Light Sources for Architectural Lighting

Edition 1.1 - (2000)

1.0) INTRODUCTION

The modern lighting specifier has many different choices regarding the selection of light sources for architectural lighting applications. This was not always the case. One hundred years ago, practical electric lighting was largely limited to the incandescent (electric filament) lamp. Early incandescent lighting was quite inefficient by today's standards, however it offered a much better alternative to both oil and gas lighting of previous days. During the 20th Century, there was a explosion in the development of new light sources, starting with the introduction of the fluorescent lamp in the 1930's. The latter half of the Century resulted in many new light sources being either developed or further refined.

Today, the lighting designer can chose from; incandescent, tungsten halogen, fluorescent, mercury, metal halide, high pressure sodium, low pressure sodium, cold cathode, neon, light emitting diode, induction lamps, sulfur lamps, and other new light sources.

Light sources for the human environment are evaluated and selected in respect to their light or lumen output, their lumen efficacy, color temperature, color rendering index and life. Other considerations include initial cost, operating cost and maintenance cost. A brief description of the more important properties, follows:

2.0) LUMINOUS EFFICACY

Lamp 'efficacy' refers to the 'lumens per watt' produced by different types of light sources. The 'lumen' is the name of the unit used in measuring the amount of light given off by a light source. The higher the lumen efficacy, the more efficient the source is at producing light.

Edison's first electric filament lamp produced only 1.4 lumens per watt. Research over the years slowly brought improvements in lamp efficiency. The common incandescent lamp of today, produces approximately 15-25 lumens per watt. The balance of the electrical energy is transformed into heat. It is estimated that 40 lumens per watt is about as high as can be obtained by a tungsten filament, just before it reaches the melting point (3370 degrees C.)

About 1938 the lighting industry was revolutionized with the introduction of the fluorescent lamp. Lumen efficacies were suddenly raised and today the modern fluorescent lamp has an efficacy of between 65 and 100 lumens per watt.

Luminous efficacy increased again with the development of the Metal Halide and High Pressure Sodium lamps, to up to 140 lumens per watt. The Low Pressure Sodium lamp pushed efficacy up to about 200 lumens per watt.

Scientists have determined that if all of the electrical energy put into a lamp could be converted into white light, a lamp would give out 220 lumens for each watt of energy put in.

Today the lighting designer should endeavor to use the most efficient light source possible while still maintaining proper color rendering qualities required by the specific lighting application.

The following table shows how lumen efficacies have gradually increased over the years.

SOURCE		LUMEN EFFICACY (lumens/watts)
Candle (equivalent)		0.01
Oil Lamp (equivalent)		0.03
Edison lamp	(1879)	1.4
Carbonized bamboo	(1879)	2.0
Carbonized cellulose	(1891)	3.0
Metalized (Gem)	(1905)	4.0
Drawn Tungsten	(1911)	10.0
60W Tungsten C.C.	(1968)	14.7
Filament Lamp	(1970)	10 - 18
Tungsten Halogen	(1980)	17 - 22
Stage/Studio Lamps	(1980)	20 - 40
Cooper-Hewitt Lamp	(1901)	13.0
Mercury Lamp (modern)		55 - 60
Fluorescent Lamp	(1938)	65 -100
Metal Halide Lamp		85 -120
HPS Lamp		80 -140
LPS Lamp		120 -200

3.0) COLOR TEMPERATURE

As most objects are heated they give off light. As the temperature is raised the object first glows red, then yellow, white, pale blue and then finally brilliant blue. Color temperature is a measure of the 'whiteness' of a source and is expressed in degrees K. (Kelvin).

Tungsten filament lamps used for general lighting applications have color temperatures of between 2600 and 3000 degrees Kelvin. Stage and studio lamps used for theatre and television applications generally have a color temperature of between 3000 and 3400 degrees Kelvin.

The specification of color temperature technically applies only to incandescent lamps. The term 'apparent color temperature' (or correlated color temperature) is often used however to describe the degree of 'whiteness' for fluorescent and H.I.D. (high intensity discharge) lamps. Color temperatures (and apparent color temperatures) of common sources are as follows:

SOURCE	COLOR TEMPERATURE (degrees K.)
Incandescent filament lamp	2600-3000
Tungsten Halogen lamp	3000-3400
Metal Halide	3300-5700
Mercury lamp	55-60
High Pressure Sodium	2000-3200
Low Pressure Sodium	1600
Warm White Fluorescent (WW)	3000
Deluxe Warm White Fluorescent	2900
White Fluorescent (W)	3500
Cool White Fluorescent (CW)	4200
Deluxe Cool White Fluorescent	4200
Daylight Fluorescent	7000
Xenon	6000
Sunlight (at sunrise	1800
Sunlight (at noon)	5000
Sky (overcast)	6500

4.0) COLOR RENDERING INDEX

Although 'color temperature' is a measure of the visual 'whiteness' of a source, it does little to specify the source's ability to accurately show colors. This is referred to as the color rendering index (or CRI) of a light source.

The modern electric filament lamp produces a continuous spectrum with all colors present. As a result this lamp has a high CRI of 100 as it renders all colors 'correctly' to the eye.

Fluorescent and H.I.D. sources all have lower CRI's than 100 and are able to accurately render colors to varying degrees. A light source should be carefully selected to provide a high CRI only when needed. Specifically a high CRI should be used for color matching and other related applications. Lamps with CRI's of above 70 are typically used for the lighting of the human environment, including living and work areas. Some modern fluorescent lamps now have CRI'S of 85 or more.

SOURCE	COLOR RENDERING INDEX.)
Incandescent filament lamp	100
Tungsten Halogen lamp	100
Mercury lamp	15-55
Metal Halide	65-80
High Pressure Sodium	22-75
Low Pressure Sodium	0
Warm White Fluorescent (WW)	52
Deluxe Warm White Fluorescent	73
White Fluorescent (W)	60
Cool White Fluorescent (CW)	66
Deluxe Cool White Fluorescent	89
Daylight Fluorescent	79
Xenon	95

5.0) LAMP LIFE

Generally, a source type with the longest possible life should be selected for any particular lighting application. A long life lamp however should not be used at the expense of providing proper lumen efficacy, color temperature and CRI requirements.

SOURCE	LIFE - IN HOURS
Incandescent filament lamp	1000-2000
Tungsten Halogen lamp	100-2000
Mercury lamp	12,000-24,000
Metal Halide	6,000-20,000
High Pressure Sodium	10,000-15,000
Low Pressure Sodium	16,000
Fluorescents	10,000-20,000

6.0) SUMMARY AND CONCLUSIONS

The modern lighting specifier must be knowledgeable and aware of light source characteristics, particularly as applied to lighting for the human environment. It is important not to select a light source based on efficiency alone. Although lamp efficacy is very important, the color temperature and color rendering index must also be carefully considered. Other factors that must be considered include the initial cost of light source (and lighting system) in relationship to operating costs (and life). A light source with a low initial cost, may have a very high operating cost. Conversely a light source with a higher initial cost, may have a lower associated operating cost.

The following tables provide a summary of efficacy, color temperature, color rendering index, and life - for common incandescent and discharge light sources.

Table 1 - Incandescent Sources

LAMP		EFFICACY	CT.	CRI	AVG. HOURS
Candle (equivalent)		0.01	-	-	-
Oil Lamp (equivalent)		0.03	-	-	-
Edison lamp	(1879)	1.4	-	-	40 -45
Carbonized bamboo	(1879)	2.0	-	-	40-100
Carbonized cellulose	(1891)	3.0	-	-	-
Metalized (Gem)	(1905)	4.0	-	-	-
Drawn Tungsten	(1911)	10.0	-	-	-
60W Tungsten C.C.	(1968)	14.7	-	-	-
Filament Lamp	(1970)	10 - 18	2700-3000 K	100	1000-2000
Tungsten Halogen	(1980)	17 - 22	2850-3050 K	100	1000-2000
Stage/Studio Lamps	(1980)	20 - 40	3200-3400 K	100	100-1000

Table 2 - Discharge Sources

LAMP		EFFICACY	CCT		CRI	AVG. HOURS
Cooper-Hewitt Lamp	(1901)	13	-		-	-
Mercury Lamp (modern)		55 - 60	3300-5700	K	15-55	12-24,000
Fluorescent Lamp	(1938)	65 -100	3000-6500	K	52-92	10-20,000
HPS Lamp		80 -140	2000-3200	K	22-75	10-15,000
LPS Lamp		120 -200	1600	K	0	16,000
Metal Halide Lamp		85 -120	3000-5200	K	65-80	6-20,000
CSI = Compact Source Iodine		70 - 80	4000	K	85	500
Compact Iodine Daylight		80 - 90	5500	K	85	500
HQI (Osram)		-	3000-6000	K	81-93	-
XENON (Osram)		-	6000	K	95	800-2,000

EFFICACY - in lumens per watt.
CT = Color Temperature.
CCT = Correlated Color Temperature
CRI = Color Rendering Index.

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