LOWER ENERGY CONSUMPTION IN PUBLIC LIGHTING NETWORKS USING ENERGY EFFICIENT LAMPS AND BALLASTS

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Abstract–The reduction of energy consumption is a growing concern at the global level. An important domain where the reduction of energy consumption can be achieved is public lighting. Energy charges for street and pedestrian lighting applications represent the largest part of all expenses for public lighting. This is conditioned by many factors, one of them being the use of energy in-efficient lamps and ballasts.

This paper's goal is to present and underline possibilities to reduce energy consumption in public lighting systems by the use of energy efficient lamps and ballasts. Some solutions used nowadays to increase efficiency in public lighting are represented in the paper.

The results of a search regarding to existing solutions to fulfill the increase of the public lighting network performances will be presented. These will include energy efficient solutions for every type of lamp and energy efficient solutions for lamp and ballast combination used in street and pedestrian lighting applications.

Key words: Energy efficiency, lamp, ballast, public lighting

I. INTRODUCTION

Energy efficient policies around the world seek to encourage the deployment of more energy-efficient lighting, but also lighting must be responsive to human needs. Matching these two requirements is not always simple and often the consumer, regardless of the sector, has only a limited idea of the options that are available, or of the trade-offs inherent in any lighting choice. In general, though, consumers are always interested in receiving a good-quality and economical lighting service, even if they are less concerned by the technologies inherent in the specific lamp and ballast on offer.

II. LAMPS AND BALLASTS USED IN PUBLIC LIGHTING

Although lamps and ballasts used around the world employ largely the same technology, they're electrical or photometrical characteristics can be different. The main types of lamps and ballasts used for street and pedestrian lighting applications are presented in this part. The main goal of this research was to evaluate and compare some parameters related to energy efficiency like luminous efficacy of lamps, luminous efficacy of lamp-ballast systems and ballast losses.

Considering the fact that starting with 2009 incandescent lamps with wattage over 100 were phased out this type of lamp was not considered in this study. Another lamp that is used in public lighting but was not considered in this study is the high pressure mercury vapor lamp that starting with the year 2015 will also be phase out, according to EuP directive (Eco-design Requirements for Energy-using Products, 2005/32/EC) [1].

1. Compact fluorescent lamps

The development of rare-earth phosphors in the late 1970 enabled the production of compact fluorescent lamps. These types of lamps were first commercialized in the early 1980s and are offered in two types with the ballast either integrated into the lamp or not [2].

Several lamps catalog of different producers where studied and some conclusions are presented below:

- The main advantages of these light sources include low cost of purchase comparing to other discharge lamps, low life-cycle cost, good luminous efficacy comparing to incandescent, high pressure mercury and even some high pressure sodium lamps, good color rendering index (80…89), lifespan up to 36000 hours (for some models when used with preheat electronic ballast) and the possibility to be dimmed (for some models).

- The main disadvantages of these light sources include low luminous efficacy comparing to some discharge lamps and LEDs lamps and dangerous mercury wastage.

A comparison of luminous efficacy (e) as a function of light output (Φ) for compact fluorescent lamps produced by different manufacturers is presented in fig.1 for different levels of light output.

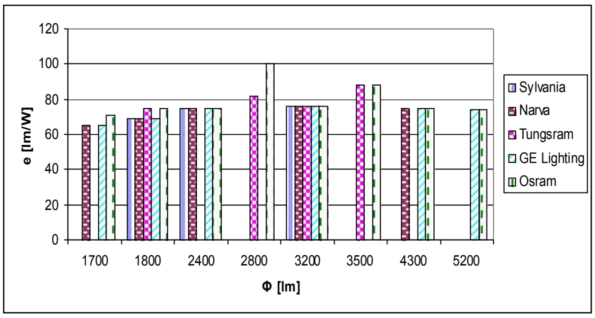

Fig. 1. Comparison of luminous efficacy between CFLs

A recent CFL development is the use of amalgam technology to better control the light output of the lamp over a broad temperature range. Amalgams optimize the amount of mercury vapor present in the arc discharge. Too little mercury vapor reduces lamp light output and efficacy, too much reduces output and causes the lamp to operate at less than rated watts. However the luminous efficacy of amalgam lamps is pretty much the same as that of lamps that function without amalgam technology as it can be seen in fig.2.

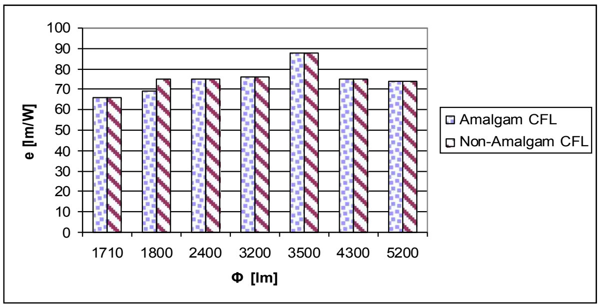

Fig. 2. Comparison of luminous efficacy between Amalgam and Non-Amalgam CFLs

Ballasts that operate CFLs are either electromagnetic or electronic. Electronic ballasts have lower ballast losses comparing to electromagnetic ballasts and also lamps working with high frequency electronic ballasts have a higher light output (up to 15% more). Electronic ballasts are presented more detailed below:

- Rapid-start (RS) electronic ballasts heat lamp electrodes continually during starting and operation. Also electronic RS ballasts are available for one, two, three and four lamp operation.
- Instant-start fluorescent ballasts apply a relatively high voltage to the lamp to quickly start the lamp and heat the lamp cathodes. There is no separate cathode-heating circuit as with RS systems, instead the operation is slightly more efficacious since less power is used to heat the cathode.
- Step electronic ballasts or "two-level" increase the flexibility of standard electronic ballasts by allowing the system light output to be switched between a low (typically 50%) and full output level. This ballast can be used with outdoor motion sensors and photocells.
- Electronic ballasts for partial and full-range dimming permit the light output of the lamp to be smoothly and continuously controlled over a wide range. All fluorescent dimming ballasts operate the lamps in rapid-start mode [3].

When used in public lighting the main applications for this type of lamp are residential and pedestrian areas.

2. Low pressure sodium lamps

Low-pressure sodium lamps have been in use since the 1930s and were improved in the 1960s when visible-light transparent, infrared-reflecting coatings based on tin oxide were added to the inside of the tube to produce what are called SOX lamps [2].

The main advantages and disadvantages for this type of lamp are presented below as a result of the research performed on different lamp manufacturers:

- The main advantages include no glare effect, no dangerous mercury wastage and little effect on nocturnal wildlife.
- The main disadvantages include no colour rendition (monochromatic color), relatively small lifespan (of 16000 to 18000 hours), difficult to control optics and large physical size.

A comparison of luminous efficacy (e) as a function of light output (Φ) for low pressure sodium lamps produced by different manufacturers is presented in fig.3.a and fig.3.b for different levels of light output.

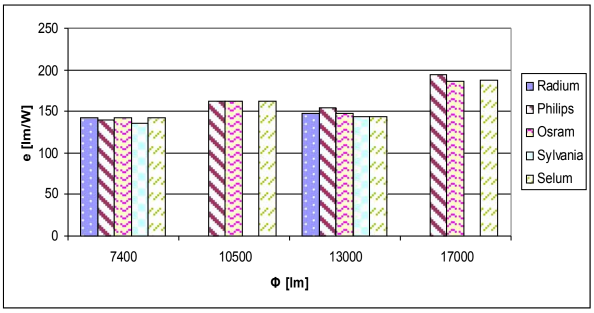

Fig. 3.a Comparison of luminous efficacy between low pressure sodium lamps

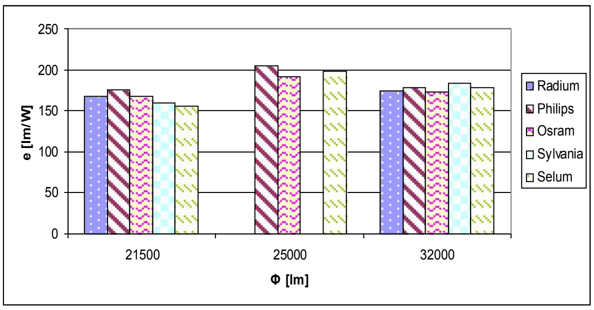

Fig. 3.b Comparison of luminous efficacy between low pressure sodium lamps

Although low pressure sodium lamps can be dimmed this is not advisable. As with all discharge lamps, low

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pressure sodium lamps require a ballast to operate. The ballast can be either electromagnetic or electronic (in this case they also need an igniter).

A comparison of luminous efficacy (e_g) as a function of light output (Φ) for some lamp-ballast systems are presented in fig.4.a and fig.4.b. The research is based on the data offered by different lamp manufacturers.

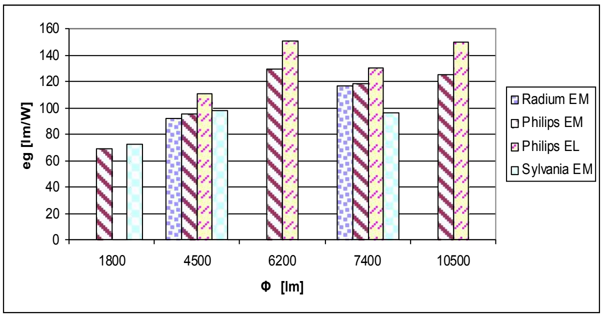

Fig. 4.a Comparison of luminous efficacy between lamp-ballast systems

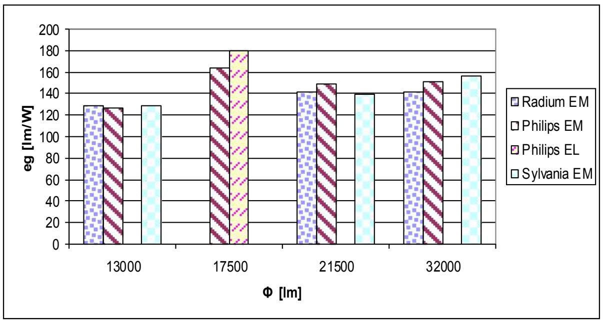

Fig. 4.b Comparison of luminous efficacy between lamp-ballast systems

A comparison between ballast losses (ΔP_b) for different lamp-electromagnetic ballast systems as a function of power consumed by the lamp (P_c) was realized using data provided by the lamp manufacturer and the results are presented in fig.5.

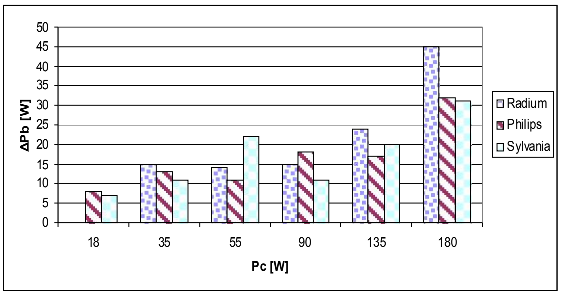

Fig. 5. Comparison of ballast losses for lamp-ballast systems

As the power consumed by the lamp grows so does the ballast losses and as it can be seen in the figure above for example if a lamp consumes 35 W the ballast losses will be in the best case 11W, so the lamp-ballast system actually consumes 46W.

When used in public lighting the main applications for this type of lamp are street lighting.

3. High pressure sodium lamps

High-pressure sodium lamps were developed in 1961 and introduced commercially in the mid 1960s as energy efficient sources for exterior, security and industrial lighting applications. High pressure sodium lamps rapidly found their ideal application niche in public lighting service as rated life increased from the initial 6000 hours [3].

Lamps catalogs of different producers where studied and some conclusions regarding high pressure sodium lamps used in public lighting are presented below:

- The main advantages include a long lifespan (up to 40000 hours), large variety of lamp wattages with moderate to high light output, high luminous efficacy comparing to some discharge lamps, good color rendering index (up to 80 for white light high pressure sodium lamps), moderate cost of acquisition.
- The main disadvantages include a low color rendering index (for orange-yellow high pressure sodium lamps) and dangerous mercury wastage.

A comparison of luminous efficacy as a function of light output for high pressure sodium lamps produced by different manufacturers is presented in fig.6.a, fig.6.b and fig.6.c for different levels of light output.

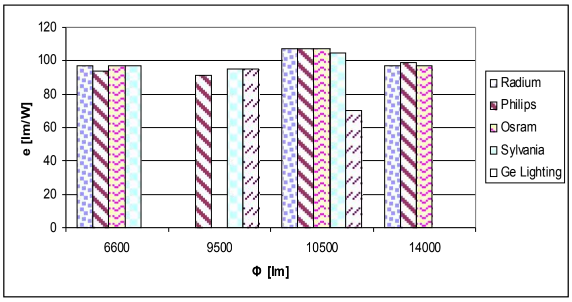

Fig. 6.a Comparison of luminous efficacy between high pressure sodium lamps

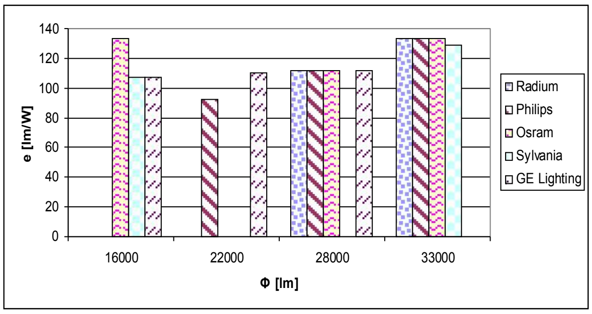

Fig. 6.b Comparison of luminous efficacy between high pressure sodium lamps

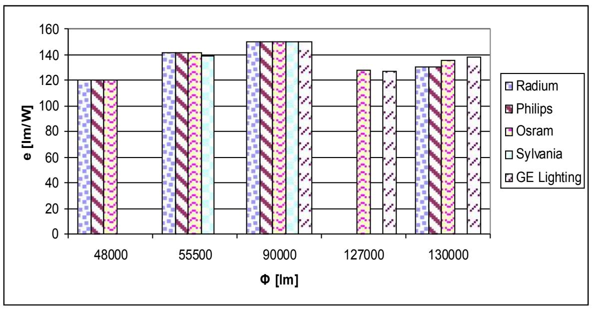

Fig. 6.c Comparison of luminous efficacy between high pressure sodium lamps

The high pressure sodium lamp is a discharge lamp so it requires a ballast to operate (they also need an igniter). The ballast can be either electromagnetic or electronic. It is also important to mention that the majority of high pressure sodium lamp can be dimmed.

A comparison of luminous efficacy (e_g) as a function of light output (Φ) for some lamp-ballast systems are presented in fig.7.a, fig.7.b and fig.7.c. The research is based on the data offered by different lamp manufacturers.

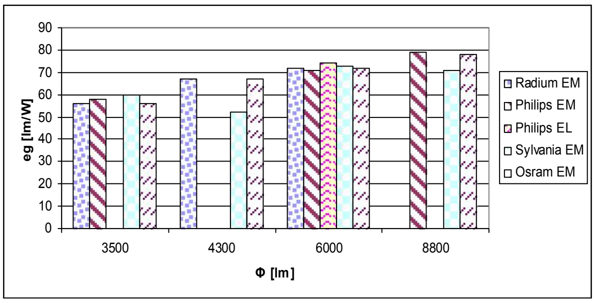

Fig. 7.a Comparison of luminous efficacy between lamp-ballast systems

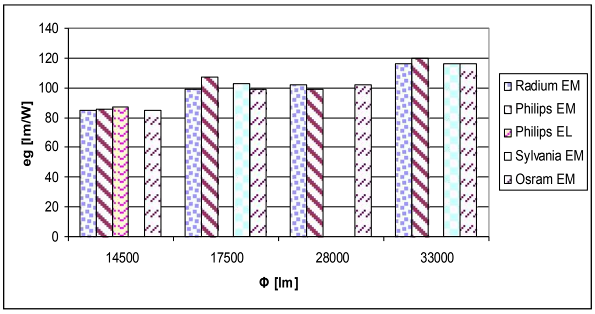

Fig. 7.b Comparison of luminous efficacy between lamp-ballast systems

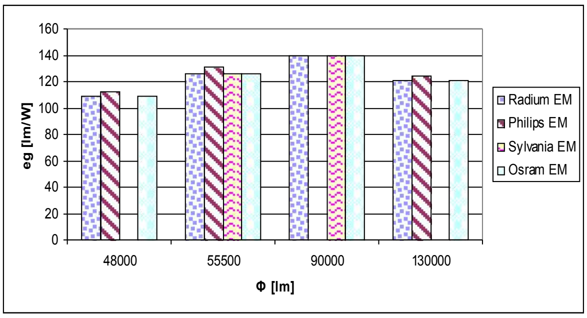

Fig. 7.c Comparison of luminous efficacy between lamp-ballast systems

Another comparison realized is that between ballast losses (ΔP_b) for different lamp-ballast systems as a function of power consumed (P_c) by lamps using data provided by the lamp manufacturer and the results are presented in fig.8.a and fig.8.b.

When used in public lighting the main applications for this type of lamp are street and pedestrian lighting applications. The range of wattages for lamps used in public lighting is 35 to 1000 W.

4. Metal halide lamps

Metal halide lamps were originally developed in 1965 and marketed "as better than mercury lamps" since they were more efficient and provided white light for exterior and industrial lighting. Since that time the technology has expanded considerably to include lamps with a variety of types, shapes, wattages and colors [3].

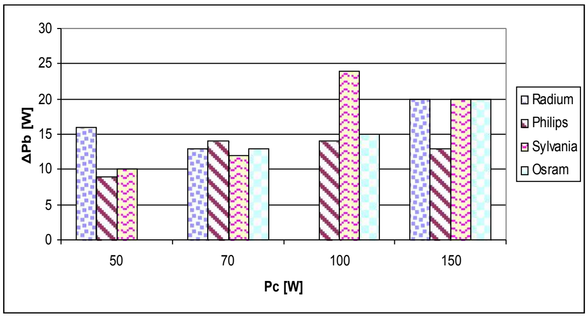

Fig. 8.a Comparison of ballast losses for lamp-ballast systems

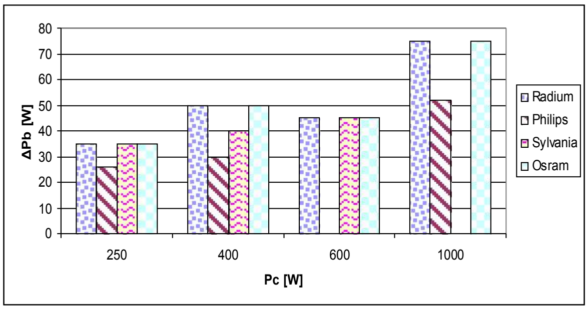

Fig. 8.b Comparison of ballast losses for lamp-ballast systems

I. Metal halide lamps with quart technology

Metal halide lamps with quart technology used in public lighting have a luminous efficacy that ranges from 64 to 118 lumens per watt. The wattages of metal halide lamps usually vary from 70 to 1000 watts. They are mainly used in pedestrian lighting applications like parking lots and residential areas. Some important advantages and disadvantages of metal halide lamps with quart technology are presented below as a result performed on different lamps catalogues:

- The advantages include a good color rendering index (up to 93), good luminous efficacy, large range of wattages, universal burning position, compact dimensions and a natural white light emitted.
- The main disadvantages include a short lifespan (10000-20000 hours) and the need to function in enclosed luminaries (to protect people in case of lamp rupture from dangerous mercury wastage).

Eliminating the third starting electrode from standard metal halide lamps improves lumen maintenance, color stability and life. Lamp efficacy for pulse start metal halide lamps remains however the same. No data were available about the possibility to dim both standard and pulse start metal halide lamps with quart technology.

A comparison of luminous efficacy (e) as a function of light output (Φ) for metal halide lamps with quart technology produced by different manufacturers is presented in fig.9.a, fig.9.b and fig.9.c for different levels of light output.

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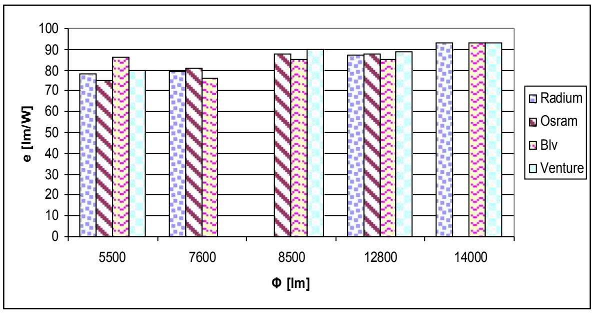

Fig. 9.a Comparison of luminous efficacy between metal halide lamps with quart technology

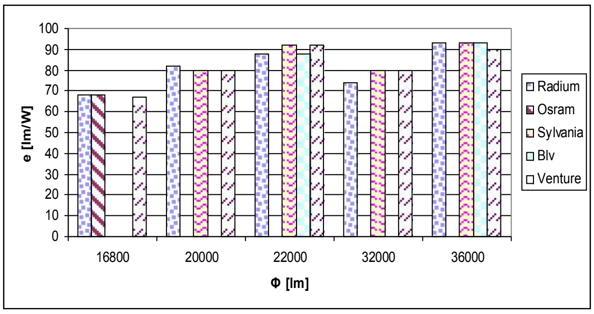

Fig. 9.b Comparison of luminous efficacy between metal halide lamps with quart technology

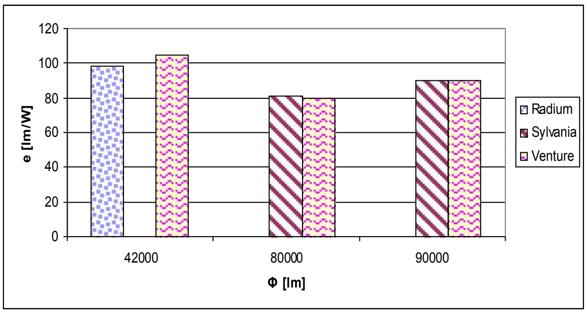

Fig. 9.c Comparison of luminous efficacy between metal halide lamps with quart technology

This type of lamp needs a ballast and an igniter to function. The ballast can be either electromagnetic or electronic. Based on these facts a comparison of luminous efficacy (e_g) as a function of light output (Φ) for some lamp-ballast systems was achieved and the results are presented in fig.10.a and fig.10.b. The research is based on the data offered by different lamp manufacturers.

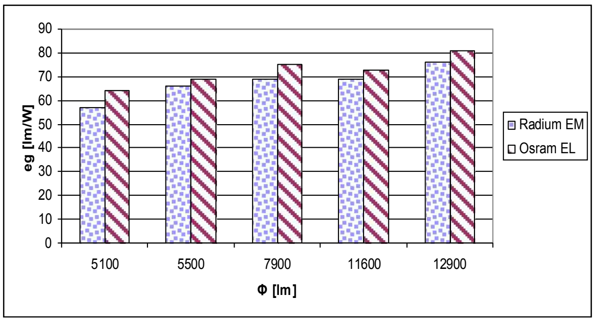

Figure 10.a Comparison of luminous efficacy between lamp-ballast systems

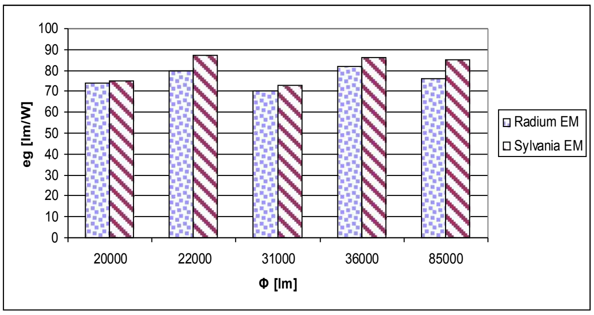

Fig. 10.b Comparison of luminous efficacy between lamp-ballast systems

Another comparison realized is that between ballast losses (ΔP_b) for different lamp-ballast systems as a function of power consumed (P_c) by lamps, using data provided by the lamp manufacturer and the results are presented in fig.11.

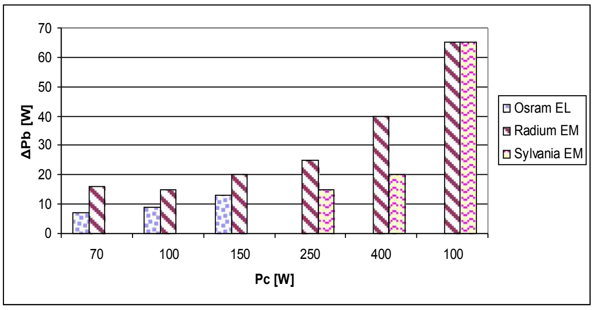

Fig. 11. Comparison of ballast losses for lamp-ballast systems

II. Metal halide lamps with ceramic technology

The metal halide lamp with ceramic technology is a new generation discharge lamp that overcomes some of the difficulties in the older technologies and has a great energy-savings potential that can be used in public lighting applications. Some important advantages and disadvantages of metal halide lamps with ceramic technology are presented below:

- High CRI of up to 93, excellent color-point stability, high luminous efficacy (up to 120 lm/W, which makes them the most energy efficient white light source), good optics, large range of wattages, low cost of life-cycle and the possibility to be dimmed .
- Short lifespan (6000-20000 hours), small luminous efficacy compared to orange-yellow light sources like low and high pressure sodium lamps.

The luminous efficacy of metal halide lamps with ceramic technology varies from 80 to 120 lm/W. A comparison of luminous efficacy (e) as a function of light output (Φ) for different lamp producers was realized and the results are presented in fig.12.a and fig.12.b.

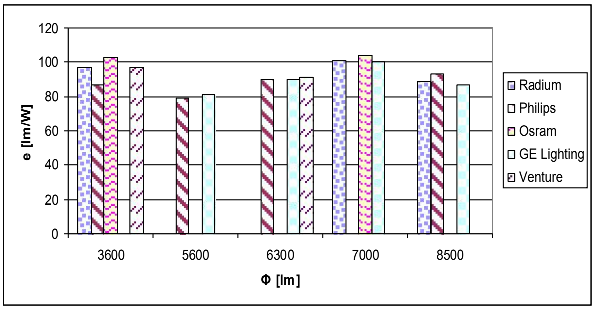

Fig. 12.a Comparison of luminous efficacy between metal halide lamps with ceramic technology

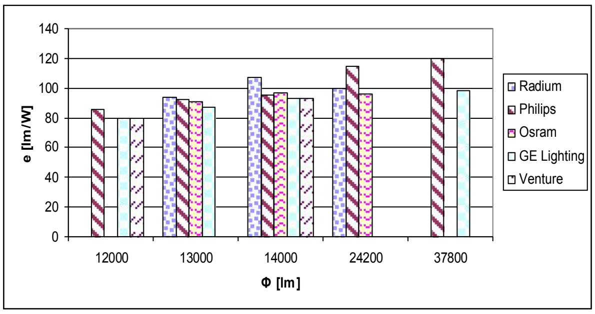

Fig. 12.b Comparison of luminous efficacy between metal halide lamps with ceramic technology

When used in public lighting this type of light sources needs a ballast and a starter to function. The ballast can be either electromagnetic or electronic. Some metal halide lamps with ceramic technology can use the ballast of high pressure mercury lamps or the ballast of metal halide lamps with quart technology. Knowing these details a comparison of luminous efficacy as a function of light output for some lamp-ballast systems are presented in fig.13.a and fig.13.b. The research is based on the data offered by different lamp manufacturers.

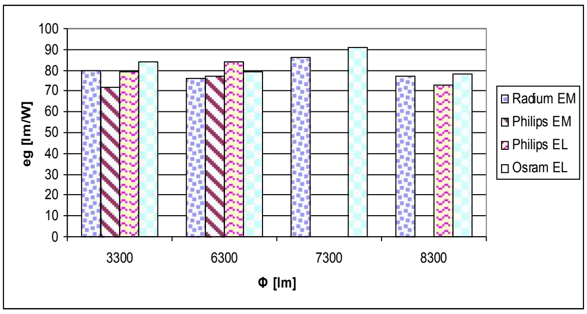

Fig. 13.a Comparison of luminous efficacy between lamp-ballast systems

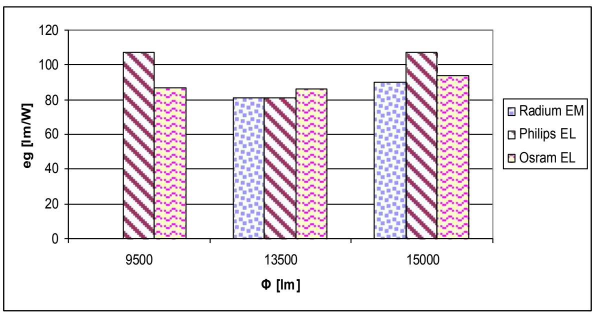

Fig. 13.b Comparison of luminous efficacy between lamp-ballast systems

It is well known the fact that the higher ballast losses are the luminous efficacy of lamp-ballast systems has a lower value. To highlight this aspect a comparison was realized between ballast losses (ΔP_b) for different lamp-ballast systems as a function of power consumed by lamps (P_c). Data provided by the lamp manufacturer were used and the results are presented in fig.14.

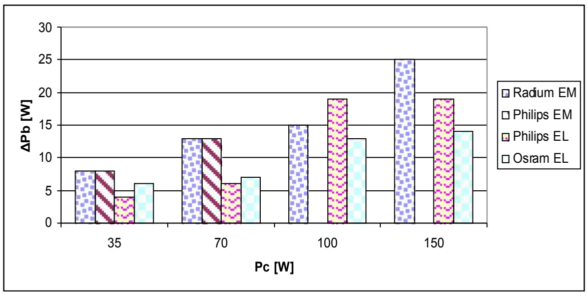

Fig. 14. Comparison of ballast losses for lamp-ballast systems

This type of lamp can be used both in street and pedestrian lighting applications. The range of wattages for lamps used in public lighting varies from 35 to 400 W.

5. LEDs lamps

Solid-state lighting (SSL) in the form of light-emitting diodes (LEDs) was first applied in the 1960s, but only in recent years has it matured sufficiently that people are now considering it as a potentially serious contender for public lighting applications like street and pedestrian lighting. The main advantages and disadvantages of LEDs lamps are presented below as a result of the research performed on different lamps catalogues:

- Good luminous efficacy (values between 47 to 108 lm/W), very high lifetime (up to 70000 hours), no UV and IR radiation, instantaneous switch-on, good color rendering index (up to 85), easy dimmable, no mercury wastage, instantaneous switch-on and low voltage are some of the main advantages.
- High price of acquisition, color and intensity shift with temperature, driving current and lifetime and the difficulty of reproducibility (semiconductor processing) are the main disadvantages.

The luminous efficacy of LEDs lamps as a function of light output for different lamp producers was realized and the results are presented in fig.15.a and fig.15.b.

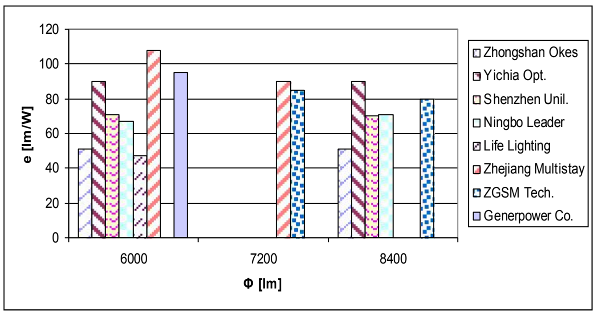

Fig. 15.a Comparison of luminous efficacy between LEDs lamps

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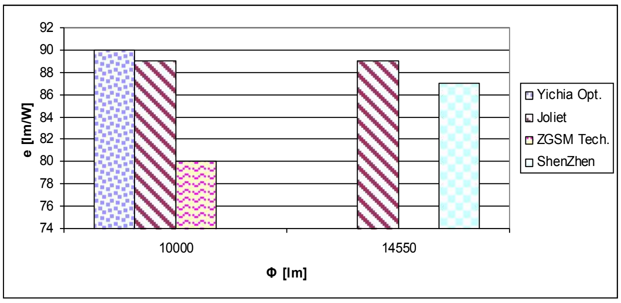

Fig. 15.b Comparison of luminous efficacy between LEDs lamps

To be operated this type of lamp needs resistive ballast, sometimes called "driver". A comparison of luminous efficacy (e_g) as a function of light output (Φ) for some lamp-ballast systems are presented in fig.16.a and fig.16.b. The research is based on the data offered by different lamp manufacturers.

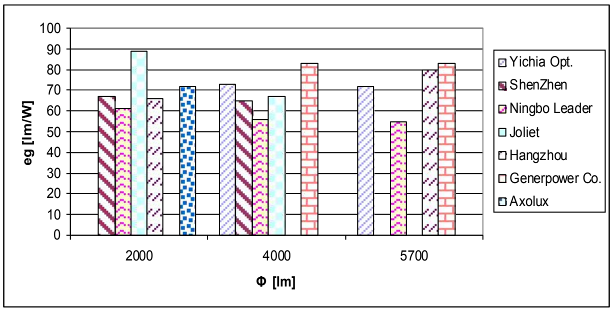

Fig. 16.a Comparison of luminous efficacy between lamp-ballast systems

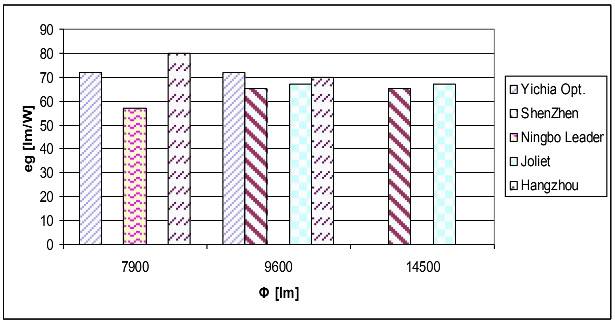

Fig. 16.b Comparison of luminous efficacy between lamp-ballast systems

It is well known the fact that the higher ballast losses are the luminous efficacy of lamp-ballast systems has a lower value. To highlight this aspect a comparison was realized between ballast losses (ΔP_b) for different lamp-ballast systems as a function of power consumed by lamps (P_c). Data provided by the lamp manufacturer were used and the results are presented in fig.17.

The technology of LEDs lamps used in public lighting has not reached yet full maturity and problems like heat dissipation still represent an inconvenient that can affect the performances of these lamps.

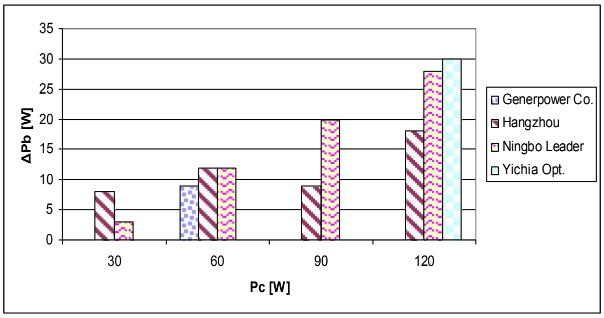

Fig. 17. Comparison of ballast losses for lamp-ballast systems

III. WHITE LIGHT VS. ORANGE LIGHT IN PUBLIC LIGHTING

It has long been thought that the human eye is most sensitive to orange light. This meant that the relatively cheap and energy efficient orange low pressure sodium lamps but also high pressure sodium lamps were perfect for street and pedestrian lighting. Experiments realized in the last years have proved however that below a certain luminance level, this ceases to be true. Various researches have demonstrated that the frequency with the highest sensitivity for the human eye shifts towards the blue/green spectrum at a certain point [4].

Across Europe there is a strong trend towards white light and white lamps can be expected to gain even more ground. In many street and pedestrian application orange light sources like high and low sodium lamp are being replaced by CFLs, warm-white high pressure sodium, metal halide and LEDs lamps.

A comparison of luminous efficacy (e) as a function of light output (Φ) for orange light sources is presented in fig.18 while in fig.19 the same comparison is realized for white light sources as a result of the research performed on lamp catalogues.

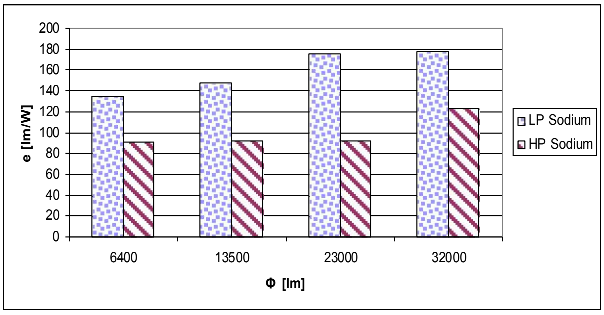

Fig. 18. Comparison of luminous efficacy for orange light lamps

As it can be seen from the two figures above some white light sources (ceramic metal halide lamps) at low and medium light output levels (under 32000 lumens) have a higher luminous efficacy then high pressure sodium lamps but still smaller then low pressure sodium.

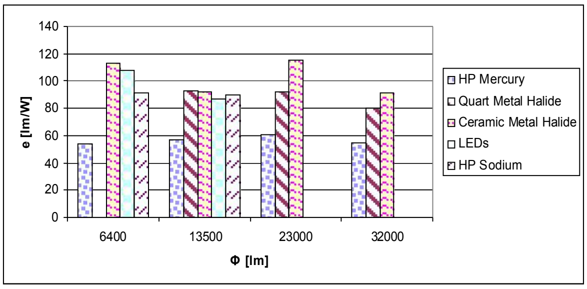

Fig. 19. Comparison of luminous efficacy for white light lamps

IV. CONCLUSIONS

When choosing a lamp for a street or pedestrian application an important step is to study the different options available on the market. Energy efficient solutions can be obtained just by analyzing the offers of different producers. When it comes down to choosing the ballast suited for your application it was observed that electronic ballasts (preferably ballasts that can also dim the lamps) have lower ballast losses then electromagnetic ballast and this results to higher luminous efficacy for lamp-ballast systems. Another important factor in obtaining an energy efficient system is to choose lamps that can be dimmed as this allows the light output to be reduced at one point during the night.

Orange light lamps have often been the first choice in street and pedestrian lighting for many years, basically because they produce high levels of illumination for a given amount of energy and have a long, reliable lifespan.

However, their distinctive yellow/orange light makes it difficult to distinguish colors and details.

This problem can be solved using white light lamps which have gained more popularity because they resolve the problems mentioned above and also have a good luminous efficacy, so these types of lamps are now more recommend to be used.

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