



Performance Assessment of Lighting Systems

An Online Continuing Education Course for Engineers

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Performance Assessment of Lighting Systems

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Abstract

Energy conservation is important—no one doubts that. But in context to lighting, the energy conservation decisions are normally based after productivity, safety and quality. The dollar savings derived from energy savings alone may be small compared to the overall value derived from more effective lighting.

This is not to say that one is exclusive of the other. Often, more effective lighting also results in lower energy consumption. The benefits of energy conservation are hidden. A large percentage of the energy input into the lighting system shows up as heat in the conditioned space, which impact the air-conditioning costs. High-efficiency lighting along with reduced air-conditioning reduces the peak electricity demand and usually raises power factor, both of which yield spare capacity on transformers. High efficiency lighting also contributes to reductions in emissions of pollutants associated with global warming, acid rain and smog.

Therefore, the objective must be to achieve the maximum lighting effectiveness with least energy consumption. This course provides a general overview of good lighting practices and discusses the performance assessment methodology.

Performance Assessment of Lighting Systems

Lighting plays a vital role in enabling people to carry out their tasks safely, efficiently and without discomfort, however electric lighting can account for around 30-40% of your electricity bill. An energy efficient lighting system combines low running and maintenance costs, with good effective lighting and can reduce the facility's lighting costs by up to a third.

Evaluating Lighting Systems

Most interior lighting requirements are for meeting average luminance on a horizontal plane, either throughout the interior, or in specific areas within the interior combined with general lighting of lower value. The objective is to get highest lighting at lowest power consumption. Two terms may be used here 1) efficient lighting and 2) effective lighting.

Although both the terms are often used interchangeably, there is a difference.

Efficient lighting

Efficient lighting systems can be described in engineering terms of performance. The term lighting efficiency measures the lamp's ability to convert input electric power into luminous power. Since electric power is measured in watts and luminous power in lumens, the unit of efficiency or efficacy is lumen per watt. If there are auxiliary devices necessary for a particular lamp operation, its energy consumption is charged towards the light source. This is the case with fluorescent, mercury, metal halide, and sodium lamps. All these lamps require ballast. Sometimes the efficiency is also defined in terms of watts per square foot.

Effective lighting

Effective lighting on the other hand, is described in terms of "how appropriate the lighting is for the function it is performing". In this usage, effective means doing the right thing.

This is not to say that one is exclusive of the other. Often, more effective lighting also results in lower energy consumption or the efficient lighting systems also provide better lighting quality.

Energy conservation issues in context to lighting shall be considered only after determining which lighting system effectively supports the particular tasks, workers, and spaces at a site. If a strategy designed to reduce energy consumption also reduces productivity, every energy dollar saved could mean \$10, \$20 or more wasted because of lost productivity. The value derived from energy savings alone may be small compared to the overall value derived from more effective lighting.

Understanding Facility Lighting Systems

Lighting Systems

A lighting fixture or luminary consists of 1) the light source (the lamp) & ballast, 2) lamp holders, 3) an optic system, 4) a means for connecting to a power supply and 5) housing.

Luminaires and controls together form a lighting system. The light source or lamp drives the system and is the starting point for lighting analysis and design.

Light Sources

Lighting professionals use the term lamp to describe light sources commonly called light bulbs and tubes. Incandescent, fluorescent, and high-intensity discharge (HID) lamps are the most common lamps used for building lighting systems.

Light sources vary considerably in terms of efficiency, color, life, and the other attributes that create better lighting. Energy-efficiency and lamp life affect economics. Lamp operation issues are also important. These include starting, flicker, thermal and vibration sensitivity, dimability, and end-of-life behavior.

The characteristics of different lamp types are described later in this course.

Ballasts

Ballasts are required to start and operate fluorescent and HID lamps. Fluorescent lamp ballasts provide the voltage to start the arc discharge and they regulate the lamp current to stabilize light output. Rapid-start ballasts also provide the heating current to the electrodes so that lower voltages are necessary to ignite the arc compared to instant-start systems.

The ballast must be compatible with the specific lamp it is operating, as well as the electrical supply voltage. Ballasts affect the system's light output, power consumption, and in some cases, lamp life. Thus, they contribute to achieving the targeted level of illumination and, importantly, to system economics.

Ballasts use energy during operation, which decreases the overall efficiency of a lighting system (ballast loss). When fluorescent lamps are operated by electronic ballast at high frequency, they convert the input power to light output more efficiently. The lumens per watt (LPW) of the lamp-electronic ballast combination increases, which means the system either produces more light for the same power or produces the same light with less power. The U.S. Department of Energy has laid a mandatory requirement that all fluorescent lamp ballasts manufactured for commercial and industrial use for both new and renovation markets must be electronic by the year 2005.

Luminaires

Fixtures include the optics that direct light where it is desired and control glare. A well-designed fixture provides the desired distribution of light, good glare control, and high efficiency. The optical system includes the lamp cavity and diffusing media plus one or more of the following components: reflectors, refractors, lenses, baffles, or louvers.

- 1) Reflectors redirect light by using the principle of reflection. Retrofit reflectors upgrade the performance of fluorescent luminaires by increasing the interior reflectance.
 - 2) A refractor is a component that redirects light by refraction.
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- 3) Lenses enclose a fixture and help to alter the directional characteristics of light passing through it. Polystyrene lenses are the least expensive but emit yellow color due to the UV radiation from lamps. Lenses made from acrylic light are light stabilized. Polycarbonate lenses are more durable than acrylic but will discolor faster; both plastic materials will attract dirt via static electricity. Borosilicate glass lenses are often used where the most durable, clean, and long-lasting optics are desired. They are heavier and more costly than plastic lenses.
- 4) Translucent sheets of milky-white plastic, called diffusers scatter light uniformly in all directions below the ceiling plane, reducing source brightness, and shielding the lamps.
- 5) Parabolic luminaires use large-cell louvers formed in a parabolic shape. The resultant light distribution reduces glare, controls light output, and has high aesthetic appeal.

Controls

Controls can reduce the electrical energy used by lighting systems in two ways:

Electrical energy can be reduced either by reducing the lighting power (kW) or by reducing the time of use (hours), and since electric use is measured and billed by kilowatt-hours (kWh), reducing either reduces electric costs. Operating hours can be reduced by switching, occupancy sensors, scheduling controls, or photocells.

The more tightly you control the lighting system, the less energy it will consume. The characteristics of different type of controls are described later in this course.

Performance Terms and Definitions

Lumen: Lumen or luminous flux is a unit of light output. The different types of lamps available in the market are labeled with an output rating in lumens.

Lux: The quantity of light that falls on a work surface, called illuminance, is measured in lux or footcandles. The lux (lx) equals 1 lumen per sq-m and the footcandle (FC) equals one lumen per sq. ft. A light meter can be used to measure the illuminance.

Average rated life: The rated life of a lamp is the value, in hours, at which half of a large group of that lamp fails under standard test conditions. Any particular lamp or group of lamps may vary from the published rated life. For fluorescent and HID lamps, the average rated life is affected by the burn cycle (the average time that a lamp is on before it is turned off).

Lamp lumen depreciation (LLD): Light sources lose their ability to produce light over time due to age. Lamp lumen depreciation (LLD) represents the percent of initial lumens remaining at 40 percent of rate life.

LLD can be calculated by dividing the design (mean) lumens by the initial lumen rating. For example, for a 32 watt T8 lamp that has an initial rate of 2,900 lumens and a design lumen rating of 2,610, $LLD=0.90$ ($2,610/2,900 = 0.90$). This means that the T8 lamp will retain 90 percent of its initial light output after 40 percent of its average rated life. Lumen depreciation is affected by the ballast used, line-voltage tolerances, and burn cycle.

Circuit Watts: Circuit watt is the total power drawn by lamps and ballasts in a lighting circuit under assessment.

Installed Load Efficacy: The ratio of the average target illuminance to the average defined area (course).
horizontal working square meter
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Luminous Power Consumption: The power consumed by a lighting fixture.
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Installed Power Density: The power density of a lighting fixture.
meter of floor working plane (W/m²/100
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Installed Power Density: The power density of a lighting fixture.
Installed Power Density (W/m²)
Installed load efficacy (lux/W/m²)

Visual Comfort Probability (VCP): is a rating of lighting systems that is expressed as a percentage of people who, when viewing from a specified location and in a specified direction, will find the lighting system acceptable in terms of discomfort glare. The IESNA minimum recommendation of electronic offices is 80.