



Introduction to 'Energy Effective' Light Sources

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Our Sponsors:



Our Mission:

To Promote Energy Efficiency and Quality Design Thru:

1. Education
2. Consultations
3. Industry Alliances

...AND, energy 'Effective' practice that is better than standard practice!



Education:

Annual Classes

(2) in the spring, (2) in the fall on a variety topics, held throughout the Pacific Northwest (WA, OR, ID, MT)
Additional classes as requested



Lighting Lab Tours

Color Boxes & Inter-Active Display
Lamp Technologies
Lighting Vignettes (displays in a real world environment)

Demonstrations

Full Scale Mock-up Facility



Education:

Website and Newsletter

- Commercial Lighting Guides
- Downloads of lighting presentations
- Links to allied sites
- Lighting articles
- Codes and Standards downloads

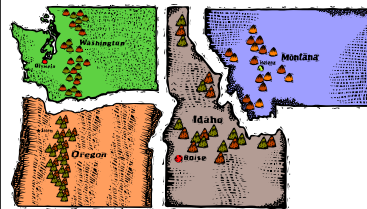
Library Resources:

- Manufacturers catalogs
- Full IES Library
- Text and Reference materials



Consultations:

In-House and On-site Consultations



Project -OR- Specifier must be in the region






Industry Alliances:

- ASHRAE:** American Society of Heating, Refrigerating and Air Conditioning Engineers
- IES:** Illuminating Engineering Society
- NCQLP:** National Council on Qualifications for the Lighting Professions
- USGBC/LEED:** U.S. Green Building Council/ Leadership in Energy and Environmental Design

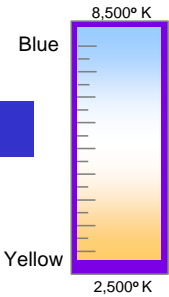
Light Sources: Characteristics

- Luminous Distribution:** Directional -vs- Omni-directional
- Lamp Shape:** A - Z
- Light Output:** Lumens
- Color Temperature:** K°
- CRI:** 0 - 100
- Efficacy:** Lumens-per-watt
- Rated Life:** 750 - 100,000 hrs.

Characteristics: Correlated Color Temperature

Think of it as a way to quantify the apparent color of a light source.



Note: The higher the Color Temp. the **bluer** the light emitted!

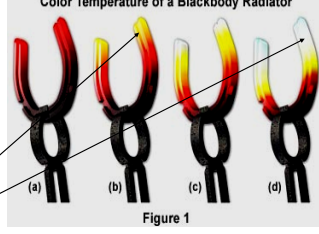
© 1998 Lighting Design Lab / Seattle City Light • All Rights Reserved

Characteristics: Correlated Color Temperature

The absolute temperature of a blackbody whose chromaticity, (*appearance*), most nearly resembles that of the light source.

Imagine heating a piece of iron that could not melt:

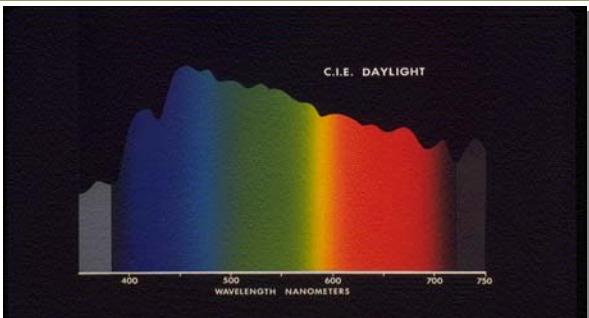
- At ~2700° K it would glow the color of an incandescent lamp.
- At ~5000° K and it's glow would approach the color of sunlight.



Color Temperature of a Blackbody Radiator

Figure 1

Characteristics: Spectral Power Distribution - SPD

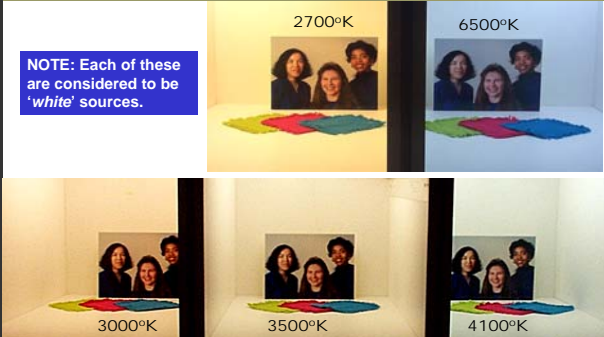


C.I.E. DAYLIGHT

WAVELENGTH NANOMETERS

Characteristics: Common Color Temperatures

NOTE: Each of these are considered to be 'white' sources.



2700°K


6500°K

3000°K

3500°K


4100°K

Characteristics: Color Temperature Range



Cool	6500°K	Daylight	
	5000°K		Sunlight
Common fluorescent range.	4100°K	MH	
	3500°K		Color temperature in °Kelvin
	3000°K		
	2700°K		
	2200°K		
1500°K			
Warm		Halogen	
		Inc. HPS Flame	


Characteristics: Application



The Influence of Color Temperature on Mood and Lighting Applications

COLOR TEMPERATURE	WARM	NEUTRAL	COOL	DAYLIGHT
Kelvin Range	3000K	3500K	4100K	5000K
Associated Effects and Moods	Friendly Intimate Personal Exclusive	Friendly Inviting Non-threatening	Neat Clean Efficient	Bright Alert Exacting coloration
Appropriate Applications	Restaurants Hotel lobbies Boutiques Libraries Office areas Retail stores	Public reception areas Showrooms Bookstores Office areas	Office areas Conference rooms Classrooms Mass merchandisers Hospitals	Galleries Museums Jewelry stores Medical examination areas Printing companies

Characteristics: Color Rendering Index - CRI



The ability of a light source to accurately render colors as we expect them to be rendered with respect to a reference light source is called its Color Rendering Index.

The CRI scale range is from 0 - 100

Best	100
Excellent	80+
Good	70+
Poor	50
Bad	25
Worst	0

NOTE: Color Temperature and Color Rendering are **NOT** related!

Characteristics: Color Rendering




CRI 85




CRI 70

Courtesy: Philips





NOTE: A CRI of 80 should be considered as minimum for most interior applications

Characteristics: Color Rendering




Being able to see colors accurately is especially important in certain settings:



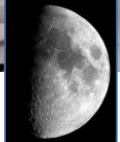
- Health Care facilities
- Retail Applications
- Industrial Applications
- Scientific environments
- Architectural Design

Characteristics: Source Size



The apparent size of the light source in relation to the surface it is lighting, will have an effect on the ability of a luminaire to; shape the light, the appearance of 3D objects, and the ability of users to perform visual tasks.

Characteristics: Point Sources

The smaller the light source is, relative to the surface it is lighting, the "harder" or more defined the shadow.

Any light source can act as a point source, it is a function of distance and relative size.

- Some typical point sources; direct sun*, arc lamp, tungsten filament, T5 (at a distance).

The Sun's rays hit the earth more or less parallel to the surface.

Characteristics: Linear Sources

- Linear sources (neon, fluorescent, linear diffuse skylights)
- May be used to outline or delineate a shape or space, or may be repeated in a pattern to light an entire space. They tend to minimize contrast and shadow.
- Intensity decreases proportional to the distance from the lamp.

Characteristics: 'Soft Shadows'

The larger the light source is relative to the surface it is lighting the "softer" or less defined shadows become. Almost any light source can be made to act as a large source by either moving it close to the subject and/or diffusing the outer envelope or the lamp.

This could be an overcast sky, fluorescent lamps, or coated or frosted lamps, (at close range).

Electric Light Sources: Terms & Definitions

Lamp: a generic term for a source created to produce optical radiation.

A more accurate way to describe a 'light bulb'.

The 'bulb' is merely the glass portion of the lamp.

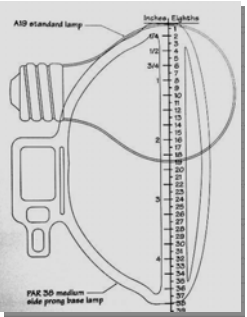
Terms & Definitions: Common Lamp Shapes

Terms & Definitions: Directional vs Omni-Directional

Some lamps put out light in all directions, and others deliver light in one direction. They are usually *not* interchangeable for a given fixture type.

50W	30° BEAM
flux at beam centre	Spot Ø in m.
1000	1m 0.54
250	2m 1.07
110	3m 1.61
65	4m 2.14

Terms & Definitions: Lamp Designations



In the US most lamp types are designated according to:

Shape:

- T – Tubular
- G – Globe
- PAR – Parabolic Aluminized Reflector
- MR – Multi Mirror Reflector

Nominal Wattage

Diameter (in 1/8" increments)

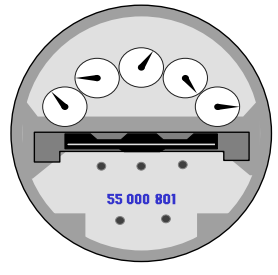
Beam Spread (if directional)

F32T8/830

- Fluorescent
- 32 Watts Nominal
- Tubular
- 8/8" = 1" Diameter
- 80+ CRI
- 3000k CCT – "warm"

Terms & Definitions: Efficacy

The ratio of light output, to power input – Stated as Lumens-per-Watt



Incandescent:	5 to 20	l/w
Halogen:	15 to 35	l/w
CFL:	20 to 80	l/w
Fluorescent:	60 to 100	l/w
HID:	25 to 180	l/w


***Think miles per gallon!**

Terms & Definitions: Lamp Life

"The life value assigned to a particular type lamp. This is commonly a statistically determined estimate of average or of median operational life."

IESNA

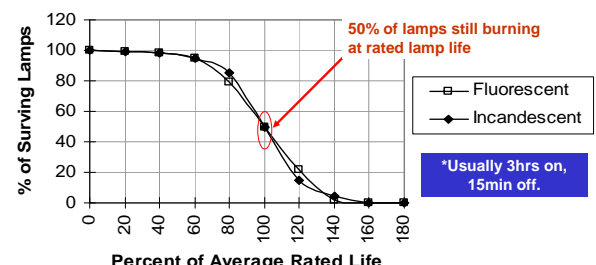
Incandescent:	800 to 3,500 hrs*
CFL:	10,000 hrs*
Fluorescent:	20,000 – 44,000 hrs*
HID:	6,000 to 40,000 hrs*



*** Estimates only**

Terms & Definitions: Rated Lamp Life

50% burn out rate of a large sample on a pre-determined burn cycle*.



50% of lamps still burning at rated lamp life


Legend: □ Fluorescent, ● Incandescent

***Usually 3hrs on, 15min off.**

Terms & Definitions: Rated Lamp Life

Other Lamp Life considerations:

- Lumen depreciation
- Color shift
- Efficacy reduction
- Lamp starts to cycle
- Lamp instability through aging
- Probability of failure increasing (Need for re-lamping policy: Group -vs- Spot)

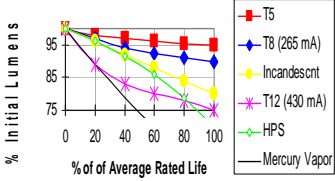


Terms & Definitions: Lamp Lumen Depreciation

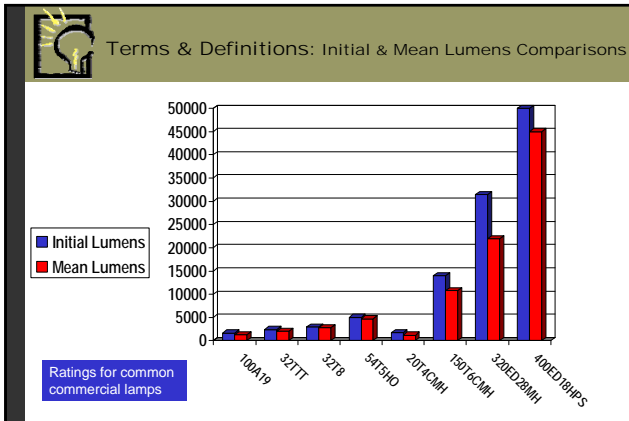
All light sources lose light as they age

Manufacturers supply data:

- **Initial lumens**, the light output *after* 100 hour of "burn in".
- **Maintained lumens**, (or design lumens) the light output at 40% of lamp life.



Legend: ■ T5, ◆ T8 (265 mA), ● Incandescent, * T12 (430 mA), ◇ HPS, — Mercury Vapor



Electric Light Sources: Families of Lamps

- Incandescent**
 - Standard
 - Halogen
- Fluorescent**
 - Linear
 - Compact
- High Intensity Discharge- HID**
 - Mercury Vapor
 - Metal Halide
 - High Pressure Sodium
 - Low Pressure Sodium

Emerging Technologies

- LED
- Induction
- Electroluminescent

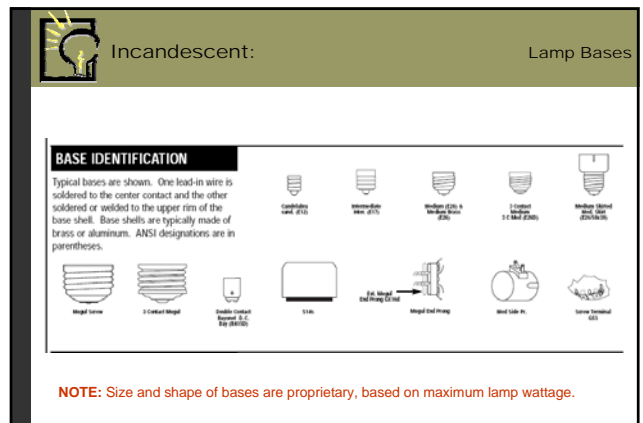
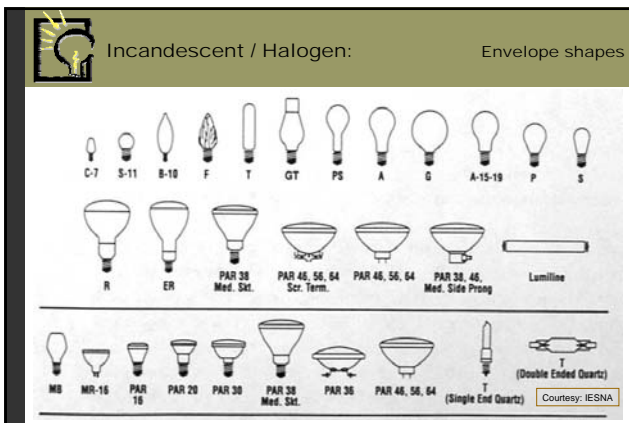
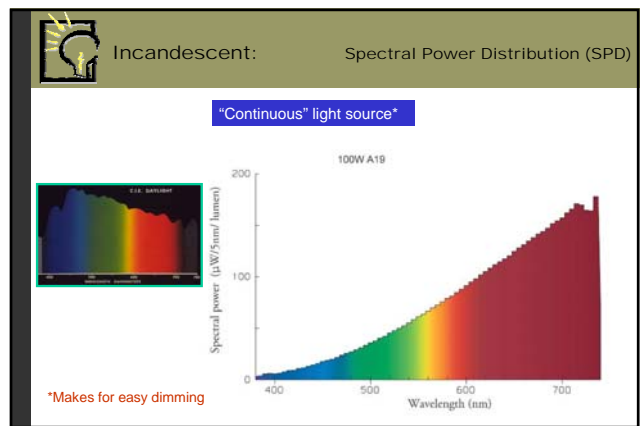
Puyallup City Library
Genette Beaudette Lighting

Electric Light Sources: Incandescent

A lamp in which light is produced by a filament heated to incandescence by an electric current.

Still the most common light source, the incandescent lamp gives only about 5 to 20 lumens per watt.

This means that less than 10% of the energy that goes into an incandescent bulb comes out as light. The rest is heat!



Incandescent: Maximum Overall Length (M.O.L.)

Bulb size - Max. Diameter (Divide by 8)

- A-21 - 21/8 = 2 5/8" Dia.
- G-40 - 40/8 = 5" Dia.
- T-12 - 12/8 = 1 1/2" Dia.
- PS-30 - 30/8 = 3 3/4" Dia.

NOTE: Critical to reflector design

Incandescent: Manufacturer's cutsheet

A19 Bulb Shape SoftWhite Finish Medium Aluminum Base 60Watt 120Volt Retail Pack

Abbrev. With Packaging (LPS)	60AWRP 120V 24/CS 2/SKU
Approx. Lumens	850
Average Rated Life (hr)	1000
Base	Medium
Bulb	A19
Class	C (ps)
Color Rendering Index (CRI)	100
Color Temperature/CT (K)	2850
Diameter (in)	2 3/8
Diameter (mm)	60.325
Flament	CO-6
Lamp Finish	Soft White
Light Center Length - LCL (in)	3.125
Light Center Length - LCL (mm)	79
Maximum Overall Length - MOL (in)	4.438
Maximum Overall Length - MOL (mm)	112.7125
Nominal Voltage (V)	120.00
Nominal Wattage (W)	60.00

Incandescent: Beam Spread

The angle at which light drops 50% from the CBCP

Field Angle = The angle at which light drops to 10% of the CBCP

Field Angle

CBCP

Center Beam Candle Power

Directional lamps only

Beam Angle

Distance (m)	Spot Ø in m.
1m	0.54
2m	0.7
3m	1.01
4m	1.36

Incandescent: Manufacturer's cutsheet

CAPSYLITE PAR30 Reflector Lamp Medium Base 50Watt 120Volt Narrow Flood Beam

Abbrev. With Packaging (LPS)	50PAR30CAP/SPL/NFL25 120V 1/CS
Approx. Lumens	7450
Average Rated Life (hr)	500
Base	50 Medium
Beam Angle (Deg)	35
Beam Type	NFL
Sub	PAR30
Vertical Beam Diameter (in)	3.024
Class	2 (ps)
Color Rendering Index (CRI)	100
Color Temperature/CT (K)	2850
Diameter (in)	3.75
Diameter (mm)	95.25
Voltage	120
Lamp Brand Name	CAPSYLITE PAR30 NFL
Flament	FL-3
Horizontal Beam Angle (Deg)	35
Maximum Overall Length - MOL (in)	3.025
Maximum Overall Length - MOL (mm)	76.9375
Nominal Voltage (V)	120.00
Nominal Wattage (W)	50.00
Nominal Beam Angle (Deg)	35

Incandescent: Tungsten Halogen

- Tungsten filament**
 - (Same as non-halogen)
- Small envelope**
 - (T-3 & T-4)
- Quartz envelope**
 - Not silicone glass
- Halogen gas filled**
 - Halogen cycle

Incandescent: Halogen Cycle

Halogen incandescent lamps (a.k.a. tungsten halogen, quartz halogen) use a halogen gas, iodine or Bromine, inside a small quartz capsule that encloses the filament. The halogen gas combines with the tungsten filament as the filament evaporates. The tungsten is then re-deposited back on the filament, keeping the bulb wall clean.

NOTE: The cycle requires high temperature and pressure. Permanent dimming will reduce lamp life.

Incandescent: Halogen Infrared

320fc 450fc 500fc

150 watt PAR 38 Standard
90 watt PAR 38 Halogen
60 watt PAR 38 Hal. IR

Incandescent: + / - Voltage Relationships

LIGHT OUTPUT:
At 90% rated voltage, light output is 75%
At 110% rated voltage, light output is 135%

LAMP LIFE:
At 90% rated voltage, life is 250%
At 110% rated voltage, life is 35%

Voltage (%)	Light Output (%)	Lamp Life (%)	Color Temperature (K)	Energy Consumption (%)	Luminous Flux (%)
90	75	250	~2700	~100	~100
100	100	100	~2800	100	100
110	135	35	~3000	~135	~135

Incandescent: Low Voltage

Today, low voltage lamps are generally a special case of halogen lighting, (except for landscaping)

Lowering the voltage increases the current and allows for a smaller point source filament.

APPLICATIONS:

- Accent Lighting
- Superior Optical Control
- Sparkle and Glitter
- Myth: LoVo is more energy efficient than halogen*

NOTE: Requires a transformer

Incandescent: Point Source Applications

Beam Control: when a light source is relatively small compared to the size of the reflector, beam control of the light is increased (6v. AR111 has a 4 deg. Beam spread)

Dramatic Shadows: lighting a space w/ point sources can yield high contrast, defined shadows, and/or dappled light.

Incandescent: Point Source Comparisons

75R30 35MR16 50PAR30

Electric Light Sources: Fluorescent

A low pressure mercury electric-discharge lamp in which a fluorescing coating (phosphor) transforms some of the ultraviolet energy generated by the discharge into light.

Base Phosphor Cathode

Bulb (Envelope) Gas Mercury

Fluorescent: Lamp Phosphors

A phosphor coating on the inside of the lamp transforms the **ultraviolet mercury arc radiation into visible light**.

The combination of various phosphors creates distinctive color temperatures and good or poor color qualities (CRI).

Abbreviation	Color
CW	Cool White
CWX	Cool White Deluxe
C50	China's Callitone 50
DSGN50	Design 50
D	Daylight
DX	Daylight Deluxe
N	Natural
W	White
WW	Warm White
WWX	Warm White Deluxe
827	2700K RE
730 / 830	3000K RE
735 / 835	3500K RE
741 / 841	4100K RE
750 / 850	5000K RE

Fluorescent: SPD (Tri-Phosphor)

"Discontinuous" light source

Cones are sensitive to:

- long wavelengths of light (**red light**)
- medium wavelengths of light (**green light**)
- short wavelengths of light (**blue light**)

Fluorescent: Bulb Shapes

- T-2 subminiature Axial base (2/8" diameter)
- T-5 Miniature Bipin (5/8" diameter)
- T-8 Medium Bipin (1" diameter)
- T-12 Medium Bipin (1-1/2" diameter)
- T-8 Recessed Double Contact (1" diameter)
- T-12 Recessed Double Contact (1-1/2" diameter)
- T-8 Single Pin Slimline (1" diameter)
- T-12 Single Pin Slimline (1-1/2" diameter)
- T-12 U-Bend Medium Bipin
- T-8 U-Bend Medium Bipin
- T-5 Twin-tube
- 2-D
- T-9 Circine
- Screw-base Compact Fluorescent
- Pin-base Compact Fluorescent

Fluorescent: Base Types

The basic functions of the base is to conduct electricity to the cathode and to hold the lamp in the socket.

- BIPIN
- SINGLE ENDED 4-PIN
- RECESSED DOUBLE CONTACT
- SINGLE PIN
- SINGLE ENDED BIPIN
- SINGLE ENDED FOUR PIN
- MEDIUM SCREW-TYPE

Fluorescent: Pin Base CFL

Compact Fluorescent lamps are available in a huge array of styles.

For new construction, the current lamp of choice are the **Triple Tube Lamps**

Labels: Twin tube, Quad tube, "Biax"

Fluorescent: Screw-In CFL

Designed as a replacement for standard A-lamps

They are *similar* in; size, shape, light distribution, light quality...

BUT...

... there are some important differences.

Comparing: 60w. A-lamp -vs- 15w. CFL

CFL	"A"-Incandescent
Watts: 17 w/ballast	Watts: 60
Lumens: 825 - 900	Lumens: 865
Life: 10,000 hours	Life: 1,000 hours
First cost: +/- \$5.00	First cost: +/- \$.50
• Screw in type	• 120volt frost
\$13.50 life cycle cost*	\$35.00 life cycle cost*

*At \$.05 per kWh w/out labor cost.

Fluorescent: Self Ballasted CFL

Self ballasted, or screw base, Compact Fluorescent lamps are also available in a huge array of styles.

These lamps should generally be used only when it is not possible to use a pin based lamp.

Fluorescent: CFL Reflector lamps

When a relatively large light source is put into a relatively small reflector, (R-30 or PAR 38) then the optics are compromised and, light & heat are trapped. All of these things affect performance.

Fluorescent: Linear

F40 T12 40 Watt Lamp	(55-82 l/w)
F40ES T12 34-Watt Lamp	(56-85 l/w)
F32T8 32-Watt Lamp	(63-97 l/w)
F28T5 28-Watt Lamp	(104 l/w)
F54T5HO 54-Watt Lamp	(93 l/w)

NOTE: l/w values are nominal and do not include ballast losses

Fluorescent: Linear

Cool White T12	T8 / 80	T5 / 80
70 l/w	92 l/w	93(HO) – 104 l/w
62 CRI	85 CRI	85 CRI
Flicker with magnetic ballast	Imperceptible lamp flicker with electronic ballast	Imperceptible lamp flicker with electronic program start ballast
20,000 hrs.	24,000 – 44,000* hrs.	30,000 – 36,000 hrs.
lumen maintenance 60-70%	lumen maintenance 80 - 90%	lumen maintenance 90 - 95%
	Better optical package	Best optical package

T-12 T-8 T-5

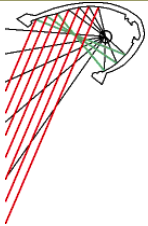
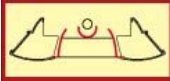
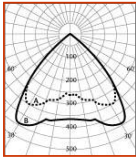
Fluorescent: Comparison of Relative Output

Lamp Model	Mean Lumens
T12/CW/ES	2300
T12/RE/ES	2520
T12/RE	2880
32T8	2800
28T5	2750
54T5HO	4740

*Lumens / watt

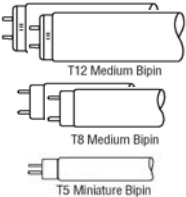
Fluorescent: Benefits of T8 over T12

Higher lumens for lower wattage
Smaller diameter = lower profile and smaller fixtures,
- OR -
Improved optical advantage w/ the same size fixture.

Fluorescent: Use of Resources/Disposal

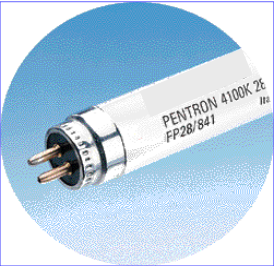
Lamp Type	Material Content
2 x T12	100%
2 x T8	67%
1 x T5 HO	21%



Impacts: Lamp, Ballast, Luminaires, Components, Shipping (Raw & Finished), Warehousing, Handling, Installation & Disposal

Courtesy: Osram/Sylvania

Fluorescent: T5



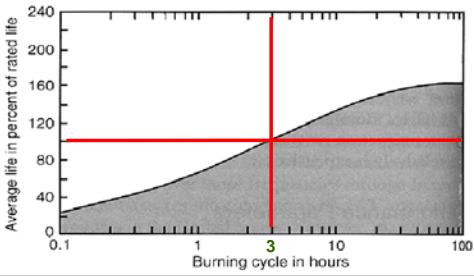
Standard 28w.
High efficacy rating (104 l/w)
5/8" profile optimizes fixture performance.
Small diameter for smaller fixture size and better optical performance.
Low LLD, 95%

High Output (HO) 54w.
High surface brightness (glare)
Can be a challenge to uniformity
Lower efficacy than 28 watt

NOTE: T5 lamps are metric lengths

Fluorescent: Lamp Life

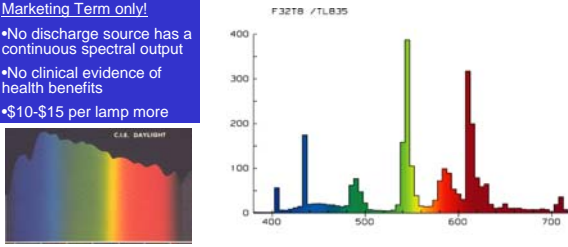
Fluorescent Lamp Life is dependent on the number of lamp starts and the length of the burn cycle. Rated lamp life is based on a 3 hour burn cycle.



Fluorescent: Full Spectrum, (the Myth)

Marketing Term only!

- No discharge source has a continuous spectral output
- No clinical evidence of health benefits
- \$10-\$15 per lamp more



"Full spectrum" lamps typically have a CRI ~90. The Cool White and Warm White T12 lamps they generally replace have a CRI ~ 60. Do you suppose the "health" benefits are visual ones making use of the higher CRI to make us look and feel better?

Electric Light Sources: High Intensity Discharge- HID


Low Pressure Sodium
Rarely used, very poor color properties

Mercury Vapor
Much less popular now, poor efficacy, LLD & color

High Pressure Sodium (HPS)
Widely used, poor color, high efficacy


Poor choice for security or interior use.

Metal Halide (MH)
Widely used, good to excellent color & efficacy



Characteristics: HID


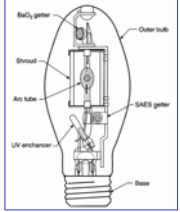
- Compact arc tube:** resulting in high temperature & pressure
- Ballast:** usually magnetic, (electronics emerging)
- Strike time:** range from 2 to 10 minutes
- Re-strike period:** lamp must cool down to relight (MH)
- Lamp life:** varies widely from type and wattage
- Color properties:** poor to excellent
- Output:** point source like, easily controlled, but high potential for glare
- Wattages & types:** wide range, very versatile



HID: Standard Metal Halide

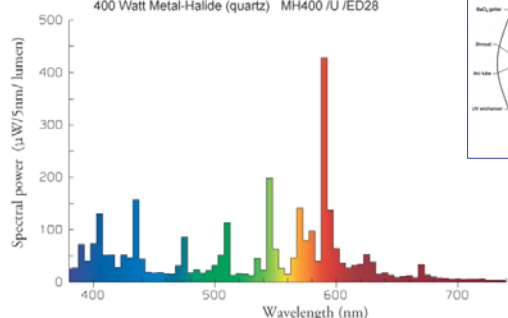
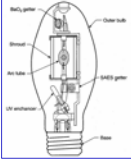
- Color temperature:** 3000K° - 4300K°
- Lamp life:** 10,000 to 20,000 hrs.
- Starting temperature:** down to -12°C
- Lamp Orientation:** sensitive, (V/H/U)
- Efficacy:** 60 - 86 l/w
- CRI:** 60 - 75

NOTE: Noticeable color shift as lamp ages

Metal Halide: SPD Chart

400 Watt Metal-Halide (quartz) MH400 /U /ED28





Metal Halide: Pulse Start Lamps

Characteristics:

- higher 'initial' lumens
- improved lumen maintenance
- longer life (on long burn cycles)
- better color stability
- faster warm-up
- reduced restrike time
- colder starting


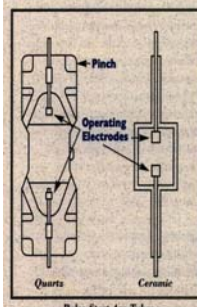
NOTE: Compared to standard and probe start lamps



Metal Halide: Ceramic Metal Halide (CMH)

Ceramic arc tubes resist the highly corrosive action of sodium and their migration through the arc tube.

Sodium corrosion and migration are causes of lamp failure and color shift.

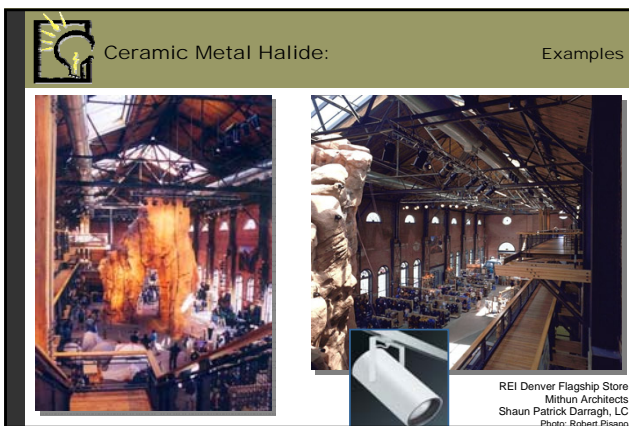
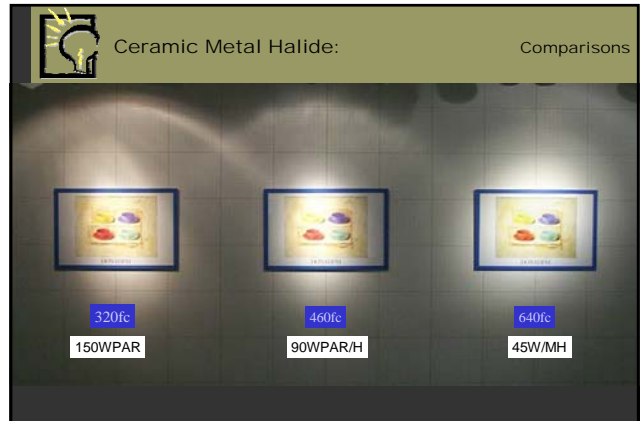
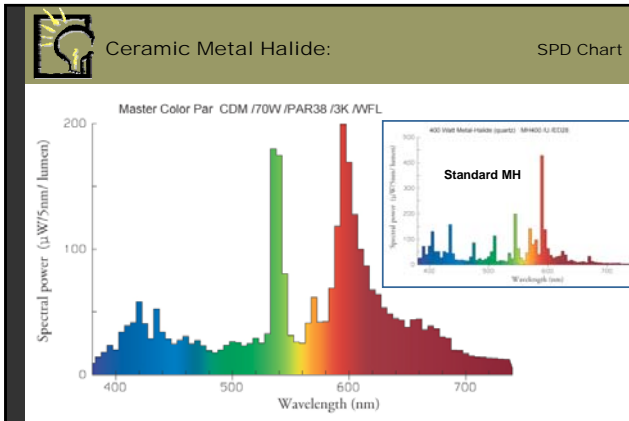



Metal Halide: Ceramic Metal Halide (CMH)

- Color temperature:** 3000K° - 4100K°
- Lamp life:** 10 to 20,000 hrs.
- Starting temperature:** down to -12°C
- Efficacy:** 50 - 93 l/w
- CRI:** 80 - 93
- Color Shift:** less than 200K°

Pacific Place
NBBJ / Elkus Manfredi
Photo: James Housel



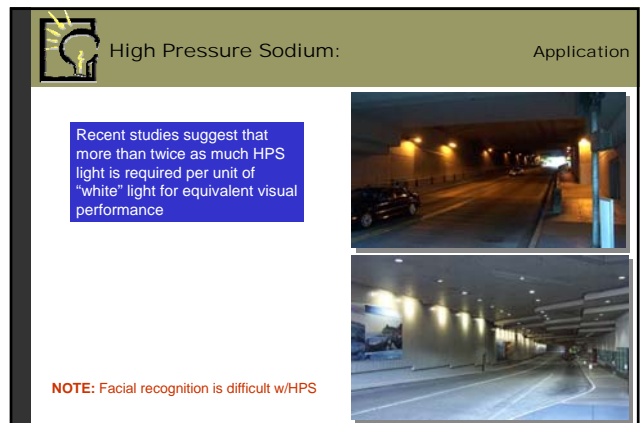
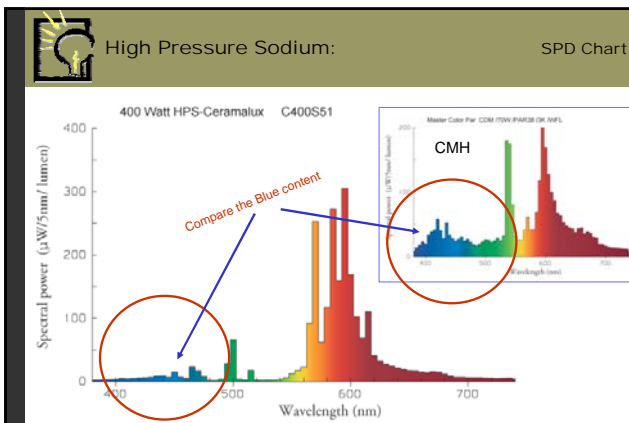
HID: High Pressure Sodium (HPS)

- Color: (yellowish) 2100k°
- Life: 24,000+ hrs.
- Starting Temp: down to -30°C
- Orientation: not sensitive

- Efficacy: 85 – 120 l/w
- CRI: 22
- (Some improved color lamps available)

NOTE: May "cycle" at end of life.

Courtesy: Sylvania



High Pressure Sodium: Comparison

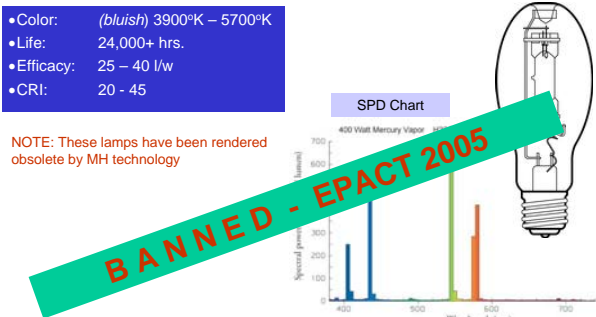


Metal Halide w/daylight High Pressure Sodium

HID: Mercury Vapor

- Color: (bluish) 3900°K – 5700°K
- Life: 24,000+ hrs.
- Efficacy: 25 – 40 l/w
- CRI: 20 - 45

NOTE: These lamps have been rendered obsolete by MH technology



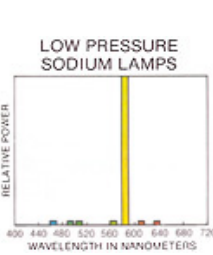
SPD Chart

400 Watt Mercury Vapor


HID: Low Pressure Sodium (LPS)

- Color: (yellow) 1700°K
- Life: 18,000 hrs.
- Efficacy: 180 l/w
- CRI: unlisted

These lamps are by code, used near observatories where monochromatic light can be easily filtered. But they remain a very poor choice where human vision is important.



LOW PRESSURE SODIUM LAMPS




HID: Strobing

All HID sources can produce a stroboscopic effect. The lamp will flicker 120 times per second (if powered by a magnetic ballast on a 60 Hz power supply).

While the eye may not detect it, to an occupant observing a rotating machine such as an electric motor operating at a speed in multiples of 60Hz. (such as 1800 rpm.), the machine may appear motionless, or at some altered rate.


Adding a supplemental 'layer' of light from an electronically ballasted source, or from daylight, may mitigate the effect.



Electric Light Sources: Induction

- Life: 100,000 hrs.*
- Efficacy: 64 - 72 l/w
- Color: 3000°K – 4100°K
- CRI: 80+
- Starting Temp: down to -30°F
- Re-strike: instant
- Low-pressure mercury gas


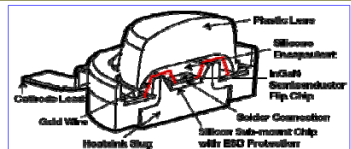
Started by RF signal



Useful in areas that are hard to maintain

*Not really


Electric Light Sources: Light Emitting Diodes (LED)

- Solid State Light Source
- Extremely Flexible
- Potentially Long Lamp Life
- Dynamic Color possibilities
- Poor White Color Rendering

Courtesy: Color Kinetics, Lumileds, Nichia

LED: Appropriate -vs- Inappropriate Applications



Exit Signs:	Excellent
Flashlights:	Excellent
Track Lighting:	Not yet
Accent Lighting:	Not yet
Down Lighting:	Not yet
Architectural:	Good*
Traffic Signals:	Excellent
Street Lighting:	Not yet
Transportation:	Excellent


* but Expensive!!

LED: Excellent Application


Most traffic signal lighting in the US still relies on outdated incandescent lamp technology

Replacing these lamps with LED based upgrades can:


- Save 80-90% of the energy used
- Lower the risk of accidents at intersections through improved reliability
- Lower liability costs
- Last up to 10 years, compared to less than two years for conventional traffic signals;
- Save on maintenance costs
- Simplify inventory control



LED: Examples




Nortel Networks



Pfizer Learning Center

LED: White LED's

Saturated colors, and dynamic color changing are needed for some applications, but for most architectural uses, 'white' light is needed. LED's produce 'white' light by mixing individual red, green and blue LED's. Newer products use a blue LED (InGaN) with a photoluminescent phosphor (yellow). The result however, is an unsatisfactory bluish white output, and a lower l/w rating.



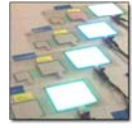

LED: Electric Light Sources: Electroluminescent

A process whereby a phosphor converts a very small amount of AC energy directly into light, (no gas discharge required).

A phosphor layer is sandwiched between two, 2-dimensional conductors.

An AC field is established between the two conductors, energizing the phosphor.

Very long lived, and useful in low-level emergency exit lighting.

LED: Resources:

Lighting Design Lab	lightingdesignlab.com
IES	www.ies.org
US Green Buildings Council	www.usgbc.org
Lighting Controls Association	www.aboutlightingcontrols.org
Lighting Research Institute	www.lrc.rpi.edu
Northwest Energy Education Institute	www.nweel.org
ASHRAE	www.ashrae.org