FACTS

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Mission: To improve the care of artworks & keepsakes through education, research & consensus standards

USEFUL INTERIOR LIGHTING TERMS

Principles of Electricity

A flow of electricity is called *electric current*; the rate of flow of an electric current is measured in *amperes (amps, A)*. The potential of the flow of electricity is called voltage; it is measured in units called *volts (V)*.

Power Consumption

A *watt (W)* indicates the rate at which electricity is changed into another form of power-light or heat. Power consumption in watts is calculated by multiplying volts times amps (W = V x A). Incandescent lamps are usually sold by wattage; this is the measure of how much electricity the lamp uses.

Energy is the amount of electric power consumed over a period of time; it is measured in *kilowatt-hours (kWh)*. One kilowatt (kW) = 1000 W. Hence, kWh = kW x hours used. For example, a 150 W lamp is equivalent to 0.15 kW. When operated for 40 hours it uses 6 kWh (0.15 kW x 40 hrs = 6 kWh). Utility rates are based on monthly kWh usage.

Lamp Life

Manufacturers determine *lamp life* by burning a large group of lamps continuously. During this process, some lamps will fail relatively early, while others will burn long after their rated life. When half of a group of lamps burn out, the manufacturer assigns lamp life. Lamp life is an *average*. Its filament temperature determines the life of the lamp and the light output.

Which Voltage Lamps Will Last Longer?

130-volt lamps have a bigger filament than 120-volt lamps, thus allowing them to last longer if your facility's voltage is between 118 and 130 volts. The 130-volt lamp has a bigger filament and is designed to operate at a higher voltage. If your facility is below 118 volts, you will lose efficiency, your color temperature will shift towards yellow, and the lamp's expected life might be reduced. Over voltage operations result in higher wattage, higher efficiency and a higher output, but a shorter life.

If you do not know what your operating voltage is, find out. It is important to use the correct voltage lamp in order to get the best color temperature, color rendering, lamp life, and energy savings.

Tungsten Halogen Lamps

Tungsten Halogen lamps, commonly referred to as halogen lamp, are very popular for gallery track lighting. The desirable characteristics of tungsten-halogen lamps are: excellent color rendering, long life, high efficiency, compact size, and reduced bulb blackening during the lamp's life.

The tungsten halogen lamp is an incandescent lamp with a selected gas of the halogen family sealed into it. As the lamp burns, the halogen gas combines with tungsten molecules that sputter off the filament and deposits the tungsten back on the filament, rather than on the bulb wall. This keeps the bulb wall clean and at the same time builds up the filament wire to compensate for the evaporative loss that reduces its diameter, thus maintaining relative constant wattage. The result is a lamp that delivers almost its full light output throughout its life.

Halogen lamps are available in four configurations: (1) single-ended T; (2) double-ended T; (3) integral reflector AR, MR, and PAR; and (4) modified A-lamp MB and TB shapes.

Low-Voltage Lamps

Low-voltage lamps are simply incandescent lamps that operate between 6 volts and 75 volts (V).

The wattage of all filament lamps is the product of the voltage delivered at the socket times the amperes flowing through the filament. The lower the voltage of the lamp of a given wattage, the higher the current and the larger the diameter of the filament wire required to carry it.

The increased diameter of the filament wire of low-voltage lamps allows for a more compact filament. The more compact the filament, the more precise the beam control. This is the main advantage of low-voltage lamps.

An increase in the diameter of a filament wire raises the temperature at which it can be operated without danger of excessive evaporation. High-wattage lamps, therefore, are more efficient than low-wattage lamps of the same voltage and life rating. Lower voltage lamps, because their filament wire is of greater diameter, are also more efficient than higher-voltage lamps of the same wattage; thus, a 120 V lamp is more efficient that the 250 V lamps used in much of the rest of the world.

Low-voltage reflector lamps with narrow beam spreads are energy saving when their concentrated distribution is used to light small objects or large objects at great distances because light is confined to the lighted object without spilling past. Where wider beams are required, low-voltage lamps are often less efficient than standard lamps.

The low voltage lamps commonly used for architectural applications operate at 12 V. They include PAR, AR, and MR lamps.

Beam Spread

Beam spread is the measurement, in degrees, of the light distributed by a lamp. For example, a 40°-beam spread is considered a "flood"; a 10°-beam spread is considered a "spot."

Specular reflection is a primary technique for modifying and controlling the direction and distribution emitted by a light source. Commonly used specular reflectors include actual or modified (1) ellipses, (2) parabolas, and (3) circles.

Diameter of a Lamp

The diameter of a lamp is measured in 1/8-inch increments. For example, a PAR 16 divided by 8 equals 2 inches in diameter. A PAR 30 divided by 8 equals 3.75 inches in diameter, and so on.

Measurement of Light

Five terms are commonly used in photometry (the science that measures light) to quantify light: intensity, flux, illuminance, luminance, and exitance.

1. ***Intensity*** is the light emitted in a specific direction by a source. Properly called *luminous intensity* or "flux per solid angle in a given direction," it is measured in candelas (cd). Intensity in a succession of directions is plotted on a distribution curve or polar graph (available from lamp manufacturers).

2. ***Flux*** is the light emitted in all directions by a source. Properly called *luminous flux* or "time rate flow of light," it is measured in lumens (lm).

3. ***Illuminance*** is the density of light on a surface. Properly defined as "density of flux incident on the surface measured perpendicular to the surface," it is measured in foot-candles (fc).

4. ***Luminance*** is the accepted term for light that is reflected from a surface in a given direction (back toward the eyes). Properly defined as "intensity of flux leaving a surface in a given direction," it is measured in candelas per square foot (cd/ft^2).

Color Temperature

Color temperature describes how a lamp appears when lighted (not to be confused with color rendering). Color temperature is measured by kelvins (K), a scale that starts at absolute zero (-1273°C).

At room temperature, an object such as a bar of steel does not emit light, but if it is heated to a certain point, it glows dull red. Instead of a bar of steel, physicists use an imaginary object called a blackbody radiator. As the steel bar, the blackbody radiator emits red light when heated to 800 K; a warm yellowish "white" at 2800 K; a daylight-like "white" at 5000 K; a bluish, daylight "white" at 8000 K; and a brilliant blue at 60,000 K. The theoretical blackbody is necessary because the bar of steel would melt at these high temperatures.

Incandescent lamps closely resemble blackbody radiators in that they emit a continuous spectrum of all of the visible colors of light. Consequently, the incandescent spectrum is accurately specified by color temperature in kelvins.

Because color temperature describes chromaticity and not actual temperature, it is expressed in kelvins only (not in degrees). Incandescent lamps used in architectural lighting have color temperatures in the 2600 K to 3100 K range; tungsten-halogen lamps (without filters) have a color temperature of 2,900 K - 3,100 K; north skylight is arbitrarily called 10,400 K.

Unfortunately, the apparent color temperature of discontinuous spectrum light sources fails to provide information about its spectral energy distribution. Fox example, cool white and cool white deluxe fluorescent lamps have the same apparent color temperature, yet their spectral distribution curves and their effects on colored objects are quite different. The Color Rendering Index (CRI) rating provides practical information for predicting how colors will appear under a light source.

Color Rendering

Halogen lamps are frequently used because of their excellent color rendering. Color rendering expresses how colors appear under a given light source. For instance, a shade of red will be rendered lighter or darker, more crimson or more orange, depending on the spectral distribution properties of the light falling on it. The most accepted method to determine the color-rendering ability of a light source is a rating system called the Color Rendering Index (CRI).

The CRI first establishes the real or apparent color temperature of a given light source. Second, it establishes a comparison between the color rendition of the given light source and a reference light source. If the color temperature of a given source is 5000 K (kelvin) or less, then the reference source is the blackbody radiator at the nearest color temperature. If the color temperature is above 5000 K, then the reference source is the nearest simulated daylight source.

The comparison is expressed as an R factor, on a scale of 100, which is a percentage indicating how closely the given light source matches the color-rendering ability of the reference light source. Comparisons are valid only for a specific color temperature reference. Therefore, it is inappropriate to compare two light sources unless their color temperature is similar - within 100 K to 300 K.

R is an average of the color rendering ability of eight test colors; better performance at some wavelengths is concealed when averaged with poorer performance at other wavelengths. Consequently, two lamps that have the same color temperature and CRI may have different spectral distributions and may render colored materials differently.

The color of objects can be perceived more accurately under lamps with a high CRI. Tungsten-halogen lamps typically have a CRI of 100. High CRI light sources also produce a higher perceived level of light (they look brighter), which in turn makes them more energy effective.

5. ***Exitance*** is the total quantity of light emitted, reflected, or transmitted in all directions from a surface. Properly defined as "density of flux leaving a surface," it is measured in lumens per square foot (lm/ft^2).

The candlepower distribution curve represents the amount of luminous intensity (cd) generated in each direction by a light source in a plane through the center of the source. Consequently, the candlepower curve gives a picture of the total light pattern produced by a source. Candlepower distribution curves are available from the luminaires manufacturer and are often found on the back of the product data sheet.

Illuminance is frequently used to measure the quantity of light in architectural space because it is the easiest and least expensive unit to measure (photographic light meters). Yet, it is impossible to see a footcandle. What is seen is *luminance*, which is a function of the amount of light falling on a surface and the reflectance of that surface. One sees an object or surface only when light is reflected from that object or surface back toward the eyes, or when it is emitting light itself ("self-luminous").