

Thursday, Jan 25

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Posted on: 07/08/2000

## Fluorescent Solutions for Industrial Lighting

By DAVID FETTER and JAY BARNETT

**Better performance and dramatically lower energy costs may be possible with modern fluorescent industrial luminaires**

Lighting professionals have embraced fluorescent lamps, ballasts, and luminaires for use in commercial office buildings, learning institutions and medical facilities because of advances in these technologies. But even as the new technology displaces old fluorescent, incandescent, and high-intensity discharge (HID) sources in these types of facilities, the use of fluorescent lighting in heavy commercial and industrial facilities has been largely overlooked. Years ago fluorescent systems took a back seat to high-pressure sodium (HPS) and metal halide (MH) light sources because, at the time, these systems offered greater system efficacy, better lighting performance at medium to high mounting heights, and lower life cycle costs (LCC). Today, however, many manufacturers are developing fluorescent industrial and commercial luminaires which, applied properly, will provide improved visual performance and lower life cycle costs over HID technologies.

With the advent of synthesized luminaire computer modeling, manufacturers are able to predict the performance of these systems even before they go into production. Many manufacturers have been able to develop fluorescent luminaires that provide up to 95% luminaire efficiency. Although important, luminaire efficiency is only partially responsible for long-term system performance. Coupling these high-efficiency luminaires with new fluorescent T8 lamp and electronic ballast technology, manufacturers are delivering low-bay and high-bay luminaire designs capable of producing comparable illumination to 400-watt (W) MH high-bay designs, while providing 50% energy savings and significant maintenance savings.

## Light Loss Considerations

One consideration in choosing lighting equipment is the degradation over time, of illumination as compared to initial system performance. Developing an understanding

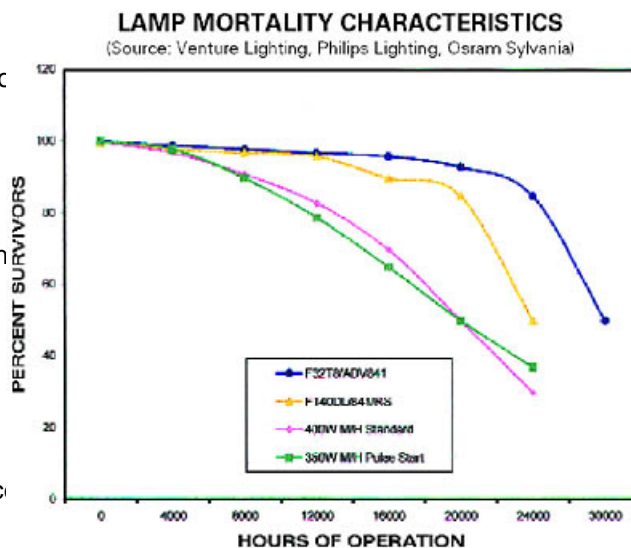


Figure 1. Lamp Mortality Characteristics.

of light loss factors and applying them to the lighting design process reveals maintenance challenges for MH systems and performance advantages for fluorescent luminaires.

Primary light loss factors are:

- Luminaire dirt depreciation (LDD): LDD represents the loss of light from a luminaire due to the accumulation of dust and dirt. Oxidation of reflector components and degradation of finishes from ultraviolet light and heat can also contribute to LDD. Newer fluorescent luminaire designs include an envelope that prevents airborne dust and dirt from settling on the luminaire's reflective surfaces. Additionally, the use of non-porous reflector materials inhibits dust and dirt particles from adhering to the surfaces. MH luminaires are typically vented and allow air to travel up through the reflector and lamp cavity, but despite some cleaning action by this airflow, significant LDD may develop.
- Lamp mortality: Lighting specifiers often overlook how the lamp failure mechanisms of different lamps produce different failure rates and mortality profiles (Figure 1). For instance, only 15% of T8 fluorescent lamps will have failed at 80% of rated life. For MH lamps, lamp mortality rises to 30%. The greater mortality rate and the relatively fewer number of MH typical of these installations will often create large dark and dangerous spots on the floor.

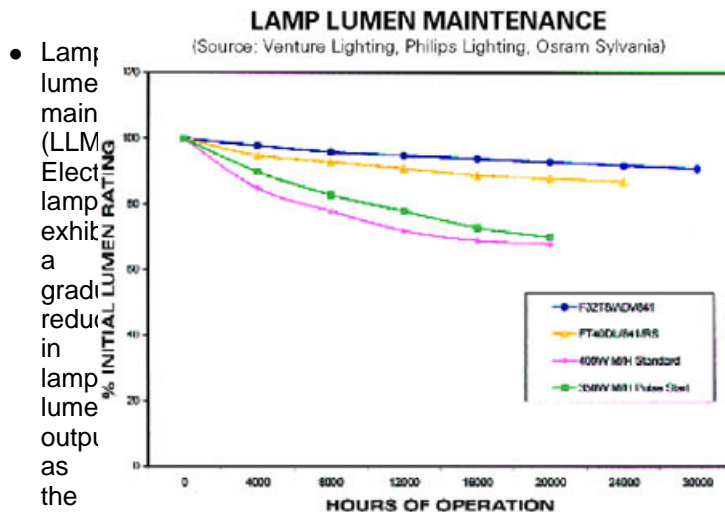


Figure 2. Lamp Lumen Maintenance.

This trait is more severe in MH lamps than in new fluorescent lamp technology (Figure 2). LLM is expressed as a ratio of lamp lumen output at intervals throughout the life of the lamp compared to initial lamp lumen output (100 hr). The latest T8 technology produces LLM values of 93% at 80% rated life. MH lamps produce LLM values of only 70% at 80% of rated life.

- Ballast factor and voltage performance: Luminaire performance is determined by system lamp lumen performance. Ballast factor describes the ability of the ballast to produce rated lamp lumen output as referenced to that lamp operated on a laboratory reference ballast.

Electronic ballasts are available with a multitude of ballast factors (.01BF to 1.6BF) and should be selected to provide optimum luminaire efficiency. HID ballasts generally provide fixed ballast factors (.95BF to 1.0BF). Ballast performance is also determined by service voltage. Generally speaking, an increase in voltage will produce an increase in wattage and lumen output. A decrease in voltage will cause similar decreases in wattage and lumen output. MH lamp life is adversely affected by high and low ballast voltage. Different ballast types will experience different variations.

- Luminaire ambient temperature: Fluorescent lamp lumen output is temperature dependent. Generally speaking, fluorescent lamp lumen output is optimized at a still ambient air temperature of 77 F. The lamps will experience lumen loss more rapidly in cold climates than in warmer climates, but proper luminaire design and ballast selection will minimize these effects. Temperature variation is not a factor with MH systems.

### Light Loss Factor Calculation

The light loss charts (Figure 3) identify total light loss factors for a typical 400-W MH industrial luminaire and a six-lamp industrial shrouded fluorescent luminaire. Bottom

Luminaire: 400-W MH High Bay, 460 System W Lamp Type: MH400W/U Metal Halide		Lamp Lumen Rating: 36,000						
HOURS								
Light Loss Factor (multiplier)	NEW	4,000	8,000	12,000	16,000	20,000	26,000	30,000
Lamp Lumen Depreciation	100%	85%	78%	72%	69%	68%		
Lamp Mortality	100%	97%	91%	83%	70%	50%		
Luminaire Dirt Depreciation	100%	97%	95%	93%	89%	86%		
Ballast Factor	100%	100%	100%	100%	100%	100%		
Total Lumen Output	100%	80%	67%	59%	42%	29%		
Luminaire Efficiency	78%	78%	78%	78%	78%	78%		
<b>Total Luminaire Output</b>	<b>28,080</b>	<b>22,464</b>	<b>18,834</b>	<b>15,444</b>	<b>11,796</b>	<b>8,143</b>		
Assumptions: No effect from adverse voltage conditions, Philips Lighting Lamp Data, Category III Luminaire, very clean conditions, 12 hr burn.								
Luminaire: ESI 6 Lamp Power Strip, 228 System W Lamp Type: F32T8/ADV841 (8,100 Lumens Each)		Lamp Lumen Rating: 18,600						
HOURS								
Light Loss Factor (multiplier)	NEW	4,000	8,000	12,000	16,000	20,000	26,000	30,000
Lamp Lumen Depreciation	100%	98%	96%	95%	94%	93%	92%	91%
Lamp Mortality	100%	99%	98%	97%	96%	93%	85%	50%
Luminaire Dirt Depreciation	100%	98%	96%	95%	94%	93%	92%	90%
Ballast Factor	118%	118%	118%	118%	118%	118%	118%	118%
Total Lumen Output	118%	112%	106%	103%	100%	95%	85%	48%
Luminaire Efficiency	93.8%	93.8%	93.8%	93.8%	93.8%	93.8%	93.8%	93.8%
<b>Total Luminaire Output</b>	<b>20,587</b>	<b>19,540</b>	<b>18,494</b>	<b>17,970</b>	<b>17,447</b>	<b>16,574</b>	<b>14,830</b>	<b>8,374</b>
Assumptions: No effect from adverse voltage conditions or temp. variations, Philips Lighting Lamp Data, Category I Luminaire, very clean conditions, 12 hr. Burn, Howard Ballast Data, Instant Start Operation.								

Figure 3. Light loss factor calculations.

figures reflect the total light output from the luminaire at various stages of service. For purposes of this evaluation, lamp mortality losses have been applied proportionally to the lumen output from a single fixture.

Far too often, lighting systems are designed based on the initial system performance of luminaires. Alternately, false light loss factors are applied, because real world barriers to ideal maintenance of the lighting system are not fully understood during the design process.

After only 8,000 hrs of maintenance-free operation, the fluorescent industrial shrouded fixture performance is at par with that achieved by the 400-W MH system.

At this point, costly spot relamping will need to be performed to the MH fixture just to keep up with the performance of the maintenance-free fluorescent industrial fixture.

### Quality of Light

Although the quantity of light is an important measure of how a system will perform, other factors contribute to the overall viewing experience.

- Glare: HID luminaires will generally produce greater levels of disability and discomfort glare than that produced by fluorescent luminaires. Discomfort glare produces annoyance or pain caused by lack of uniformity in the visual field. Disability glare is caused by scattering of light within the ocular media of the human eye. This scattering of light decreases contrast and blurs the viewing task.
- Distribution, diffusion, and shadows: Since no industrial facility is the same, luminaires should be capable of providing various distribution patterns. Using computer modeling methods and state-of-the-art computer numeric control (CNC) equipment, manufacturers can provide custom reflector solutions for optimum visual comfort, visual

performance, uniformity, and efficiency.

- Color quality of light: Today's demanding industrial environment relies heavily on color for coordination, communication, and identification. Some fluorescent lamps are available having color rendering indexes (CRI) of 85, which improves appearance of objects and people in a space compared to fluorescent lamps having lower CRI. These high CRI lamps are available in common color temperatures (3,500 Kelvin [K], 4,100 K, 5,000 K, and full spectrum). The Illuminating Engineering Society of North America (IESNA) reports that fluorescent lamps with a color rendering index of 85 CRI provide similar brightness impressions using 25% less light than lamps with a color rendering index of 60. MH lamps generally provide 65 CRI and are available in limited color temperatures.

### Industrial Lighting

The practice of defining source and equipment standards is influenced by many factors, including the nature of the visual task, size and shape of the room, energy costs, maintenance factors, and the overall economy of the decision. Among basic design considerations are:

- Analysis of the visual task: Prior to establishing illumination standards for industrial installations, it is important to evaluate various space and task combinations. Understanding the nature of the visual task influences system, source, and equipment decisions.
- Lighting quality: The importance of quality considerations varies from facility to facility. However, factors such as luminance ratios, direct glare, veiling reflections, and room surface finishes should never be neglected.
- Pleasing environment: Creating an appealing visual experience is important for worker satisfaction and productivity. Many benefits are derived from the use of sources which provide good color rendition and are coordinated with interior textures and finishes.
- Room shape: Selecting a luminaire with appropriate distribution characteristics for a given room shape will ensure efficient and effective performance.
- Initial costs: Although an important consideration in the design process, operational cycles should weigh in the importance for low initial cost. In areas where lighting equipment is operated continuously, initial cost is a minor consideration. Initial cost for equipment is of greater concern for systems operated for shorter intervals.
- Energy costs: Energy costs are a primary consideration that has a significant influence on fixture selection. The need for energy-efficient designs is compounded by operating lighting equipment for long burn cycles.

lighting equipment for long burn cycles.

- Maintenance costs: Understanding light source characteristics and facility environmental conditions is the first step to a well-planned and -executed maintenance program. The selection of equipment with low depreciation factors permits the use of fewer initial fixtures and optimizes maintenance dollars.

### Lighting Costs

Any lighting decision is weighed by the cost factors associated with the design. True cost performance

OPERATIONAL COSTS					
Description	Input Watts	# Fixtures	Annual Energy Costs	Annual Maintenance Costs	Annual Operating Costs
ESL Power Strip	228	625	\$65,054	\$13,267	\$78,320
ESL 2X2 High Bay	249	625	\$65,624	\$26,214	\$91,838
320-W MH P/S	365	625	\$104,143	\$16,594	\$120,736
400-W MH	465	625	\$132,675	\$23,061	\$155,736

PROJECT ECONOMICS					
Description	Annual Savings	Project Costs	Simple Payback	IRR	NPV
ESL Power Strip	\$77,415	\$134,821	1.74	57%	\$356,151
ESL 2X2 High Bay	\$63,157	\$156,250	2.47	39%	\$247,723
320-W MH P/S	\$34,999	\$101,452	2.90	32%	\$123,456
400-W MH	N/A	0	N/A	N/A	N/A

SYSTEM PERFORMANCE				
Description	Watts / Ft <sup>2</sup>	Initial Avg. Illuminance	System Depreciation	Maintained Avg. Illuminance
ESL Power Strip	0.57	82 fc	0.10	74 fc
ESL 2X2 High Bay	0.55	74 fc	0.10	67 fc
320-W MH P/S	0.91	110 fc	0.34	73 fc
400-W MH	1.16	110 fc	0.36	70 fc

Figure 4. Lighting Analysis

is determined by calculating life cycle costs for the equipment, including initial purchase, installation, maintenance, and energy costs.

Figure 4 is a life cycle cost benefit analysis (LCCBA) which illustrates the cost factors associated with industrial lighting designs. This LCCBA follows the format established by the IESNA.

Additional analysis has been performed with the latest pulse-start metal halide technology. Despite minor energy efficiency advantages with this technology, it is still hampered by many of the same characteristics that reduce the cost effectiveness of standard MH lighting.

The LCCBA indicates dramatic differences in life cycle costs of both metal halide systems as compared to fluorescent industrial luminaires. Examination of the LCCBA reveals that significant savings can be developed even in the area of system maintenance. In this scenario, the customer who installs fluorescent industrial luminaires will enjoy annual energy, operational, and maintenance savings of \$123 per luminaire, while maintaining lighting levels comparable to MH systems.

### The Future of Industrial Lighting

Coupling high-performance fluorescent luminaires with dimming ballasts and building energy management systems will create a powerful tool for shaping building load profiles to take advantage of low energy costs, real-time pricing strategies, and load-shedding incentives from energy commodity suppliers of the future.

Certainly not all applications can be effectively replaced with fluorescent systems. However, fluorescents should be considered as a quality alternative to HID products; if not for their lighting

performance, certainly for their efficient use of energy.

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