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A comparative economical study of roadway lighting systems using High Intensity Discharge (HID) lamps in Egypt

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ABSTRACT

In this work a comparative economical study has been carried out for three road way lighting systems containing HPM, HPS and MH lamps to reveal the influence of lamp type on the economics of such systems. It is clear that systems employing higher lumen output lamp is the most economical in terms of (L.E) per lux. The study includes some input data concerned the local economical situation in Egypt it has been shown that, it is preferred to use HPM system for pedestrian area and HPS system for conflict area.

KEYWORDS: lighting- cost- lamps- roadway.

I-INTRODUCTION

Basically the HID lamps having a wide use in roadway lighting system.. Today, the major light sources being considered are high pressure mercury (HPM), high pressure sodium (HPS) and metal halide lamps (MH). There appear to be no inherent characteristics in any of these sources that would prevent their successful application on many different roadway configurations and at various mounting heights. However each lamp will have its own limitation due to physical size, practical optical control (glare control and uniformity) and economics.

In this work in addition to the engineering criteria that must met for specific system another consideration in selecting a particular design is that of relative cost. As the energy prices have so greatly increased over the last decades, in general it depends on the economical situation of each country. Hence studying the economics of lighting systems is of great importance and the most desirable system is that which is the most economical. So this study summarizes the economics of the following three lighting systems which utilize

1- 125 watt high pressure mercury
2- 150 watt high pressure sodium
3- 150 watt metal halide lamps.

According to CIE [(1)] criteria for road lighting the lighting areas have the following categories;

1- Motorized traffic, i.e. fast area, M,
   (For drivers of motorized vehicles)
2- Conflict area, i.e. mixed area, C, (where traffic streams intersect or run into areas with pedestrian , cyclists, or there is change in geometry or parking areas).
3- Pedestrian i.e. low speed areas, P, (for needs of pedestrian).

Also the road width and the pole distance corresponding to the three categories of road areas concluded from the expert inquiry are represent in table (1)

Table (1)

Category	Fast road M	Mixed road or Conflict area C	Slow road or Pedestrian areas B
Average width of road (m)	20	10	8
Average Pole distance (m)	45	30	20

Also CIE recommended that the lighting design must be based on illuminance for the cases of P and C categories and luminance for the M category. In this work the last category M is neglected as the investigated types of lamps are not used in such case.

<u>II- theoretical :</u>

For carrying out the economical comparison for the three mentioned systems, we have to determine the basic data needed for illumination calculation, initial investment and total annual operating cost per lux.

First illumination calculation;

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For their lumen calculation exterior lighting designers use a formula very similar to that used in interior lighting, as the utilization factor diagram of the luminaire in use is given, the formula is [2]

$E= N \times \Phi_o \times MF \times UF / A$ ---------- (1)

Where E is the Average maintained illuminance

N is number of lamps used in installation,

Φ_o is initial value of the lamp luminous flux (Φ) usually after burning time (t)=100 hours.

MF is maintenance factor,

UF is the utilization factor,

A is the area (m^2) to be lit.

Putting $\Phi_d = \Phi_o \times MF$

Φ_d denoted by the design lumen or the design luminous flux.

According to equation (1) Φ_d is the value of Φ corresponding to the maintain illuminace i.e the least permissible value of illuminace. So Φ_d is the value of Φ after burning time equals to group replacement period such time usually denoted by the useful life time τ_u which corresponding to the minimum annual operating cost.[3]

Note : the ratio of initial value of illuminance to that at the moment of replacement usually denoted by safety factor (S.F) hence at t= τ_u ,

(S. F) reaches its maximum value .

III – Experimental:

To obtain the data needed for the study which we are dealing with, we classify the investigated lamps into three groups. Group I for 125 watt mercury high pressure, group II for 150 watt sodium high pressure and group III for metal halide. It is obvious that the investigated lamps are sensitive to burning position. The three types of lamps are always operated at the base-up vertical position. We use the electric circuit shown in figure (1) for burning the lamps. The lamps seasoning is carried out according to IES recommendation [4]. For obtaining the aging characteristics of the lamps we use the system illustrated in figure (2). The integrated sphere for luminous flux measurement and the electric circuit for the measuring the current A_L, voltage V_L and wattage W_L of the lamp. Also the power consumed in the ballast can be measured using the power meter.

Note: the lamps should be operated on AC power supply at supply voltage 220 V and the ballast must be selected such that the current must be meeting the specification issued by IEC document for each lamp [5a, b, and c].

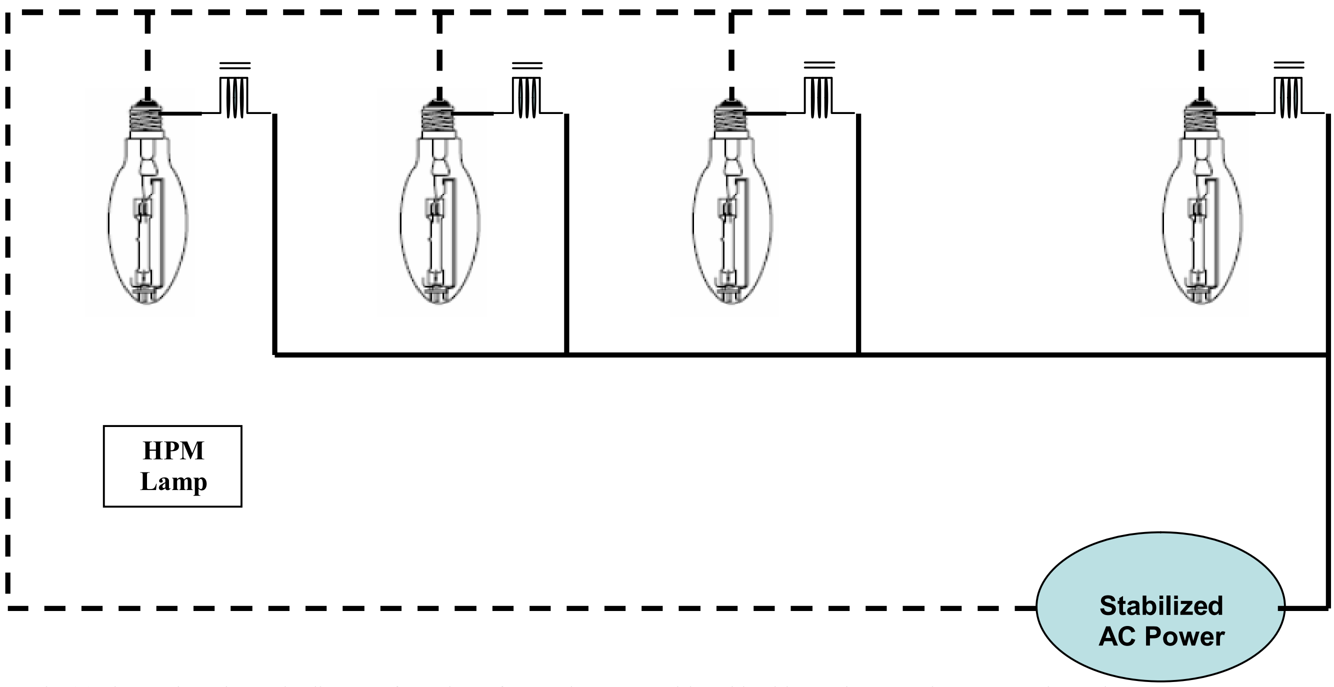

Fig (1) shows the schematic diagram for aging of HPM lamps considered in this work. For aging HPS and MH lamps, we use the same diagram.

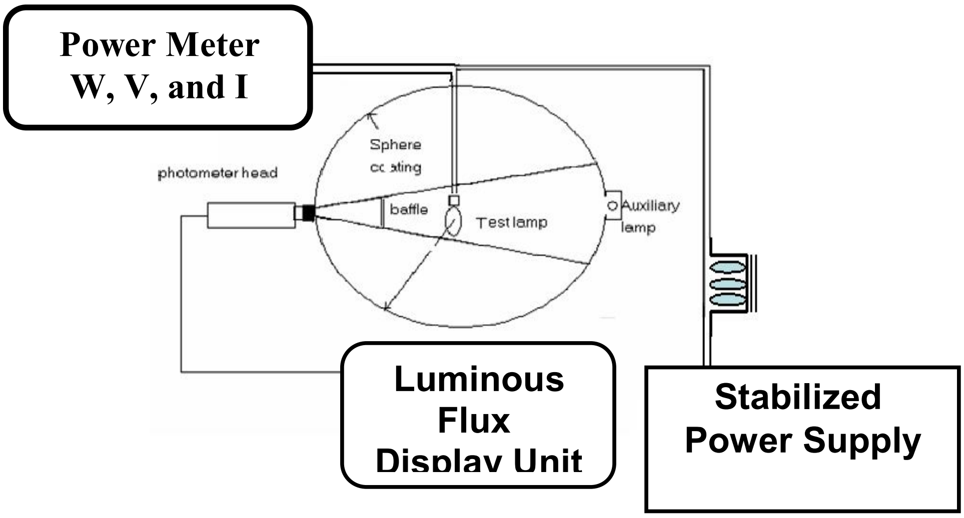

Fig (2) NIS 2.5 m integrating sphere set up for routine measurements.

The luminous flux measurement is carried out using the well known [6] integrating sphere method. As the luminous flux of the lamps changes significally with ambient temperature, which must be controlled within 25±1 before starting the measurements and the lamps should be stabilized for 15 minute with integrating sphere open. Note: the burning of the lamp is carried for the whole rated life time and should be cycled 11 hours on and one hour off as in the actual use for road lighting. The measurement of Φ and the other electric parameters are carried out each 33 burning hours.

The variation of the lamp wattage versus burning time for each lamp type are illustrated in fig (3). Also the mortality and maintenance curves for the three lamp types are illustrated in fig (4), (5), (6)

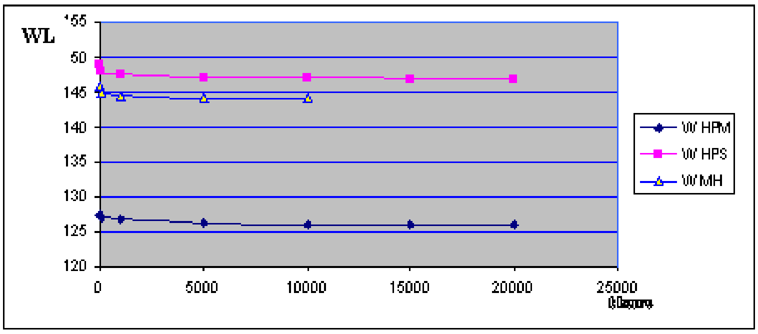

Fig (3) the variation of lamp wattage versus burning time through the rated life time for the three lamp types.

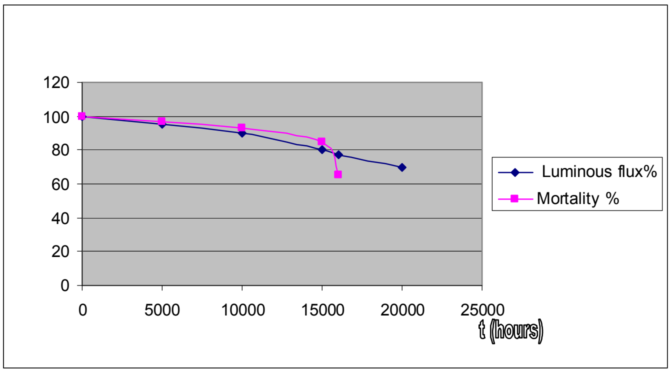

Fig (4) mortality and maintenance curve for HPM lamp

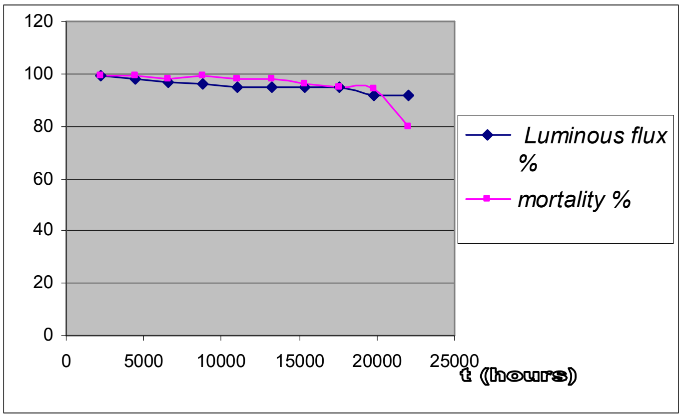

Fig (5) mortality and maintenance curve for HPS lamp

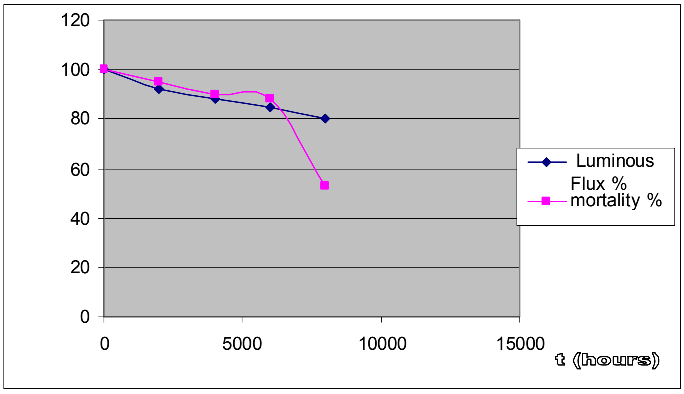

Fig (6) mortality and maintenance curve for MH lamp

For each lamp type, we consider the average value of ten lamps with standard deviation ≤ 0.2 for the different parameters. To carry out the actual economical study we must determine experimentally the following techno economical parameters for the three lamp types:

1- The nominal value of the lamps Φo (after 100 burning hours)
2- The consumed electrical power per luminaire (lamps and ballasts)
3- Maintenance factor, which can be determine from the maintenance curve Φ (t) and mortality curve N (t).
4- The rated life time

IV- Calculations and results :

To simplify the comparison we assumed that the three systems have the same mounting height and the same pole cost. The basic data needed for illumination calculation according to equation (1) are the following data providing that each system consist of ten poles each of which contains one lamp:

1- The value of Φ_o and MF for each lamp type such data have been experimentally.
2- The road area A which must be lit this is taken from table (1) for the different categories of road area
3- The values of UF for the three lighting systems are taken from literature [(7)]

The obtained average maintained illuminance for the three lighting system are represented in Table (4)
The initial investment and annual operating cost [(8)] are represented in tables (5, 6)

Table (2) Table (3)

Lighting Category	Eavge		Lighting Category	Eavge
C0	50		P1	15
C1	30		P2	10
C2	20		P3	7.5
C3	15		P4	5.0
C4	10		P5	3.0
C5	7.5		P6	2.0

Tables (2) and (3) : The CIE recommended values of illuminance for the categories P and C of road area

Table (4)

The parameter	HPM	HPS	MH
Φ (lumen)	6300	15550	9000
U.F	0.22	0.39	0.25
M. F	0.5	0.88	0.42
E (lx) ave. for slow speed or Pedestrian area	4.33	33.35	5.90
E(lx) ave. for Mixed road or Conflict area	2.31	17.78	3.15

Table (4): The obtained average maintained illuminance for the three lighting system

Table (5)

factor	HPM	HPS	MH
Quantity of luminaire	10	10	10
Luminaire cost each L.E.	320	600	469
Luminaire cost total L.E	3200	6000	4690
Quantity lamps per luminaire	1	1	1
Quantity lamps	10	10	10
Lamp cost each L.E	20.9	70	285
Lamp cost total L.E	209	700	2850
Equipment ballast, wire, switch, etc L.E	60	130	*130*
Total initial equipment included lamps L.E	3469	6830	7670
Relative initial equipment investment	**1**	**1.969**	**2.211**

Table (5) : Initial equipment investment

Table (6)

factor	HPM	HPS	MH
Equipment wire, switch etc. L.E	10	10	10
Luminaire L.E.	20	20	20
Total initial labour L.E.	30	30	30
Total initial investment L.E.	3499	6830	7700
Relative initial investment	1	1.95	2.12
Price of one lux for slow speed (P) L.E.	808.08	204.79	1305.08
Price of one lux for mixed road (C) L.E.	**1514.71**	**384.13**	**2444.44**

Table (6): Initial labour investment:

Table (7)

factor	HPM	HPS	MH
Kilo watt per luminaire	138w/1000	168/1000	166/1000
Total system kilo watt	1.38	1.68	1.66
Annual operation	4000 h	4000 h	4000 h
Total energy kilowatt hours per year	5520	6720	6640
Energy cost per kilowatt hour L.E	0.4	0.4	0.4
Annual kwh cost L.E	2208	2688	2656
Group replacement period (hours)	16000	17600	8000
Replacement lamp cost R_L L.E.	52.25	15.9	*1425*
Annual operating cost. L.E.	**2260.08**	**2703.9**	***4081***

_Table (7): Annual operation cost:

Table (8)

Parameter in L.E.	HPM	HPS	MH
R'_L is the cost of relamping	12.5	11.35	25
Ra is the cost of amortization	8.002	15.57	12.74
Rs is the cost of servicing	50.45	120.9	120.9
Rc is the cost of cleaning	10	9.1	20
Annual maintenance cost	80.952	156.92	178.64
Total annual operating cost	2341.032	2860.82	4259.64
Annual operation cost per lux for slow speed (P)	540.65	85.78	721.97
Annual operation cost per lux for mixed road (C)	**1013.43**	**160.90**	**1352.26**

_Table (8): Annual maintenance cost [9]:

DISCUSSION AND CONCLUSION

1- From the data represented in table (4) it is clear that the values of illuminance using HPM and MH systems satisfy the CIE recommendations for the pedestrian area as they are near the levels P5 and P4 respectively (see table 3). While in case of HPS the obtained value of illuminance is so high. So it is not preferred to utilize the HPS system for the pedestrian areas.

2- Also referring to the data represented in table (4) for the case of conflict area (C) the HPS system which can be used to provide the CIE recommended values of illuminance as the obtained values is near to C1 (see table 2).

3- From table (6) the total initial investment per lux for HPS system is the cheapest for both the cases of the pedestrian and conflict areas. But as mentioned above it is used for conflict area only. So HPS system is the most suitable from the technical and economical point of view in such case.

4- From the experimental data representing in table (4) and the calculated data representing in tables (5,6,7 and 8) one can conclude that the HPM system is the most suitable for pedestrian areas and HPS system for conflict areas.

REFERENCES

1- "Lighting of Roads for Motor and Pedestrian Traffic" CIE publication No. 115:2008

2- Ir.W.J.M. van Bommel and J.B. De Boer, " Road Lighting" , Philips Technical Libraryp 91. 1980.

3- M. Haridi. Msc,thesis,"Studying some photometric characteristics of certain types of commercial lamps, luminaries and local daylight", Faculty of science, EL-Azhar university, Girls branch. . 2002, p.(17-20).

4-"IES Guide to Lamp Seasoning", Journal of illuminating engineering society, IES LM-54-1984.

5a- International Electrotechnical commission (IEC) 60188, “High-pressure mercury vapor lamps / Performance specification”, 2001-2005.

5b- International Electrotechnical commission (IEC) 662, “High-pressure sodium lamps” 1980 inserted in which the Amendment 7, 1995-10.

5c- International Electrotechnical commission (IEC) 1167, “Metal halide lamps”, 1992-2008.

6- Osman. W.H, EL-Ganainy, M.M, Khodiar.M and Abbas.S.M.," Techno-economical study of the performance of locally manufactured fluorescent lamps', Journal of engineering and applied science , vol. 40, No. 1, Feb., , PP. 1-12. Faculty of engineering , Cairo University. 1993.

7-P. Van Tichelen, T. Geerken, B. Jansen , M. Vanden Bosch (Laborelec),V. Van Hoof, L. Vanhooydonck (Kreios), A. Vercalsteren., "Final ReportLot 9: Public street lighting", Study for the European Commission DGTREN unit D3, 2005, p. 137-140

8- R.E. Faucett,the new economics of roadway lighting design and application, January , 1973, p (29-37).

9- EL-Ganainy, M.M, Higazy, H.H., and Nayel, A.H.,"A comparative economical study of fluorescent and incandescent lighting system in Egypt", Journal of engineering and applied science , vol. 38.1992, PP.1035-1042. Faculty of engineering, Cairo University.