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RESEARCH ARTICLE

Self-absorption Effect in Measurements of Double Ended Lamps

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ABSTRACT

In this work, the effect of self-absorption measurements on the luminous flux of double ended lamps has been studied. In this research work, three lamps of Double Ended types with different working wattage have been characterized. The experimental testing of such lamps showed that the self-absorption has a considerable effect on the measurements of total luminous flux. The Double Ended (DE) lamps have different values of corrected flux changing relatively from 4% to 5% of the measured values especially in the case of tubular lamps. Results are compared with the results of different types of lamps such as High Intensity Discharge (HID) lamps and Compact Fluorescent (CFL) lamp. The luminous flux of these lamps was measured using the integrating sphere with a diameter of 2.5 meters.

Keywords-: Double Ended (DE) lamps- self-absorption- luminous flux-photometric parameters.

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INTRODUCTION

For industrial lamps (Factories Bulb) the measurements of luminous flux is important parameter to determine the level of lighting of lamps and must be made a correction for measurements to obtain the corrected values which use and written on the lamps. The correction factors due to spectral mismatch and self-absorption were calculated. Due to unavailability of standard quality for such lamps, searching for commercially available lamps for this purpose is under test. Three groups of DE lamps are available; among them are 500-watt, 1000 watt, and 1500 watt. Halogen double-ended capsules provide a linear illumination. Generally, high wattage bulbs use a linear filament, and most have recessed single contact (R7s) bases. The high lumen output for many of these bulbs is ideal for flood lighting wide areas, both indoor and outdoor. Stage and studio lighting area common application of these lamps. Most of these bulbs require the use of enclosed fixtures. When replacing an existing bulb, make sure to match the overall length, measured end to end the three lams have code J118, J189, and SL.

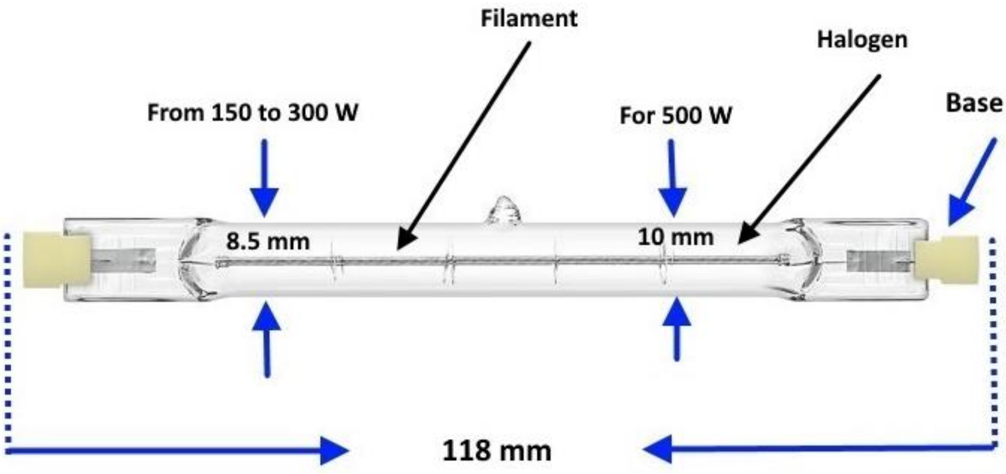

Figure-1: Double ended halogen lamp

Lamps Operation and Seasoning

It is obvious that the investigated lamps are sensitive to burning position. The three types of lamps are always operated at the horizontal position and base - up vertical for HID lamps and compact lamps. The lamps should be operated on AC power at supply voltage 220 V and the ballast (For HID) will be selected such that the current must be meeting the specification issued by IEC document for each lamp type.(1,2,3) As the luminous flux of the lamps changes significantly with ambient temperature, which must be controlled within $25^o \pm 1^o$ before starting the measurements and the lamps should be stabilized for 15 min. with integrating sphere open. The lamps should be seasoned until the photometric and electric characteristics remain constant. In the present work according to IES guide. (4,5) the DE lamps must be seasoned for _100_ operating hours and should be cycled _11_ hours on and one hour off. After the stabilization of the lamps, the measurement of the aging characteristic must be performed for each lamp type.

Experimental Realization

An Integrating sphere

A schematic diagram of the integrating sphere available at NIS Egypt is shown in

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Fig-2.The integrating sphere has a dimension of 2.5 meters and equipped with some optical tools such as V (λ) –corrected filter, cosine –corrected detector, a baffle screen, auxiliary lamp, a temperature sensor, and spectroradiometer. The V (λ) corrected detector is LMT standard photometers equipped with opal glass diffuser. The total luminous flux from 0.01 to 106 lm can be measured indirect substitution with a total luminous flux ofstandard lamps of any wattage. The sphere wall is coated with barium sulfate paint with diffuse reflectance approximately 0.97 in the visible region. The spectral through the sphere isobtained by measuring the relative spectral irradiance of a tungsten lamp operated inside and outside the sphere with the spectroradiometer. The integrating sphere is also equipped with auxiliary lamp (100 watts) tungsten on the sphere wall to measure the self-absorption effects of a lamp in the sphere. The room temperature of the photometry laboratory is controlled to be about 24°C

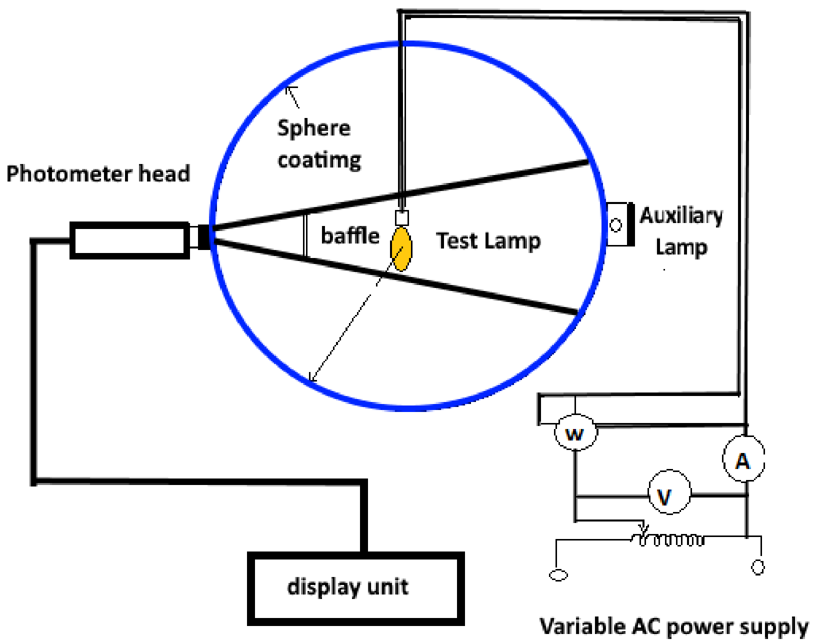

Figure-2: NIS 2.5 m integrating sphere set up for routine calibrations.

The integrating sphere is also equipped with an auxiliary lamp (100-watt tungsten) on the sphere wall to measure the self-absorption effects of a lamp in the sphere. A temperature sensor is mounted to measure the air temperature of the area inside the sphere. During lamp operation, the ambient temperature in the sphere is approximately 25°C (±1°C). [6]

Electrical Facility

The electrical circuit for lamps measurement is shown in Fig 1. The lamp is mounted in the base up position. The impedance of the ballast and the supply voltage are adjusted so that the lamp current equals the specified value. During photometric measurements, the supply voltage V(220V), the lamp current A_L, the lamp voltage V_L and the lamp power WL are measured and recorded.

A. Luminous flux standard lamps

The results of luminous flux measurements carried out using the sphere photometer by the substitution principle will be correct if the light

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source to be measured and the luminous flux standard lamp used to have [7]

- The same spectral distribution

-The same dimension and shape

-The same spatial light distribution.

If the light source to be measured and the standard lamp differs +in one or more of these properties, then measurement errors may occur. The influence of different spectral distributions can be eliminated by using the mismatch correction factor which depends on full details of the spectral response of the measuring equipment (including the photometer head and sphere paint) and the spectral power distributions of the measured and the standard light source. A correction for the influence of different dimensions and shapes is possible by the use of an auxiliary lamp to determine the self-absorption correction. It has been found that the most suitable standard lamp to measure the DE lamps is a 200-Watt primary standard lamp in NIS photometry lab.

B. The correction in measurements

For carrying the measurements of luminous flux using sphere photometer the following corrections must be carrying out.

C. The spectral mismatch correction and its determination

The spectral mismatch correction factor ccf of each lamp type against the 200 Watt primary standard lamp is given by

$$ccf(S_t, S_s) = \frac{\int S_S(\lambda)R_S(\lambda)d\lambda \int S_t(\lambda)V(\lambda)d\lambda}{\int S_s(\lambda)V(\lambda)d\lambda \int S_t(\lambda)R_S(\lambda)d\lambda} \text{----------(1)}$$

Where S_t (λ) and, S_s (λ) isthe relative spectral power distribution of test and **standard lamp, V (λ) is the spectral luminous efficiency function and R_s (λ) is** the relative spectral responsivity of the sphere system.

R_s (λ) can be obtained by measuring the relative spectral responsivity of the detector R_d (λ) and the relative spectral throughput of the integrating sphere T_s (λ) using the following equation

$$R_s(\lambda) = R_d(\lambda) \times T_s(\lambda) \quad \text{------ (2)}$$

T_s (λ) can be obtained by measuring the relative spectral irradiance of tungsten standard lamp operating inside the sphere and outside the sphere with a spectroradiometer and dividing these values. From the equation (1) the value of the ccf (S_t , S_s) depends on S_t(λ)and hence on Correlated Color Temperature (CCT) of the calibrated lamps. This correction may neglect when the lamps (standard and test) take the same spectral distribution

D. Self-absorption correction and its determination:

We mean by the self-absorption correction the ratio between the quantity of the absorbed light by the lamp and baffle inside the sphere in case of standard and tested lamps. The auxiliary lamp (100 Watt) is used for the three lamp types. To determine the self-absorption correction, we follow the following steps

1-The standard lamp inside the sphere is switched off and the auxiliary lamp lit. The reading of the photometer

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corresponding to the luminous flux of the auxiliary lamp and absorption for the presence of standard lamp is measured r_s

2-The standard lamp is replaced by the lamp under test (DE) which is not switched on. The auxiliary lamp remains lit and the reading of the photometer corresponding to the luminous flux of the auxiliary lamp and absorption of the lamp under test is measured r_t and hence the self-absorption will be equal to

$$r_s / r_t$$

E. Correction for the sphere detector temperature:

The responsivity of the sphere detector slightly changes with its temperature and is monitored with a temperature sensor installed in the detector package. So to avoid such error, the detector temperature must be controlled at its calibrated value.

F Note: the correction for the spatial nonuniformity of the sphere response is neglected as in this work the considered DE lamps have no reflector and hence have a regular spatial distribution. [8]

In this work we concern only on self – absorption correction factor and we comparison with another types of lamps such as High intensity discharge lamps (HID)such as High pressure mercury (HPM) , High pressure sodium (HPS) and metal halide (MH)and so with different shapes of compact fluorescent lamps (W1-W3) [9,10].

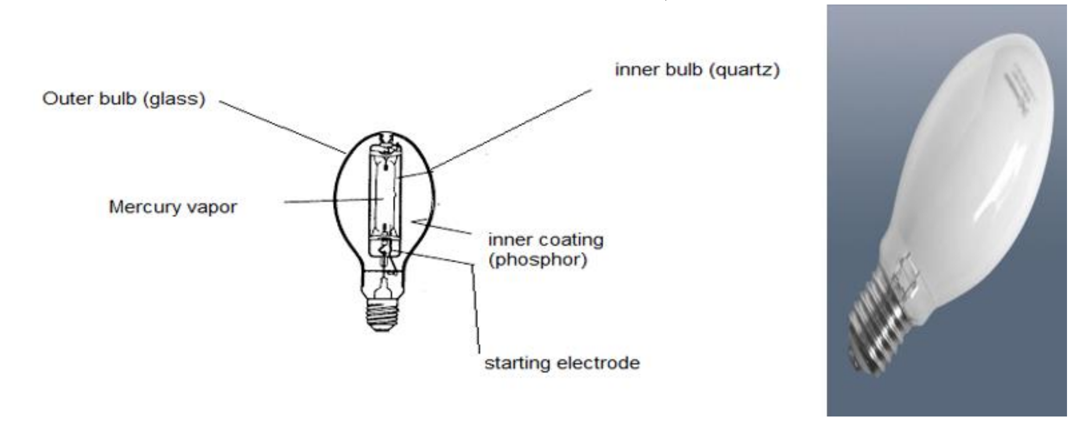

Figure-3: High Pressure mercury Lamp

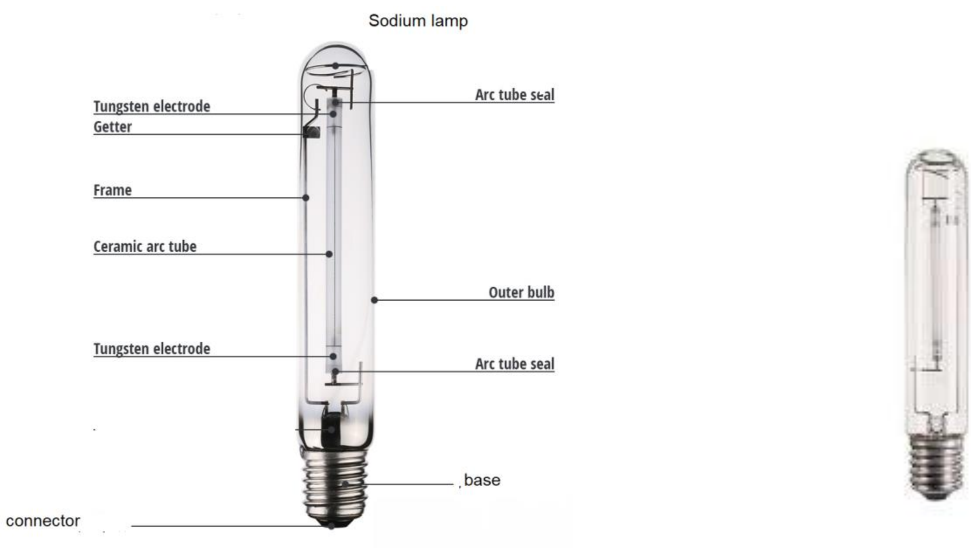

Figure-4: High Pressure Sodium Lamp

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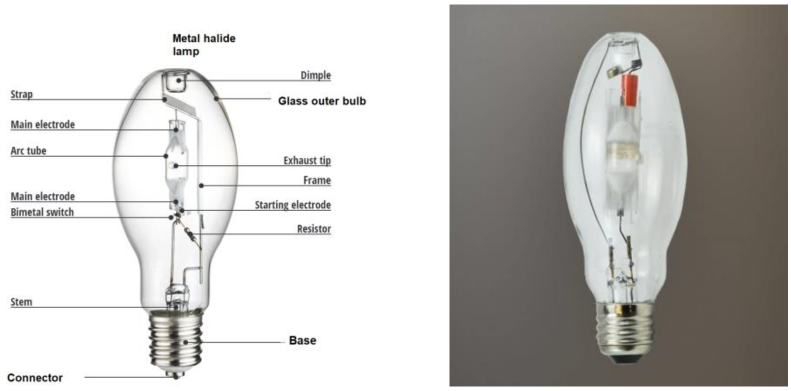

Figure-5: Metal halide Lamp

Figure-6: Compact fluorescent lamp

RESULTS AND DISCUSSION

The determination of self-absorption:

Self-absorption correction has been measured three times for each lamp types accordingly the values of self-absorption corrections are illustrated in table 1.

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Table-1: Average values of self-absorption correction for three lamp types of DE halogen lamp

Lamps	lamp J118	lamp J189	lamp SL
self-absorption correction	**1.04**	**0.96**	**0.95**

2- Performance of the three lamp types at supply voltage 220V.

The average values of the measuring $Ø_L$,W_L,I_L, V_L and efficacy for the three types are represented in table 2.

Table-2: The performance of each DE halogen lamp types and effect of self-absorption

lamps	**V(main)**	**$Ø_L$ flux (lumen)** Before measure self-absorption	**$Ø_L$ flux (lumen)** After measure self-absorption (corrected value)	**Power (Watt)**	**I_L Current (Ampere)**
lamp J118	**220**	**7086.33**	**7377.66**	**431.5**	**1.961**
lamp J189	**220**	**13771**	**13260.96**	**862.5**	**3.920**
lamp SL	**220**	**20186.66**	**19189.79**	**1258.8**	**5.722**

Table-3: Measurements of self-absorption for DE lamps J118

lamp J118	**Measured value of flux (Lumen)**	**Auxiliary lamp on Standard. Off**	**Auxiliary on Test(DE) off**	**Self absorption r_s/r_t**	**Corrected value of flux (Lumen)**
Read 1	**7086**	**25**	**25**	**1**	
Read 2	**7087**	**26**	**24**	**1.08**	
Read 3	**7086**	**26**	**25**	**1.04**	
Average	**7086.33**			**1.04**	**7377.66**

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Table-4: Measurements of self-absorption for DE lamps J189

lamp J189	Measured value of flux (Lumen)	Auxiliary lamp on Standard. Off	Auxiliary on Test (DE) off	Self-absorption r_s/r_t	Corrected value of flux (Lumen)
Read 1	**13770**	**25**	**27**	**0.925**	
Read 2	**13771**	**26**	**27**	**0.96**	
Read 3	**13772**	**26**	**26**	**1**	
Average	**13771**			**0.96**	**13260.96**

Table-5: Measurements of self-absorption for DE lamp SL

lamp SL	Measured value of flux (Lumen)	Auxiliary lamp on Standard. Off	Auxiliary on Test(DE) off	Self absorption r_s/r_t	Corrected value of flux (Lumen)
Read 1	20190	25	27	0.925	
Read 2	20180	26	27	0.96	
Read 3	20190	26	27	0.962	
Average	20186.66			0.95	19189.79

Table-6: Average values of self-absorption correction for three lamp types of High Intensity Discharge lamps (HID)

Lamps	High pressure mercury **(HPM)**	Metal halide **(MH)**	High pressure sodium **(HPS)**
self-absorption correction	**1.01**	**0.98**	**0.99**

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Table-7: Measurements of self-absorption for HPM lamps

HPM (125W)	Measured value of flux (Lumen)	Self absorption r_s/r_t	Corrected value of flux (Lumen)
Read 1	6300	1.01	
Read 2	6330	1.01	
Read 3	6250	1.01	
Average	6293.33	1.01	6356.26

Table-8: Measurements of self-absorption for MH lamps

MH (150Watt)	Measured value of flux (Lumen)	Self absorption r_s/r_t	Corrected value of flux (Lumen)
Read 1	9340	1.00	
Read 2	9370	0.99	
Read 3	9300	0.98	
Average	9336.667	0.99	9243.3

Table-9: Measurements of self-absorption for HPS lamps

HPS (150Watt)	Measured Value of flux (Lumen)	Self absorption r_s/r_t	Corrected value of flux (Lumen)
Read 1	16800	0.98	
Read 2	16900	0.97	
Read 3	16900	0.97	
Average	16866.67	0.97	16360.67

Table-10: Measurements of self-absorption for three Compact lamps

lamp	Measured value	Self absorption r_s/r_t	Corrected value of flux
W1 (77 watt)	4500	0.99	4455
W2 (87)	5809	0.98	5692.82
W3 (52 watt)	2459	1.00	2459

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Table-11: Percentage of the change of flux for all lamps

Lamp type	The difference between the corrected and measured value	Percentage %
DE J118	291.33	3.9
DE J189	-510.04	-3.8
DE SL	-996.87	-5.2
HPM	62.930	1.0
MH	-93.36	-1.0
HPS	-506.00	-3.0
Compact lamp W1	-45.00	-1.0
Compact lamp W2	-116.18	-2.0
Compact lamp W3	0	0

CONCLUSIONS

The experimental results of the luminous flux are obtained for each type of lamps; the results are measured at their working voltage. The double ended lamp has shown higher self-absorption due to the tubular shape of lamps like HPS compared with other types of lamps. Lower values of self-absorption are accompanied with small lamps shape such as MH and compact lamp types. This, in turn, reflects the importance of self-absorption calculation to reveal the actual values of luminous flux given by the lamp under operation.

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