

The experimental determination of the luminous flux emitted by a few types of lighting sources

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Abstract. This paper aims to determine the luminous flux of several types of power sources used for the artificial lighting inside. The luminous flux was determined using a photometer integrator (lumenmeter Ulbricht) and a luxmeter from the laboratory of Electrical and Lighting University "Eftimie Murgu" Resita. Based on a reference source, the constant of the integrator photometer k was determined. The paper presents the measuring results of the luminous flux on several lighting sources: with incandescent, fluorescent, and LED. It has been found that the amount of luminous flux in the nominal data written in the box of lighting sources, does not correspond to the actual measured value. Using the photometric sphere, the actual light output from various sources where it is not known, can be determined.

1. Introduction

To ensure a certain visual comfort, lighting sources must emit a certain luminous flux. When acquiring a specific source, its nominal data are marked on the box, including the light output.

From tests conducted on various sources with the same technical features, it has been found that for the acquired light source, the luminous flux value marked on the box does not agree with the measured value.

There are situations where the value of the emitted flux by a certain source of lighting is not part of the nominal data and is necessary to be determined. This determination is necessary in order to establish the aging degree of the source and whether it should be replaced. This is done by measuring the flux values issued by it in different time intervals. Keeping in function a lighting source that is no longer capable to emit a corresponding visual luminous flux, causes discomfort and unnecessary electricity consumption.

Therefore it follows that, for certain applications, it is necessary to determine the actual value of the light output of the light sources. To help increase the lighting energy efficiency, it is useful, from time to time, to measure the luminous flux emitted by different sources, to be replaced in time.

2. Luminous flux, lighting, luminous efficacy

The luminous flux of a source is defined as the radiant power of that source evaluated after the produced light feeling. The light feeling is dependent on the radiation spectrum wavelength λ according to the relative visibility curve (Figure 1). The sensitivity is maxim ($V_\lambda = 1$), - for a normal eye - at a radiation with the wavelength $0.555 \mu\text{m}$ (green) [1-3].



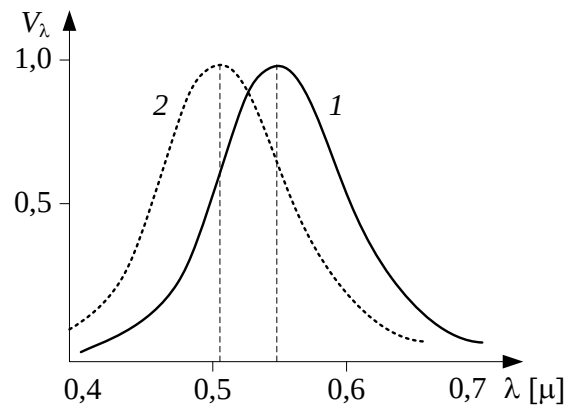


Figure 1. $V_\lambda=f(\lambda)$ curve for diurnal vision – 1; night vision – 2

The luminous flux is dependent radiant power (energy flow Φ_e), through the relative visibility curve of the normal eye. The monochromatic light flow Φ_λ is defined by the relationship:

$$\Phi_\lambda = P_\lambda \cdot V_\lambda \quad (1)$$

where: P_λ is the power required for the wavelength λ , and V_λ is the relative visibility of the eye for the wavelength λ . The relative eye visibility is defined as the power corresponding to the exciting agent for the 0,555 μm wavelength and the required power for the λ wavelength, to produce the same lighting feeling:

$$V_\lambda = \frac{P_{0,555}}{P_\lambda} \quad (2)$$

The measurement unit of the luminous flux is a radiated watt per 0,555 μm wavelength, called watt light [Wl]. In the international system (IS) the measuring unit for flux is lumen [lm], one watt light is equal to 683 lm.

The value of the luminous flux can be measured using the photometer integrator – Ulbricht lumen meter, which consists of a empty metal or fiberglass sphere, with a diameter of 0,5÷4 m, painted in interior with matt, very fine grain white color, that produces a multiple diffuse reflectance. The white color used for painting the photometer is characterized by a certain reflection factor r .

The illumination of a surface at a certain point of it, is the luminous flux $d\Phi$ ratio received by an elementary surface surrounding the point and the area of that surface dS :

$$E = \frac{d\Phi}{dS} \quad (3)$$

The measurement unit of illumination in the international system is lux [lx], defined as illumination of an area that receives a luminous flux of one lumen, uniformly distributed, over a surface of 1m^2 .

To light level is measured using an luxmeter. This is based on the action of the light on a photosensitive element.

The luminous efficacy of a light source is defined as the ratio of luminous flux Φ emitted by the source and the power P consumed by the source:

$$e = \frac{\Phi}{P} = 683 \cdot \eta_l \left[\frac{\text{lm}}{\text{W}} \right] \quad (4)$$

where η_l is the efficiency of the light source.

The luminous efficacy is the size that establishes a relationship between bright-technical characteristics of the source and electric power consumed by it. This is very important in choosing the sources types in lighting design and analyze their effectiveness.

3. Case Study

To measure the light levels and to determin the luminous flux, we used a benchmark source, were the issued flux was known, a luxmeter and a lumenmeter, those being in the Laboratory of Electrical installation and Lighting.

In Figure 2 we presented the digital luxmetrul, from UNITEST, which uses a silicon photodiode as sensor.



Figure 2. Digital Luxmetru Unitest

It is composed of:

- 1 - LCD display;
- 2 - display measuring range;
- 3 – start button;
- 4 - data memory button;
- 5 - choice button;
- 6 - sensor (photodiode with silicon).

The digital used lux meter has four measuring ranges, ie 0-20 lx, 0-200 lx, 0-2.000 lx and 0-20.000 lx, the corresponding errors to the four areas being 0,01 lx, 0,1 lx, 1 lx and 10 lx.

To determine the luminous flux emitted by different sources, the Ulbricht lumen meter, shown in Figure 3, was used. His property is a uniform light scattering or diffusion effect. The incident light rays on any point on the inner surface of the sphere are evenly distributed at all points of the sphere, by multiple reflections with the purpose to create an equal light flow over the inner surface of the sphere.

The effects of the original light direction are minimized. The integrating photometer is generally used as an light source and a detector to measure optical power.



Figure 3. Integrator photometer

The integrator photometer has in its composition:

- glass fiber sphere, with a diameter of 1 m ($R = 0.5$ m), with one fixed and one mobile hemisphere;
- fastening bracket of the sphere;
- power supply system of the light sources which are to be tested. The system allows the supply of 220V AC , 24V DC voltage and 12V DC voltage;
- Closure gasketed system and mounting gripper;
- fastening bracket of the light source that has to be tested;
- A screen to block the reception by luxmeter of the direct wave emitted by the light source.

The integrator photometer has a window where the photosensitive cell of the luxmeter, that measures the light caused by multiple reflections (infinite) of light rays (Figure 4), is entered.

To hamper the light rays fall directly on the photometer window, different types of screens (Figure 4) for each of the types of tested light sources (Figure 5), were made.

To determine the k constant of the integrator photometer and the reflectance factor r of the paint, an benchmark source was used, where the value of light output was known. The benchmark source was a halogen lamp whose flux value was 204 lm. Measuring with the luxmeter the brightness from the window, it was found that it had the value of 295 lx.

Knowing the relationship between the measured illumination in the window and the flux of the benchmark source [1-3]:

$$E = k \cdot \Phi \quad [\text{lx}] \quad (5)$$

the value of the photometer integrator constant k was determined $k = 1,44 \text{ lx/lm}$.



Figure 4. Illumination measurement



Figure 5. Made screens



Figure 6. Tested sources

Knowing the value of this constant, the value of the reflection factor r of the white paint integrator photometer color was determined too:

$$k = \frac{r}{1-r} \cdot \frac{1}{4 \cdot \pi \cdot R^2} \quad [\text{lx/lm}] \quad (6)$$

whence:

$$r = \frac{4 \cdot k \cdot \pi \cdot R^2}{1 + 4 \cdot k \cdot \pi \cdot R^2} \cong 0,82 \quad (7)$$

Several types of lighting sources have been tested, some where the luminous flux was known from the nominal data box, others where the nominal flow was not known. The types of tested sources and the obtained or calculated values are shown in Table 1.

Table 1. Tested sources, measured and determined values

Current number	Source type	Power [W]	Nominal luminous flux Φ_N [lm]	Measured lighting [lx]	Calculated luminous flux Φ_c [lm]	Real light effectiveness e [lm/W]
1	Halogen	23	204	295	204,86	8,907
2	Incandescence	100	-	1940	1347,22	13,47
3	LED 1	18	1750	2200	1527,77	84,88
4	LED 2	5	400	548	380,55	76,11
5	LED 3	5	400	558	387,5	77,5
6	LED 4	5	400	562	390,27	78,05
7	LED 5	7	700	915	635,41	90,77
8	Auto 24 V	5	-	856	594,44	118,88
9	Fluorescent	18	1040	1280	888,88	49,38

The calculated luminous flux was determined taking into account the value of k constant of the integrator photometer and the real luminous efficacy was calculated with the relationship:

$$e = \frac{\phi_c}{P} \quad [\text{lm/W}] \quad (8)$$

To determine whether the value of the luminous flux posted on the box with the nominal data of the sources is equal to the real (determined by measurements) we purchased and tested 25 LED sources with the same power and the same rated light output.

Table 2 presents the measured and calculated values of the parameters of interest. The tested sources were LED type, with 7 W power and luminous flux of 700 lm, resulting a luminous efficacy of 100 lm / W.

Using efficient lighting sources in the optimal design process of lighting systems leads to efficient use of electricity by reducing power source at the same luminous flux [4].

Taken in consideration the LEDs characteristics an analysis of harmonics introduced by them is required [5].

4. Conclusion

Interpreting the results of measurements and calculations we found that:

- the luminous efficacy is totally unacceptable for incandescent source, being 5.94 times lower than the acceptable value. This low luminous efficacy lead to the elimination of these sources from the manufacturing process and trading;
- the luminous efficacy is almost of 80 lm / W (an acceptable) for the LED 2, LED 3 and LED 4 sources, for LED 1 source the luminous efficacy exceeds the acceptable value;
- the halogen source is exhausted and must be replaced, due to extremely low luminous efficiency;

Table 2. Tested sources, measured and determined values

Current number	Nominal luminous flux Φ_N [lm]	Measured lighting [lx]	Calculated luminous flux Φ_c [lm]	Real light effectiveness e [lm/W]
1	700	868	602,78	86,11
2	700	917	636,81	90,97
3	700	896	622,22	88,89
4	700	893	620,14	88,59
5	700	887	615,97	88,00
6	700	924	641,67	91,67
7	700	908	630,56	90,08
8	700	915	635,42	90,77
9	700	905	628,47	89,78
10	700	916	636,11	90,87
11	700	912	633,33	90,48
12	700	924	641,67	91,67
13	700	922	640,28	91,47
14	700	928	644,44	92,06
15	700	873	606,25	86,61
16	700	889	617,36	88,19
17	700	895	621,53	88,79
18	700	912	633,33	90,48
19	700	909	631,25	90,18
20	700	890	618,06	88,29
21	700	910	631,94	90,28
22	700	892	619,44	88,49
23	700	910	631,94	90,28
24	700	906	629,17	89,88
25	700	904	627,78	89,68

- for any light source, the output light written in the nominal data on the products box was not corresponding;
- the luminous efficacy for the 25 LED 7W sources tested in the laboratory, is 89.7 lm / W, which represents 89.7% of efficiency resulting from the use of the written information on the products box.

By measurements using lumen meter and luxmeter we can determine the status of the light sources and the decommissioning of those who are no longer adequate. The measurement results can be used in optimizing the design [6], [7] and the use of indoor and outdoor lighting installations.

The results obtained for the 25 LED sources lead to the idea of passing a law through the producing and importing companies are required to verify the accuracy of the written data on the consumer packaging lighting sources.

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