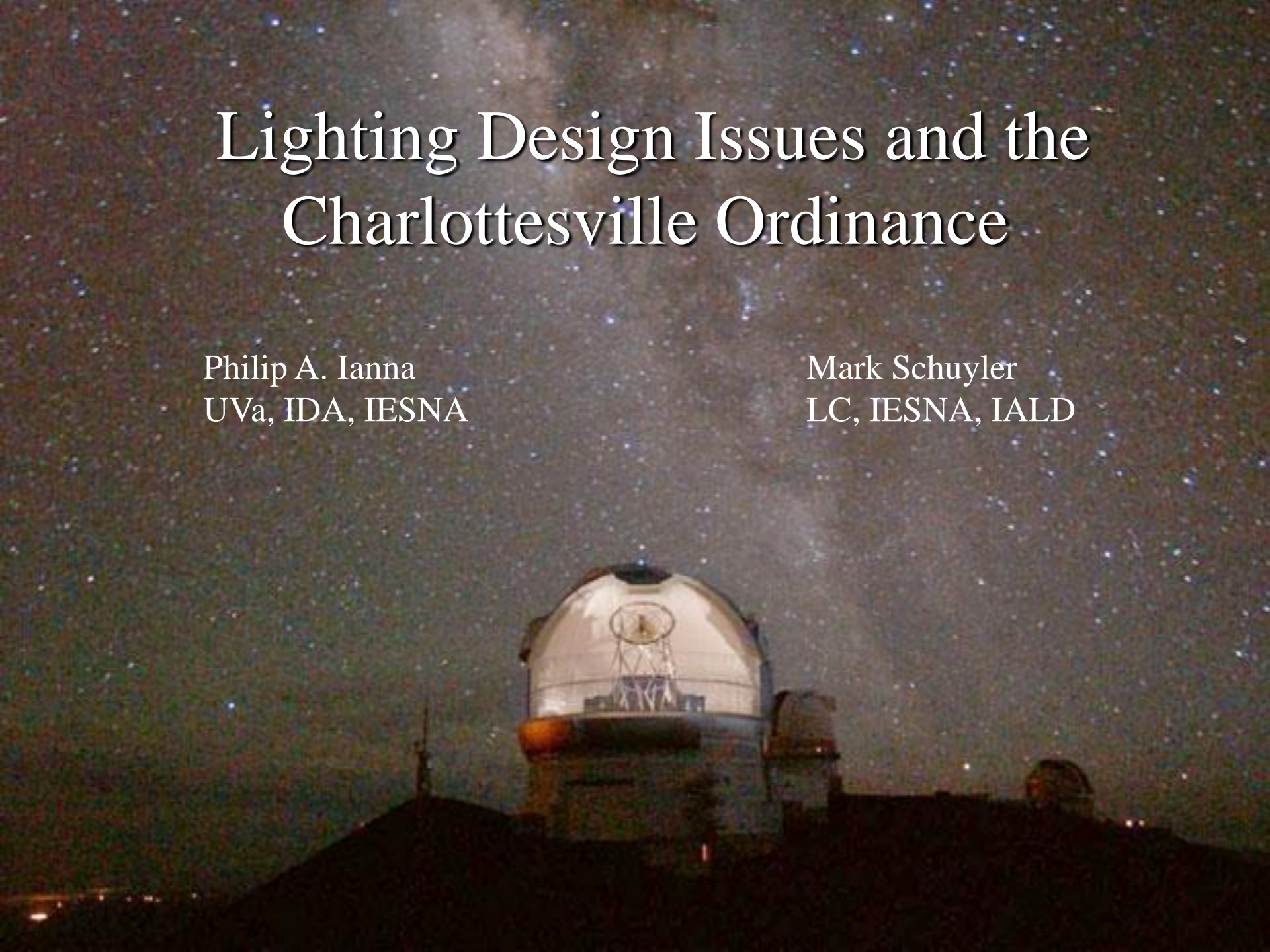# Lighting Design Issues and the Charlottesville Ordinance

Philip A. Ianna
UVa, IDA, IESNA

Mark Schuyler
LC, IESNA, IALD

Quality Lighting Design addresses:

Human Factors
  Visibility
   Performance and Productivity
   Visual Comfort (lighting levels, glare)
    Mood, social interactions
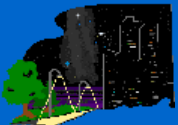   Health, Safety, and Security issues

 Architecture
    Design Aesthetics (fixtures, results)
    Codes and Standards conformance

 Economics and Environment
    Life Cycle Costs (purchase, operate, maintain)
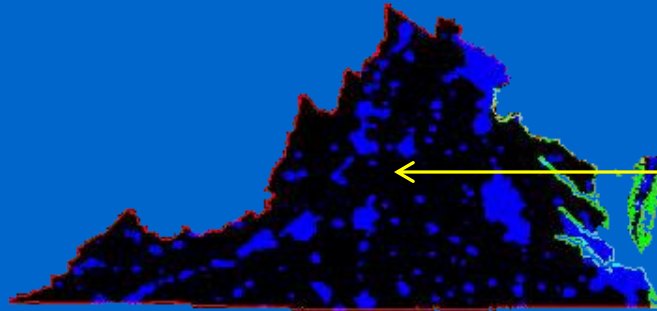   Environmental issues (energy, Hg disposal, etc)

The UVa Observatories

At Leander McCormick, no more Kodak moments

We light the
  undersides of clouds

Fan Mountain

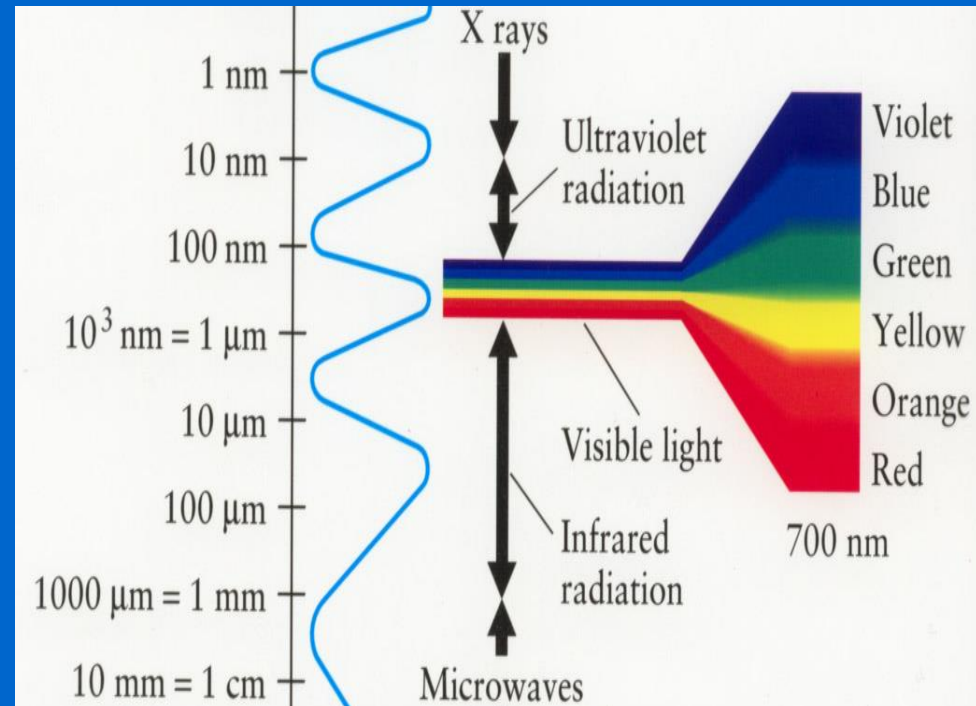Contrib. to excess

C' ville – 51%
Waynes – 11%
Lynchb. – 9%
Richmn. – 9%

Characterizing Light

- A rainbow is the visible part of the electromagnetic spectrum.

- The electromagnetic spectrum includes all radiant energy from gamma rays and x-rays through the ultraviolet and the visible to the infrared and radio.

- We see one octave from about 400 nm to 800 nm

Lighting Metrics

- we are familiar with watts (and don't worry that it is power in joules per second); lighting metrics are no more peculiar, just not as commonly used.

- some things are *luminous*, other things are *illuminated*.

- we need precise quantitative descriptors.

Lumens

- A *lumen* is the quantity of light to which we are most sensitive produced by a lamp. It is the flow of light or total luminous flux.
  - 60 watt incandescent emits ~1000 lumens
- *initial lumens*: output after 100 hrs operation for gas discharge lamps.
- lumen output decreases as a lamp is operated: *lamp lumen depreciation* (LLD).

Illuminance

- *Illuminance* is the amount of light falling on some area of a surface, as in some number of lumens per sq. ft. => *footcandles* (fc). Can be V or H.

- or *lux* (lumens per sq. meter) [10.76 x fc]

- the Illuminance value varies inversely with the distance from the source, that is, the emitted light is spread over a larger area as it gets farther from the source, the so-called *inverse square law*. (if you double the mounting height, you have ¼ the amount of light on the ground)

A few examples of Illuminance levels

- Sunlight 11,000 fc

- Full moonlight 0.02 fc

- University Hall West Parking ~1 fc

- McIntire Park ~4 fc

- Martha Jefferson Hospital Parking 40 fc

- Barracks Road Amoco 80 fc

The Intensity of Light

- The luminous intensity (past: candlepower) of a light source in a specific direction is the candela (cd). It is the 'force' generating the flow (like pressure).

Luminance

- The brightness we see as light emitted from (or through) a surface, such as a frosted lamp bulb, or as an illuminated surface, such as the ground, is the *luminance*. We see surfaces by reflected light. We do not see illuminances.

- Luminance is measured as cd/m^2

# A few examples ...

- Illuminance
  - solar disk: 1.6 billion cd/m^2
  - moon: 2,500 cd/m^2
  - clear sky: 8,000 cd/m^2
  - 60 w inside frosted lamp: 12,000 cd/m^2
  - av. ground, sunny day: 3,000 cd/m^2
  - darkest sky: 0.0004 cd/m^2
- Reflectance
  - specular aluminum 95%
  - new snow 74%
  - concrete 40 %
  - vegetation (mean) 25%
  - asphalt 7%

Human Vision

- The eye accommodates to a brightness range of at least 10,000,000 through pupilary, photochemical, and neurological changes

- Under bright conditions, *cone* receptors operate (photopic vision); they are near the center of the retina

- At very low light levels, the *rods* are the receptors (scotopic vision); they are spread over the peripheral retinal, and do not see color

photopic peak: 555 nm; scotopic peak: 507 nm

pai 7 Mar 2005
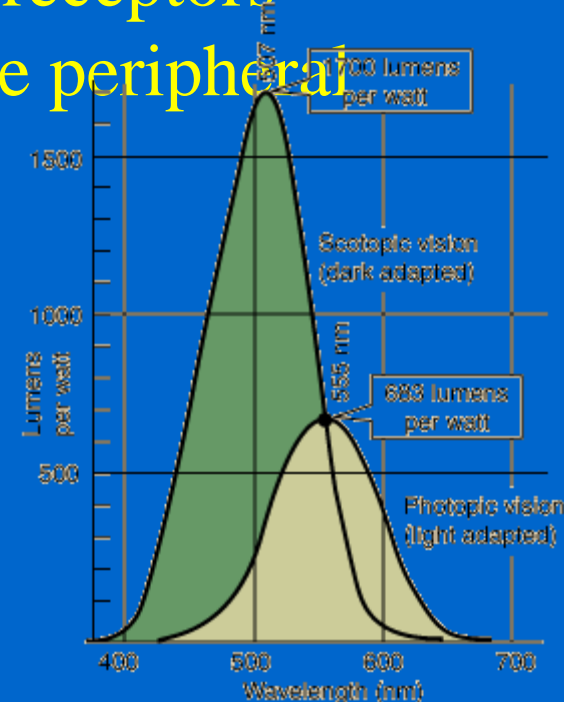
Glare

- Discomfort and Disability Glare
- *Veiling luminance* is the 'veil' of light produced by bright sources in the field of view reducing contrast and visibility.

Light Sources

- Six lamp families: Incandescent, Fluorescent, Mercury Vapor (MV), Metal Halide (MH), High-Pressure Sodium (HPS), and Low-Pressure Sodium (LPS).

- These are gas discharge sources (except INC), i.e. light is emitted when an electric current passes through a gas.

- MV, MH, and HPS are high-intensity discharge (HID) lamps.

- All gas discharge lamps require Ballasts to provide preheat, ignition voltages, operating voltage, and to limit lamp current.
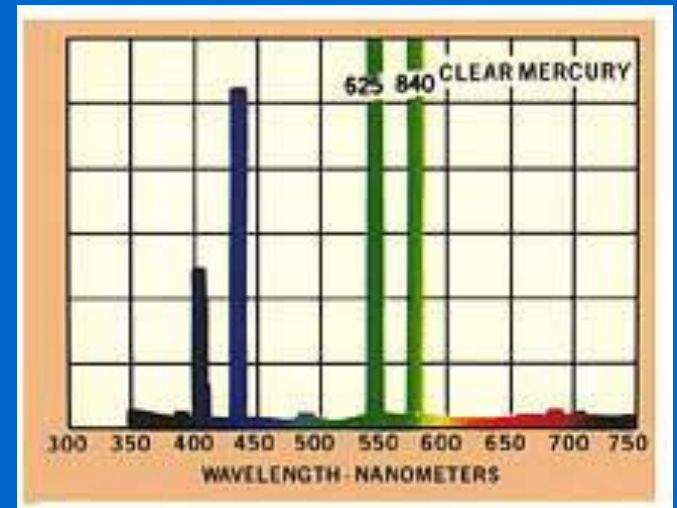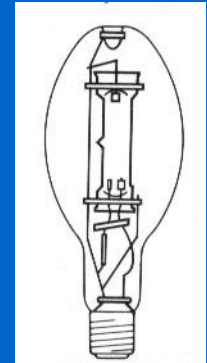
Incandescent Lamps

- 7 – 1500 watts.

- 45 – 34,000 lumens (150 w: 2600 lm).

- ~ 1000 hrs rated life.

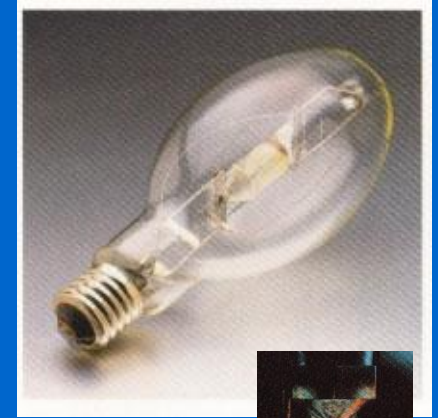- 6 – 23 lm/w.

- inefficient, short lifetimes.
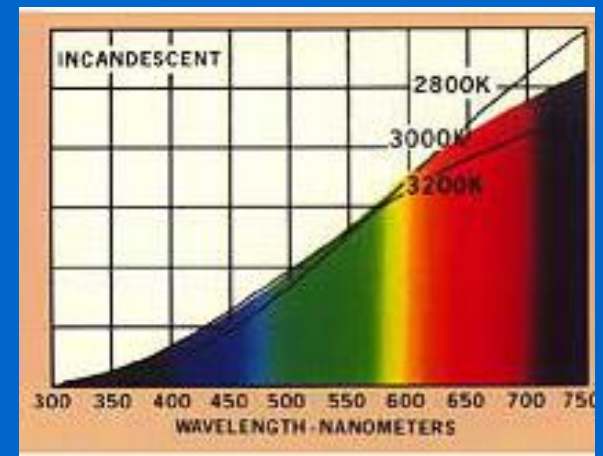
Mercury Vapor, since 1903

- 50 – 1000 watts

- 1580 – 60,000 lm (75 w: 2800 lm)

- 24,000+ hrs

- 32 – 60 lm/w

- inefficient, high lumen depreciation, poor color
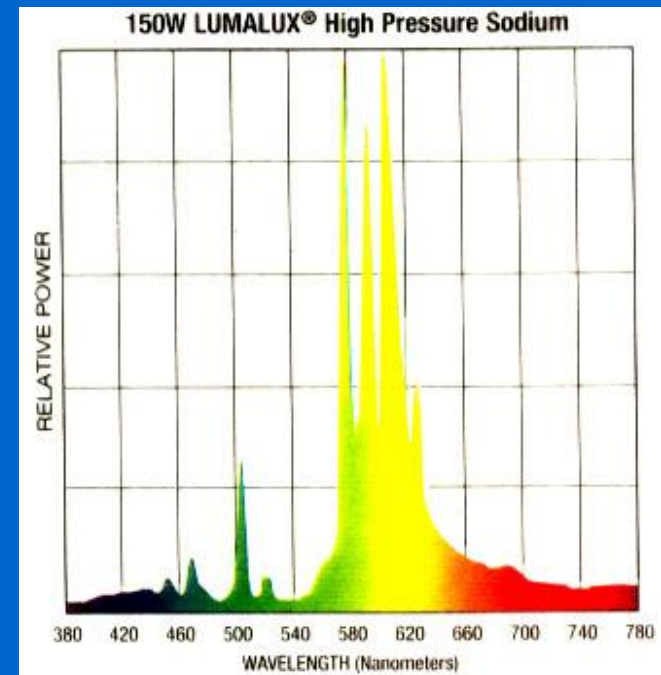
Metal Halide (iodides) ~1965

- 39 – 1800 watts
- 3000 – 150,000 lm (40 w: 2600 lm)
- 6,000 – 10,000 hrs
- 80 – 110 lm/w
- 5 – 20,000 hrs
- vertical, horizontal burn; pulse-start, ceramic
- color shifts

typical arc: 30,000,000 cd/m^2

High Pressure Sodium, ~1961

- 35 – 1000 watts

- 2250 – 140,000 lm (35 w: 2250)

- 24,000 hrs

- 64 – 140 lm/w

- not great color rendition

150W LUMALUX® High Pressure Sodium

RELATIVE POWER vs WAVELENGTH (Nanometers)
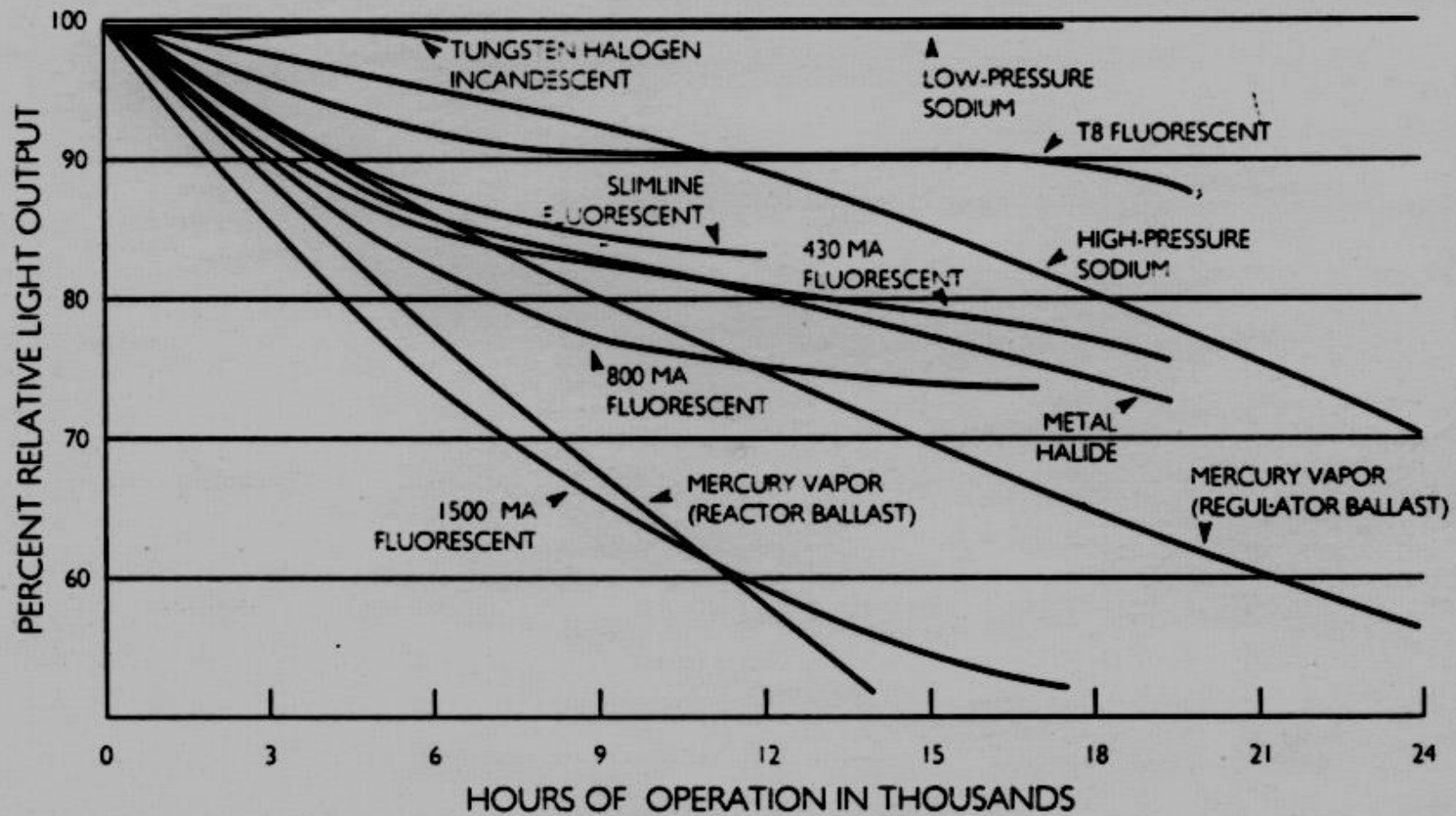380 420 460 500 540 580 620 660 700 740 780

Low Pressure Sodium, since 1933

- 18 – 180 watts

- 1800- 33,000 lm

- 18,000 hrs

- 100 – 183 lm/w

- efficient, low glare, no color rendition (only 589 nm out), little lumen depreciation
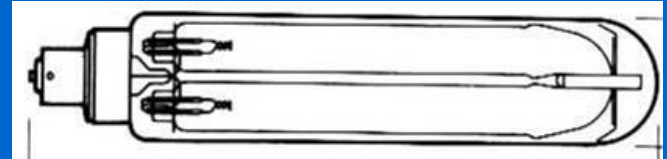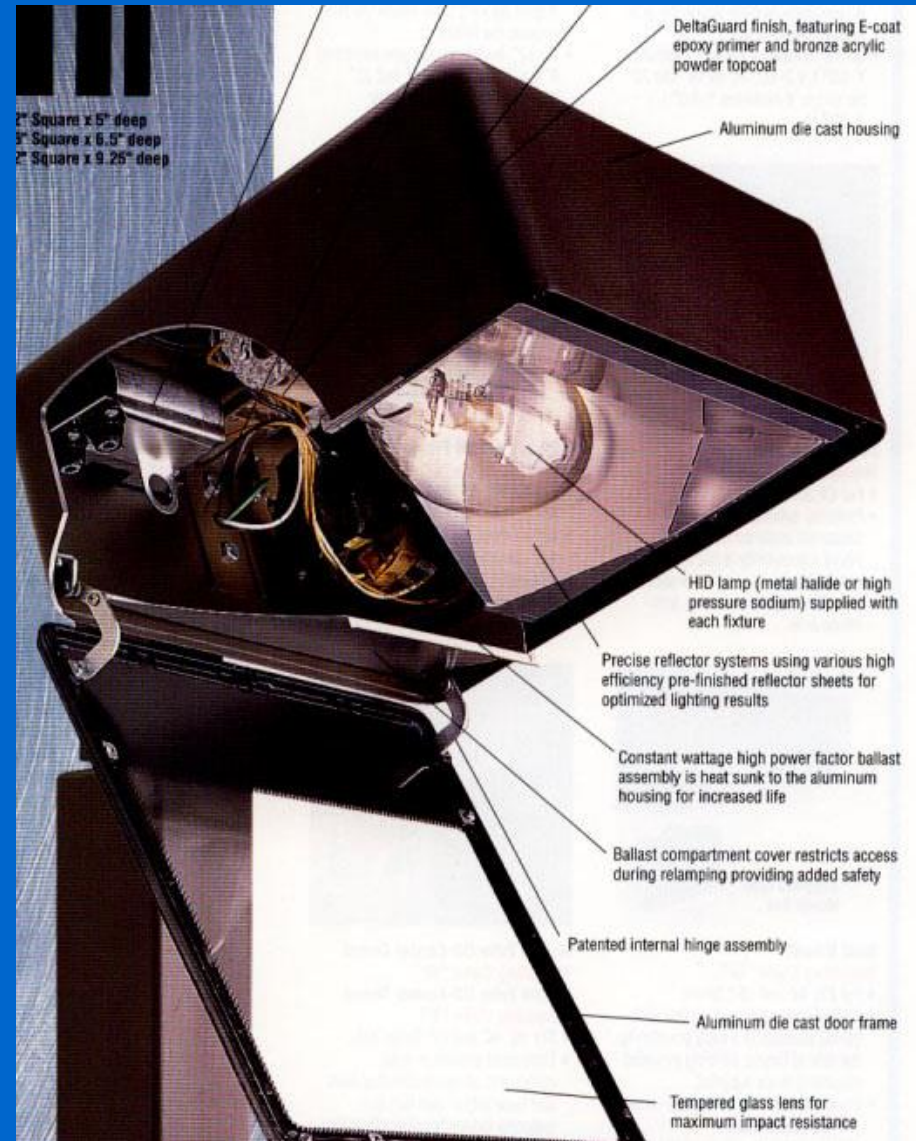
Lamp Lumen Depreciation

FIGURE 3: Lamp Lumen Depreciation (LLD) of Commonly Used Lamps

A Luminaire

- A luminaire consists of the lamp, optics, electrical components and housing.

- Does the light get out efficiently?

- Where does it go?

DeltaGuard finish, featuring E-coat epoxy primer and bronze acrylic powder topcoat

Aluminum die cast housing

2" Square x 5" deep
3" Square x 6.5" deep
2" Square x 9.25" deep

HID lamp (metal halide or high pressure sodium) supplied with each fixture

Precise reflector systems using various high efficiency pre-finished reflector sheets for optimized lighting results

Constant wattage high power factor ballast assembly is heat sunk to the aluminum housing for increased life

Ballast compartment cover restricts access during relamping providing added safety

Patented internal hinge assembly

Aluminum die cast door frame

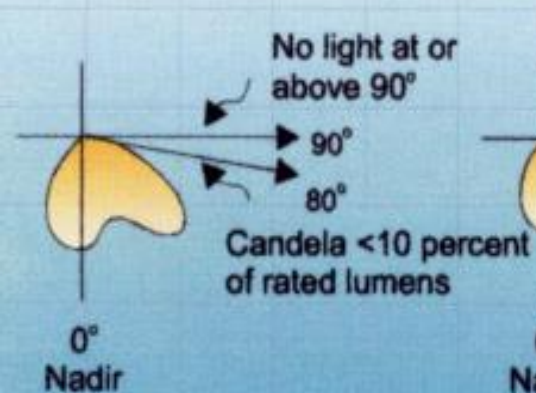Tempered glass lens for maximum impact resistance
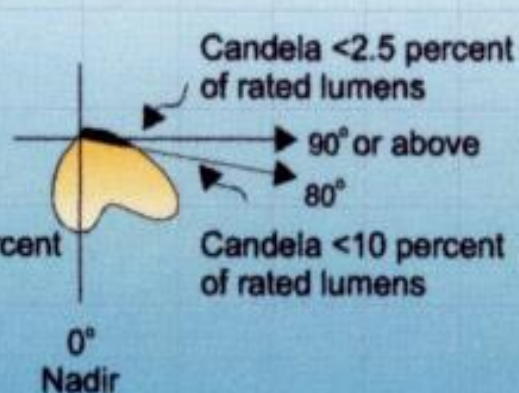
Luminaire descriptors

- There is an enormous variety of shapes and sizes: shoeboxes, hockey pucks, cobra heads, globes, lanterns, barn lights, wall packs, bollards, etc

- The *coefficient of utilization* (CU) is the quantity of light falling where intended compared to the total lumens from the lamp in the fixture

- *Light Loss Factor* (LLF): a multiplier to account for dirt accumulation, LLD, operation and maintenance conditions and applied by a designer
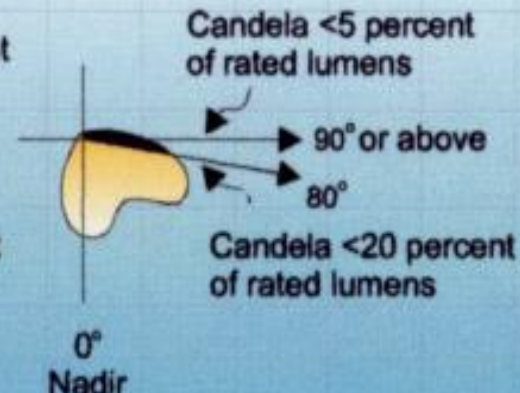
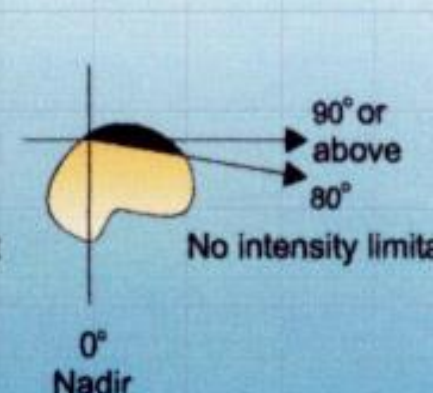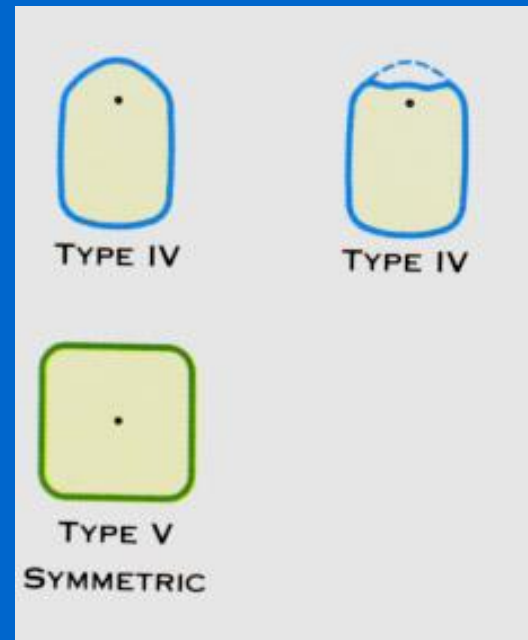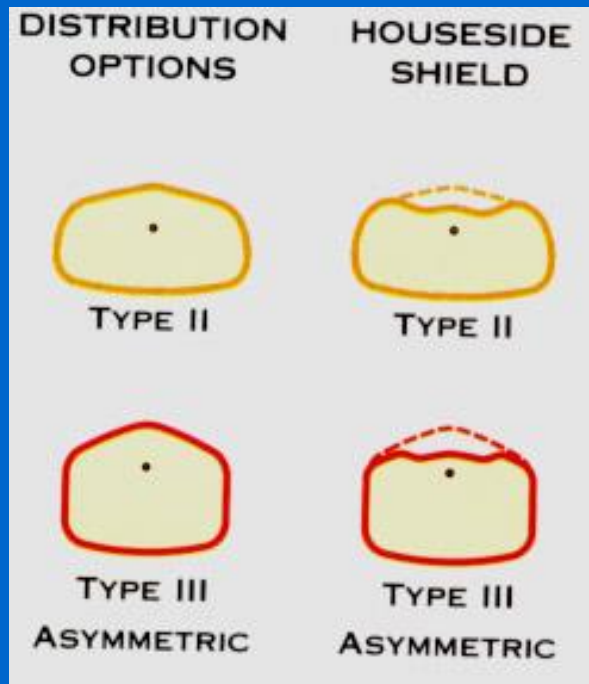# Fixture Cutoff Classifications

Full Cutoff

No light at or above 90°
90°
80°
Candela <10 percent of rated lumens
0°
Nadir

Cutoff

Candela <2.5 percent of rated lumens
90° or above
80°
Candela <10 percent of rated lumens
0°
Nadir

Semicutoff

Candela <5 percent of rated lumens
90° or above
80°
Candela <20 percent of rated lumens
0°
Nadir

Noncutoff

90° or above
80°
No intensity limit
0°
Nadir

IESNA Luminaire Distributions

DISTRIBUTION OPTIONS — HOUSESIDE SHIELD

TYPE II — TYPE II

TYPE III ASYMMETRIC — TYPE III ASYMMETRIC

TYPE IV — TYPE IV

TYPE V SYMMETRIC

in fixture Product No.

Candela Distribution

Little light emitted from socket end

Socket
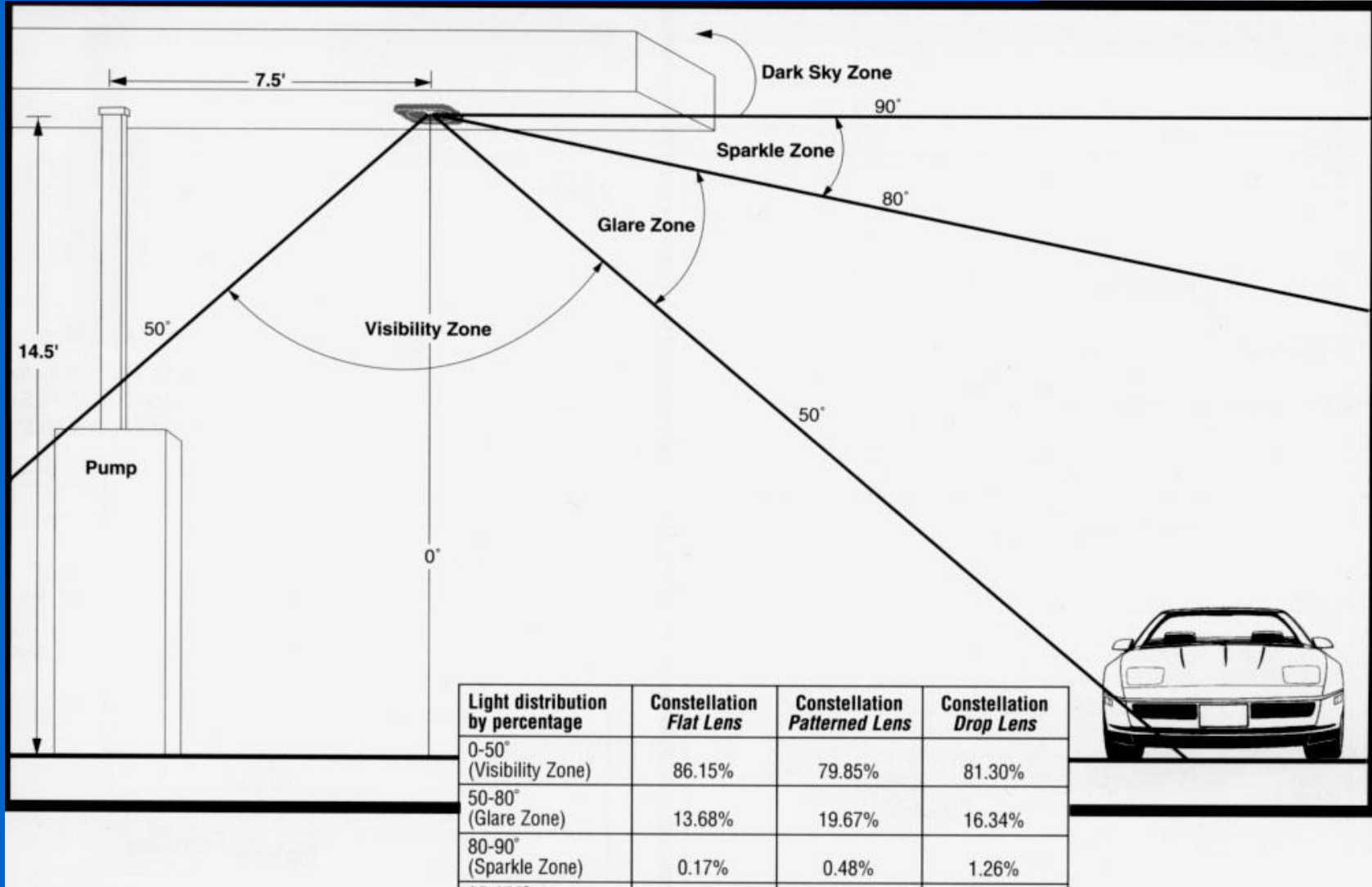
Arc Tube

Little light emitted from lamp tip

Greatest energy emitted perpendicular to arc tube
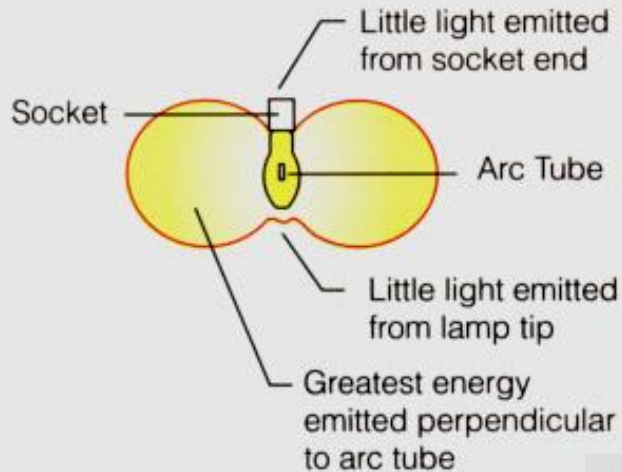
LAMP, REFLECTOR, AND LENS INTERACTION

Raw lamp distribution

Upper reflector directs light to higher angles

Compact Profile

Direct distribution from lamp provides illumination directly below luminaire
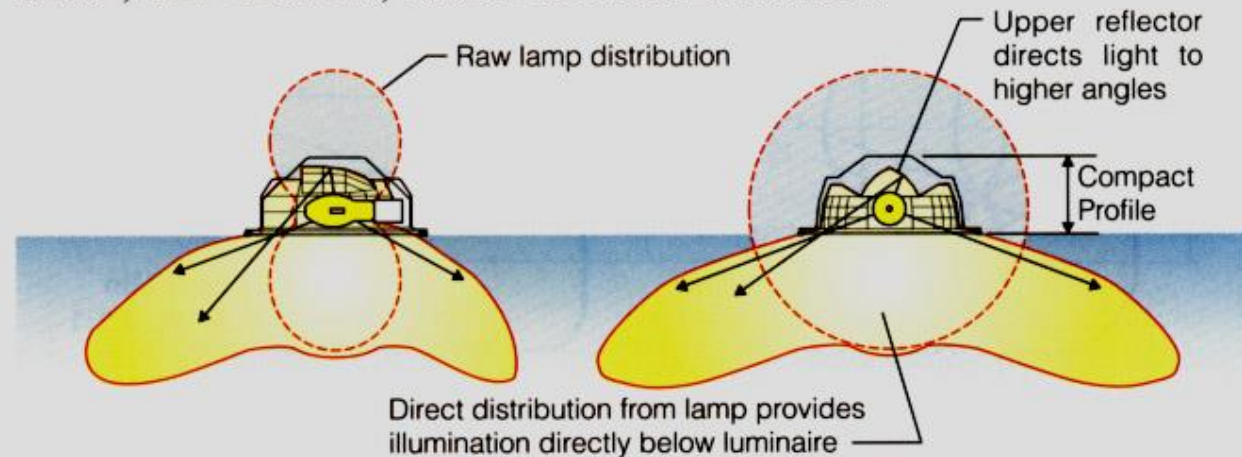
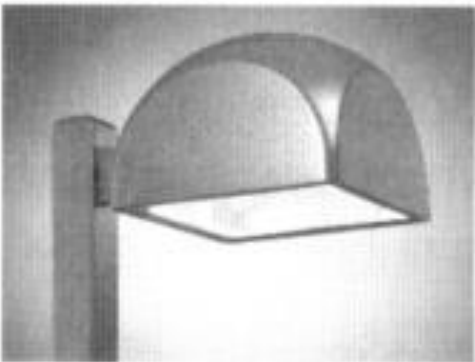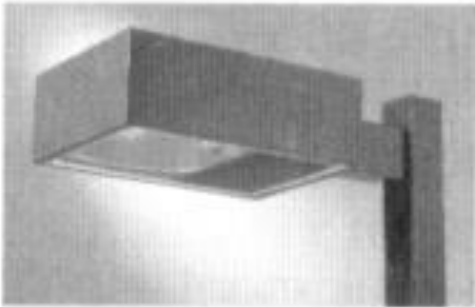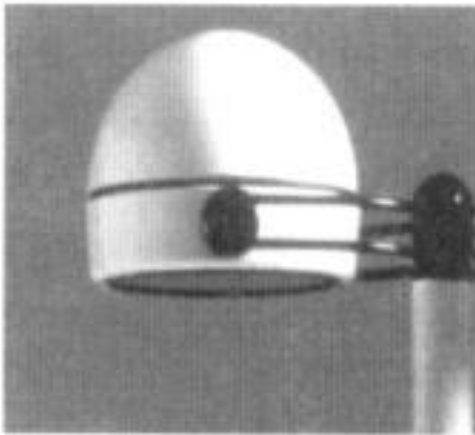**HORIZONTAL LAMP WITH FLAT LENS** is well suited for asymmetric distributions with very sharp cutoff control.

Zonal Lumens

| Light distribution by percentage	Constellation *Flat Lens*	Constellation *Patterned Lens*	Constellation *Drop Lens*
0-50° (Visibility Zone)	86.15%	79.85%	81.30%
50-80° (Glare Zone)	13.68%	19.67%	16.34%
80-90° (Sparkle Zone)	0.17%	0.48%	1.26%
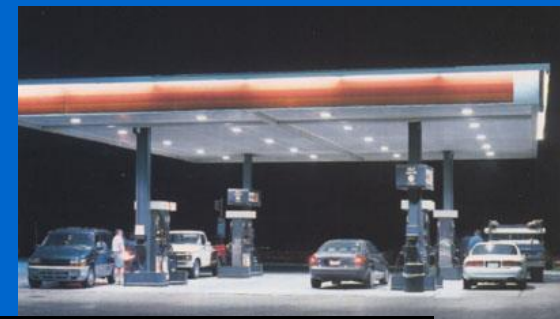
Architectural Luminaires

Applications: Roadways, Parking lots, Walkways, etc. where daytime appearance and/or light pollution and trespass are important.

Sources: HPS, Metal Halide- 70-400 watts

Distribution: Roadway types I to V, forward throw.

Mounting: Structures and poles 15' or higher with decorative arms

Controls: Time clocks, photo-cells
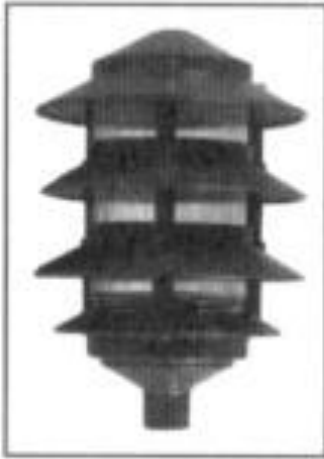
Landscape Luminaires

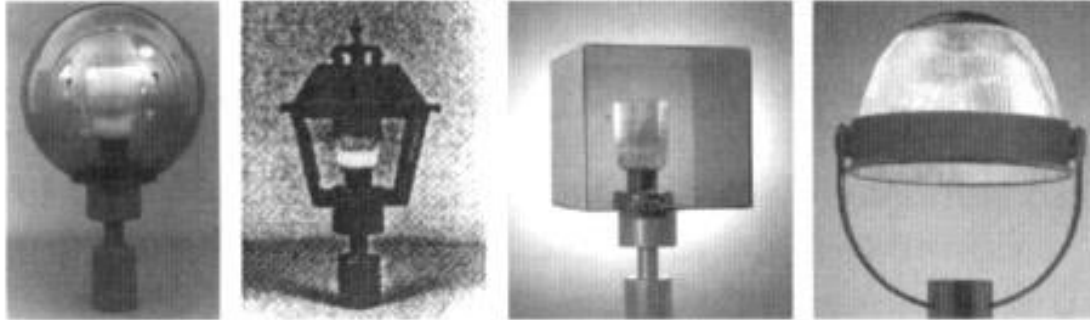**Applications:** Residential, small commercial
Sources: Incandescent, fluorescent, metal-halide, mercury, HPS
Distribution: Floodlight and Type V
Mounting: Ground, trees, structures
Controls: Time clocks, photo-cells, motion detectors (incandescent only)

Post-tops

Post-top Luminaire
A wide varioety of styles in clear and colored enclosures

Applications: Walkways, residential parking areas where lower lighting levels are satisfactory
Sources: Incandescent, fluorescent, metal-halide, HPS
Distribution: Symmetrical, most with uplight
Mounting: Wall bracket, poles up to 15'
Controls: Time clocks, photo-cells

General purpose fixtures

General Purpose Floodlights

Applications: Parking areas, recreation, facade lighting

Sources: Incandescent, Fluore-scent, HPS, Metal Halide

Distributions: NEMA types 1-7. **Note:** Rectangular units have Horizontal X Vertical designations. 3X6 etc.

Mounting: Poles, structures, ground

Controls: Time clocks, photo-cells, motion detectors (incandescent only)

Prismatic   Cutoff

General Purpose Luminaires

Applications: Small parking and rural areas. Cutoff units reduce glare, light pollution and trespass.
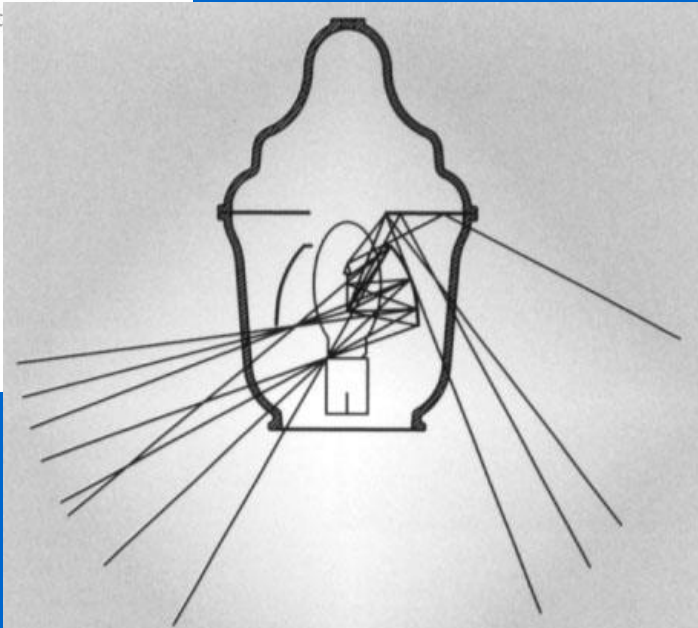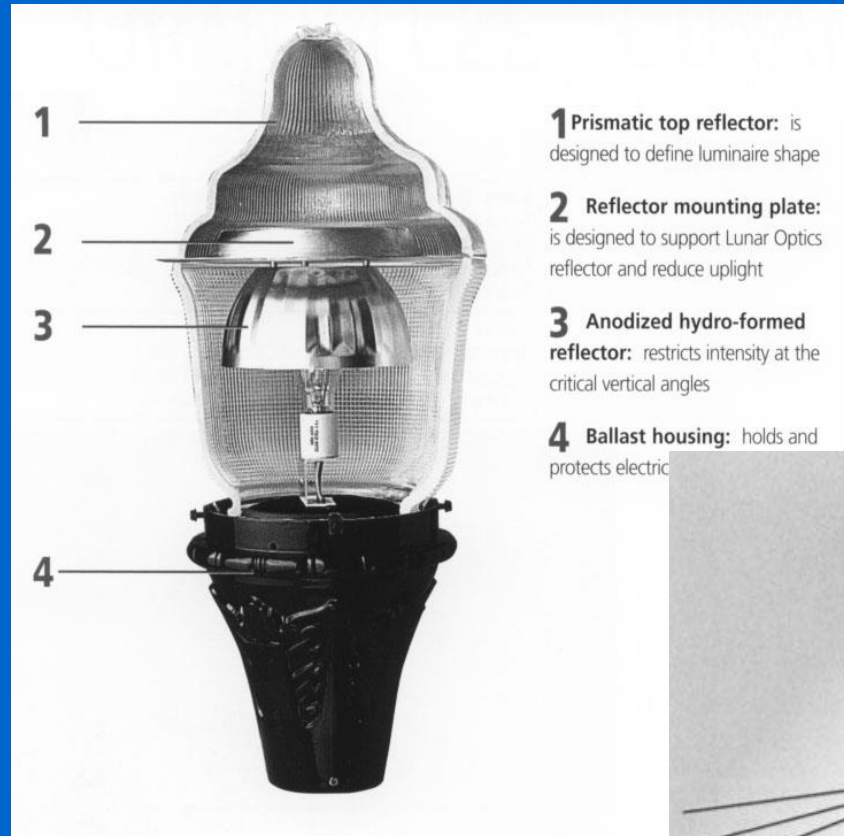**Sources:** Mercury, HPS, Metal Halide-70-150 watts
Distribution: Roadway type V
Mounting: Structures and poles
**Controls:** Time clocks and photo-cells

Post-top example

1 Prismatic top reflector: is designed to define luminaire shape

2 Reflector mounting plate: is designed to support Lunar Optics reflector and reduce uplight

3 Anodized hydro-formed reflector: restricts intensity at the critical vertical angles

4 Ballast housing: holds and protects electric

The GranVille
type II, III, V
most lamps
house side shields

Lunar Optics has been designed to reduce the lighting intensity at the critical vertical angles to achieve IES Cutoff.

pai 7 Mar 2005

UVa Edgewater

Spring City EFED7-VC5-100MH-Quad
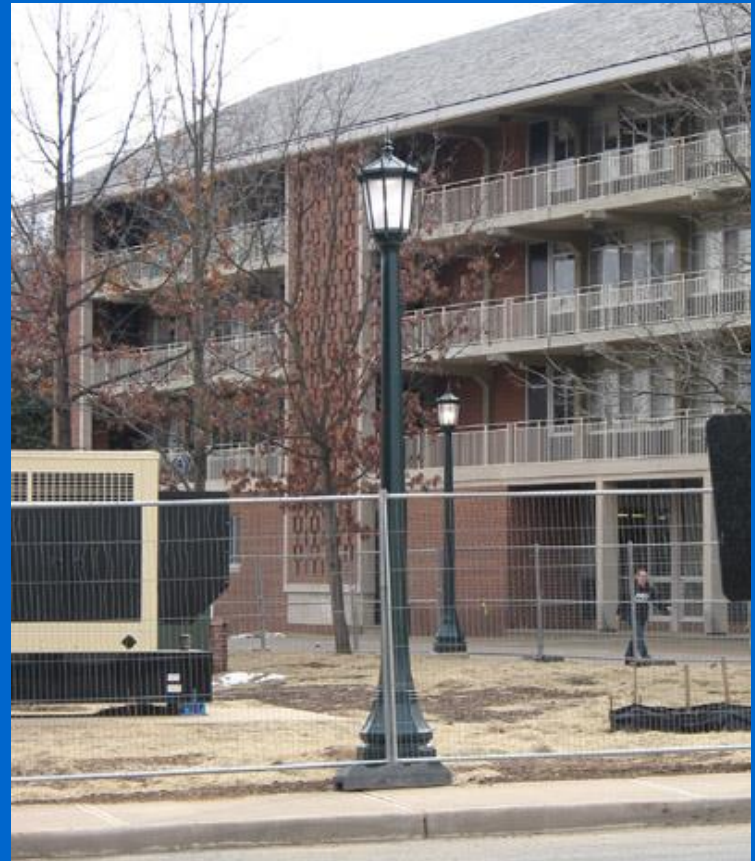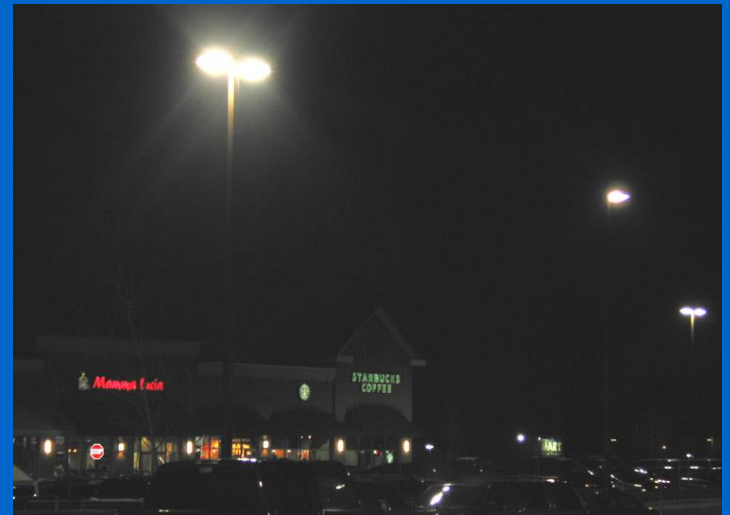
Lumec Post Top

Sag Lens Area Fixture
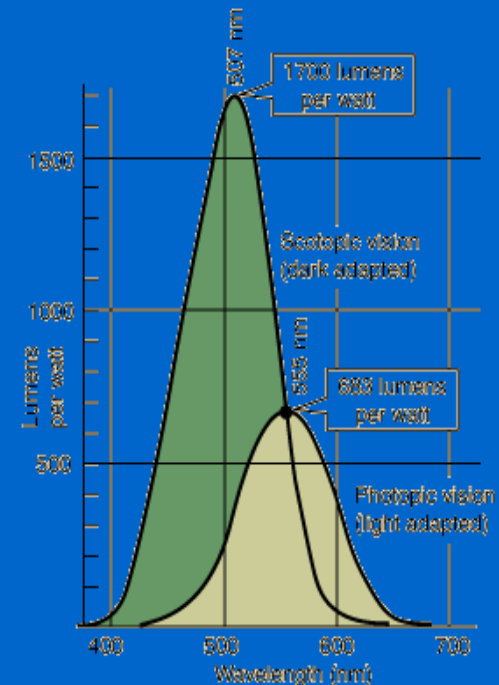
How much light do we need?

Full Moonlight: 0.02 fc

Dark Sky 0.0004 cd/m^2

Photopic level: > 3 cd/m^2; Scotopic: <0.003 cd/m^2

can see ~ 0.000001 cd/m^2

Scotopic, Mesopic, Photopic issues

IESNA RP 2, 8, & 33, G-1

Recommended Minimum Illuminances

Minimum Average Maintained Horizontal Illuminance Levels

Sidewalks	
Commercial Area	1.0
Residential Area	0.2
Car Dealerships at Roadway	10-20 Max
Pump Island Area	
Dark Surrounds	5.0
Light Surrounds	10.0

The Thomas Jefferson Light

1.3 Billion candlepower

Seen from Spartanburg, SC

Used for nighttime road construction, and runway light at "Wood's Field"

Charlottesville's 1925 Monticello Hotel, once the proud bearer of a very bright light.
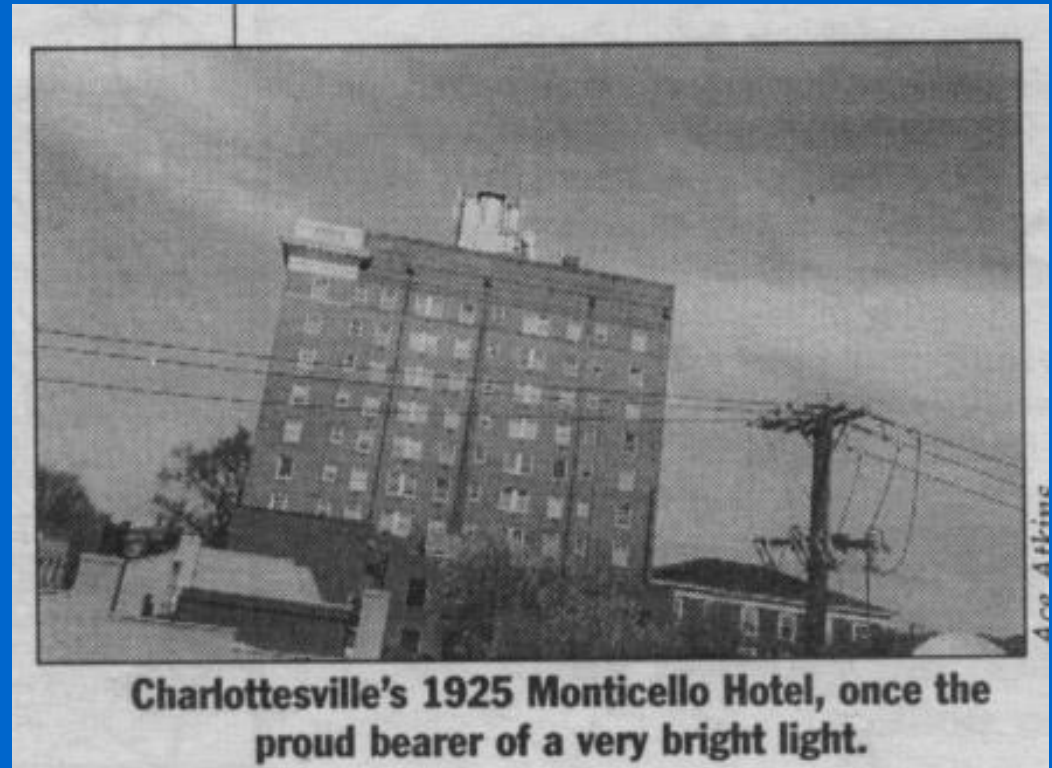
Web resources

- [IDA] www.darksky.org
- [gen. info.] www.lightsearch.com
- [gen. info.] www.lighting.com
- [lamps] www.VentureLighting.com
- [lamps] www.sylvania.com
- [info] www.nema.org
- [world map] www.lightpollution.it/dmsp/
- [turtles] www.turtletime.org/lighting/cover.htm
- [lighting] www.newbuildings.org
- [lighting] www.energy.ca.gov/outdoor_lighting/index.html
- [birds] www.flap.org
- [pop] www.npg.org

The End