IN DEFENSE of LPS

By Mark S. Rea and John D. Bullough

Low pressure sodium (LPS) lamps seem to have fallen from favor with specifiers. According to figures from the U.S. Department of Commerce, LPS lamp shipments totaled only three percent that of high-intensity discharge (HID) lamps in the U.S. in 1992. Even in the U.K., one of the largest worldwide markets for LPS, sales have fallen more than 40 percent between 1995 and 2003. Perhaps LPS can be added to the list of endangered light sources such as carbon arc lamps.

To many, this is as it should be because LPS is essentially a monochromatic (589 nm) light source making color perception impossible. Indeed, there has been a general world movement toward "white" light sources; even high pressure sodium (HPS) is becoming less prevalent in outdoor applications. Twenty years ago the ground was orange when viewed from an airplane at night. Today in North America the same ground is a patchwork of white and orange. This transformation in outdoor lighting is interesting, because objective assessments of LPS lead one to wonder why it is going the way of the passenger pigeon.

Making the Case

Efficiency. LPS is a very efficacious light source. A 180-W LPS lamp, the most common available, generates light at about 180 lumens per watt (lm/W). Since the lighting requirements for almost all lighting applications[1] are specified by IESNA in terms of lumens per unit area (i.e., illuminance), LPS is the most efficacious source for meeting specified light levels. Presently there is no other formally recognized criterion for "light" than the lumen. Although the lumen is sometimes, and sometimes correctly, [2] deprecated as a measure of the stimulus for visual perception, the lumen is still a robust representation of "light" for visual performance,[3] visual acuity[4] and on-axis reaction times.[5] Probably rightly then, the lumen remains a quite satisfactory, if not completely useful, measure of "light" emitted from all light sources. Until the definition of "light" changes, LPS will probably remain the most efficacious source for achieving specified illuminance levels.

LPS is also efficacious for off-axis vision. Recently there has been a great deal of interest in off-axis (peripheral) night-time vision and its important role in outdoor lighting.[6] Many lighting practitioners know that the photopic lumen is based upon the combined spectral sensitivity of cones and that the scotopic lumen is based upon the spectral sensitivity of rods. The peak spectral sensitivity of rods is at a shorter wavelength (e.g., toward "bluer" and "greener" light) than the combined peak spectral sensitivity of cones. It is sometimes stated that LPS is a poor source for night time (mesopic) vision where both rods and cones contribute to human vision.[7] This argument is based upon the fact that the peak spectral sensitivity of off-axis vision at night is shifted away from the long-wavelength ("yellow") emission line of LPS. On an equal light level criterion, LPS does indeed perform worse for off-axis vision than lamps with greater short-wavelength ("blue" or "green") emission. But on a luminous efficacy (lumens per watt) basis, LPS continues to outperform nearly any other commercially available sources at night-time light levels simply because LPS generates light so efficaciously.[6] In other words, the mesopic (off-axis) luminous efficacy is still higher for LPS than most other sources. **Table 1** compares relative power requirements for different light sources[6] at equal mesopic luminances for dif-

GRANTED, LOW PRESSURE SODIUM IS A MONOCHROMATIC SOURCE AND IS OFTEN REJECTED FOR ITS DEFICIENCY IN SUPPORTING COLOR. BUT DESIGNERS SHOULD TAKE A SECOND LOOK AT WHAT ELSE IT HAS TO OFFER

Table 1

Derived from IESNA recommended average luminance values for a **collector road** with medium pedestrian conflict area (RP-8-00)

Source	Illuminance V(λ) (lx)	Relative Power (%)
400 W HPS	26.9	100
180 W LPS	28.8	74
400 W MH	23.5	104
32 W T8 FL. 5000K	22.3	108

Derived from IESNA recommended average luminance values for a **local road** with low pedestrian conflict area (RP-8-00)

Source	Illuminance V(λ) (lx)	Relative Power (%)
400 W HPS	13.5	100
180 W LPS	15.8	82
400 W MH	10.1	89
32 W T8 FL. 5000K	9.0	87

Comparison of illuminances and relative power required to illuminate two types of roadways (collector roads at 0.6 cd/m² and local roads at 0.3 cd/m²) using various light sources.

ferent outdoor applications.

Cost. LPS is less expensive to own and operate than any common outdoor light source except HPS. Using 2001 Means Electrical Cost Data,[8] the initial costs (equipment and labor) of LPS, HPS and metal halide (MH) lamps, luminaires and poles are all within about five percent of $1100 (**Table 2**). To provide the IESNA recommended maintained illuminance and uniformity for parking lot illumination,[1] luminaires containing 180-W LPS lamps compare favorably with systems using 400-W HPS lamps in terms of the number of poles required to meet the specifications (**Table 3**). MH lamps, because of their lower luminous efficacy and lumen maintenance (LPS has virtually 100 percent lumen maintenance) require a greater number of poles. So does the 250-W HPS system, because of the lower light output implicit in the lower wattage. The total annualized cost of a system using 180-W LPS lamps will further be lower than one using an equivalent number of poles containing 400-W HPS lamps because of the lower wattage.

Extended Source. LPS is an extended source. The lumens from this light source come from a relatively large area. Although precise control of light from LPS lamps is very difficult in small fixtures, larger fixtures mounted high above the surface to be illuminated can gather the lumens from an LPS lamp to create acceptable, if not better, uniform luminous distributions than small-area sources. Large-area sources like LPS produce relatively less discomfort glare than small-area sources because of their much lower brightness. Belgium illuminates nearly all of its major motorways with LPS systems. Compared to driving at night in North America along roads illuminated by HPS cobrahead fixtures, driving in Belgium is, at least to the first author, a much more comfortable experience because of the uniform lighting distribution and low discomfort glare provided by LPS. (The color of LPS is also beneficial with respect to discomfort glare.[10])

Dark Sky Preservation. LPS also improves astronomical observations at night. In urban areas near astronomical observatories, LPS is often used. Since LPS is essentially monochromatic, it is possible to almost completely eliminate sky glow from these sources using light pollution suppression (conveniently also called LPS) filters, thus providing astronomers with a largely unfettered view of the stars. For those who want to enjoy the night sky, and who have access to these filters, LPS is the preferred source, hands down.

Mercury Free. LPS contains no mercury. Recent concerns over products containing mercury may be somewhat short-sighted because lamps containing mercury are usually more efficacious (lm/W) than those that are not. Since fossil fuels containing mercury dominate electrical generation in North America, less mercury is

Table 2

Type of Lamp	Fixture + Lamp	Pole Cost	Number of Poles Needed	Total Cost
LPS (180 W)	$565	$615	6	$14,160
HPS (400 W)	$500	$615	6	$13,380
HPS (250 W)	$499	$615	8	$17,824
MH (400 W)	$445	$615	9	$19,090
MH (250 W)	$448	$615	12	$25,512

Initial cost comparison (per pole) for LPS, HPS and MH area luminaires.[8] Total cost is estimated by doubling the equipment cost to account for installation and wiring costs.[9]

Table 3	
Type of lamp	Total annualized cost
LPS (180 W)	$1809
HPS (400 W)	$1811
HPS (250 W)	$2239
MH (400 W)	$2623
MH (250 W)	$3447

Comparison of annualized costs (initial, energy and maintenance costs equated to an annual payment) of the installations in Table 2.[9]

put into the environment when more efficacious light sources are used. Since mercury-containing lamps like fluorescent are usually more efficacious than those that do not, especially incandescent, there is usually a net environmental gain when mercury-containing light sources are used. But LPS is an exception. Not only does LPS have very high efficacy, it is also mercury-free.

Potential Health Benefits. LPS is not very "visible" to the circadian system. There have also been recent societal concerns over light at night disrupting the circadian system.[11] The circadian system regulates our daily rhythms, most notable our sleep-wake cycle. Daily fluctuations in several hormonal levels in our bodies are controlled by the circadian system. This has led medical researchers to speculate, and then confirm, that the efficacy of chemotherapy for certain cancers is many times more effective when applied at specific times of the day.[12] Direct evidence has also shown that the "hormone of darkness," melatonin retards cancer growth.[13] Moreover, epidemiological studies have pointed to light at night as a potential risk factor in night-shift nurses because light suppresses melatonin.[14] We know that the spectral sensitivity of the circadian system peaks between 440 nm and 500 nm, with little sensitivity to light at 589 nm.[15-19] Here again, if we are to believe that light at night is, in fact, a risk factor for cancer (not a proven link, by any means, however), then LPS is an ideal light source for night time applications.

Closing Arguments

Yes, LPS is a monochromatic source and does not support color vision. And sure, no one wants to choose tomatoes or apples under a monochromatic source. But do we really care about the color of the bicycle we want to avoid when driving at night? And are we to conclude that color deficiency is the most important criterion for rejecting a light source from consideration? From a design perspective aren't (a) low life cycle costs, (b) no lumen depreciation, (c) lower discomfort glare, (d) better acuity, (e) good visual performance (both on-axis and off-axis), (f) better astronomical observations, (g) mercury-free lighting, and, theoretically at least, (h) lower health risk for night-shift workers also worth considering?

In a recent presentation, Dr. Paul Schoemaker[20] made the point that our beliefs are often based upon what we hear rather than what is true. He asked the audience to choose which killed more people in the United States:

- Stroke, or all forms of accidents
- Lung cancer, or motor vehicle accidents
- Emphysema, or homicide

The response from the audience (a show of hands) was consistent with the results presented in **Table 4** that were obtained earlier by Dr. Shoemaker. Table 4 drives home his point that our estimates of the relative numbers of causes of deaths more closely follow what we hear and see in the press than what actually occurs. In a similar exercise, we asked subscribers of the National Lighting Product Information Program to compare MH, HPS and LPS in terms of their effectiveness for night time applications, considering factors such as:

- Initial costs and operating costs (including energy usage)
- Visibility
- Color vision
- Glare
- Environmental impact
- Health effects
- Aesthetic appeal

We also reviewed lighting trade magazines in the U.S., U.K. and Canada over the past five years by simply counting the frequency of articles related to outdoor or roadway lighting that discussed MH, HPS or LPS. **Figure 1** provides a comparison of responses (more than 600 individuals responded) to our questionnaire and of our review of the number of articles dealing with these three light sources in American, British and Canadian lighting trade magazines. Figure 1 further illustrates the point that our beliefs mirror what is popular. In fact

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Perception vs. Reality ?

Table 4

Causes of Death	Annual U.S. Total (In 1000's)	People's Estimate (In 1000's)	Newspaper Reports Per Year
Stroke	209	7	8
Accidents(All)	112	89	276
Lung Cancer	76	10	3
Motor Vehicle Accident	55	41	136
Emphysema	22	3	1
Homicide	19	6	264

Comparison between the actual number of deaths in the U.S. by various causes and the public perception of the number of deaths, and the number of newspaper reports of each cause of death.[20]

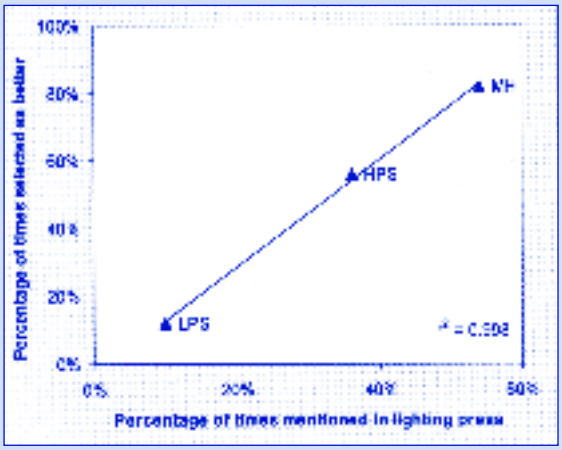

FIGURE 1. Percentage of times LPS, HPS and MH are mentioned in lighting trade magazine articles, and the percentage of times each lamp was identified as better in a survey of National Lighting Product Information Program subscribers. Correlation between the two sets of values is very high.

there is a nearly perfect correlation between the likelihood of a particular light source being selected as better and the number of times it was mentioned in the lighting trade press!

We are all very busy, balancing our professional obligations and personal pleasures. It is undoubtedly easier for us to form our beliefs from what we hear than it is to form our opinions after digging for the facts. Few of us even have time to think of the right questions, let alone find the answers to those questions. Rational arguments in favor of LPS may make little difference to the future of LPS if they are never considered in the first place. And, as shown in Figure 1, LPS is widely ignored by the lighting trade. LPS is an old technology of little interest to manufacturers interested in producing higher margin products and to specifiers interested in creating pretty places. Unless the economic, environmental and social values of all forms of lighting are more widely and openly discussed, LPS sales will continue to decline despite the many rational arguments in its favor.

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