International Commission on Illumination
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Internationale Beleuchtungskommission

PO125

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DOI 10.25039/x46.2019.PO125

from

CIE x046:2019

Proceedings
of the
29th CIE SESSION
Washington D.C., USA, June 14 – 22, 2019

(DOI 10.25039/x46.2019)

The paper has been presented at the 29th CIE Session, Washington D.C., USA, June 14-22, 2019. It has not been peer-reviewed by CIE.

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AN INVESTIGATION OF A19 LED RETROFIT LAMPS IN THE TURKISH MARKET

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DOI 10.25039/x46.2019.PO125

Abstract

The Turkish LED market receives from a significant number of different brands, providing the end user with similar retrofit lamps easily purchasable from different shopping channels. This variety in products results in a broad quality spectrum among LED light sources. This study aims at evaluating off the shelf A19 LED retrofit lamps in the Turkish market as of November 2018 through electrical, photometric, spectral and temporal measurements. In order to do this, 50 different A19 type E27 base LED retrofits have been analysed. The rated values of the LED retrofits have been compared to the values obtained through measurements and the results have been analysed according to the relative differences between the rated and measured results as well as values defined by European standards. The main objective of the study is to evaluate the properties of LED retrofits consumers frequently buy and utilize in their interior lighting environments.

Keywords: Lighting, LED (Light Emitting Diode), LED Retrofit, Energy Efficiency

1 Introduction

Light Emitting Diode (LED) technology has become an important tool for energy savings and is utilized in all lighting areas, most importantly in general lighting. The phase out of inefficient light bulbs by the European Union (EU) was followed by Turkey, which increased the demand for more efficient alternatives, directing users to the purchase of LED retrofits. The Turkish LED market receives from a significant number of different brands, providing the end user with similar retrofit lamps easily purchasable from different shopping channels. This variety in products results in a broad quality spectrum among LED light sources. The differences in quality are mainly related to luminous flux, colour temperature, lifetime and the occurrence of catastrophic failures. The product information is usually limited to the packages of the lamps and most of the time deficient, especially for low price products, and this fact reduces the confidence of the end user in these products (European Commission, 2010, European Commission, 2011). Examples in the literature show that LEDs the large variety in electrical, thermal and photometric properties in LEDs is not specific to Turkey and that the rated operating conditions and actual working conditions of these light sources are contradictory most of the time (Sun et al., 2015, Hong Kong Consumer Council, 2017, De Santi et al, 2015).

Turkey, as a member of the Customs Union as well as a candidate for the European Union (EU) membership adopts EU Regulations, obligating the CE mark for the import and sale of LED retrofit lamps in the Turkish market. The Turkish Standards Institute makes detailed inspections of the conformity of LED lamps entering the Turkish customs, however, the inspections are on a sample of the products provided by the importing company and may not be representative of the entire population. The after-market monitoring system then removes the unsatisfactory products from the market if and when there are customer complaints and through random selection and testing. Within this context, this study aims at evaluating off the shelf A19 LED retrofit lamps in the Turkish market as of November 2018 through electrical, photometric, spectral and temporal measurements. In order to do this, 50 different A19 type E27 base LED retrofits have been selected. In selecting the retrofits, the major approach has been to choose retrofits which are readily available at easy access purchase channels such as supermarkets, hardware stores and popular online shopping stores. The purchase price per retrofit has been kept under 20 Turkish Liras. The main objective of the study is to evaluate the properties of LED retrofits which consumers frequently buy and utilize in their interior lighting environments.

2 Measurement Methods

The retrofits used in the study are non-dimmable frosted A19 lamps with E27 lamp bases. Using the values given on the lamp packages as rated values if and when available, luminous flux, power, current, voltage, frequency, power factor, lifetime, number of switching cycles, energy efficiency class, correlated colour temperature (CCT), colour rendering index (CRI), minimum operating temperature, maximum operating temperature, mercury content, relative humidity, lamp size and the light distribution angle values have been recorded for comparison to the results which will be obtained from the measurements. Following the documentation of all available information, the luminous flux, power, current, voltage, frequency, power factor, total harmonic distortion, correlated colour temperature (CCT), colour rendering index (CRI), colour fidelity and colour gamut according to IES TM 30-15, flicker index, percentage flicker and SVM values have been measured for each retrofit. In addition to the measurements, efficacy and energy efficiency index calculations have been performed. For the luminous flux measurements Everfine 1 m diameter Integrating Sphere and for the electrical measurements, Everfine PF9811 digital power meter have been used. For spectral properties Everfine SPIC 200 model spectrometer and for flicker measurements UPRTek 350N hand held spectrometer have been utilized. Figure 1 shows the general experimental setup in the dark room of Istanbul Technical University, Electrical Engineering Department and Figure 2 shows a sample retrofit that has been utilized in the study. The measurements were carried out according to IES LM-79-08; the retrofits were initially stabilized through measurements of luminous flux and power to maintain a variation less than 0.5 % for at least 3 readings over a period of 30 minutes taken 15 minutes apart. The stabilization periods have also been recorded for each retrofit (IES, 2008).

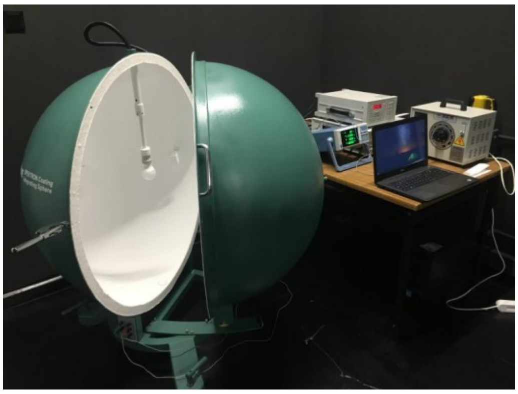

Figure 1 – Experimental Setup

Figure 2 – Example LED Retrofit

3 Measurement Results and Evaluations

The results obtained from the measurements are analysed in three separate sections; electrical and photometric, spectral and temporal results. The values obtained from the measurements are compared to the rated values from the boxes of the retrofits and discussed in terms of current standards. Due to the large number of retrofits and thus measurements, the results that show a significant difference in comparison to rated values are reported along with problematic values in comparison to values defined by standards. In rated value vs. measured value comparisons, a relative difference higher than 10 % has been taken as a significant difference.

3.1 Electrical and Photometric Results

3.1.1 Luminous Flux, Power, Efficacy and Energy Efficiency Index

Table 1 shows the stabilization time t_s, rated power consumption P_0, measured power consumption P_1, relative difference between the rated and measured power values ΔP, rated luminous flux Φ_0, measured luminous flux Φ_1, relative difference between the rated and measured luminous flux values $\Delta\Phi$, efficacy calculated using the rated luminous flux and power values e_0, efficacy calculated using the measured luminous flux and power values e_1, the relative difference between these two efficacy values Δe according to the sample number (#).

Grey values in the table are marked for retrofits where the difference between the expected and measured values is greater than 10%.

Table 1 – Electrical Measurements and Comparisons

#	t_s [m]	P_0 [W]	P_1 [W]	ΔP [%]	Φ_0 [lm]	Φ_1 [lm]	$\Delta\Phi$ [%]	e_0 [lm/W]	e_1 [lm/W]	Δe [%]
5	55	9,0	9,48	5,33	850	803,8	-5,4	94,4	84,8	-10,2
8	50	9,0	9,62	6,89	800	762,2	-4,7	88,9	79,2	-10,9
10	55	8,0	9,19	14,88	680	764,0	12,3	85,0	83,1	-2,2
13	50	6,0	5,94	-1,00	490	571,9	16,7	81,7	96,3	17,9
15	55	10,0	9,03	-9,70	910	871,2	-4,3	91,0	107,6	18,3
16	65	7,6	7,25	-4,61	806	780,4	-3,2	106,1	86,0	-18,9
18	60	5,8	5,6	-3,45	470	568,2	20,9	81,0	101,5	25,2
22	55	9,0	9,14	1,56	810	1038,3	28,2	90,0	113,6	26,2
24	55	10,0	8,54	-14,60	850	846,0	-0,5	85,0	99,1	16,5
25	65	10,0	8,46	-15,40	810	774,9	-4,3	81,0	91,6	13,1
27	55	9,0	4,56	-49,33	720	218,9	-69,6	80,0	48,0	-40,0
29	45	9,0	6,74	-25,11	630	377,9	-40,0	70,0	56,1	-19,9
31	45	10,0	8,22	-17,80	1000	610,6	-38,9	100,0	74,3	-25,7
32	50	9,0	5,98	-33,56	530	360,3	-32,0	58,9	60,2	2,3
33	70	11,0	10,18	-7,45	990	1044,7	5,5	90,0	102,6	14,0
34	75	11,0	10,36	-5,82	990	884,2	-10,7	90,0	85,3	-5,2
35	50	7,0	3,61	-48,43	420	242,4	-42,3	60,0	67,1	11,9
36	45	7,0	4,74	-32,29	385	319,8	-16,9	55,0	67,5	22,7
37	75	8,0	7,79	-2,63	700	825,5	17,9	87,5	106,0	21,1
38	130	9,0	6,31	-29,89	-	281,3	-	-	44,6	-
42	35	9,0	8,73	-3,00	900	647,3	-28,1	100,0	74,2	-25,8
43	45	9,0	3,56	-60,44	-	236,7	-	-	66,5	-
44	45	12,0	5,33	-55,58	900	394,8	-56,1	75,0	74,1	-1,2
45	50	9,0	3,5	-61,11	-	158,6	-	-	45,3	-
47	50	9,0	5,45	-39,44	-	284,3	-	-	52,2	-
48	45	9,0	6,62	-26,44	350	514,3	46,9	38,9	77,7	99,8
49	80	9,0	5,19	-42,33	650	326,5	-49,8	72,2	62,9	-12,9
50	55	9,0	6,38	-29,11	-	438,5	-	-	68,7	-

When the power consumption was examined, it was observed that 17 of the retrofits have more than 10% difference between the rated and measured values. Only one of these 17 retrofits consumes more power from grid than the value specified in the package, 9,19 W compared to the rated value of 8 W. The largest difference is experienced with Retrofit #45 with a relative difference of 61,11 %; the package information claims a power value of 9 W while the actual energy consumption is only 3,5 W. For luminous flux, the largest difference is seen in retrofit #27 with -69,6 %; the rated flux is 720 lm while the measured flux is 218,9 lm, an unacceptable difference in terms of light output. Here, 6 retrofits show values above rated luminous flux values, while 10 retrofits fall short of their rated light outputs. Among the retrofits that were analysed in this study, the efficacy values were not rated, therefore the values presented in

Table 1 were calculated using the rated power and luminous flux values and compared to the values obtained from the measurements. As can be expected, the differences in power and luminous flux values translated into differences in efficacy values as well. The largest difference is experienced with retrofit #48; for this retrofit, the relative difference in power is -26,44 % while the relative difference in luminous flux is 46,9 percent, the resulting efficacy value being 99,8 % higher than expected. In total, 18 retrofits show significant differences from expected efficacy values.

To take a look at the entire population of relative differences for power, luminous flux and efficacy, Figure 3 gives box plots of the values for all 50 retrofits. Here, the respective average and median values are -12,31 % and – 4,19 % for power; -6,1 % and -2,1 % for luminous flux and 2,93 % and 1,51 % for efficacy. The previously mentioned high differences can be seen in the box plots as outliers.

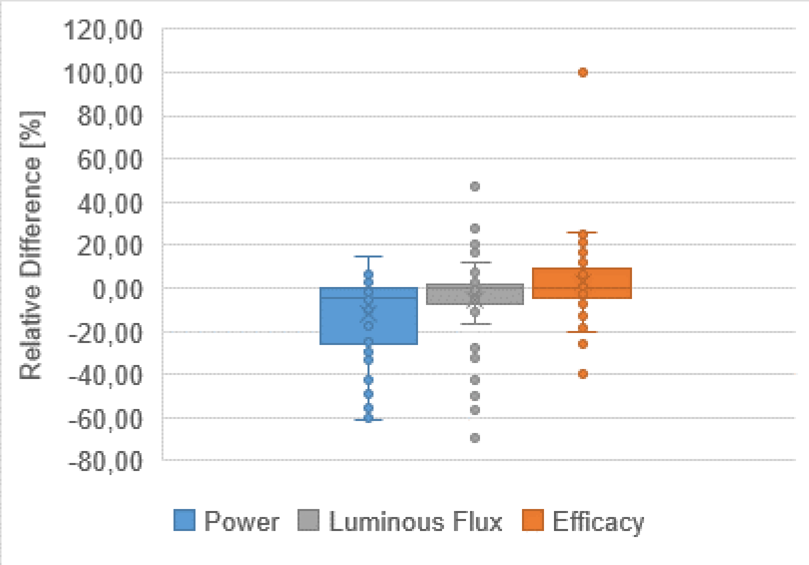

Figure 3 – Box Plot for Relative Differences in Power, Luminous Flux and Efficacy for all retrofits

While efficacy ratings were unavailable, the energy efficiency classes were available for 47 out of 50 of the retrofits, 7 A class, 35 A+ class, 4 A++ class and 1 claiming to be A+ and A++ at the same time. A simple calculation of energy efficiency index according to EU Regulation 874/2012 using the measured power and luminous flux values showed that 9 retrofits were one class below their rated energy class and 3 were actually above their rated energy class (European Commission, 2012a, Yurtseven, 2016).

Looking at the results, it can be seen that 17 retrofits in power values, 16 retrofits in luminous flux values and 18 retrofits in efficacy values show significant differences in terms of rated vs. measured and calculated numbers. This translates into problems in approximately 34 % of the analysed retrofits, constituting an important problem for the end user who buys a certain product for its rated power or luminous flux value and ends up with a different result than expected.

3.1.2 Power Factor and Total Harmonic Distortion

Power Factor and Total Harmonic Distortion (THD) are two very important electrical properties that maintain grid quality. The Electromagnetic Compatibility (EMC) standard IEC 61000-3-2-2014 defines the limits of current total harmonic distortion (THD_C) for lighting equipment above 25 W, however, the standard does not specify a limit for systems below 25 W, thus the retrofits analysed in this study are not subjected to this standard in terms of THD_C (IEC, 2014). The American Standard ANSI C82.77-10 on the other hand requests a maximum THD_C of 20 (Djuretic et al., 2019). Among the measured retrofits, there is only 1 that adheres to the ANSI standard, retrofit #22 with a THD_C value of 15,4. Of the remaining retrofits, 32 lamps have THD_C values above 100 %, the highest reaching 148,6 %. The remaining 17 retrofits have THD_c values ranging between 24,4 – 58 %.

According to the Directional Lamps, Light-emitting Diode Lamps and Related Equipment Directives published by the European Union (EU) under the Eco-design regulation, no power factor is specified for lamps below 2 W. For power values between 2 W and 5 W, the power factor must be higher than 0,4, between 5 W and 25 W, higher than 0,5 and for values above 25 W, the power factor must be higher than 0,9 (European Commission, 2012b). The retrofits analysed in the study have power consumption values between 3,5 and 10,1 W corresponding to 0,4 and 0,5 for power factor values. The measurement results show that unfortunately 14 out of 50 lamps do not provide the values specified by the EU.

3.2 Spectral Results

Table 2 gives the rated and measured values for colour rendering index R_{a0} and R_{a1}, IES TM 30-15 colour rendering metrics colour fidelity R_f and colour gamut R_g (IES, 2015), rated relative colour temperature CCT_0, measured relative colour temperature CCT_1 and the relative difference between these values ΔCCT. For the colour rendering index, the relative difference has not been calculated since most of the R_a values are not specified on the package or either are expressed as greater than a certain value when they are specified.

Table 2 – Spectral Measurements and Comparisons

#	Ra_0	Ra_1	R_f	R_g	CCT_0 [K]	CCT_1 [K]	ΔCCT [%]
3	-	78,9	81,2	93,4	2700	2986	10,6
5	-	82,9	81,6	92,2	2700	2995	10,9
6	80	87,7	82	92,4	6500	7829	20,4
15	> 80	71,3	72,3	92,7	2700	2982	10,4
27	-	79,9	74,9	92,1	6400	8581	34,1
29	> 70	77,5	72	95	6500	7963	22,5
38	-	79,5	71,2	96,3	7000	8879	26,8
39	-	68	70	88,9	2700	2999	11,1
44	-	68,2	63,6	95,4	6500	7147	10,0
50	-	69,7	68,2	92,9	2700	4264	57,9

The results show that 3 retrofits fall short of the minimum colour rendering index for indoor lighting according to IEC 12464-1 of 70, while 1 has a measured value below the rated value (IEC, 2011). R_f and R_g values are important on the basis of application; low R_f values also correspond to low R_a values. All R_g values are below 100, suggesting that with all the retrofits in hand, colours would appear less saturated compared to a reference light source. For correlated colour temperature (CCT) values, the comparisons between the rated and measured results show that 9 retrofits have differences of 10 % and above. The highest difference is experienced with retrofit #50, where the rated CCT is 2700 K and the measured CCT is 4264 K. The authors believe that the highest user dissatisfaction would be experienced with retrofits #27 and #38 where the measured CCT values go above 8500 K, resulting in a much cooler white light than expected.

3.3 Temporal Results

Visual perception effects such as flicker, stroboscopic effect and the phantom array effect are known as temporal light artefacts (Veitch 2018). The CIE Technical Note 006-2016 defines flicker as “perception of visual unsteadiness induced by a light stimulus the luminance or spectral distribution of which fluctuates with time, for a static observer in a static environment” (CIE, 2016). Currently, three common metrics are utilized for the quantification of this perception, namely the Flicker Index defined by IESNA, the percent flicker value, defined again by IESNA (IESNA, 2000) and finally the stroboscopic effect visibility measure (SVM) proposed by Perz and his colleagues (Perz et al., 2015). IESNA recommends the flicker index value to be lower than 0,1 for good lighting quality. The percent flicker value on the other hand is a relative value, giving the maximum luminance decrease compared to the peak luminance value and as this value increases, flicker also increases. The SVM on the other hand quantifies the visibility of the stroboscopic effect, as its name implies. The SVM value is evaluated as greater than 1, equal to 1 and less than 1, translating into a visible stroboscopic effect with a probability of 0,5 or more, stroboscopic effect at the visibility threshold and stroboscopic effect that is not visible with a probability less than 0,5, respectively.

In Table 3, the measured flicker percentage, flicker index, stroboscopic effect visibility measure (SVM) values that are above the specified limits are reported. The percentage flicker values above 50 %, flicker index values above 0,1 and SVM values above 1 have been marked with grey in the Table.

Table 3 – Temporal Measurements

#	% Flicker	Flicker index	SVM
7	99,093	0,501	5,200
13	31,968	0,086	1,047
19	88,240	0,040	0,020
21	53,400	0,156	1,903
22	35,939	0,108	1,313
28	0,366	0,110	1,326
32	59,032	0,163	1,965
36	75,114	0,212	2,568
37	30,953	0,091	1,116
48	83,626	0,255	3,071
49	70,561	0,202	2,446
50	91,926	0,270	3,226

According to the measurements, 8 retrofits present with percentage flicker values that are above 50 %. With flicker index values, 9 retrofits are above the IESNA recommended flicker index value of 0,1. Finally, the SVM values show that 11 retrofits have values above 1. As can be seen from the Table, the results for these three different metrics are quite consistent with each other; the usual presentation is that all flicker metrics show problems for these retrofits. On the other hand, retrofit #19 for example shows a high flicker percentage of 88,2 but good flicker index SVM values. While current flicker metrics only correspond to high quality lighting recommendations, the measurement results show that especially with high SVM values such as 5,2 experienced in retrofit #7 could result in both user dissatisfaction and even safety hazards when these light sources are used in work areas equipped with objects which have moving parts.

4 Conclusion

This study aimed at analysing a variety of different LED A19 retrofit lamps available in the Turkish market. In order to do this, 50 retrofits were evaluated through measurements regarding electrical, photometric, spectral and temporal properties. The results have been assessed in terms of significant differences between rated and measured values and those values with relative differences above 10 % have been reported. In addition to the comparisons of rated and measured values, conformity to current standards have also been investigated. Examined results show that the majority of the lamps adhere to the rated values given on their packages. However, important differences have been spotted for a significant number of lamps, especially in terms of luminous flux, power, expected efficacy, CRI and CCT values which are very important attributes for lighting quality.

In terms of power, luminous flux and efficacy, approximately one third of the lamps showed significantly different results compared to their rated values. Among electrical properties, the current THD values are not regulated by the European Standard as the retrofits had power values below 25 W; this resulted in quite high values of current THD. The power factor values of 28 % of the lamps on the other hand was unsatisfactory. Spectral measurements showed 3 lamps below the necessary color rendering index of 70 and 3 retrofits showed major differences in rated and measured CCT values. In terms of temporal properties, when the flicker percentage, flicker index and stroboscopic effect visibility measure (SVM) values obtained from the measurements are examined, common problems were encountered for approximately 20 % of the retrofits.

Overall, the results indicate that while the majority of these commonly used light sources adhere to their rated values and standards, there’s still an important percentage of light sources that do not. Most of the quantities evaluated in the study are beyond the average customer’s knowledge; this fact indicates that steps should be taken to make the after-market monitoring for LED retrofit lamps much stricter. The Turkish Standards Institute has already taken comprehensive measures to increase the reliability of the lighting products entering the Turkish market, however, as it is impossible to monitor every single product, a stricter regulation of the after-market monitoring as well as greater sanctions on manufacturers that do not adhere to the standards and regulations must be established in order to increase the quality of the available products. The elimination of defected products will most definitely ameliorate lighting quality and energy efficiency while maintaining a better experience for the end user at the same time. This study will be carried out further with long term measurements to elaborate the ongoing performance of the analysed retrofits.

Acknowledgements

This study has been supported by the Istanbul Technical University Scientific Research Unit Project MAB-2018-41220, “The Analysis of Electrical, Thermal and Photometric Properties of LED Retrofits in the Turkish Market”.

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