LIGHTING SYSTEMS

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Abstract. This article provides information on important indicators in the field of lighting systems. This article mainly examines and analyzes the level of illumination that varies depending on the function of buildings and offices.

Key words: lighting systems, lumens, lux, lamp, kelvin, color rendering index, electricity, timer schedules, occupancy sensing.

Lighting systems normally account for more than 20 percent of the electrical energy consumed in commercial buildings. Lighting systems not only consume power directly to generate light, in air-conditioned build- ings they also indirectly account for some of the power consumed by airconditioning systems, as the heat added by lighting has to be removed by the building cooling systems.

However, lighting is essential for buildings to ensure the comfort, productivity and safety of the building's occupants. Therefore, lighting systems need to be carefully designed to achieve the desired illumina- tion level while using the minimum amount of energy.

Energy savings from lighting systems can be achieved by means such as optimizing lighting levels, improving the efficiency of lighting sys- tems, using controls, and daylighting (using natural light). This chap- ter provides a brief description of some basic concepts of lighting followed by typical energy saving measures for lighting systems.

Lumens. Lumens is the SI unit for luminous flux, which is the quantity of light emitted by a source or the quantity of light received by a surface.

Typical values of luminous flux emitted by some common sources of light are given in Table 1.1.

TABLE 1.1 Luminous Flux Emitted by Common Light Sources

№	Lamp	Lamp wattage	Lumens
1	Torch lamp	3 W	30
2	Incandescent lamp	75 W	950
3	Compact fluorescent lamp	15 W	810
4	Fluorescent lamp	36 W	2,400
5	High-pressure sodium lamp	100 W	10,500
6	Low-pressure sodium lamp	131 W	26,000

Candela. Candela (cd) is a measure of luminous intensity. Originally luminous intensity was measured in units called candles (based on the approximate amount of light emitted by a candle flame). Later the term candela was adopted to allow for consistent and repeatable measure- ments of light, where 1 candela is equal to 1 candlepower.

Lux. Lux is the SI unit for illuminance, which is a measure of the direct illumination on a surface area of one square metre. One lux is one lumen/m 2 . Some typical lux values are given in Table:

TABLE 1.2 Typical Lux Values

№	Location	Lux level
1	Basement car parks	15
2	Offices	500
3	Under the shade of a tree	10,000
4	Under the midday sun	100,000

Luminous efficacy. Luminous efficacy is the ratio of luminous flux emit- ted by a lamp to the power consumed by the lamp and its control gear. This ratio indicates the efficiency of a lamp in converting electrical power into light. The units of efficacy are lm/W.

Edison’s first electric filament lamp had an efficacy of 1.4 lm/W. However, with research and development, the efficacy of lamps has improved significantly over the years. Typical values of efficacy for some common lamps are given in Table:

TABLE 1.3 Typical Efficacy of Lamps

№	Lamp type	Efficacy (lm/W)
1	Incandescent	10–15
2	Halogen	13–25
3	Compact fluorescent	50–60
4	Fluorescent lube	69–100
5	Metal halide	85–120
6	High-pressure sodium	80–140
7	Low-pressure sodium	150–200

Color temperature. The color temperature of a light source is a numerical measurement of its color appearance. It is based on the fact that when an object is heated to a temperature high enough it will emit light and as the temperature is increased, the color of the light emitted will also increase. For example, when a blacksmith heats a horseshoe, it will first appear red and will change to orange, followed by yellow and later white. Color temperature is defined as the temperature of a blackbody radiator which emits radiation of the same chromaticity as the lamp. The unit of color temperature is Kelvin (K). The degree of “warmth” or “cool-ness” of the space is related to the color temperature of the light source.The lower the color temperature, the “warmer” the light appears. Light sources that appear violet or blue color are “cool” while those that are red, yellow or orange are “warm.”

Typical values of color temperature and associated warmness or coolness are given in Table:

TABLE 1.4 Color Temperature and Warmness of Common Types of Lamps.

№	Lamp type	Color temperature (K)
1	Incandescent filament lamp	2600–3000
2	Tungsten halogen	3000–3400
3	Warm white fluorescent	3000
4	Cool white fluorescent	4000
5	Daylight fluorescent	5000
6	Metal halide	3300–5700
7	High-pressure sodium	2000–3200
8	Low-pressure sodium	1600

Color rendering. While color temperature is a measure of the color of a light source, the color rendering index is an indication of the ability of a light source to accurately show colors.

Color rendering expresses the appearance of object colors when illuminated by a given light source as compared to its appearance in a reference light source. It is usually expressed as an index called the color rendering index (CRI), which is an indication of the appearance of an object illuminated by a light source compared to its appearance under natural light. Natural light will have a CRI of 100. Electric filament lamps produce a continuous spectrum with all colors present and, there-

fore, they have a CRI of 100. Normally, CRI below 80 is considered poor color rendering while CRI above 80 is considered good. Typical values of CRI are given in Table:

TABLE 1.5 Typical Values of Color Rendering Index.

№	Lamp type	Color rendering index (CRI)
1	Incandescent filament lamp	100
2	Tungsten halogen	100
3	Fluorescent	80–95
4	Metal halide	65–80

5	High-pressure sodium	25
6	Low-pressure sodium	0

The lighting level or lux level required for a space depends on the type of space, tasks performed in the space, and other visual requirements. General guidelines for the illuminance range for different applications that need to be used when designing of lighting systems are available in lighting reference books and codes of practice. Asummary of recommended lighting levels for some common building spaces are given in Table 1.6.

TABLE 1.6 Recommended Illuminance Levels

№	**Type of area**	**Illuminance (lux)**	**Recommended design value (lux)**
1	General offices, conference	300–750	500
2	rooms, computer workstations	-	-
3	School classrooms	200–500	300
4	Shops, departmental stores	300–750	500
5	Supermarkets	500–1000	750
6	Hospitals	200–500	300
7	Lobbies, corridors	100–200	150
8	Hotel rooms:	-	-
9	General	75–150	100
10	Local	200–500	300
11	Car parks:	-	-
12	Parking areas	10–20	15
13	Entrance	50–300	100

The lighting levels given in Table 1.6 are used generally as a guideline to ensure that lighting levels provided are adequate for the specific tasks to be performed while preventing unnecessary wastage of electricity due to excessive lighting levels.

Lighting controls. Energy consumed by lighting can also be reduced by minimizing their usage by better matching operations with demand through lighting controls. Various systems such as timers, occupancy sensors, and light sensors can be used to control lighting operations.

a) Timer schedules. Simple timers can be used to switch on and off all or some lighting circuits at predetermined times based on occupancy sched-ules. Provision for manual override can be incorporated into the controlsso that occupants can extend the operating hours of lighting circuitsbased on individual requirements. Lighting control systems can consist of simple timers that have 24-hour clocks to switch on and off lighting daily at preset times, or more sophisticated timers that can be used to program lighting schedules for a year or more, where holidays and other special requirements can be programmed in advance. Often lighting operating schedules can also be programmed into building automation systems to control the operating hours of lighting.

b) Occupancy sensing. Occupancy sensors can also be used to switch on lighting when a space is occupied and switch off the lighting after a preset time delay when the space is not occupied. Typical applications for occupancy sensors are in toilets, car parks, meeting rooms, storage areas, and common corridors. The two basic technologies used in occupancy sensing devices are infrared and ultrasonic. Infrared sensors scan the area around them to detect heat generated by occupants. They are ideal for small open areas such as offices and classrooms. Ultrasonic sensors emit high frequency sound waves to detect occupancy. The are generally used in large or obstructed areas. Due to the relative advantages and disadvantages of the two types of technologies, sensors that incorporate both types of technologies are available with more effective sensing capabilities.

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