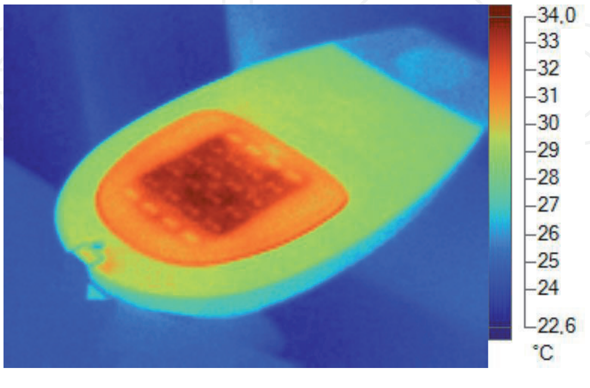

Figure 38.
Thermal data of the diffuser. Reddish area plastic emissivity 0.92. Source: Own elaboration from software SmartView 4.1 Fluke.

3.5 Evolution of the temperature of the luminaires and maximum temperatures of the same

In **Figure 39**, the evolution of the temperature is represented as the operating time increases.

Approximately after 5 h of operation, as shown in **Figure 39**. It is appreciated that the ATP luminaire reaches a higher temperature due to the nominal power of operation that is 200 W, significantly higher than the rest of the luminaires. As we could imagine.

Table 4 shows the maximum temperatures obtained in the last measurement of each luminaire in the heatsink or housing depending on the luminaire and the diffuser. It is appreciated that depending on the design, power, distribution of LEDs and materials, the temperatures vary from one luminaire to another.

Figure 40 shows the nominal power of each luminaire compared to the maximum temperature reached in the heatsink/housing of each luminaire when the temperature has stabilized. It is observed that there is no linearity of the nominal power with respect to the maximum temperature reached due to the different designs of the luminaires themselves and the characteristic materials that form them. With an appropriate design of the luminaire, having a sufficient sink contact

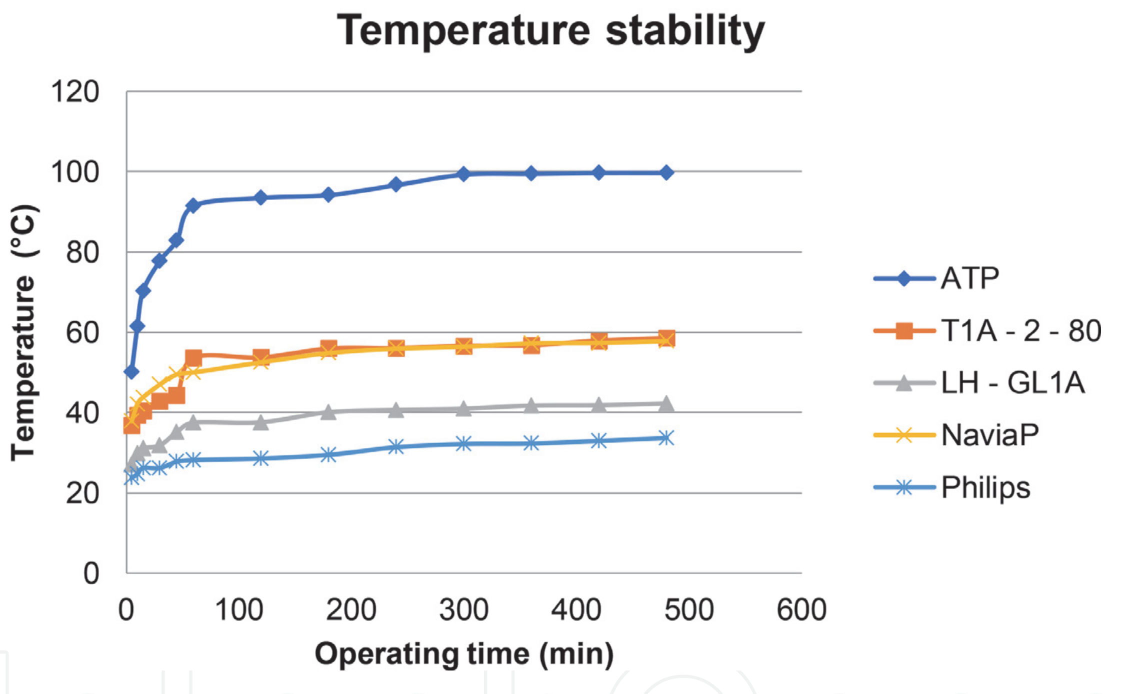

Figure 39.
Operating time (min) vs. temperature (°C). Source: Self made.

Model	Maximum temperature heatsink/casing (°C)	Maximum diffuser temperature (°C)
ATP Aire Serie 7	99.7	40.2
Sólidy NaviaP	57.7	39.3
LH-GL1A	42.3	67.8
T1A-2-80	58.5	52.1
Philips 20 W	33.7	34.0

Source: Self made.

Table 4.
Summary table of the maximum temperatures of each luminaire.

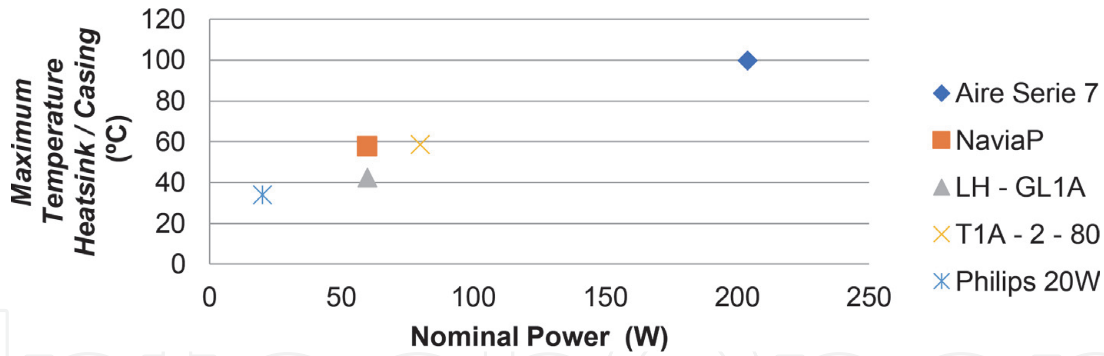

Figure 40.
Nominal power (W) of each luminaire vs. maximum temperature dissipater/housing (°C). Source: Self made.

surface and a selection of materials where the thermal conductivity is high, the results of thermal dissipation will be improved. As shown in **Figure 40**.

4. Conclusions

The purpose of this study is to compare the results of thermal simulations with experimental data acquired in the laboratory. The main objectives are compiled and concluded in this section.

This study focuses on thermal analysis to verify the materials of the luminaires and verify that the temperature of the LEDs is not too high for the proper functioning of these light-emitting diodes, causing a decrease in the useful life and a variation of the light properties of the LEDs. All electronic devices and circuits generate excess heat and require greater attention to avoid premature failures. The LEDs convert 15% of the applied energy into light and the remaining 85% into heat, this heat must be dissipated so that the durability and properties of the LEDs are not affected by the increase in temperature [10, 20–24].

The thermal measurements give the engineer information about the temperature and the air flow inside the equipment. They allow engineers to design cooling systems to optimize the design and reduce energy consumption, weight and cost, and verify that there are no problems when the equipment is built. Most thermal simulation software uses computational fluid dynamics (CFD) techniques to predict the temperature and air flow of an electronic system.

In this study, experimental data of five LED luminaires of different powers and models have been acquired and in the same conditions of contour in the lighting laboratory with the FLUKE Ti 25 thermal camera, it is indicated that the design is indeed important due to the dissipation heat of the luminaires for the effective operation of electronic devices.

At the time of favoring heat dissipation, the dissipator is the most important component to reduce the binding temperature. Most heatsinks are designed with fins to increase their contact surface with air and dissipate more heat [25]. It will be necessary to improve the design of the components of the luminaire to facilitate the dissipation of heat and favor the passage of air through the heatsink of the luminaires to lower the temperature of electronic devices. To improve the cooling, ventilations can be incorporated to improve the flow of the air inside and that can go to the outside.

A major problem with high power LED luminaires is the heat generated inside. The distribution of the LEDs and the effect of the number of LEDs lit affect the junction temperature and strongly participate in the degradation of the LED [26]. Most luminaires contain aluminum heatsinks as a solution. Currently, materials with new alloys and formulations for an effective thermal dissipation are being investigated, for example, aluminum nitrate has been developed to be applied as a thin layer in the dissipaters that has certain advantages over conventional dielectrics based on polymers or ceramic substrates such as excellent thermal dissipation and low thermal resistance [27]. The topic of thermal dissipation is the order of the day, materials are being investigated to be used as heat sinks that promote greater durability of LEDs due to an improvement in thermal dissipation [28].

Due to which, it is necessary to bear in mind that the lighting fixtures of public lighting of discharge and where they are replaced by LED technology, leaving the housing of the luminaires previously installed, ends up affecting the electronic devices if there is not good thermal dissipation. As previously mentioned in this section, the use of natural or forced vents would favor the dissipation of heat from the electronic components.

Electronic devices are affected by high temperatures. A high LED junction temperature reduces the useful life, varies the chromaticity and decreases the luminous flux, reducing the luminous properties.

To summarize, it has been shown that the input power is the heat generated by the luminaire and, depending on the design and the choice of materials, the joining temperature of the LEDs is higher due to the low heat dissipation that occurs in them, being detrimental to the proper functioning of LEDs. The choice of an LED, which has a lower junction temperature than can be reached in the luminaire, could decrease its properties up to 100%, making this LED unusable for what corresponds to its operation.

A good design of the luminaire where the circulation of air is favored for the benefit of the dissipation of the junction temperature of the LEDs will favor the useful life and improve the efficiency and reliability of the LEDs having better lighting properties. Apart from the design, a good selection of materials for the components of the luminaire where the thermal conductivity is high favors the thermal dissipation of the luminaire.

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Author details

Hermoso-Orzáez Manuel Jesús[1]*, Hervás-Pulido Manuel Jesús[1],
Unión-Sánchez Juan de Dios[1], Ogáyar-Fernández Blas[2] and Gago-Calderon Alfonso[3]

1 Department of Graphic Engineering Design and Projects, Universidad de Jaen, Jaen, Spain

2 Department of Electrical Engineering, Universidad de Jaen, Jaen, Spain

3 Department of Graphic Expression, Design and Projects, Universidad of Málaga, Malaga, Spain

*Address all correspondence to: mhorzaez@ujaen.es

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