Anatomy of a Lighting System

A Pacific Energy Center Factsheet

Pacific Gas and Electric Company
Pacific Energy Center

Introduction

What is a lighting system? Most people would answer that a lighting system consists of the components—lamps, ballasts, luminaries and controls—that provide light in the space. While this definition may be adequate for some purposes, it fails to consider other critical elements—environmental, human and task components—that are also part of the lighting system in a broader, more comprehensive sense. Since a lighting system is actually a complicated interaction between the lighting hardware, the environment, human vision, and the task, let's examine each of these elements in more detail.

Lighting Components

Power Source: Voltage
The power source provides the source of energy to the lighting system. Voltage is a given condition provided by the utility and is analogous top pressure in a water system. Variations in the power source's voltage can reduce lighting levels or, in some cases, cause problems with ballasts, both in starting and in operation.

Power Controller: Switching and Dimming
The power controller modifies or regulates the operation of the lighting system. Controls can affect both the amount of time that the lighting system operates, and the amount of power that it consumes while operating. Because the energy equation is Energy = Power x Time, a major component of lighting energy can be reduced through proper use of switching and dimming controls.

Power Regulator: Ballasts
The ballast provides the starting voltage and regulates the current to gaseous discharge lamps. The ballast determines the input wattage and the light output of the lamp, and is matched to the specific lamp type. The lamp/ballast combination is the primary factor affecting the overall efficacy of a lighting system.

Light Source: Lamp
The lamp is the lighting system component that generates the light. Lamps use various physical phenomena to produce light, and each type has its own starting and operating characteristics. For this reason, different lamps are generally not interchangeable within the lighting system. In some cases, suitable substitute lamps can be used without changing other lighting system components.

Optical Control: Luminaire
The luminaire determines the way in which light is distributed. Luminaries function as the housing for the light source, and include optical assemblies consisting of reflectors and lenses to direct the light from the source into the space. The optical components of luminaries are generally designed for specific lamp types, and the use of different lamps will change the light distribution of the luminaire.

Environmental Components

Room Finishes: Reflectances and Texture
The reflectances and textures of room finishes affect the lighting levels and apparent brightness of the room. Dark finishes and heavy textures absorb light so that it is not reflected back into the room. Light finishes help to reflect more light into the space, thus making the lighting system more efficient. The effect of lighter wall and ceiling finishes is to increase the measured light level and to make the space appear even brighter.

Spatial Envelope: Room Boundaries
The room boundaries have the most effect on how a space is perceived and how a lighting system will perform. Since long narrow spaces have different proportions than large open areas, the efficiency of selected lighting systems will depend largely on the geometry of the room. The Room Cavity Ratio (RCR) is the ratio of the surface area of walls to the floor area and is often used in lighting calculations in determining how well luminaries will perform for given room proportions. In addition, the spatial characteristics strongly influence how we react to a space, and the lighting components must interact with the envelope to help define and create the way the space is perceived.

Fenestrations: Windows and Skylights
Windows and skylights admit daylight into a space. Natural lighting has an effect on the perception of time and place, which is psychologically beneficial in working environments. Windows present a challenge in work environments due to the potential for glare and/or contrast between the windows and the surrounding space. Diffuse skylights can contribute significant amounts of light into a space, offsetting the need for electric light.

Human Components

Visual Receiver: Eye
The eye receives visual input from the physical world and presents images to our minds for interpretation. Although all eyes are not equal, we can generalize about what is considered to be "normal" vision. Many factors relating to the eye's anatomy are currently under study to find how the eye reacts to color and light levels. This recent research in the physiology of the eye has revealed more clearly how we see.

Visual Acuity: Vision
Vision is the human component of the lighting system that determine show well the eye can distinguish detail. While visual acuity is impossible to predict with 100% accuracy, relationships between age and vision are well known and somewhat reliable. The eye undergoes physical changes as we grow older so that we lose approximately 10% of our vision by the time we reach age 40. Beyond 40, we tend to loose 10% more of our vision every decade, making it more difficult to see as we get older.

Visual Decoder: Brain
The brain interprets the visual images that are transmitted from the eye and is responsible for the subjective impressions of what we see. The feelings associated with our visual experiences are based on past experience more than any objective rules; there are, however, norms of human behavior and reaction's to lighting and space that are generally predictable and reliable.

Task Components

Task Finishes: Texture, Color, Reflectance, Specularity
Task finishes are the component of the lighting system that allows us to see and recognize the objects and the materials of which they are made. Understanding the properties of the task surface is important when considering proper lighting solutions.

Task Size: Object Size
The size of the visual task is determined by the physical size of the task and the distance of the task from the observer. In this case, size is measured by the visual angle that the object being viewed subtends on the eye. Larger objects can be seen at longer distances. Small objects must be relatively close for the eye to discern them in detail.

Task Brightness: Luminance or Exitance
Exitance is the measured value of the brightness of a surface. It is equal to the amount of light falling onto the surface multiplied by the reflectance of the surface. Luminance is also a measure of the brightness of a surface but considers the direction in which light leaves the surface. One's perception of brightness depends on the adaptive state of the eye. For example, an automobile headlight seems very bright at night, but during the day, that same headlight is barely noticeable.

Contrast: Brightness Ratios
Surface contrast is the relationship between the luminance of an object(e.g. print) compared to that of its immediate background (e.g. paper).Tasks with high surface contrast are easier to see than tasks with low surface contrast. Outline contrast is the relationship between the luminance of the immediate background (e.g. paper) compared to that of the surrounding area (e.g. desk). Excessive outline contrast may make the task harder to see.

Speed and Accuracy: Time
Tasks that must be performed efficiently and accurately require fairly high luminance and contrast. Tasks for which time is not a critical factor can be performed under conditions of low luminance and low contrast. Reading a newspaper on the BART train is an example of a low-luminance, low-contrast task where time is not a critical factor. Filling a prescription in a pharmacy is an example of a task requiring fast and accurate visual performance. In conclusion, because the performance of a lighting system depends on a wide range of hardware, environmental, human, and task components, lighting design can be a complicated issue. Through a thorough understanding of these components, however, it is possible to design an appropriate and energy-efficient solution for any application.

For More Information

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