Mercury vapor lamps (수은등)

- The first HID lamp
- A mercury-vapor lamp operates by passing an electric arc through high-pressure mercury vapor contained in a quartz arc tube.
- This produces radiation in both the UV region (as in the low-pressure fluorescent lamp tube) and the visible region, principally in the blue–green band.
- The outer glass bulb (even a clear bulb) absorbs most of the UV radiation while transmitting light. (Fig. 15.16)
- Low CRI and low efficacy → being replaced by MH/L, HPS lamps (현재 거의 적용되지 않음)
- Principally in outdoor applications (light streets, gymnasiums, sports arenas), and in relatively inaccessible locations because of its reliability, extremely long life (24,000h), acceptable efficacy (25-55 lpw), and low price.

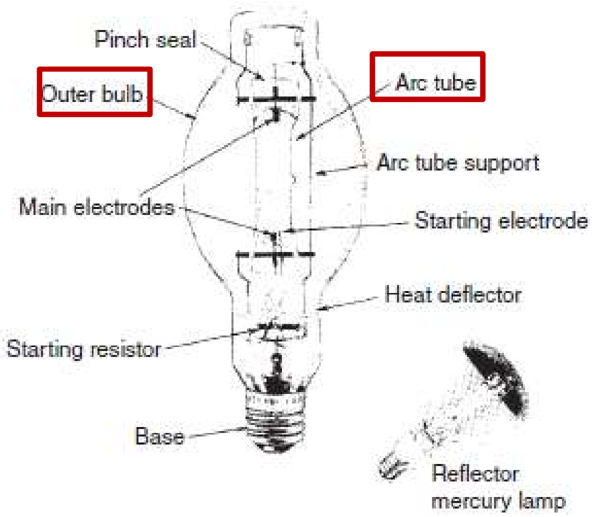


Fig. 15.16 Construction of a typical clear mercury-vapor lamp.

Characteristics

- UV radiation: If the outer bulb is broken, the unfiltered UV radiation becomes a safety hazard to the skin and eyes.
- Lamp life: 24,000h or more based on 10 burning hours per start (not suitable for applications subject to constant switching)
- Color rendering
  - Clear lamp CRI = 20, deluxe white lamp = 50
  - Blue-green light from a clear mercury lamp distorts almost all object colors.
- Efficacy
  - 50W bulb = 25 lpw
  - 1,000W bulb = 55 lpw

Two mercury vapor streetlights mounted on the side of this house are much too big and bright for the purpose illuminating the driveway. The glare is terribly blinding and unpleasant as well...especially for the neighbors whose windows are only a few feet away. (http://www.cofc.edu/~richardt/LPStuff/LPInfo.htm)

Characteristics

- From 3 to 6 minutes are required for a lamp to reach full output because heat must be generated by electron flow to vaporize the mercury in the arc tube before the arc will strike.
- Once turned off, a lamp must cool before restrike. This restart delay amounts to 3 to 8 minutes → important consideration in design.(Momentary power outage leave the interior space in the dark. Other lamps must be used together specially for interior area)
- Dimming도 가능
- Self-ballasted lamps (a lamp with an internal ballast): the ballast is integrated into the lamp as a non-removable part.
- Applications:
  - parking lots, light streets, where color rendition is not important
  - Disappearing in the market

Metal-Halide lamps (MH/L)

- Began in the early 1960s as a modified mercury-vapor lamp.
- By the addition of the halides such as thallium, indium, and sodium (수은등에 할로겐 화합물 첨가), resulting in the changes in the output, efficacy, color, and lamp life.
- Lamp configuration: similar to mercury lamp (Figs.15.17, 15.18)
- Better CRI and efficacy than mercury lamp
  - Efficacy: 75 – 105 lpw
  - CRI: 65 – 85
  - Life: 10,000 – 20,000 h (10 hours per start)
  - Wattage rating: 50 – 1,500 W
- MH/L arc tubes have a tendency to explode; therefore, the lamp must be used in an approved enclosing luminaire.

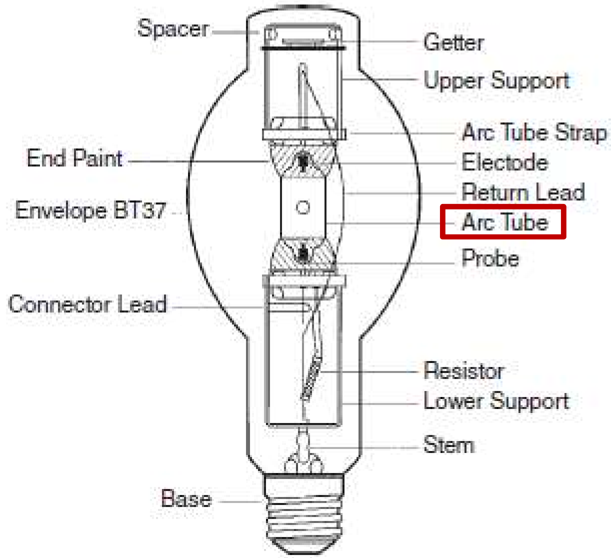


Fig. 15.17 Construction details of a 400-W standard metal-halide lamp, which can be mounted either horizontally or vertically. (Courtesy of OSRAM Sylvania.)

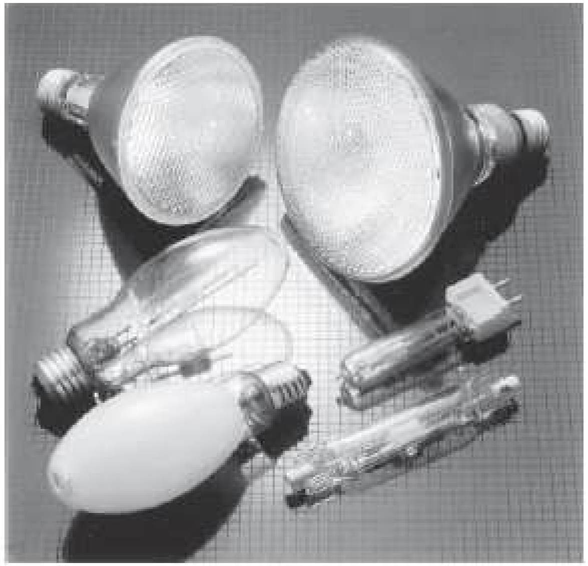


Fig. 15.18 Various configurations of metal-halide lamps. Clockwise from the bottom left: phosphor-coated and clear elliptical bulbs; PAR 30 and 38 reflector lamps; single-ended and double-ended tubular lamps—all have ceramic arc tubes and a CRI greater than 80. (Courtesy of GE Lighting.)

MH/L operating characteristics

- Not instant-starting: 2 to 3 minutes for initial startup and 8 to 10 minutes for restrike. → When used for indoor installations, a secondary instant-start source must be available.
- The light spectrum of a MH/L changes as a lamp ages. → Where color rendering is important, or where the lamp is used with other light sources, a designer should choose metal–halide lamps that are specially made for color stability. (e.g. not to vary in CCT more than 200K over the lamp life).
- Dimming is not recommended because of the very noticeable color shift that occurs when dimmed.

MH/L applications: where color rendition is important

- Excellent color characteristics → almost unlimited applicability
- Interior: malls, manufacturing plants, supermarkets
- Exterior: stadiums, parking lots

Courtesy of Lightolier

High Pressure Sodium Lamps (HPS/L): 고압나트륨등

- Type: Figs. 15.20, 14.21
- Operating characteristics
  - Wattage: 50 to 1,000
  - Lamp efficacy: 65 – 135 lpw
  - Efficacy (w/ ballast loss): 55-115 lpw
  - Lamp life: 24,000 h (10h/start)
  - Lumen maintenance: 80-90% at 50% life
  - Warm up time: 3-4 min
  - Restrike time: 30 seconds – 1min 30 seconds
  - extremely low CRI: 20 - 22 (in exterior areas and for road lighting)
- Color-corrected HPS: Table 14.8 (12th Ed.) (at the expense of efficacy and lamp life)

High pressure sodium wall-mounted lamp. Note the color difference between the HPS light and the background sunlight (http://calgary.rasc.ca/lp/definitions.html)

HPS/L characteristics

- In contrast to mercury-vapor and metal–halide lamps, high-pressure sodium lamps do not emit any appreciable UV radiation.

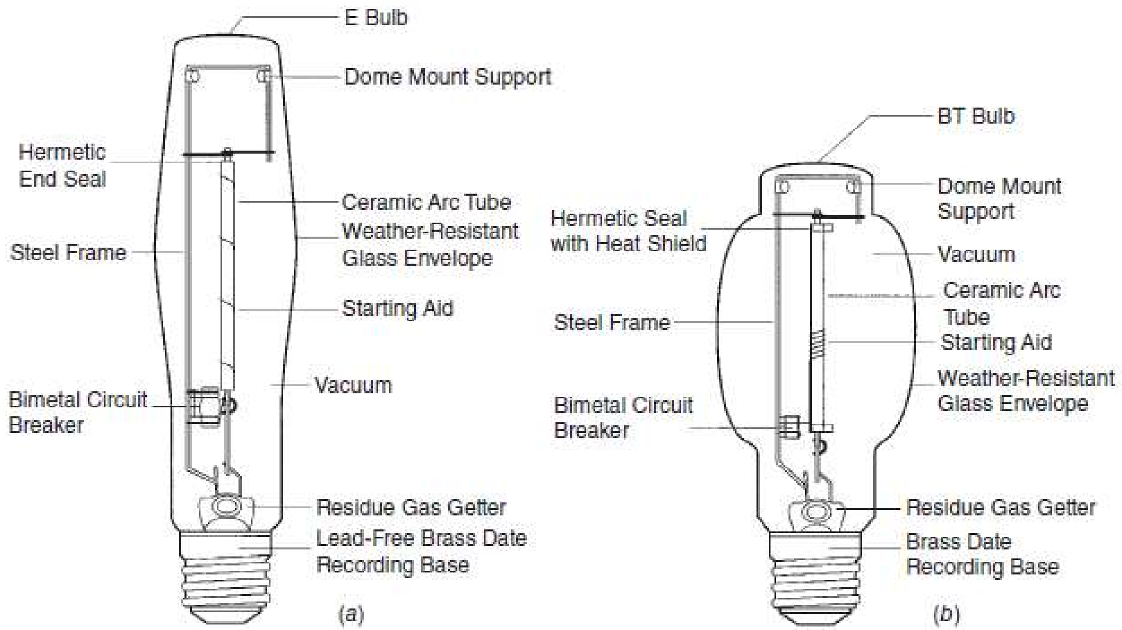


Fig. 15.20 *Simplified drawings of the internal construction of two high-pressure sodium (SON) lamp designs. (a) Noncycling lamp (in an E-shaped glass bulb) designed to indicate by a special color when the lamp has reached the replacement stage. Unlike standard HPS lamps, this lamp will not cycle on and off at the end of its useful life. (b) Retrofit HPS (SON) lamp in a BT bulb, intended for direct replacement of an existing mercury-vapor lamp. This lamp operates efficiently on a mercury-lamp ballast. (Drawings courtesy of OSRAM Sylvania.)*

Image source: MEEB 12th Ed.

TABLE 14.8 Typical Data for Clear[a] High-Pressure Sodium-Vapor Lamps

Watts	Bulb[b]	Life (H)	Initial Lumens[c]	Lamp Efficacy (LM/W)[d]
	"WHITE" LAMPS: CRI: 85, CCT: 2700 K			
35	T10	10,000	1250	36
50	ED-17	10,000	2000	40
100	ED-17	10,000	4200	42
COLOR-CORRECTED LAMPS: CRI: 60, CCT: 2200–2300 K				
100	ED-17	15,000	7300	73
250	ED-18	15,000	22,000	88
400	ED-18	15,000	37,000	93
STANDARD HPS LAMPS: CRI: 22, CCT: 1900–2100 K				
50	ED-17	24,000+	4000	80
100	ED-17	24,000+	9500	95
250	ET-18	24,000+	28,000	112
400	ET-18	24,000+	48,000	120
750	BT-37	24,000+	110,000	147
1000	E-25	24,000+	133,000	133

Note: Data extracted from current manufacturers' catalogs.

[a]Data are identical for coated lamps except for bulb shapes and lumen output.

[b]Other bulb shapes are available in some sizes. See Fig. 14.15 for bulb data.

[c]Initial lumens for coated lamps are 6% to 9% lower.

[d]Based on initial lumens. Efficacy with ballast is approximately 10% lower.

Low-pressure sodium lamps (SOX):저압 나트륨등

- monochromatic saturated yellow color → inapplicable for general lighting
- Very high efficacy: 150+ lpw
- Lamp life: 18,000h+
- 100% lumen maintenance
- CRI close to 0
- Applied wherever color rendition is not an important criterion but energy efficiency is. Thus, SOX lamps are used for street, road, parking lot, and pathway lighting.

The characteristic golden yellow color of low pressure sodium. This fixture is shielded to put most of the light onto the ground. (http://calgary.rasc.ca/lp/definitions.html)

Solid state lighting

- LED (Light-Emitting Diodes)
- LEDs have been used in 1960s.
- Common LED uses in architectural illumination:
  - signage, retail displays, emergency lighting (exit and emergency signs) and accent lights for pathways.
  - Nowadays, increased use in residential and commercial projects.

Primary characteristics of LED

- Lamp life: easy to install, last longer than incandescent or fluorescent lamps: some claims suggest 25,000+ hours.
- Available in a full range of colors, are small (3mm across, micro light source), and have a fast response.
- A very broad range of color temperature from 2200 K to 7000 K
- a typical CRI value = 82. This matches fluorescent lamp. An extended color range of the LEDs can produce up to CRI of 90.
  - LEDS emits narrow wavelengths of red, green, and blue (R, G, B).
  - Either combining more than 3 diode colors (RGB) (color-mixed) or use RGB in combination with a phosphor → higher CRI

Dimming of LED

- Reducing voltage and current is not recommended (negative impact on efficacy, noticeable variation in CCT)
- For most LED lamps: "pulsewidth modulation" (PWM) used.
- This causes the LED to flicker off and on at a rate that is undetectable to the human eye.
- By controlling the rate of flicker and the cycle of light output, it is possible to reduce the amount of light emitted from the lamp source.
- Most LED drivers have been designed with a PWM generator, which controls the on and off cycle of the LED lamp.
- Because the frequency of this altered signal should not be visible to the human eye, it is important to use a driver designed to work with the specific LED lamp assembly.

Primary characteristics of LED

- Good efficacy: (100-130 lumens per watt), do not produce nearly as much heat as an incandescent lamp
- Directional light output (as opposed to the spherical light output of a conventional bulb-shaped lamp)
- Improved environmental friendliness relative to mercury-based lamps
- Advantages: high efficacy and long lamp life (25,000+ hours)

Comparison between incandescent, CFL and LED

- Case I: a 60W incandescent
- Case II: a 14W CFL
- Case III: a 12W LED
- The 14W CFL has a payback period of only 0.3 years over the 60W incandescent (when operated 4 hours a day).
- The 12W LED takes closer to a year to break even with the cost of purchasing and operating a 60W incandescent, but the LED achieves the greatest life-cycle net cost savings. Despite the higher upfront costs of the lamp itself, the annual energy savings and extended lamp life (25,000 hours in this example) of the LED lamp means a greater life-cycle net cost savings over both the incandescent and CFL lamps.

TABLE 15.6 Comparison of Bulb Life, Annual Electricity Cost, and Life-cycle Energy Savings Between a Traditional 60W Incandescent, and a 14W CFL and 12W LED Lamp (Operated 4 Hours a Day)

	14W CFL	12W LED
Lamp Life	10,000 hours	25,000 hours
Annual Electricity Cost Savings	$8.00	$9.00
Life-cycle Energy $ Saved (%)	~77%	~80%
Life-cycle Net Cost savings*	$49	$110
Simple payback period**	0.3 years	1.0 years

Source: U.S. Department of Energy, How Energy-Efficient Light Bulbs Compare with Traditional Incandescents. https://www.energy.gov/energysaver/save-electricity-and-fuel/lighting-choices-save-you-money/how-energy-efficient-light.

**Life-cycle Net Cost Savings refers to the life-cycle electricity cost savings plus the avoided cost for replacement, minus the purchase price of the lamp.*

***Simple payback is the time required to offset the additional cost of the LED lamp through accrued savings in energy (ignoring the time value of money).*

Organic Light-Emitting Diodes (OLED)

- first introduced in digital displays such as computer monitors, television screens, and mobile phones, but are now being incorporated into architectural lighting applications.
- As a flexible emissive surface (Fig.15.24), OLED sources offer unique application potential.
- Philips Lighting offers a brand called “Lumiblade,” which contains a series of OLED panel products.

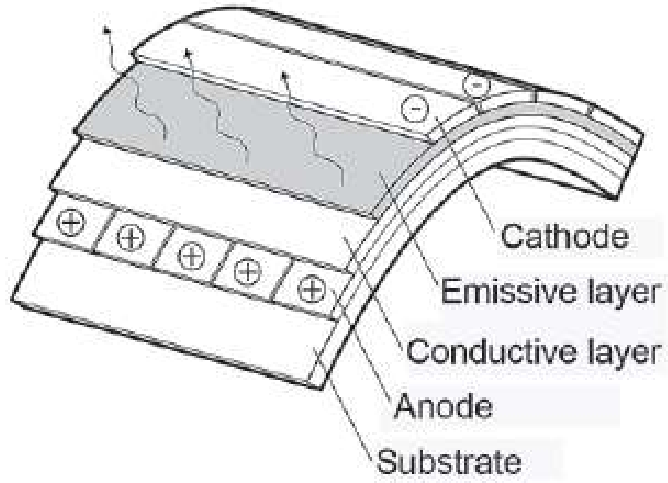
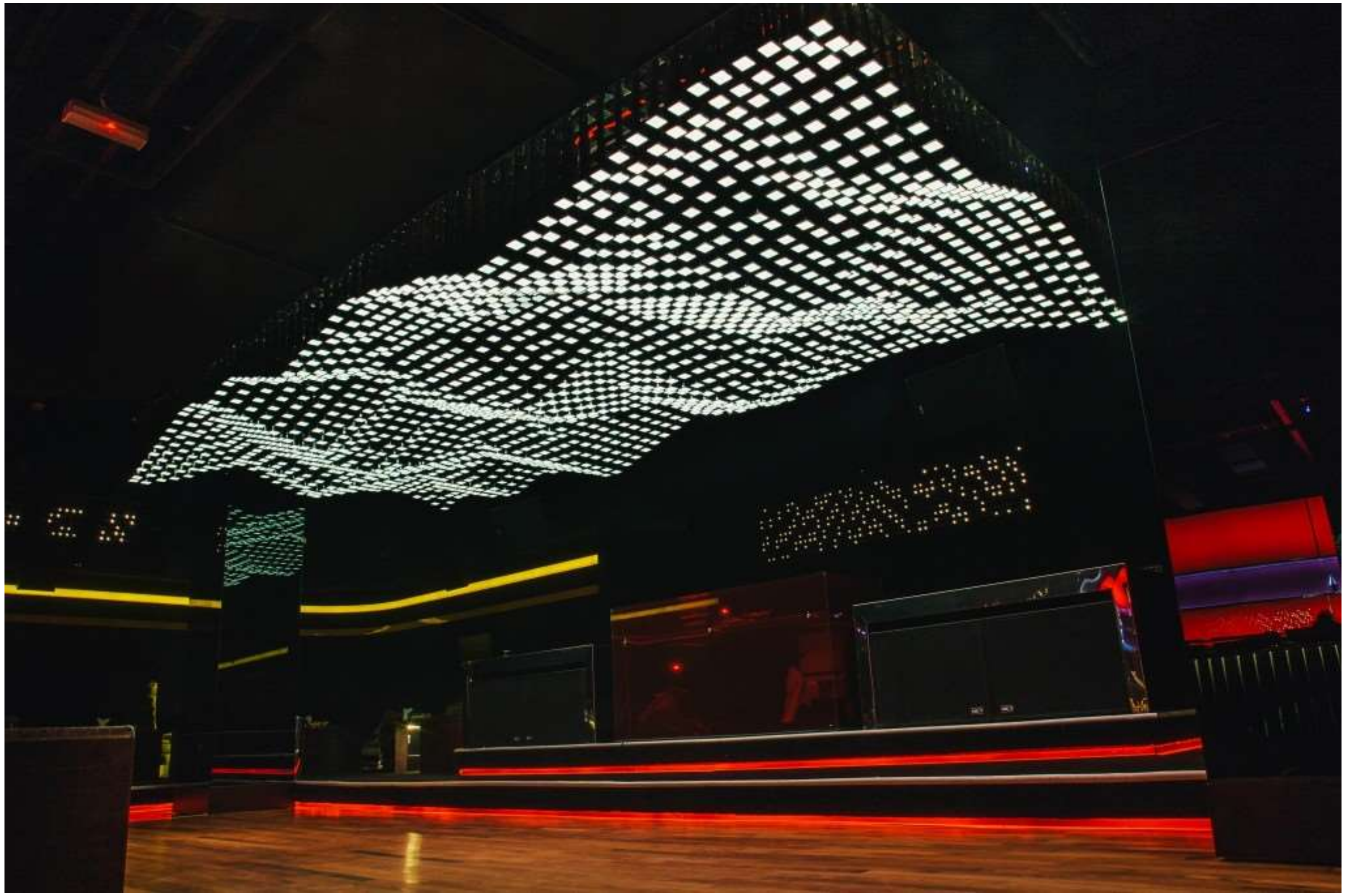


Fig. 15.24 *OLED structure. (Drawn by Siobhan Rockcastle, © University of Oregon, Baker Lighting Lab.)*

Examples



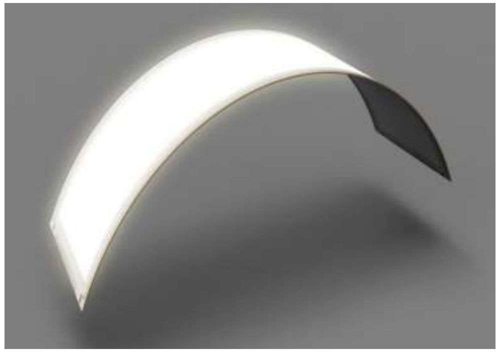
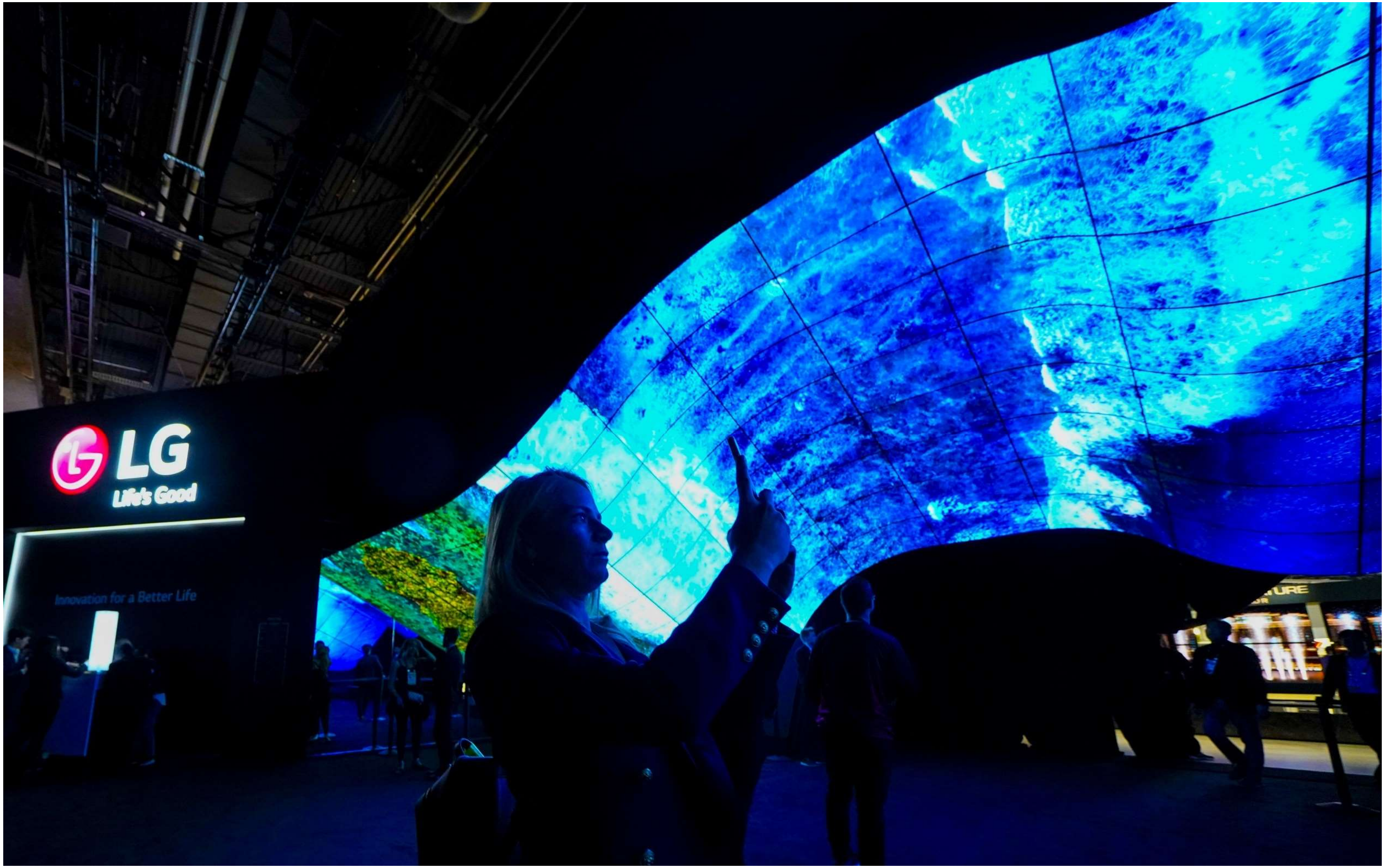


Image sources: http://en.olednet.com/category/focuson-en-en-en/lighting/
http://en.olednet.com/category/focuson-en-en-en/lighting/
https://www.architonic.com/en/microsite/philips-lumiblade-oled/3103808
http://p.ledinside.com/led/2014-01/1389767698_80163.jpg


LG
Life's Good
Innovation for a Better Life

Other lamps: Induction lamp (유도램프)

- Nikola Tesla demonstrated the technology in the late 1890s.
- Due to high upfront costs and the availability of other low-cost sources, this technology was not introduced to the market until the 1990s due to market pressure for energy-efficient solutions.
- This lamp is filled with low-pressure mercury vapor. When ionized by a high-frequency induction coil inside the lamp, the mercury vapor, produces UV radiation, which then strikes a phosphor coating on the inside of the lamp, producing light.
- Similar to the light-producing process of fluorescent lamps; the difference is that the gas is ionized by an induction coil rather than an electron stream (전극으로 방전하지 않아서 일명 무전극 램프로 호칭)

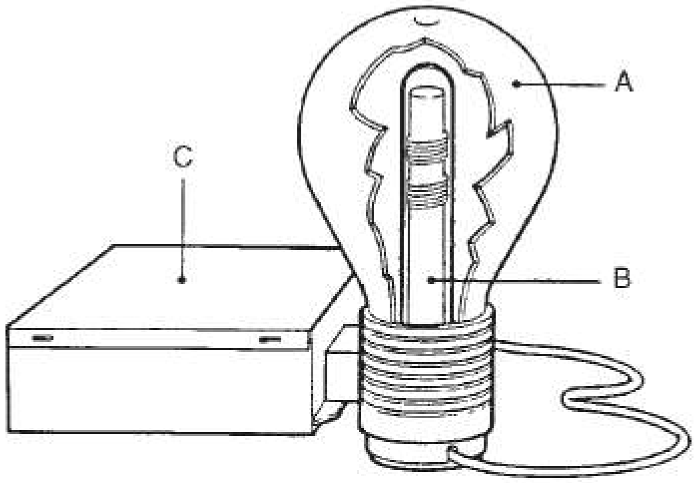


Fig. 15.25 Schematic diagram of an induction lamp (rated 85W, including all losses) showing the operating principles. The lamp is 4.3 in. (109 mm) in diameter and 7.5 in. (191 mm) high overall. The generator (C) produces a high-frequency current, which circulates in the coil on the power coupler (B). This ionizes the mercury vapor inside the lamp (A), producing UV radiation. The UV radiation strikes the fluorescent coating inside the lamp, producing light. (Illustration courtesy of Philips Lighting Company.)

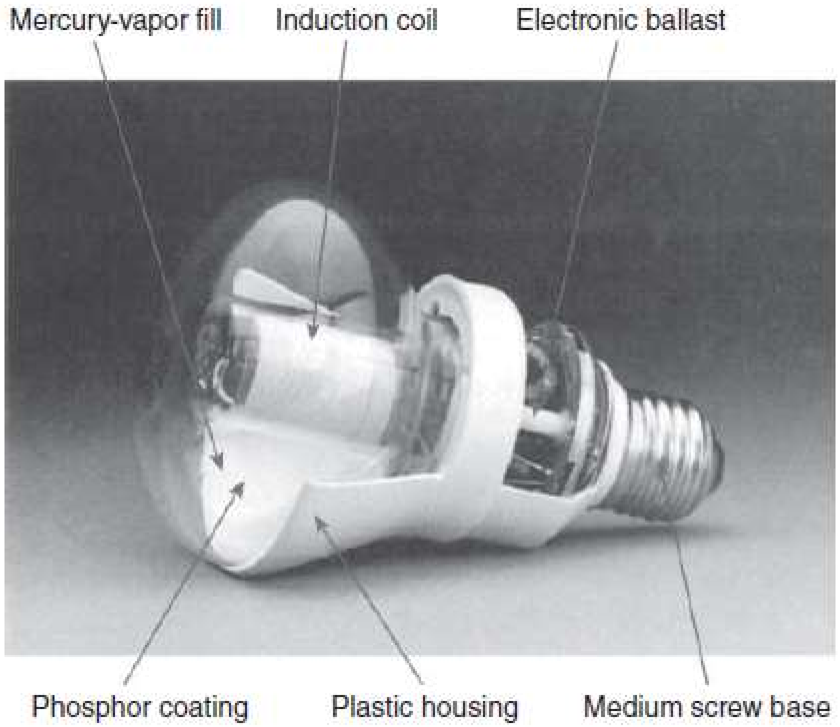
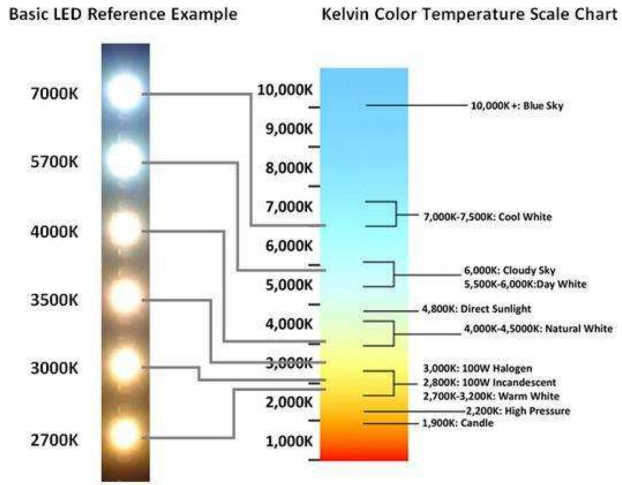


Fig. 15.26 Cutaway of the GE induction lamp showing the essential elements: induction coil, phosphor-coated bulb with mercury-vapor fill, and electronic ballast. This 23W lamp in a modified R (reflector)-shaped bulb has a height just under 5 in. (127 mm) overall and a 3 in. (76 mm) maximum bulb diameter. (Photo courtesy of GE Lighting.)

Induction lamp



- High upfront cost !!
- High efficacy: 70+ lm/w
- Excellent CRI: 80+
- Instant strike
- A broad range of color temperature: 2,700–6,500 K
- Extraordinarily long lamp life: 100,000 hrs
- Excellent lumen maintenance at 70% life: 75%
- Can be beneficially used where relamping is difficult (보수 교환이 어려운 장소에 적합)

Sulphur lamp

- A golf ball size globe filled with an inert gas and a few milligrams of sulphur (유황) powder
- Microwave energy excitation (the microwave energy excites the gas to five atmospheres pressure, which in turn heats the sulfur to an extreme degree forming a brightly glowing plasma capable of illuminating a large area.)
- A prototype lamp was a 6 kW unit that emitted more than 400,000 lumens (a lot of light).
- A more recent version
  - Initial lumens: 130,000 (101 lpw) w/ 1,320W input
  - Lamp life: 60,000 hours
  - Small size & full-spectrum light (CRI: 80)
  - CCT: 5,600K
  - Lumen maintenance: very high
  - Commercially available soon

Fiber optics

- Fiber optics
  - 1920s: available
  - 1950s: medical diagnostics
  - Recent years: communications
  - Architectural applications
  - Will be dealt with in Chapter 17.

Light guide

- Hollow light guides

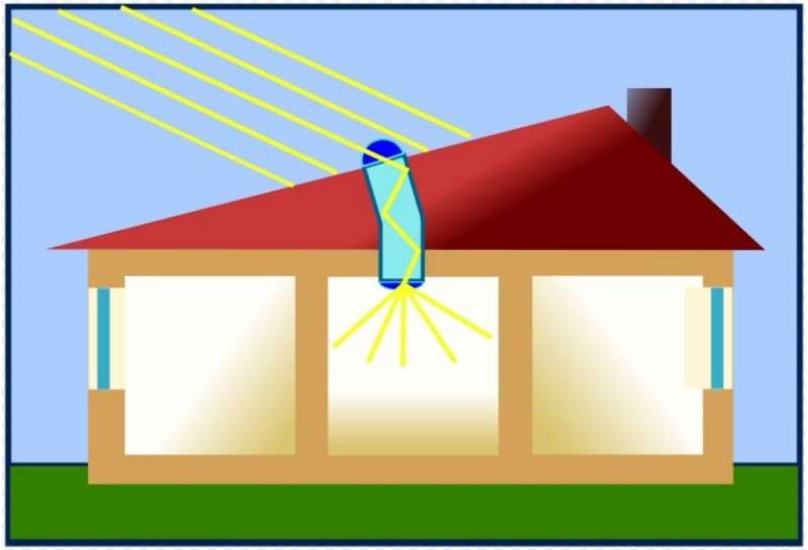


Image source: http://www.ics.ele.tue.nl/~akash/maartje/searchSystemsBySystem.php?ID=32&page=3

Tsinghua Univ. Low Energy Building

Luminaires (p.731)

Design considerations

- Overall uniform illuminance vs. local lighting only
- Control strategies
- Ceiling system (modular, movable, or integrated service)
- Ballast noise, luminaire heat distribution and maintenance
- Workstation mounted vs. built-in lighting

Luminaire characteristics

- The purpose of a luminaire or lighting fixture
  - (1) To hold, protect and electrify the light source
  - (2) to control the lamp output photometrically (i.e., reflectors, baffles, lenses, louvers)
- The problem in luminaire selection
  - The requirements are incompatible, and therefore a trade-off must be made.
  - For instance, high-efficiency installations can entail high fixture luminance with resultant glare.

Lighting fixture distribution characteristics

- Case (a)
  - Candle Power Distribution Curve (CDC): flat bottom
  - High Spacing-to-Mounting Height (from the luminaire to the working plane) (S/MH) ratio permitted
  - good uniformity
  - A fairly sharp cutoff angle, the small amount of light above 45° → high efficiency, insufficient wall lighting, little direct glare, a distinct possibility of reflected glare (refer to Fig. 6.23)
- Case (b)
  - CDC: rounded bottom
  - Closer spacing required for horizontal uniformity
  - Lower efficiency, direct glare potential, lower veiling reflection, higher diffuseness (light reaching by multiple reflections)

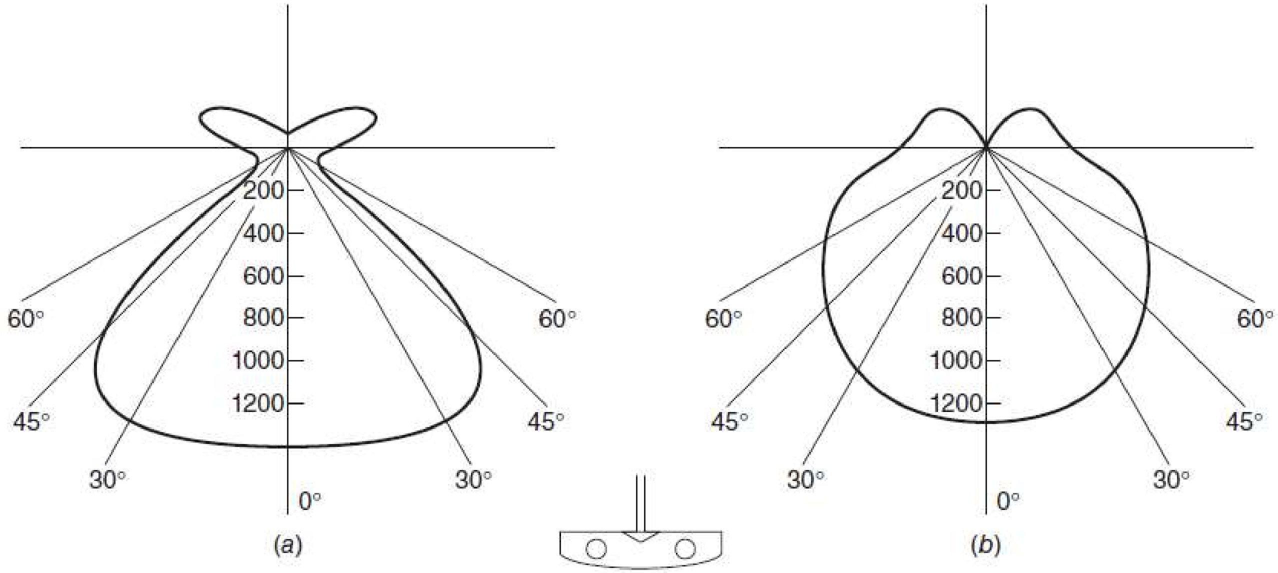


Fig. 15.27 Semi-direct fluorescent fixture crosswise distribution (two lamps, 32W each, prismatic enclosure). Note the sharp cutoff and wide, horizontally even distribution of (a) in contrast to the diffuse, broad, and horizontally uneven distribution of (b).

Shielding angle

- Shielding angle (=cutoff angle): defined as the angle between a horizontal plane through the louvers or baffles and the inclined plane at which the lamp first becomes visible as one approaches the fixture.
- For fluorescent lamps: 45°x35°(crosswise/lengthwise): excellent
- 35°x30°(crosswise/lengthwise): satisfactory (Fig.15.29)

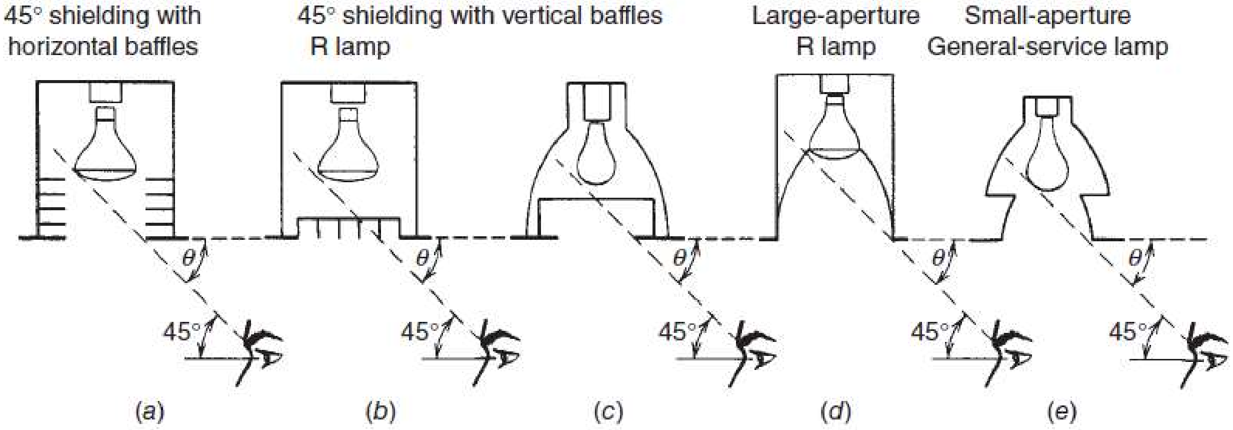


Fig. 15.28 Methods for shielding downlights using circular shields for vertically symmetrical sources such as incandescent and HID lamps. Halogen lamps mounted vertically in R lamp envelopes are symmetrical; horizontally mounted units in PAR or other reflectors are not. Baffled downlights (a–c) control unwanted high-angle light by cutoff as illustrated. Black baffles aid by absorbing light and appearing dark. Other colors give a ring of light at the baffled edge. Cones (d, e) control brightness by cutoff and by redirection of light due to their shape. They are either parabolic or elliptical. A light specular finish such as aluminum appears dull; a black specular finish appears unlighted. Black finishes require high-quality maintenance because dust shows as a bright reflection. CFL lamps in reflectors are not normally a serious direct glare concern and are considered to be vertically symmetrical. A shielding angle of 45° minimum is recommended for high-luminance lamps.

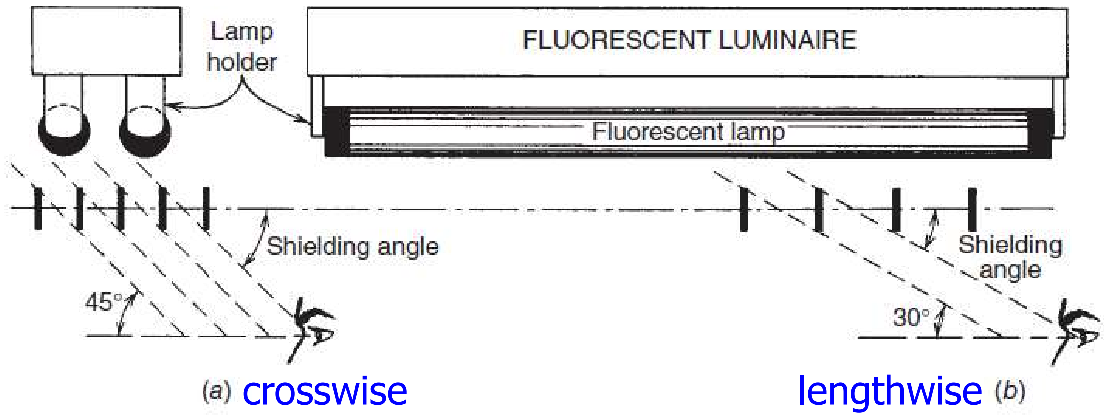


Fig. 15.29 Shielding of fluorescent lamps is less critical due to lower lamp luminance. For T12 lamps, 45° × 35° crosswise/lengthwise shielding as shown is excellent, and 35° × 30° is satisfactory. For T8 lamps, 45° × 35° should be used. Because fixture luminance is higher in the transverse direction (a) than lengthwise (b), a better cutoff angle is required. The shielding elements may be louvers or baffles. Opaque shielding elements provide better visual comfort than translucent plastic units.

Luminaire light control

- (a) Lamp shielding
  - Bare lamps are so bright and they usually become a source of direct glare.
  - Except where it is desired to use a bare lamp as a source of sparkle (e.g. chandeliers and other decorative fixtures), all lamps in interior fixtures should be shielded from normal sight lines.
  - Glare depends on the apprehended angle (closeness to the eye and the size of the lamp) and eye adaptation level.
  - In general, the range of permissible luminaire luminances is 1,000-7,000 cd/m^2 (Table 6.3, p.194) depending on variables (apprehended angle and eye adaptation level)
  - Lamp shielding (Figs. 15.28, 15.29, 15.30) is accomplished with the reflector or with baffles and louvers.

Shielding elements
1. Reflector
2. Baffles
3. Louvers
4. Two-way shields (3+4)

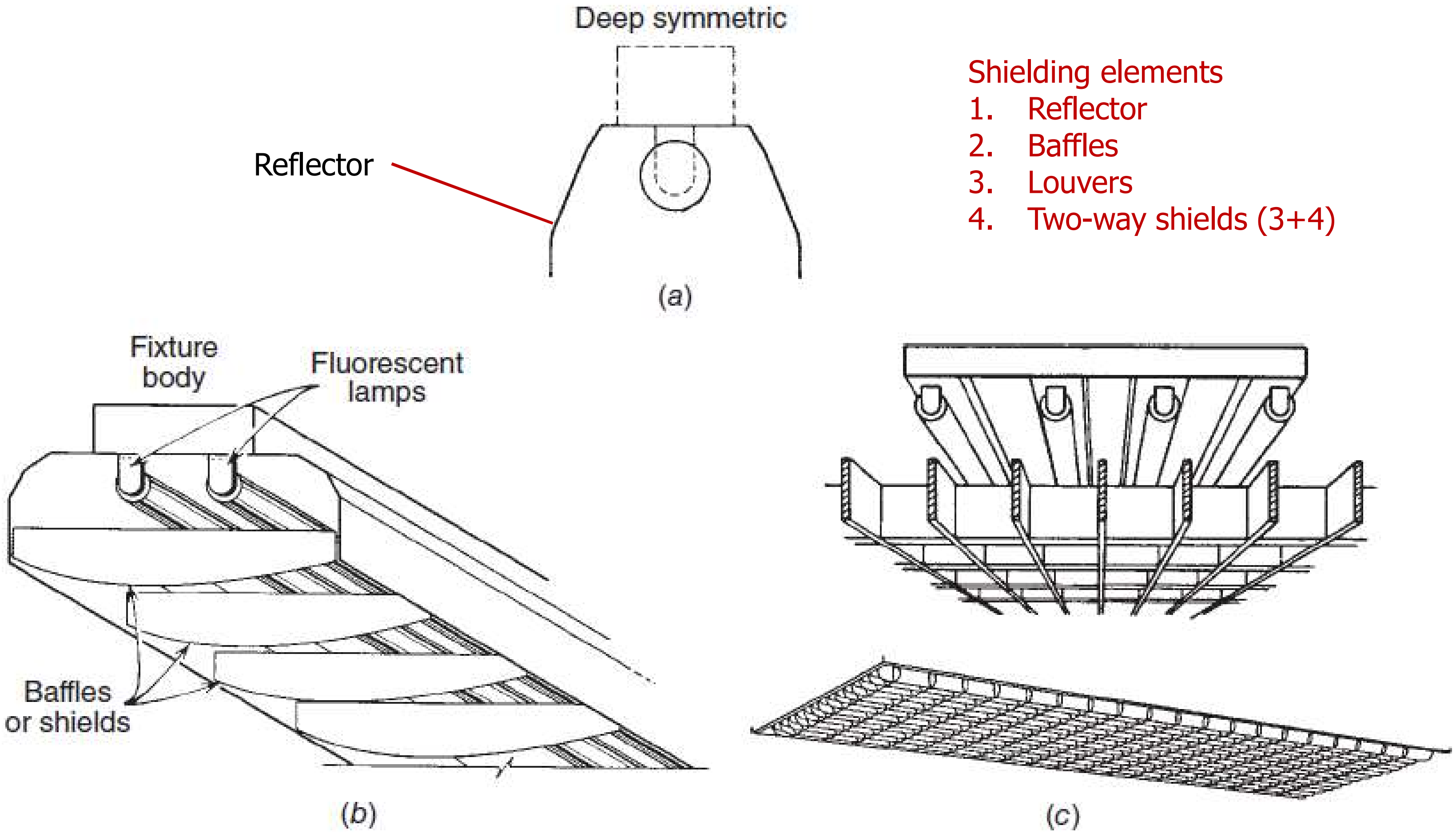


Fig. 15.30 *Shielding elements. (a) The most basic shielding element is the lamp reflector, which may double as the fixture body. (b) Shields perpendicular to the long axis of a linear fluorescent lamp are normally called baffles. They are less important than lengthwise shields (louvers) because endwise lamp luminance is lower than crosswise luminance. (c) Two-way shielding is most effective but seriously lessens luminaire efficiency. (From B. Stein. 1997.* Building Technology: Mechanical and Electrical Systems, *2nd ed.; reproduced by permission of John Wiley & Sons.)*

Parabolic reflector (포물선형 반사면)

- Reflector: the most basic shielding element. Also, a means for luminaire light control
- beam patterns from Fig. 15.31 to Fig. 15.33 → locations of source and focus

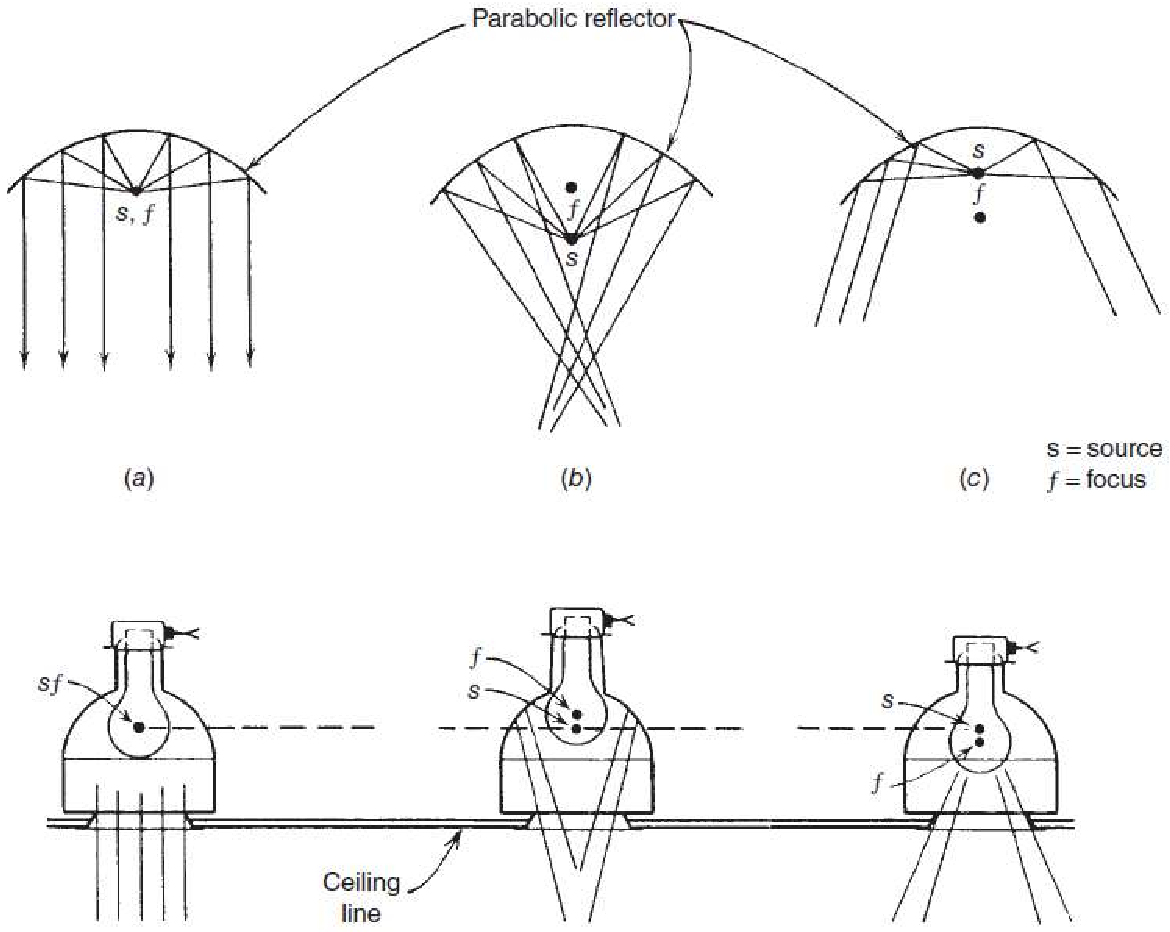


Fig. 15.31 Parabolic reflector action shown with the fixture below: (a) with the source at the focal point, rays are parallel; (b) with the source below the focal point, they converge; (c) with the source above the focal point, they diverge. This focusing action is illustrated by fixtures correspondingly designated. Note that type (c) requires a large ceiling opening to achieve even minimal efficiency.

Elliptical reflector

광원이 제 1 초점 (f_1) 상에 위치할 때, 조명기구로부터 나오는 빛은 f_2에서 수렴하는 특징.

reflector가 크지 않으면, 빛은 조명기구 안에 갇히게 되어, 효율은 급격히 떨어짐

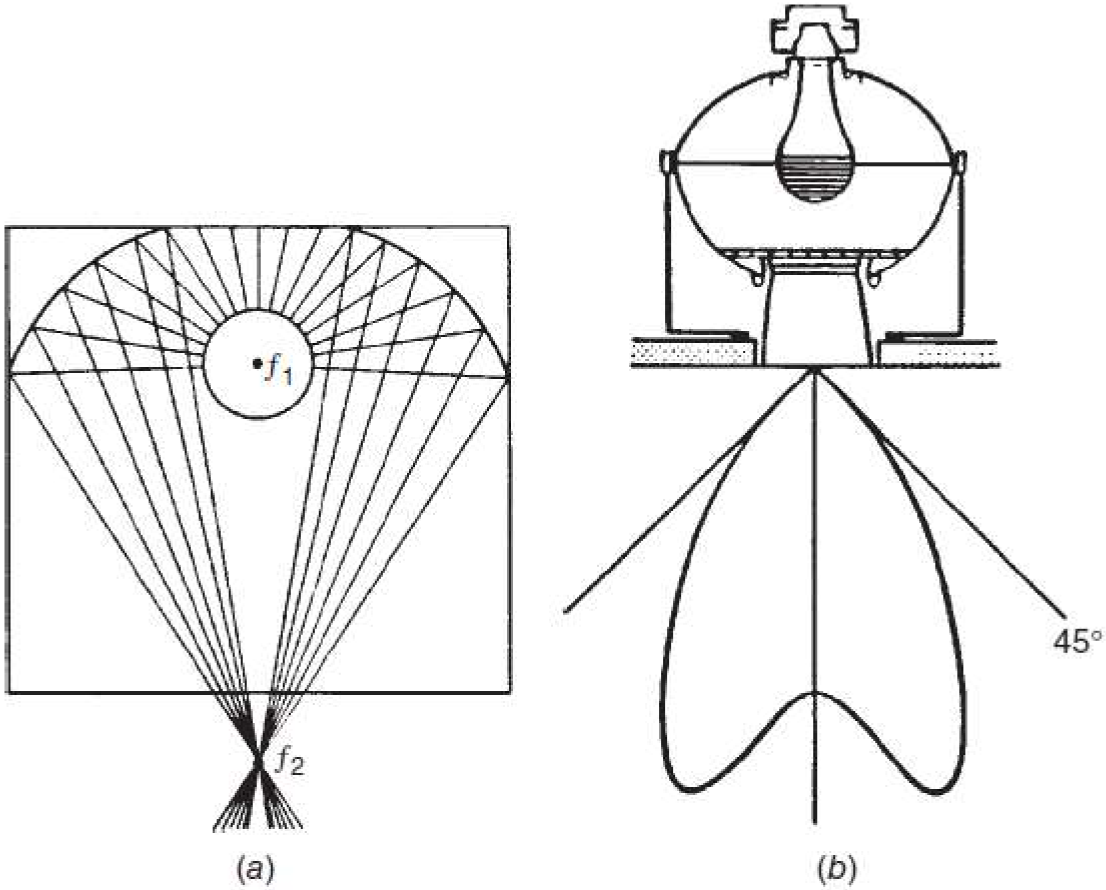


Fig. 15.32 (a) Action of an elliptical reflector section. With the light source at focal point f_1 the light converges at the other focal point, f_2. This effect is useful in fixture design, as in (b). By projecting light up only (using a silvered bowl lamp), the output light can be redirected through a constricted aperture at the other focal point, with little loss. This design is the basis of high-efficiency "pinhole" downlights.

Extended section reflector

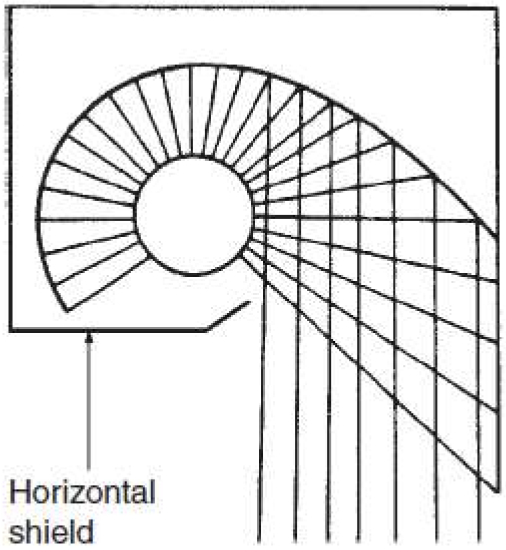


Fig. 15.33 *The extended section reflector allows the source to be concealed (shielded) while projecting its light directly down, but horizontally displaced, from the source.*

The source is concealed and projects its light directly down.

Reflector materials

- Two types
  - White gloss paint for portions of fixture body interiors: diffuse reflection
  - Anodized aluminum sheet: specular reflection (Figs.15.31-15.33)
- Reflectances of both two types: 0.84-0.88 (when new and clean) (Neither of the both is truly specular)
- High reflectance is lost by rapid aging due to elevated temperatures and accumulation of dust and dirt.
- Must be compensated for by initial overdesign (Ch.16)

Reflector retrofit analysis

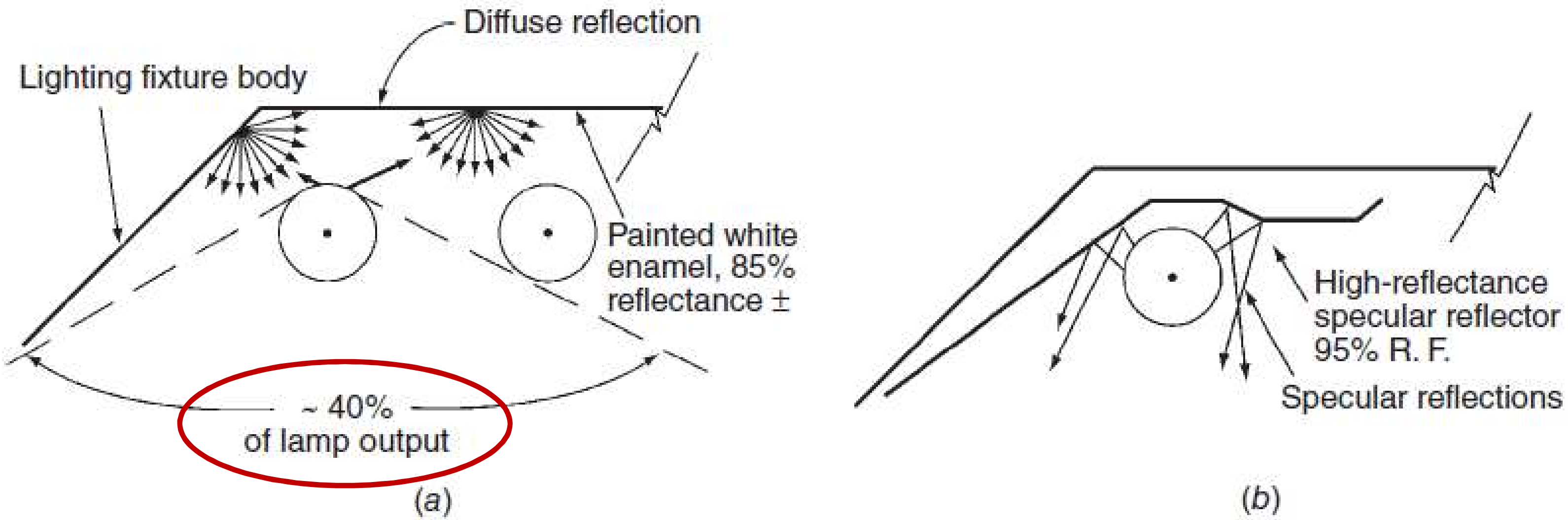


Fig. 15.34 (a) Approximately 40% of lamp output in an open linear fluorescent fixture is unrestricted. The remainder leaves the fixture after one or more reflections. (b) A mirrored reflector narrows the distribution pattern of the luminaire by specular reflection and increases output somewhat (R.F. is reflectance factor; i.e., reflectance).

- Alt #1: use an old and dirty existing reflector
- Alt #2: simple cleaning of a very dirty reflector
- Alt #3: apply a new painted reflector
- Alt #4: apply a maximum reflectance reflector

- 40% of a lamp's output directed downward. Not dependent of any reflector action.(Fig. 15.34a)
  - (Alt #1 → Alt #2) cleaning restores 20% to 25% of the light loss: 20-25%
  - (Alt #1 → Alt #3) The difference in reflectance between a new, clean, painted surface (85% R.F.) and an old, dirty surface is, at most, 50%. **60% x 0.5**=30%
  - (Alt #1 → Alt #4) The maximum reflectance of the best silver reflectors is about 95%. Compared to 85% R.F. of a new clean painted surface, only R.F. of 10% increased. Thus, in case of the silver reflector retrofit, 30% + 60% X 10% = 36%
  - Alt #2 (cleaning) vs. Alt #4: the difference is only by 11-16%.

- A cost analysis is required to determine whether the 11% to 16% differential in light output between simple cleaning (Alt #2) and silvered reflector addition (Alt #4) is economically feasible.

Luminaire diffusers

- Diffusers are the devices placed between the lamp(s) and the illuminated space.
- to diffuse the light, control fixture brightness, redirect the light, obscure (hide) and shield the lamps
- 5 types

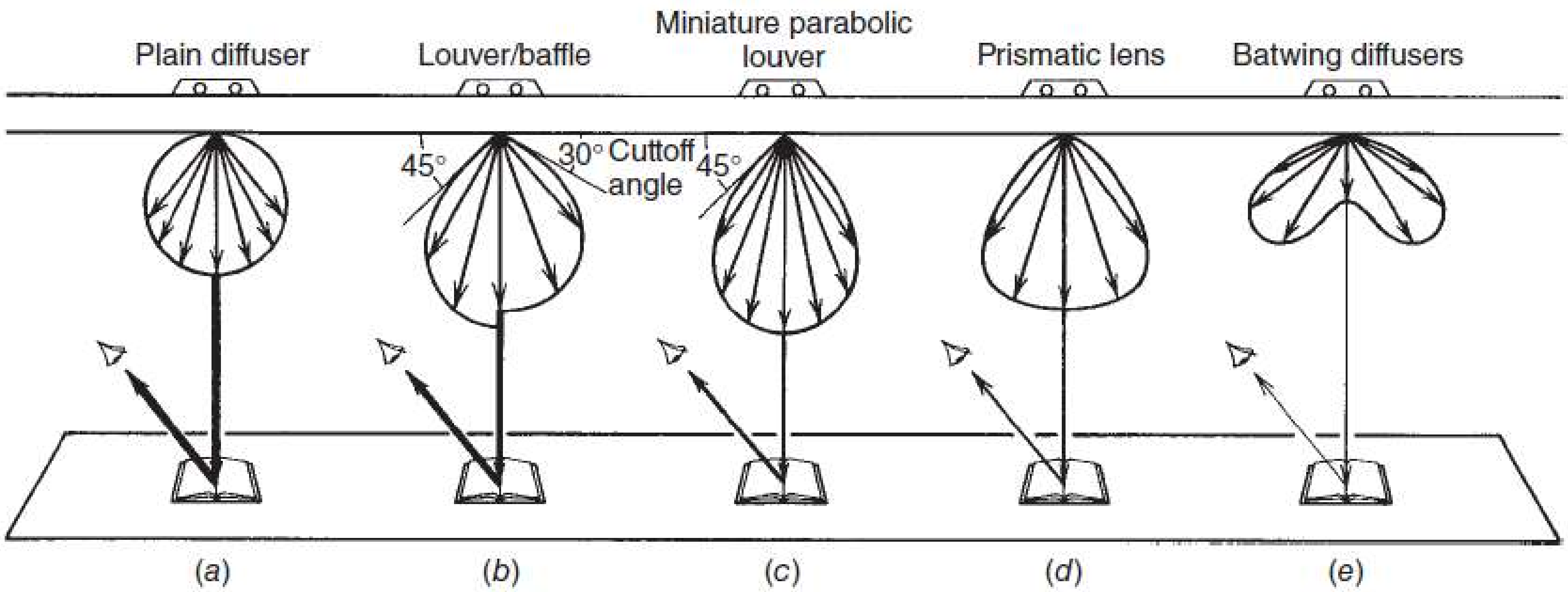


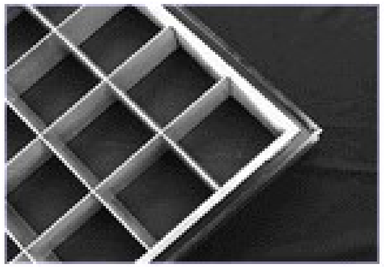
Fig. 15.35 *Comparison of typical candlepower distribution curves for common linear or PL lamp fluorescent luminaire diffuser elements (for a full description of types a–d, see text). Note that for a given geometry of viewer and luminaire, the severity of veiling reflections depends entirely on the fixture's photometric characteristic. In the individual figures, the potential to produce reflected glare is indicated by the weight of the line representing fixture output and reflectance from the work task. The batwing distribution (e) concentrates its output in the 30° to 60° range, which minimizes both direct and reflected glare potential.*

(a) Plain (translucent) diffuser

- White opal glass, frosted glass, white plastics
- These do not redirect the light but merely diffuse it
- Candlepower Distribution Curve (CDC): Fig.15.35(a): circular, similar to bare lamps.
- Lamp hiding is good.
- VCP is poor due to high angle light.
- Direct glare can be a problem.
- Veiling reflections are high.
- S(Luminaire Spacing)/MH(Mounting Height from the luminaire to the working plane)<=1.5
- Applications: corridors, stairwells, and other areas without demanding visual tasks

(b) Louvers/baffles

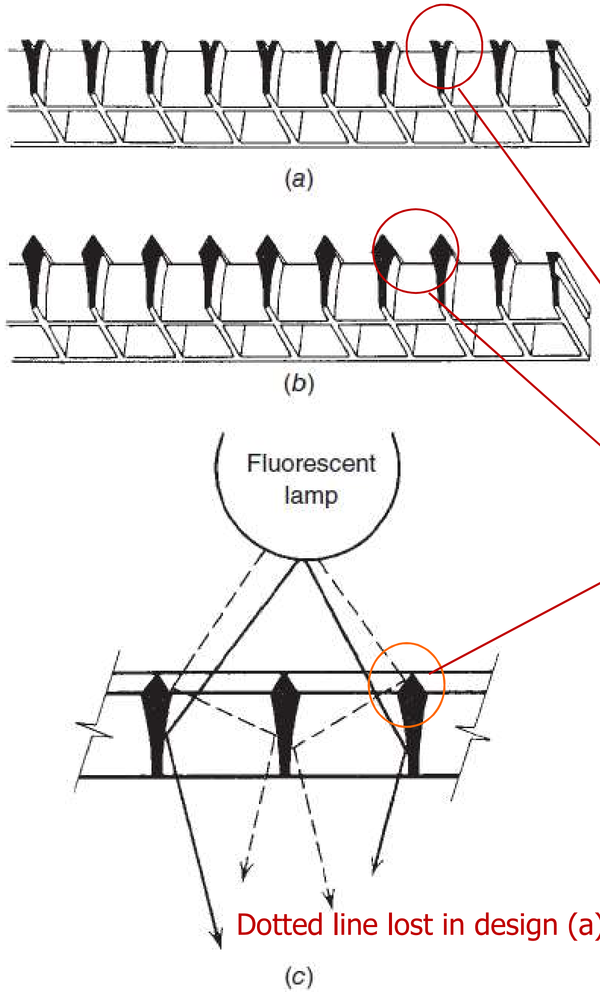
- Fig.15.28, 15.29
- CDC: Fig.15.35(b), depending on (1) the shielding angle, (2) design of baffles/louvers and (3) their finishes
- S/MH<=1.5; S/MH varies inversely with the shielding angle.



Aluminum Louvers/Baffles

Miniature egg-crate parabolic wedge louver

- A special design of louvers/baffles (Fig. 15.35b)
- A large portion of the light directly downward: they appear completely dark when viewed obliquely.



Lighting-trapping tops

This design improves the luminaire efficiency by about 20%.

Fig. 15.36 (a) Section through a conventional, miniature parabolic wedge, eggcrate type of louver. These units give exceptionally low brightness when seen at a normal viewing angle. Most such units are made of aluminized plastic. Fixtures equipped with these louvers exhibit low overall efficiency due to the large amount of light trapped by the broad top of each parabolic wedge. (b) A modified wedge design uses a curved top on each wedge to redirect and utilize light striking the top. (c) Solid lines represent light rays redirected by the bottom curve, whereas dotted lines show light redirected by the top curve, which was lost in the design of (a). Typical louver cell dimensions are a ½-in. (12-mm) cube for design (a), with a consequent 45° shielding angle, and 5/6 to 3/4 in. (21 to 19 mm) square by ½ in. (12 mm) high for design (b), giving a 35° to 45° shielding angle.

Eggcrate Louver

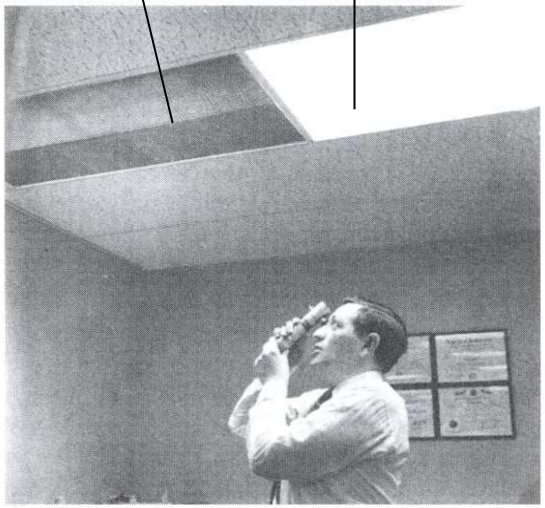


Fig. 15.11 In the illustration the designer is checking the luminance of a fluorescent fixture equipped with a miniature parabolic wedge louver, which has very low luminance above 45°. This characteristic is readily apparent in comparison to the adjacent fixture, which utilizes a prismatic lens diffuser.

Image source: From MEEB 11th Ed.

Miniature egg-crate parabolic wedge louver

- The typical CDC: Fig. 15.35(c)
- The shielding angle is usually 45°
- VCP is very high.
- Veiling reflections can be troublesome.
- Good for VDT areas
- Due to trapped light, with a maximum Coefficient of Utilization of about 0.5 (For CU, refer to Ch.16).
- S/MH varies between 1.0 and 1.5.

CU: the ratio between the lumens reaching the horizontal work plane and the generated lumens
(Ch.15, textbook p.744 & Fig.15.46, Ch.16, textbook p.774)

(c) Prismatic lens

- high coefficient of utilization
- S/MH as high as 2.0
- low direct glare (high VCP).
- Veiling reflections can be troublesome, depending upon viewing angles and position (see Fig. 6.32)

(d) Fresnel lens

- The action of this lens is similar to that of a reflector → without a reflector, it controls beam pattern. → the reflector can be eliminated, yielding a smaller fixture.
- Lamp-hiding power is poor
- Efficiency is high
- Visual comfort is good
- S/MH is seldom more than 1.5

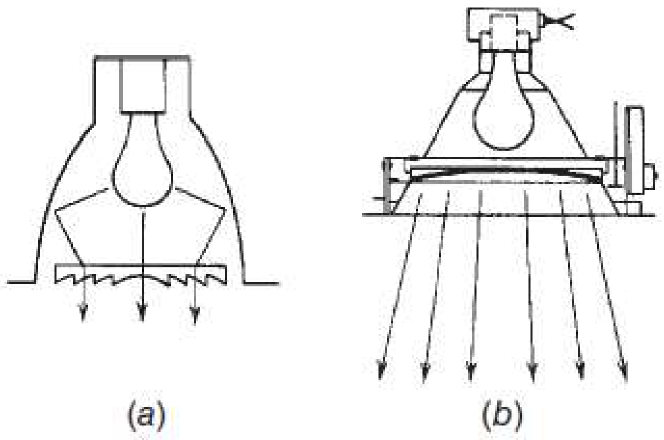


Fig. 15.38 *Action of a Fresnel lens. With a Fresnel lens fixture, a smaller housing without a reflector can be used while still maintaining beam control. The lens performs the same function as a reflector, controlling the beam as a function of source placement. By utilizing a lens fixture, the curved reflector (a) can be largely eliminated, yielding a smaller fixture while maintaining accurate beam control. A common design (b) uses a regressed lens to provide shielding, although lens brightness is not normally objectionable.*

(e) Batwing diffuser

- low direct and reflected glare (Fig 16.28)
- CDC: Fig.15.39

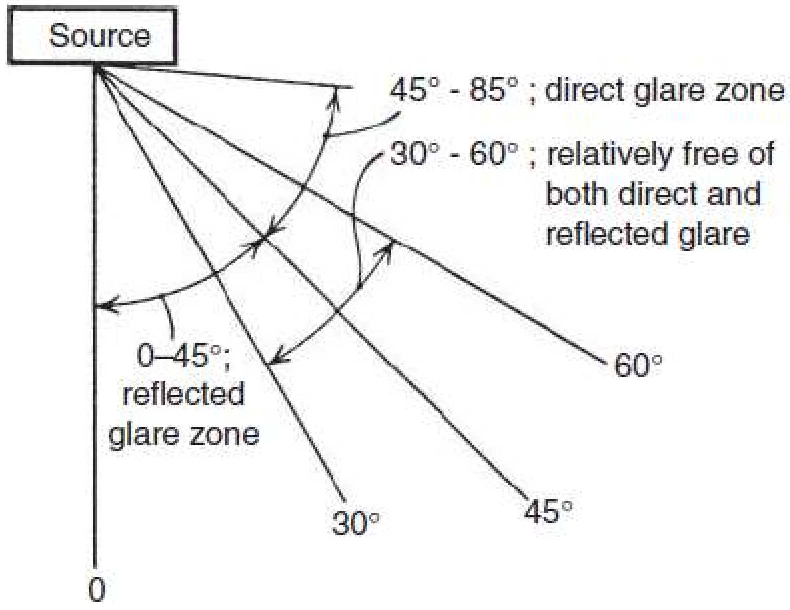


Fig. 16.28 *Glare zones are 0° to 45° and 45° to 85° for reflected and direct glare, respectively. Therefore, a diffuser that emphasizes the 30° to 60° zone will be least objectionable on both counts.*

Batwing diffuser

- Two types
  - Prismatic batwing diffusers: linear diffuser or radial diffuser (Fig. 15.39)
  - Deep parabolic reflectors: Fig.15.40
- high efficiency (low direct and reflected glare), good diffusion
- Good for VDT areas

< Prismatic batwing diffusers >

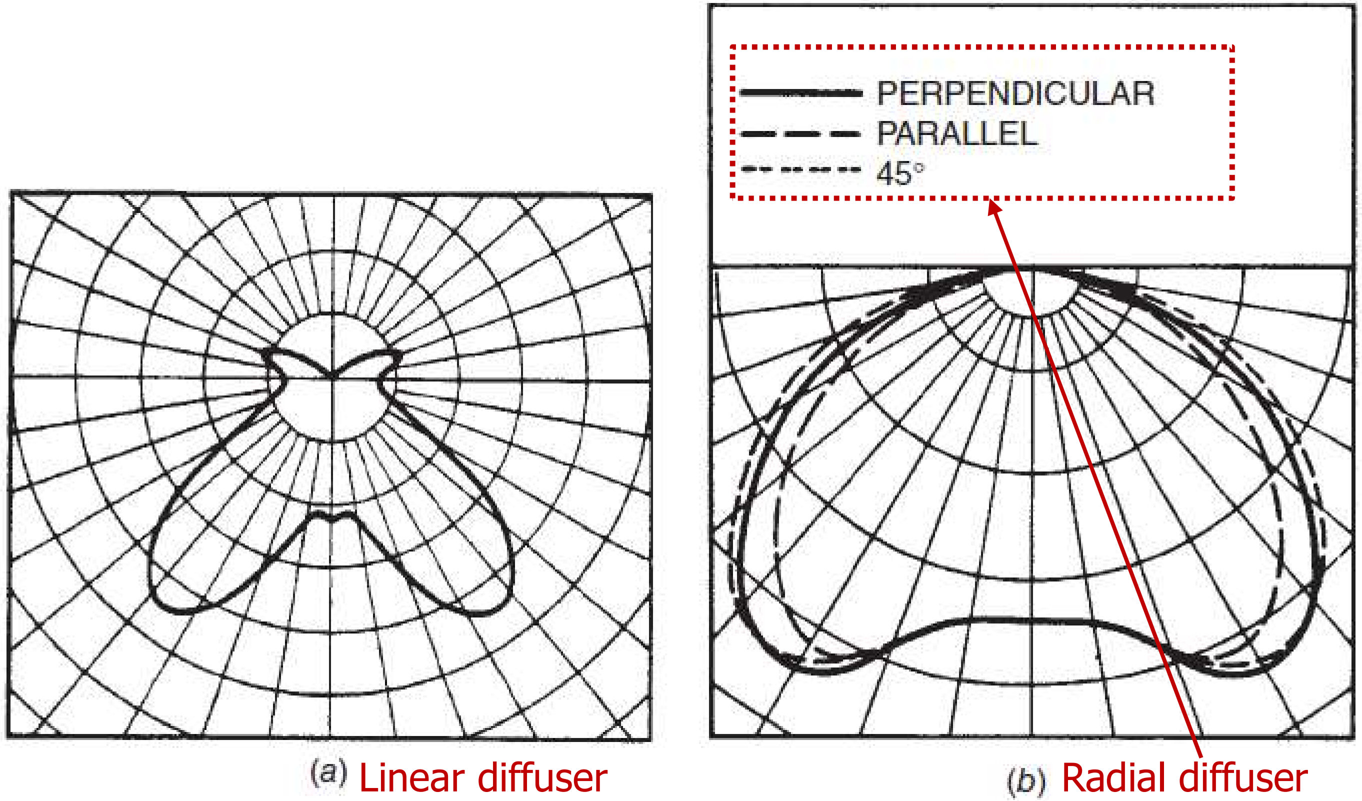
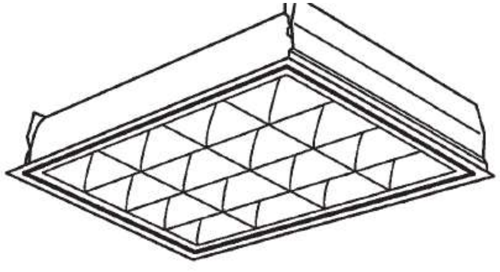


Fig. 15.39 (a) Linear batwing distribution with extremely sharp cutoff in the upper and lower ranges. The curve is taken across the lamp axis for a single-lamp unit. (b) Distribution curves for a radial batwing distribution lens. Note that the perpendicular, parallel, and diagonal curves are almost identical. Zonal flux is maximum in the 30° to 60° range and drops off at both extremes, as desired.

< Deep parabolic reflectors >



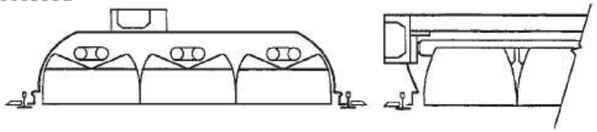
TOTAL LUMINAIRE EFFICIENCY = 66.0 %
TOTAL REFLECTANCE OF PAINT = 88.3 %
CIE TYPE – DIRECT

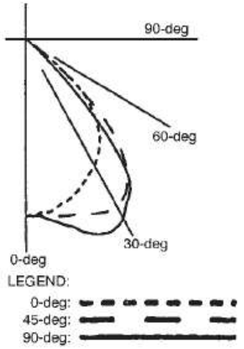
PLANE	0-DEG	90-DEG
SPACING CRITERIA	1.2	1.6
SHIELDING ANGLES	36	43
PLANE	0-DEG	90-DEG
LUMINOUS LENGTH	21.250	21.250

LUMINANCE DATA IN FOOTLAMBERTS

ANGLE IN DEG	AVERAGE 0-DEG	AVERAGE 45-DEG	AVERAGE 90-DEG
45	2451.	3101.	1927.
55	494.	639.	55.
65	0.	0.	0.
75	0.	0.	0.
85	0.	0.	0.

Recessed





Visual Comfort Probability

Reflectance - 80, 50, 20
Work Plane Illumination - 100 FC @ 2.5 ft.

VCP

Room W	Room L	Ht.	Luminaires Lengthwise 8.5	Luminaires Lengthwise 10.0	Luminaires Lengthwise 13.0	Ht.	Luminaires Crosswise 8.5	Luminaires Crosswise 10.0	Luminaires Crosswise 13.0
20	20		68	81	77		90	90	87
20	40		69	81	77		91	90	84
30	30		69	81	77		91	90	84
30	60		69	82	78		91	90	84
40	40		69	82	78		91	90	84
40	60		70	82	78		91	90	84
60	30		69	82	78		91	90	84
60	40		70	82	78		91	90	84
60	60		70	82	78		91	91	84

Coefficients of Utilization

Coefficients of Utilization
Zonal Cavity Method — Floor Reflectance - .20

RC	80				50		
RW	70	50	30	10	50	30	10
1	75	73	71	69	69	67	66
2	71	67	65	62	64	62	60
3	67	62	59	56	59	57	54
4	63	57	54	50	55	52	50
5	59	53	49	46	51	48	45
6	55	49	44	41	47	43	41
7	51	44	40	37	43	39	36
8	48	41	36	33	39	35	33
9	44	37	32	29	36	32	29
10	41	34	29	26	33	29	26

Energy Data

LER: FP-42 — **Energy Cost: $5.71***
Input Watts: 134 — **BF: .90**

The above energy calculations were conducted using a specific lamp/ballast combination. Actual results may vary depending upon the lamp and ballast used. Lamp and ballast specifications are subject to change without notice.

*Comparative annual lighting energy cost per 1000 lumens based on 3000 hours and $0.08 per KWH.

Fig. 15.40 *A 2-ft (610-mm) square, deep parabolic reflector luminaire designed for three F40, 22.5-in (572-mm) twin-tube CFL lamps, with a rated output of 3150 lm each. Total power input is 134W and ballast factor (BF) is 0.9, giving a luminaire efficacy rating (LER) of 42. The typical modified batwing crosswise distribution and circular lengthwise distribution are clearly shown. Photometric data are also shown. (Courtesy of Columbia Lighting.)*

Uniformity of Illumination (균제도)

- (max E)/(min E) on the working plane: up to 1.3 (readily acceptable)
- For general background or circulation lighting: up to 1.5
- When the luminaire's distribution characteristic is symmetrical in all directions (small source lamps such as incandescent, CFL): a single S/MH required.

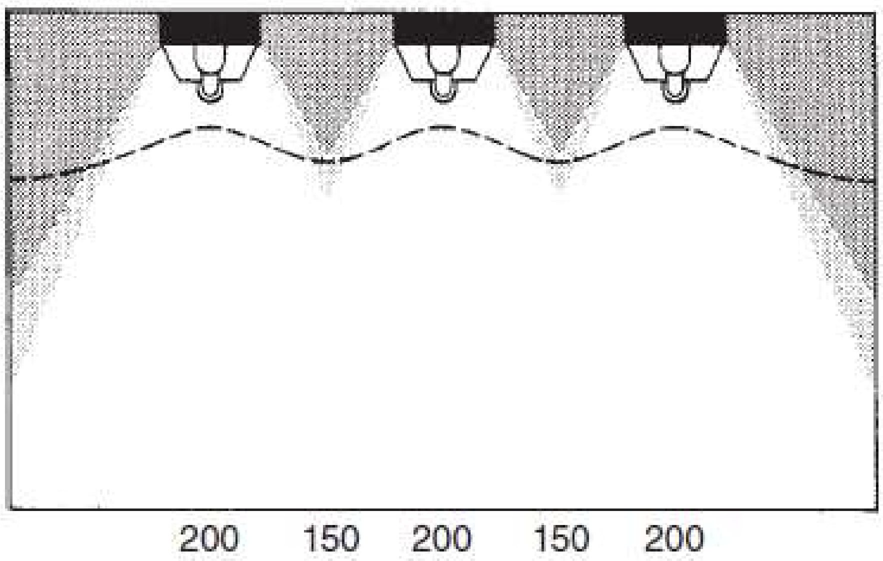


Fig. 15.41 The ratio of maximum to minimum illuminance should not exceed 1.3 in areas requiring uniform illumination.

- S/MH recommendations given by manufacturers are generally based upon a 1.0 illuminance ratio (Fig. 15.41).

Uniformity of Illumination (균제도)

- Determination of the S/MH (also called spacing criteria [SC]) for a specific luminaire: by measuring the distance between two test luminaires that yields the same illuminance on the working plane midway between them as directly under each one. Any contributions from other fixtures in a multi-fixture installation and from inter-reflections deliberately ignored.
- Asymmetrical distribution (e.g. fluorescent): crosswise and lengthwise S/MH
  - Refer to Table 16.1 from 12th Ed. in the next slide (luminaires # 26, 28, 42: two S/MH)
  - The crosswise S/MH ratio is always considerably higher than the lengthwise S/MH ratio (luminaires # 26, 28, 42 in Table 16.1)